DEVELOPMENT OF AN ASSESSMENT TOOL FOR MAINTENANCE MANAGEMENT IN PUBLIC SCHOOLS IN SAUDI ARABIA

BY
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To my *Brothers, Sisters, Wife* **and** *Children*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GPGE	:	General Presidency for Girls' Education
ISO	:	International Organization for Standardization
QMS	:	Quality Management System
LEED	:	Leadership in Energy and Environmental Design
ASHRAE	:	American Society of Heating, Refrigerating and Air Conditioning Engineers
ANSI	:	American National Standards Institute
DB	:	Decibels
IESNA	:	Illuminating Engineering Society of North America
FC	:	Foot-Candles
ISECOM	:	Institute for Security and Open Methodologies
IT	:	Information Technology
CMMs	:	Computerize Maintenance Management System

ABSTRACT

Full Name : **Saleh Ahmed M. Binlswad**

Thesis Title : **Development of an Assessment tool for Maintenance Management in Public Schools in Saudi Arabia**

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Saudi Arabia is witnessing an unprecedented development in many aspects. Most of this development is realized in the construction industry. The large facilities require extensive maintenance programs in order to keep them in good running conditions as originally intended. The purpose of this research is to formalize the development of an assessment tool for maintenance management for facilities of public schools in Saudi Arabia. The methodology adopted in this research consists of two parts. The first part employs the holistic system approach to maintenance to identify quality criteria for incorporation in the developed assessment tool. This part uses ISO 9001:2000 standards, extensive literature review and in addition a series of interviews with experts in maintenance. The second part involves the assessment of the identified quality criteria through conducting in depth, well-structured surveys of experts in the maintenance of large public organizations. Based on the results obtained from the assessment, the assessment tool has been developed and applied to evaluate the current practice in three case studies to test its practicality. The significance of this study stems from the fact that at the current time there is no such assessment tool in Saudi Arabia and it is expected to help in prolonging the life span of such public facilities. In addition, using such an assessment tool consistently will assist in improving the safety of occupants, providing a high level of satisfaction for users of these facilities, providing healthy and safe environment to improve productivity levels, and increasing the protection of the investment in public facilities.

MASTER OF SCIENCE DEGREE KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS DHAHRAN, SAUDI ARABIA
May, 2013

ملخص الرسالة

الاسم الكامل: صالح أحمد مبروك بن لسود

عنوان الرسالة: تطوير أداة لتقييم إدارة الصيانة بالمدارس العامة بالمملكة العربية السعودية

التخصص: هندسة معمارية

تاريخ الدرجة العلمية: 1434 هجرية

تشهد المملكة العربية السعودية تطورا غير مسبوق في العديد من الجوانب. معظم هذا التطور ممكن إدراكه في تشييد المنشات لاسيما المنشاءات التعليمية. إن هذه المرافق التعليمية تتطلب برامج صيانة واسعة النطاق من أجل الحفاظ عليها اثناء فترة تشغيلها لتبقى كما كانت في الأصل. إن هذه الدراسة تهدف إلى وضع أنظمة معيارية لتقييم مخرجات إدارة الصيانة الفعالة للمدارس العامة في المملكة العربية السعودية وتطبيق تلك المعايير لمعرفة فعاليتها. إن المنهجية المتبعة في هذا البحث تتكون من مرحلتين . المرحلة الأولى تعتمد على توظيف مختلف النظم الممنهجة للصيانة لتحديد معايير الجودة لإدراجها في تطوير الأداة التقييمية المنشودة. هذا الجزء يتضمن معيار ISO 9001:2000 ، مع استعراض مكثف للدراسات السابقة في هذا المجال، بالإضافة إلى سلسلة من المقابلات مع خبراء في الصيانة. الجزء الثاني يتضمن تقييما لمعايير الجودة المحددة من خلال إجراء استبيان مع الخبراء في صيانة المدارس العامة. استنادا إلى نتائج تم الحصول عليها من التقييم تم تطوير أداة تقييم وتطبيق لتقييم الممارسات الحالية على دراسة ثلاث حالات لاختبار التطبيق العملي لها. تأتي أهمية هذه الدراسة في عدم توفر أنظمة تقييم مخرجات إدارة الصيانة الفعالة في المملكة العربية السعودية وكذا حفاظا على قيمة الإستثمارات في مثل هذه المرافق وتوفير درجة عالية من الرضاء لمستخدمي هذه المرافق بالإضافة إلى توفير بيئة صحية وآمنة لتحسين مستويات الإنتاجية في المدارس العامة.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول و المعادن

الظهران. المملكة العربية السعودية

CHAPTER 1

INTRODUCTION

Saudi Arabia is witnessing unprecedented development in many aspects. Most of this development is realized in the construction industry. Examples that illustrate this development involve constructing university campuses, health-care, residential, educational, commercial facilities, etc. These large facilities require extensive maintenance programs in order to preserve them in running conditions as were originally intended. Climate conditions and use are different in Saudi Arabia than other parts of the world. Public schools in the Kingdom are organizations which are controlled by the government and faced different kinds of problems that results from poor maintenance. As a result of that there is a need for the development of an assessment tools for maintenance management to help assure of carrying out maintenance effectively and have consistent assessment among public schools. An assessment tool is a set of clauses (quality criteria) that must be met in maintaining public schools to ensure that the functionally of facilities is continued as was originally designed and demanded by users.

The Kingdom has seen tremendous development over the recent years. The government has effectively used its income to improve the citizen's life style; by building universities, hospitals, airports, electricity and telephone networks to meet the rapid urban

development. These facilities need to be maintained effectively to ensure that they optimally serve the main purpose (Al-Sultan, 1996).

The purpose of this research is to formalize the development of an assessment tool for maintenance management for facilities of public schools in Saudi Arabia. The assessment tool can be consistently applied to these facilities in order to assure the long-term protection and preservation of large public building facilities, ensure a safe and healthy environment for users, mitigate the deterioration of existing and future public building facilities, and facilitate the efficient use of government funds in support of facilities. After developing the assessment tools, the research will focus on applying the developed assessment tools for maintenance management on three public schools.

1.1 Statement of the Problem

The development of unsafe conditions at schools in the kingdom is a current hot issue and it concerns people, students, directors and government. Nowadays, public schools in the Kingdom suffer from many problems because of the lack of maintenance work at schools. As a result many fires have occurred in different schools and have caused the loss of life and property in these buildings. For example, 15 young girls died, and more than 50 were injured at a Mecca girls' school fire, in 2002 (http://en.wikipedia.org/wiki/2002_Mecca_girls'_school_fire). Saudi newspapers suggested that the school, located in a rented building, was overcrowded, and may have lacked a proper safety infrastructure and equipment, such as fire stairs and alarms. Human Rights Watch recommends that the government should investigate and also

examine conditions at the school, which is administered by the General Presidency for Girls' Education (GPGE). Another example, while conducting this study, in November 2011, two female teachers died and 46 others, most of them students, were injured in a huge fire that broke out in Jeddah girls' school. The fire broke out in the school's underground floor, which caused by an electric short circuit (Saudi Gazette, 2011).

Public schools in the Kingdom are organizations which are controlled by the government which provides a huge investment in these building. So they need an assessment tool for effective maintenance management throughout their life to ensure the efficient use of state and local funds to support these facilities. Also, students and teachers spend most of their time indoor at schools. Poor maintenance at schools will affect the performance of students and teachers. Furthermore, for any maintenance department in any public school to achieve its goals, it is necessary to know the condition of their school: whether it is maintained in the right way or whether some action should be taken to improve the maintenance system.

An interview with an engineer Al-Maged, in the Office of the Ministry of Education in the Eastern Province, it refers that maintenance work occurs on surprise visits to schools or at directors requests and they do not have maintenance management systems to evaluate their work. The major objective of this study is to formalize an assessment tool for maintenance management (a set of clauses (measurable quality criteria)) of facilities at public schools in Saudi Arabia.

1.2 Research Objectives

The objectives of this study are:

1) To develop an assessment tool for maintenance management (a set of clauses (quality criteria)) for facilities of public schools in Saudi Arabia. This involves:
    a. Identifying measurable quality criteria.
    b. Assessing the significance of the identified quality criteria by maintenance experts.
2) To conduct three case studies to demonstrate the applicability and validity of the developed assessment tool for maintenance management.

1.3 Scope and Limitations

The following are the scope and limitations of this research:

1. The distribution of the questionnaire survey and interviews are limited to maintenance managers, facility mangers, project managers and other specialized persons related to maintenance of public-school buildings who work in the Eastern Province of Saudi Arabia.

2. The case studies will be conducted in three schools in the Eastern Province of Saudi Arabia.

1.4 Significance of this Study

The significance of this study stems from the fact that at the current time there is an obvious insufficiency of maintenance work in public school and it is expected that if this assessment tool implemented, it will help in:

- Prolonging the life cycle of such public facilities if applied consistently,
- Improving the safety of occupants,
- Providing high level of satisfaction for users of these facilities,
- Providing healthy and safe environment to improve productivity levels,
- Increasing retain on investment in public schools facilities.
- Provide consistent assessment of maintenance performance of public school.

In addition it could be developed in the future as a regional standard for maintenance management.

1.5 Research Methodology

1.6.1: Achieving the first objective

The first objective will be achieved through conducting the following research activities as shown in Figure 1-1:

1.6.1.1 Phase 1: Literature Review

Extensive review of literature, including ISO 9001:2000 to identify the main elements of the assessment tools for maintenance management (measurable quality criteria).

1.6.1.2 Phase 2: Data Collection

This phase involves two research activities, as follows:

Pilot-Test of the Developed Questionnaire Surveys

Conducting a pilot-study through interviews with five maintenance management experts of large public organizations, with at least 10 years of experience, to assess the proposed quality criteria to be used for assessment tools for maintenance management and solicit additional ones.

Development of Questionnaire Surveys

Developing and administering a well-structured questionnaire (survey) to assess the identified measurable quality criteria for the maintenance management in public schools. The questionnaire will consist of two parts:

- Part I. includes general information about the maintenance management experts' organization, position, and years of experience.
- Part II. Includes a listing of the quality criteria that will be assessed by the experts using Likert type scale to solicit their opinion on the desirability of including the quality criteria. The list of the quality criteria is expected to include: response time, continuous improvement, compliance with statutory requirements, trace-ability and continual improvement. Additional quality criteria may result from this survey. The target number of respondents is 40 to ensure reliability.

1.6.1.3 Phase 3: Development of an Assessment Tool for Maintenance Management

This phase involves two research activities, as follows:

- Analyzing the obtained data statistically to identify the frequency of the measurable quality criteria by using a Likert type scale.
- Developing assessment tools for maintenance management. All assessed measurable quality criteria that are recommended by at least 67% of the survey respondents are included in the assessment tools.

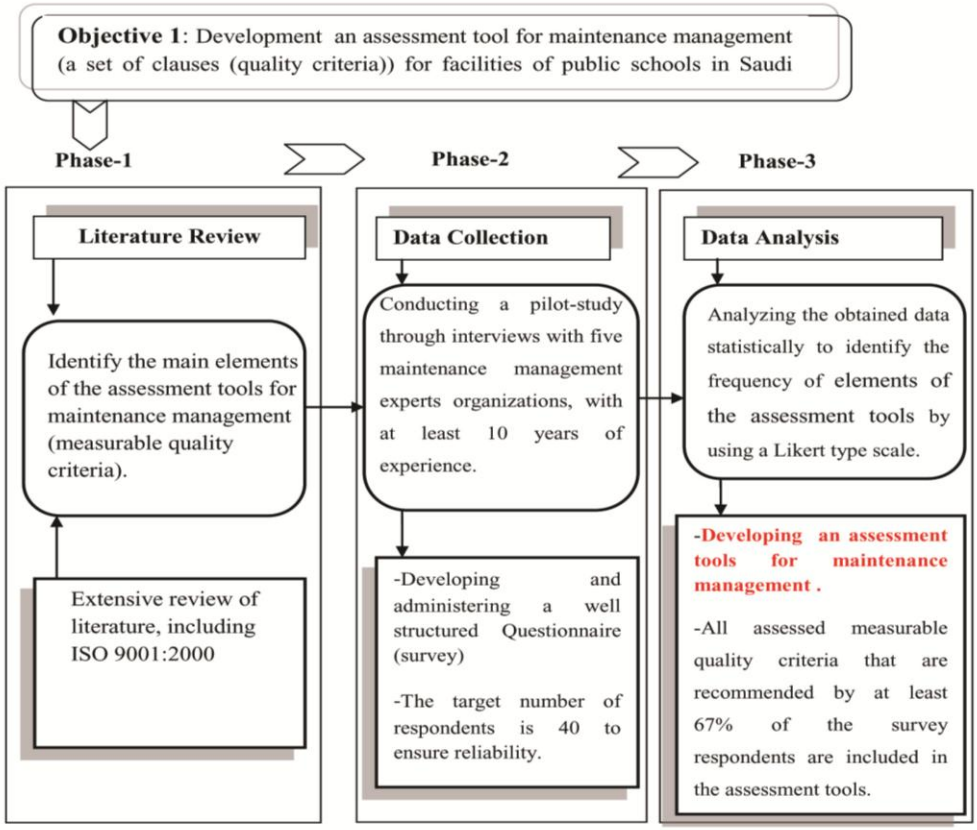

Figure 1-1 Methodology Chart for Achieving the First Objective

1.6.2: Achieving the Second Objective

The second objective will be achieved through conducting the following research activities as shown in Figure 1-2:

- Validate the assessment tools using three experts in the maintenance management of public schools.
- Apply the developed assessment tools for maintenance management on three public schools in Saudi Arabia to evaluate and assess the existing maintenance management practices. In addition, the application of the assessment tools is expected to provide additional validity for it by checking the consistency between the outcomes of the assessment tools and the maintenance management practices.
- Review and update the assessment tools in light of the above mentioned three cases.

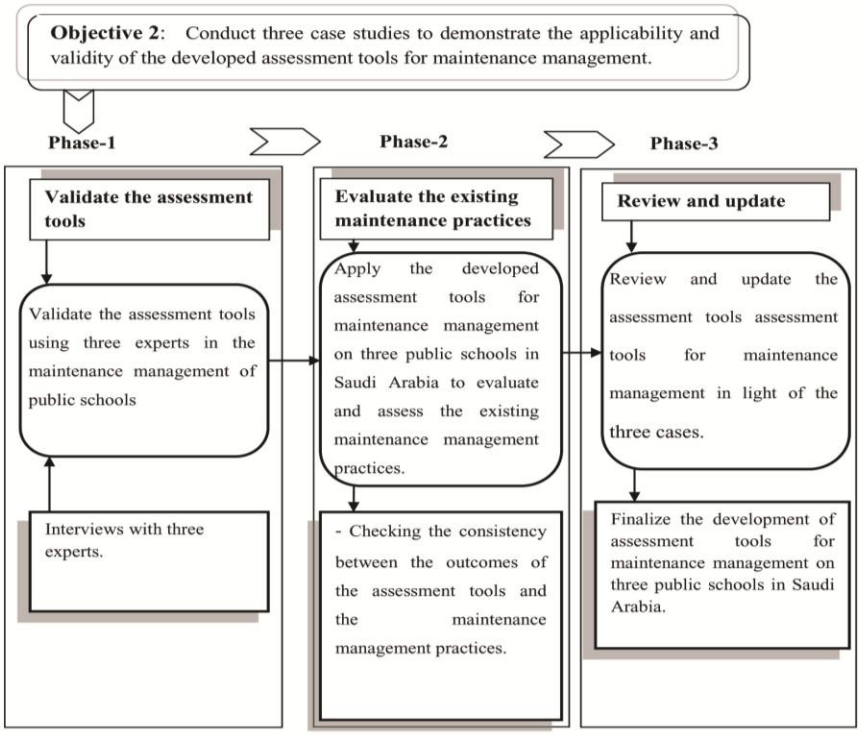

Figure 1-2 Methodology Chart for Achieving the Second Objective

1.6 Structure of the Thesis

The thesis is organized as follows:

Chapter 1: Introduction

This chapter provides background to the topic, and it presents an overview of the problem, the research objectives, and the methodology, the significance of the study, and the scope and limitations of the research.

Chapter 2: Literature Review

This chapter provides an extensive review of literature, including ISO 9001:2000 to identify the main elements of the assessment tools for maintenance management (measurable quality criteria).

Chapter 3: Development of an Assessment Tool for Maintenance Management

This chapter presents of the Statistical Analysis that used for the analysis, results, and major findings. Also, this chapter provides the developed assessment tools for maintenance management on public schools in Saudi Arabia

Chapter 4: Implementation of the Developed Assessment Tool

This chapter contains the application of the developed assessment tools for maintenance management on three public schools in Saudi Arabia to demonstrate the applicability and

validity of the developed assessment tool and assess the existing maintenance management practices.

.Chapter 5: Conclusions and Recommendations

This chapter outlines the conclusions, summarizing of present study, and makes recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the definition of maintenance and its objective as well as the state of maintenance management of public buildings in Saudi Arabia will be introduced. ISO 9000 Quality System and the process of its implementation will be discussed. Also, an overview of an effective performance maintenance management measurement system will be investigated. Lastly, the chapter will present a review of the literature through analyses and investigations of the related published research in the field.

2.2 Definition of Maintenance

The British Standard (BS 3811: 1984), defined maintenance as: "A combination of any actions carried out to retain an item in, or restore it to an acceptable condition". According to Wordsworth (2001) maintenance can be defined as "the action is referred to the initiation, organization, and implementation of series of works''. Maintenance is a key factor in extending the economic life for buildings, and so the main causes of maintenance improvement are emotions and economics (Patton, 1988). Arkansas (2009) defined maintenance as "any activity or improvement to a facility and, if necessary, related areas, such as the physical plant and grounds, that: Maintains, conserves, or protects the state of condition or efficiency of the facility; or brings the state of condition or efficiency of the facility up to the facility's original condition of completeness or efficiency''.

2.2.1 Maintenance Objectives

The primary objectives of maintenance are to preserve the asset to ensure that it serves its anticipated purpose (Arditi et al., 1999). The other objectives of maintenance are as follows (Al-Najjar, 1996 and Magee, 1988):

• Improving quality rate and effective control for maintenance process.

• Improving the work environment.

• Ensuring the safety of occupants using facilities.

• Extending the useful life of items and components.

• Higher product and machinery reliability.

• Ensuring readiness of equipment and tools needed for emergency use.

• Operate the facility utilities in the most economical way.

• Increasing user's satisfaction.

2.3 Maintenance Management of Public Buildings in Saudi Arabia

Saudi Arabia is witnessing an unprecedented development in many aspects. Most of this development is realized in the construction industry, especially in the public sector.

However, most of the public sector organizations have suffered from many problems which can be divided into six categories. These include technical problems, financial problems, management problems, human related problems, spare parts and equipment problems, and lack of institution and training facilities (Al- Hammad et al., 1995).

Al-Sultan (1996) presented seven factors that affect operation and maintenance in the Kingdom. These factors include the decrease in expenditure on new projects, the building of infrastructure items and facilities which become age and will require increased maintenance, inaccuracies in the implementation of maintenance work, inflation in the Kingdom and the resulting increase in maintenance costs over the years and the fact that the kingdom's population growing at a rate of 3.5 % . Added to this are the harsh effect of the Kingdom's climate on infrastructure and facilities, especially in the absence of the implementation of an effective standards during the design and construction phases.

Idris (1997) listed several factors that influence the maintenance programme of a large university building in Riyadh. These factors are heavy pressure on designers during phases of rapid development in the country, evaluation and selection of building materials, the harsh effects of climatic conditions, contracting systems, lack of codes and building standards and presence of chlorides and sulphates in soil and water.

Ikhwan and Burney (1999) aimed in their paper to audit the existing maintenance situation in government and private hospitals in the Kingdom of Saudi Arabia. They developed a questionnaire survey which consisted of four sections. Those are: general information, in-house maintenance, contracted maintenance, and future needs. They conducted a sample study of government and private hospitals in Jeddah and Taif cities which give some insights into the overall working of hospitals and the comparative working between government and private hospitals. The more serious problems faced are delays in obtaining spare parts, shortage of technical manpower, lack of training facilities, non-standard spare parts, not enough Saudi technicians, poor communication amongst staff, and lack of funds. On a comparative basis, government hospitals employ more staff with more skills and training in the maintenance department, implement more preventive maintenance, and have a more organized system of working and equipment databases, as shown in Table 2-1.

Table 2-1 Comparative Percentage of Hospitals Preparing Maintenance Reports (Ikhwan and Burney, 1999)

Nature of work	Percentage of hospitals responding 'Yes'	
	Government	Private
Record man-hours spent by maintenance technicians	80	50
Record material used	100	80
Have a costing system	90	60
Have inspectors for maintenance work	70	50
Carry out regular analysis of maintenance	80	70
Have a history card for each piece of equipment	60	70

Al-Nehmi (2009) identified thirty-eight factors influencing the decision to outsource the maintenance services in Saudi universities. These factors are classified under six

categories, namely strategic, management, technological, quality, economic, and function characteristics. He conducted a questionnaire survey which was distributed to 11 Saudi universities. He notes that participants agreed on quality and then cost as the most important categories, and outsourcing of the maintenance services was given priority of 77%.

Mahmoud (1994) compared maintenance and construction expenditures in Saudi Arabia from 1391H – 1402H. He notes that the maintenance and running costs are nearly half of the total cost of a facility, and the initial cost constitutes the other half. The budget for the construction industry was SR 2.411 billion in 1391 H, but it rose to SR 89.91 billion by 1402 H (Ministry of Planning, 1995). The Maintenance industry grew from SR 327.6 million in 1391H to SR 2,348.920million in 1402H as shown in Table 2-2.

Based on the above presented literature, it is evident that previous research has not addressed a holistic approach for developing the required quality criteria for generic maintenance management of public buildings .Clearly, there has been some research on maintenance management and practice in the Kingdom, but it remains very limited because most of it is written from a practitioner's perspective and very few articles focus on sound scientific solutions to maintenance problems (Al-Sultan,1996) . Furthermore, In Saudi Arabia, most research for maintenance management systems for public buildings necessitates the need to develop assessment tools for maintenance management.

Table 2-2 Maintenance and Construction Expenditures (Mahmoud, 1994)

Year (H)	Budget for Maintenance in Million SR	Budget for Construction in Million SR	Accumulative for Construction (Million SR)	% of Maintenance to Accumulated Construction.	Maintenance Needed for 1.25 % Adjustment	Amount Required for 1.25 % (Millions)	Difference Between Required & Actual(Millions)
1391	327.6	2411	2,411	13.6%	-	-	-
1392	425.8	3,543	5,954	7.2 %	-	-	-
1393	533.3	5,506	11,460	4.7 %	-	-	-
1394	686.4	9,645	21,105	3.3 %	-	-	-
1395	191.2	20,369	41,474	0.5 %	0.75%	518.4	311.1
1396	205.8	33,501	74,975	0.3 %	0.95%	937.2	712.2
1397	197.0	46,606	121,581	0.16 %	1.09%	1,519.8	1,325.2
1398	420.5	60,045	181,626	0.23 %	1.02%	2,270.3	1,852.6
1399	609.9	69,789	251,415	0.24 %	1.01%	3,142.7	2,539.3
1400	1,497.1	80,157	331,572	0.45 %	0.80%	4,144.7	2,652.6
1401	2,001.6	89,740	421,312	0.48 %	0.77%	5,266.4	3,244.1
1402	2,348.9	89,911	511,223	0.45%	0.80%	6,390.3	4,089.8
						Total	**16,726.9**

2.4 ISO 9001:2000 Standards

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The standards have been prepared by ISO technical committees. The ISO 9000 series standards have evolved since the publication of the first version in 1987. This was followed by a revision in 1994. Prior to 2000, the series has three standards which were ISO 9001, ISO 9002 and ISO 9003 and were adopted by organizations depending on the scope of certification requirements. In 2000, a new version was published that combined the three ISO 9000 series in one

integrated standard ISO 9001:2000. The new standard (ISO 9001:2000) had eight major sections and five of them specified the standards for quality criteria such as control of monitoring and measuring devices and identification & traceability as outlined in the International Organization for Standards cross reference map (2008).

ISO 9000 is essentially a series of six standards which describe the elements for establishing and maintaining a quality management system (QMS). The standard includes the following:

1) **ISO 9000** - provides guidance to quality management which is related to selection and use.
2) **ISO 9001** - provides guidance for quality assurance from design to servicing stages.
3) **ISO 9002** - provides details for the quality assurance specification.
4) **ISO 9003** - provides details for final inspection for quality assurance.
5) **ISO 9004** - provides details for quality management which consist of 20 clauses these are as follows:

(1) Management responsibility

(2) Quality system

(3) Contract review

(4) Design control

(5) Document and data control

(6) Purchasing

(7) Control of customer-supplied product

(8) Product identification and traceability

(9) Process control

(10) Inspection and testing

(11) Control of inspection, measuring and test equipment

(12) Inspection and test status

(13) Control of non-conforming product

(14) Corrective and preventive action

(15) Handling, storage, packaging, preservation and delivery

(16) Control of quality records

(17) Internal quality audit

(18) Training

(19) Servicing

(20) Statistical techniques

ISO 9008 - this is the final part of the series that cancels and replaces ISO 9004 which contains 5 main elements as the following:

(1) Scope

(2) Normative reference

(3) Terms and definitions

(4) Quality management system

(5) Management responsibility

(6) Resource management

(7) Product realization

(8) Measurement, analysis and improvement.

2.4.1 Definition of Quality

Different definitions of quality have been developed by scholars. According to the International Organization for Standardization (ISO 8402-1986), a quality can be defined as “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs”.

Robinson (1995) defined the quality as “meeting the (stated) requirements of the customer now and in the future”. Badiru and Ayeni (1987) defined the quality as “an equilibrium level of functionality possessed by a product or service based on the producer's capability and the customer's needs”.

2.4.2 Implementation of ISO 9001

Peggy (1998) in her dissertation titled "The Application of ISO 9000 Quality System in Building Maintenance of Hospitals" aimed to evaluate the impact of implementation of ISO quality system for maintenance service in hospitals. She developed eight phases for implementation of ISO -9000 process as shown in Figure 2-1. Moreover, she provided some significant factors for its successful implementation at hospitals. , These factors included management commitment, staff commitment, internal competition, preventing

unnecessary paperwork and bureaucracy, incorporating existing procedures, takes advantage of those certified hospitals' experience and knowledge of implementation, application of information technology and operating an adequate training program.

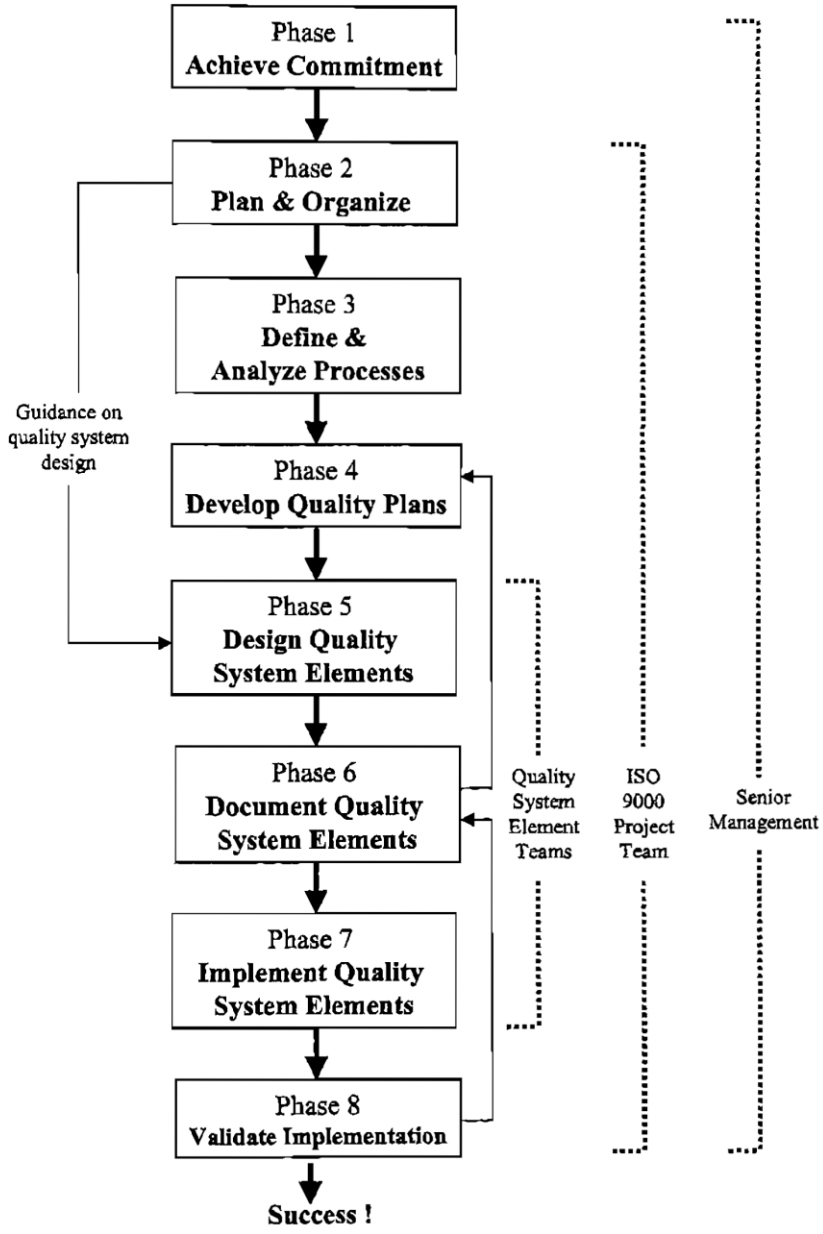

Figure 2-1 Implementation of ISO Process developed by Peggy (1998)

2.4 Previous Studies

Many studies have been conducted to develop effective maintenance management systems for large public organizations. These include the following:

Arkansas Division of Public School Academic Facilities and Transportation (2009) developed standards for custodial operations and maintenance, repair and renovation activities. The standards for custodial operations include the following elements: custodial care plan, schedule for routine care, renovation and cleaning, personnel necessary to perform custodial operations, training criteria for use and storage of supplies and equipment, chemical supplies and equipment necessary to perform custodial operations and space standards or proper storage and process and procedures for maintenance activities. The standards for maintenance, repair and renovation activities include the following elements: maintenance plan, process and procedures for maintenance, repair and renovation work-request system, personnel necessary to perform maintenance operations, training criteria for maintenance personnel in school, in-service training for maintenance personnel, process and procedures for inspection, cleaning, servicing and repair of heating, ventilation and air-conditioning systems. While the above developed different standards seem to be comprehensive, it lacks a clear methodology to ensure that the functionally of facilities is continued as was originally designed and demanded by users.

The Florida Department of Education (1998) developed a manual aiming to provide an update of acceptable and effective practices for maintenance and operations management and current standards for educational facilities. To achieve this purpose, several areas were considered, including general maintenance and operations guidelines, organizational structures of maintenance and operations departments, management of custodial programs, educational facility infrastructure management, educational facility infrastructure management, contracted services and standard procedures. This effort is similar to that of Arkansas Division of Public School Academic Facilities and Transportation (2009), but less in scope. Nevertheless, it also does not provide a methodology for ensuring that the functionally of the facilities is continued as was originally designed.

Howard (2006) reported on the practices and actions for preventative maintenance for school buildings. He further stated that "without these practices, a preventive maintenance program may not fulfill its goals". These best practices include "inventory building components and assess their conditions, build the capacity for ranking maintenance projects and evaluating their costs, plan strategically for preventive maintenance in the long-and-short-term, structure a framework for operating a preventive maintenance program, use tools to optimize the preventive maintenance program, advance the competence of maintenance workers and managers, and involve appropriate maintenance personnel in decision-making and in communicating buildings' needs". This study has not indicated how the effectiveness of these best practices can be judged to preserve the intended use of the school buildings.

The Department of Environmental Health & Safety and Code Enforcement, Florida (2009 – 2010) developed Custodial Standards which contain many categories such as clean campus committee, air fresheners/deodorants in school facilities, universal precautions, classrooms standards, restroom standards, gymnasiums standards, locker room standards, restrooms/locker areas/shower areas, administrative office/libraries/auditoriums standards, science and vocational/ technical laboratories standards, clinic rooms standards, corridors standards, entrances standards, and maintenance/storage rooms. Similarly, this effort does not illustrate a method to judge the results of their implementation.

Lavy and Bilbo (2008) in their paper have presented previous studies that showed that most school buildings in the State of Texas, USA are suffering from inadequate physical conditions. They conducted a survey of 320 school facilities managers to investigate the state of the facilities maintenance management in large public schools. They found that there is an inferior quality of facilities maintenance management and they usually do not incorporate students and staff in the maintenance plan. They recommended that the maintenance plan should be updated periodically for long-term planning to meet the requirements of the facility and its condition. This study has necessitated the need to develop maintenance management standards to ensure that the objectives from acquiring these school facilities are achieved.

The Interagency Committee on School Construction (2008) proposed average life expectancy for equipment and building components which include building enclosures, roofing systems, windows and exterior doors, interior construction, plumbing systems, elevators, heating, ventilation and air conditioning , electrical systems, site work and utilities . For example they suggested the average life expectancy for all types of elevators is 25 years. This initiative can be useful as an input in the process of developing a maintenance management standard.

Legat and Jurca (2004) in their paper that aims to show how general quality management system according to ISO 9000:2000 implemented in maintenance processes, they presented many factors for asset requirements on maintenance and achievement of defined maintenance quality characteristics. These factors include basic requirements for maintenance of assets, organizational structure, procedures and processes, maintenance financing, internal and external maintenance (outsourcing) and Information system and maintenance documentation. However they fail short of developing a standard for maintenance management.

Lewis (2009) conceptualized maintenance management as a quality assurance process by projecting the ISO 9001: 2000 standard on the maintenance management activities. He indicated that “most modern maintenance management activities are not linked to quality management systems”. However, he has not presented any quality criteria which can be clearly used for developing maintenance management standards.

There are several studies that listed several quality criteria that should be consider for developing maintenance management measurement system. It was noted, that previous research has not addressed a holistic approach for developing the required quality criteria for generic maintenance management as shown on Figure 2-2 which explain the variation in classifying maintenance management measurement for public schools. These studies include the following:

In their paper, Baharum et al. (2009) classified the measurable quality criteria for the assessment of property management service quality of purpose built office buildings into three major categories namely: functional, technical and image. The functional category included five criteria namely: reliability, responsiveness, assurance, empathy and tangibles. Also, five criteria were included in the technical category namely: cleanliness, building services, signage, security and parking. Lastly, the image category covered the criteria which focused on building aesthetics.

In their paper, Myeda et al. (2011) identified the key aspects of performance measurement for maintenance management of office buildings. Five buildings were selected as case studies. In total, 1,230 questionnaires were distributed to the end-users of the buildings. The structure of these questionnaires was divided into three parts namely, functional, technical and image. Each part has many categories that contained several quality criteria. Functional performance included five performance elements, namely: tangibles, reliability, responsiveness, empathy and assurance. Moreover, there were 12 performance elements in the technical performance. These elements include cleaning, landscaping, lightings, air-conditionings, lifts/escalators, mechanical and electrical, general maintenance, sanitary/plumbing, access, signage, parking and safety and security.

Finally, the image part included two performance elements, namely: external image and internal image.

According to Preiser et al., (1988), post occupancy evaluation (POE) process of buildings can be classified into three parts namely technical, functional and behavioural elements. The technical elements of performance deal with survival issues such as the health, safety and security and the performance of building systems. The technical elements can be characterized as the background environment for carrying out activities. The functional elements deal with the fit between the building and the user's activities.

Binggeli, (2010) in his paper, aimed to develop a custodial standard. His assessment to evaluate maintenance is based on five elements, namely cleanness, landscaping storage rooms, maintain structure systems and fire extinguisher.

Lawal and Adeyemo (2004) developed five criteria to assess maintenance of public organization which include:

Craft-hours Utilization (CU) = Total craft-hours worked/ total craft-hours clocked.

Work done Turnover (WT) = No. of jobs completed/ total number of jobs handled.

Downtime due to maintenance = Total downtime for service/ total shift hours worked.

Cost of spares and supplies = total cost of supplies and spares / total maintenance expenditure.

Cost reduction effort = Routine service workload/ cost of maintenance hours.

Ali and Wan Mohamad (2009) in their paper, aimed to evaluate maintenance management in public hospitals in Malaysia. Their assessment is based on five categorises, namely leadership, Policies, plan and procedures, Training and orientation, monitoring and supervision; and service performance. Every one of these categorises has several sub-factors; for example, when they evaluated service performance provided by contractors, they developed 12 factors which include:

(1) Asset registers management

(2) Infrastructures support

(3) Spares management

(4) PPM task lists

(5) PPM scheduling

(6) Safety management

(7) Statutory compliance

(8) Plant room management

(9) Maintenance performance

(10) Equipment history

(11) Quality assurance

(12) Competency training.

ISO 9001- 2008 developed quality management system based on five categories, namely quality management system, management responsibility, resource management, product realization, and Measurement, analysis and improvement.

In his paper, Lam (2001) listed several quality criteria such as high reliability of services, quick response to maintenance problems, on-going improvement and compliance with statutory requirements. Although these quality criteria can be used in developing maintenance management standards, Lam (2001), however, has not assessed these criteria, or suggested a way for their utilization.

Shamsuddin et al. (2004) listed several quality criteria to implement total quality management (TQM). These criteria included maintaining basic equipment condition, prevention of human error, detection of error at the source, caring for clean and tidy working environment, worker skill development for self-maintenance, maintaining operating standards, improving design weakness, establishing repair methods, prediction of deterioration, looking at the shop floor as the source of ideas, empowerment of workers, and formation of small group activities.

In his study, Alsyouf (2009) aimed at analysing the maintenance practices implemented in the Swedish industry. He presented several quality criteria that should be considered to analyse maintenance practices. The most important of these criteria included the implementation of computerized maintenance management systems (CMMS), recoding and analyzing failure data to improve causes of equipment failure, monitoring the rate of poor quality, monitoring spare parts and keeping cost at a level low, providing an

inventory between machines and comparing maintenance tasks based on statistical modelling and condition monitoring.

Cholasuke and Bhardwa (2004) presented the status of maintenance management in the UK manufacturing organizations. They conducted a survey which was divided into two parts: General information and Maintenance measurement. They developed ten elements for maintenance performance measures which included:

(1) Maintenance effectiveness,

(2) Maintenance policy and organization,

(3) Maintenance approach,

(4) Task planning and scheduling,

(5) Information management and CMMs

(6) Spare part management,

(7) Human resource management,

(8) Contracting out maintenance,

(9) Financial aspect,

(10) Continuous improvement.

Lwarere and lawal (2011) presented some factors that can be considered as the adverse consequences of effective maintenance in public facilities. These factors include "excessive machine breakdown, disproportionate investment in spare parts and maintenance materials, poor utilization of staff, low quality of service, abnormal overtime costs, irregular operating times, shortened life span of facilities, loss in production output and frequent machine breakdown".

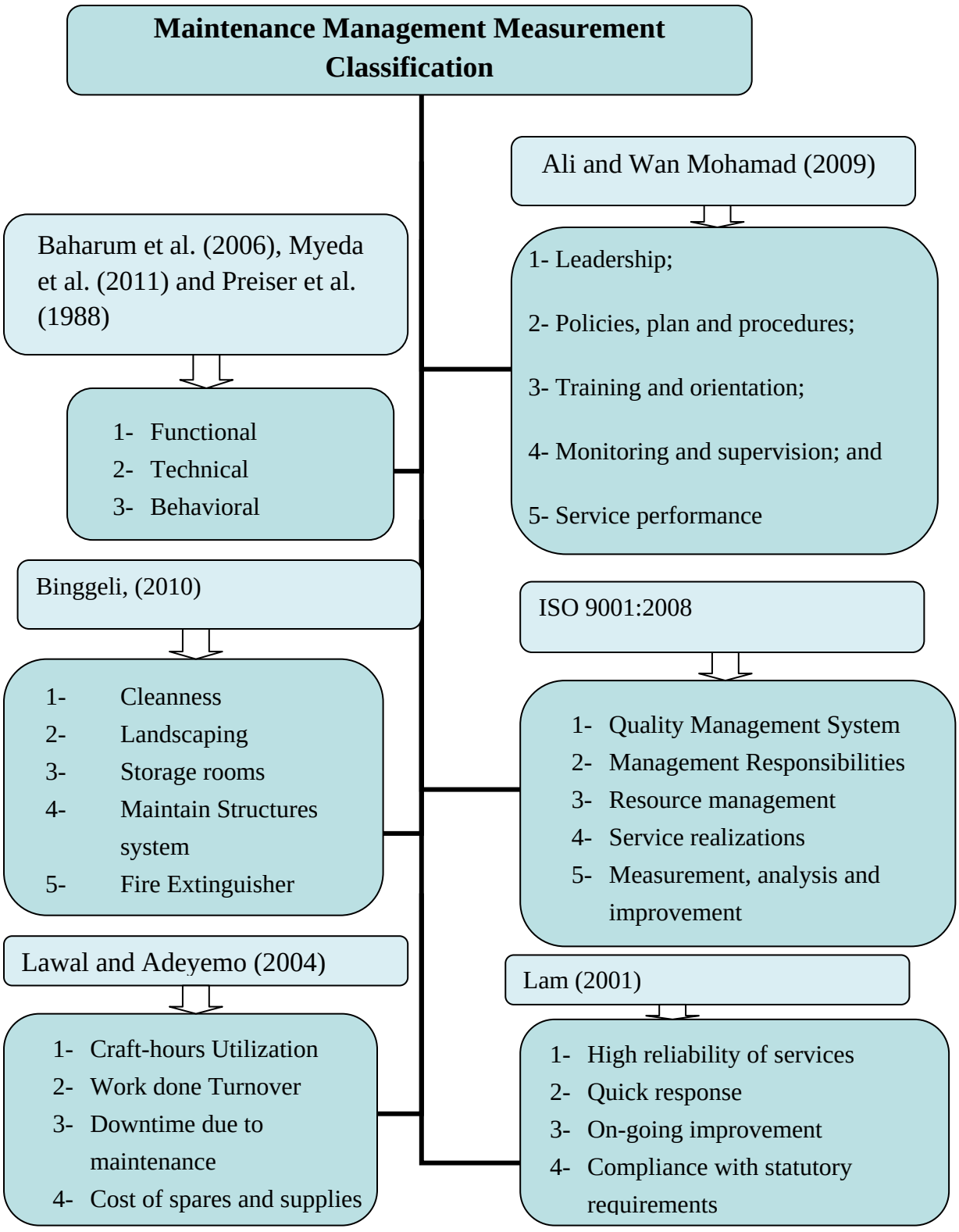

Figure 2-2 Various views on Maintenance Management Measurement Classifications

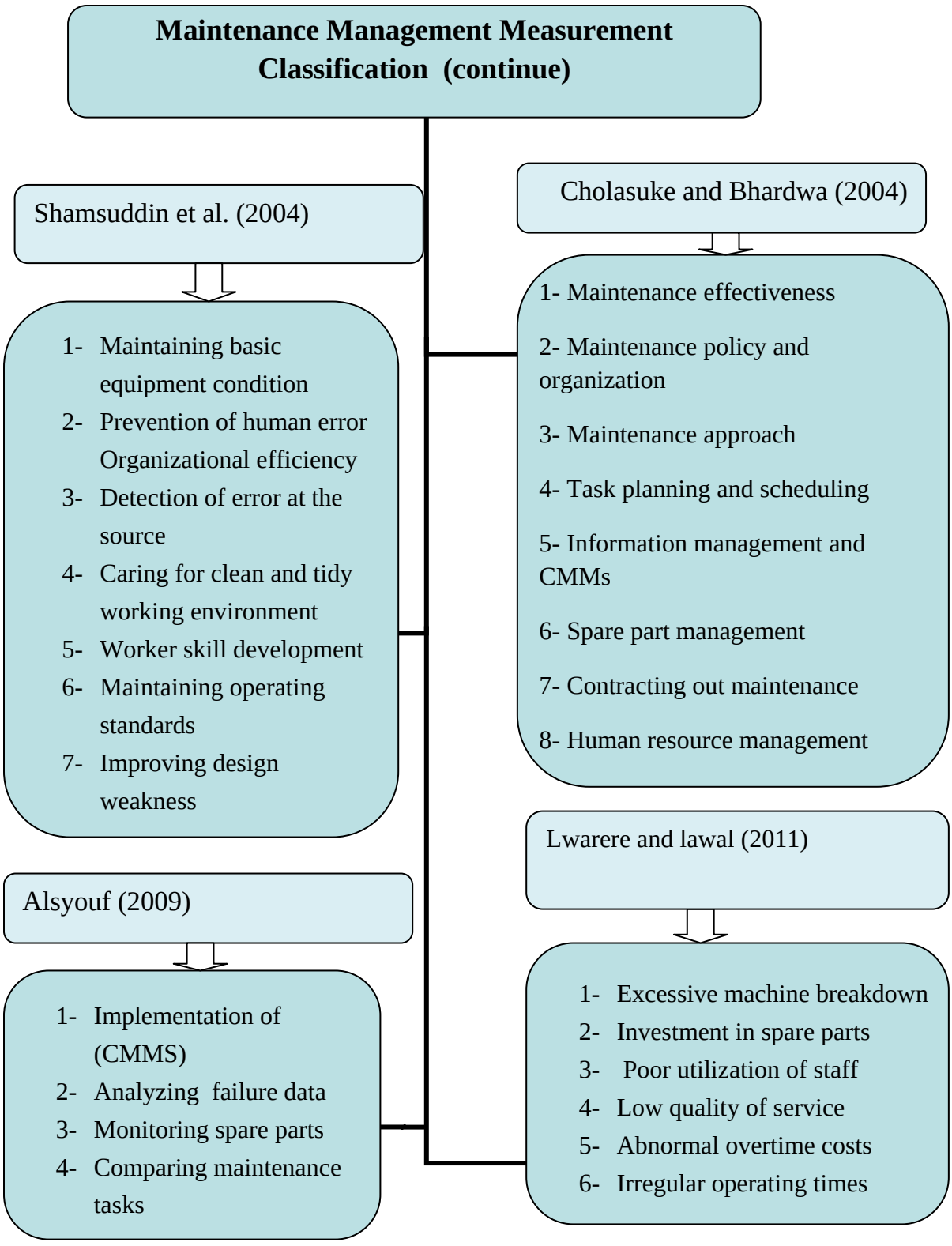

Figure 2-2 Various views on Maintenance Management Measurement Classifications (continue)

2.5 Development of an Effective Performance Measurement System

Oakland, (1995); Ovretveit, (1993); and Edvardsson et al., (1994) suggested many factors that must be considered to develop an effective performance measurement system. These factors are shown in Figure 2-3 namely purpose, criteria, method, time, evaluators, and use of the results.

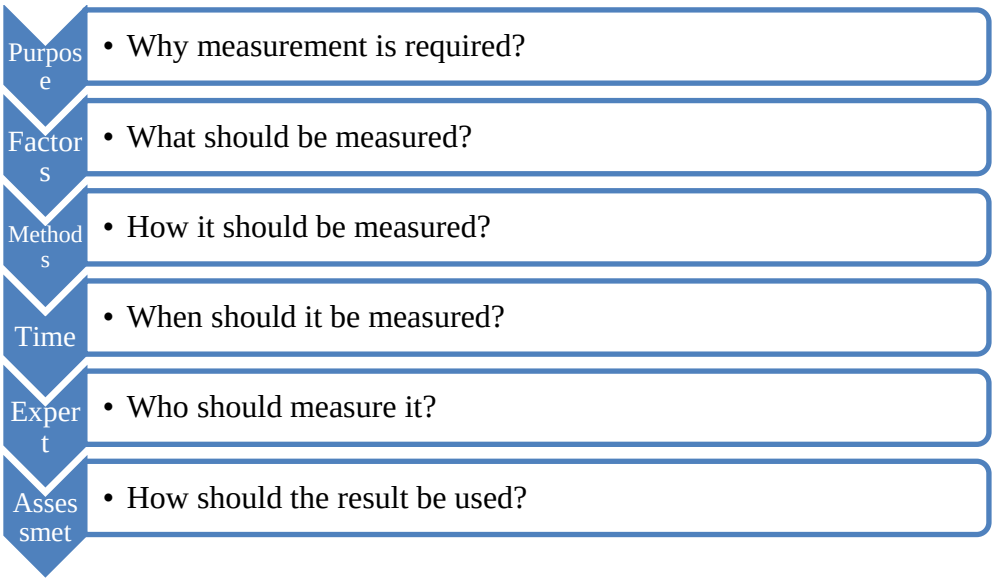

Figure 2-3 Factors Affecting Performance Measurement System

There are several studies that listed several maintenance management measurement methods. However, it was noted, that there was variation the variation in classifying maintenance management measurement methods for public buildings as shown in Figure 2-4. These studies include:

Coetzee (1998) developed comprehensive performance indicators and ratios. In doing so, classifications of 21 indices under four categories are identified below:

(1) machine/facility maintenance efficiency;

(2) Task efficiency;

(3) Organisational efficiency;

(4) profit/cost efficiency.

Brown et al. (1994) classified performance measurement methods into six types:

(1) Customer satisfaction measures;

(2) Financial measures;

(3) product/service quality measures;

(4) Employee satisfaction measures;

(5) Operational measures;

(6) Public responsibility measures.

Kutucuoglu et al., (2001), their proposed system which consisted of five types of measurement which included equipment related performance, task related performance, cost related performance, immediate customer impact related performance, and learning and growth related performance. They presented some features that should be included to develop an effective performance measurement system. These features include incorporate staff, overview of the system measured, implement multiple measured dimensions, analyze different hierarchies, link strategy to system measurement, and establish subjective and objective measurement.

The Florida Department of Education (1998) developed reference measures for maintenance and operations department effectiveness as shown in Table 2-3.

Table 2-3 Maintenance and Operation Department Effectiveness Standard (the Florida Department of Education, 1998)

Standard	**Reference Measures**
Adequate levels of maintenance	Did the department provide maintenance, custodial, and grounds services that were adequate to meet board, administration, and the general public's expectations?
Improved facility conditions	Did the department provide services that resulted in improved or enhanced conditions?
Cost effectiveness	Did the department conduct maintenance and operations activities in a cost effective manner?
Strategic plan implementation	Did the department develop and implement a strategic plan aimed at defining and addressing facility needs, shortcomings, and deficiencies in the years to come?
Cost-saving measures	Did the department implement measures to contain or reduce costs in certain areas of operation?
Educational support	How much and what types of services did the department provide that were in direct support of the educational process?
Overall effectiveness	Did the department achieve a level of effectiveness that is reflected in customer attitudes and perceptions?

Binggeli, (2010), classified maintenance measurement methods into two types are:

(1) Monthly Custodial Preventive Maintenance Sheet.

(2) Monthly Integrated Pest Management Checklist Custodial programs.

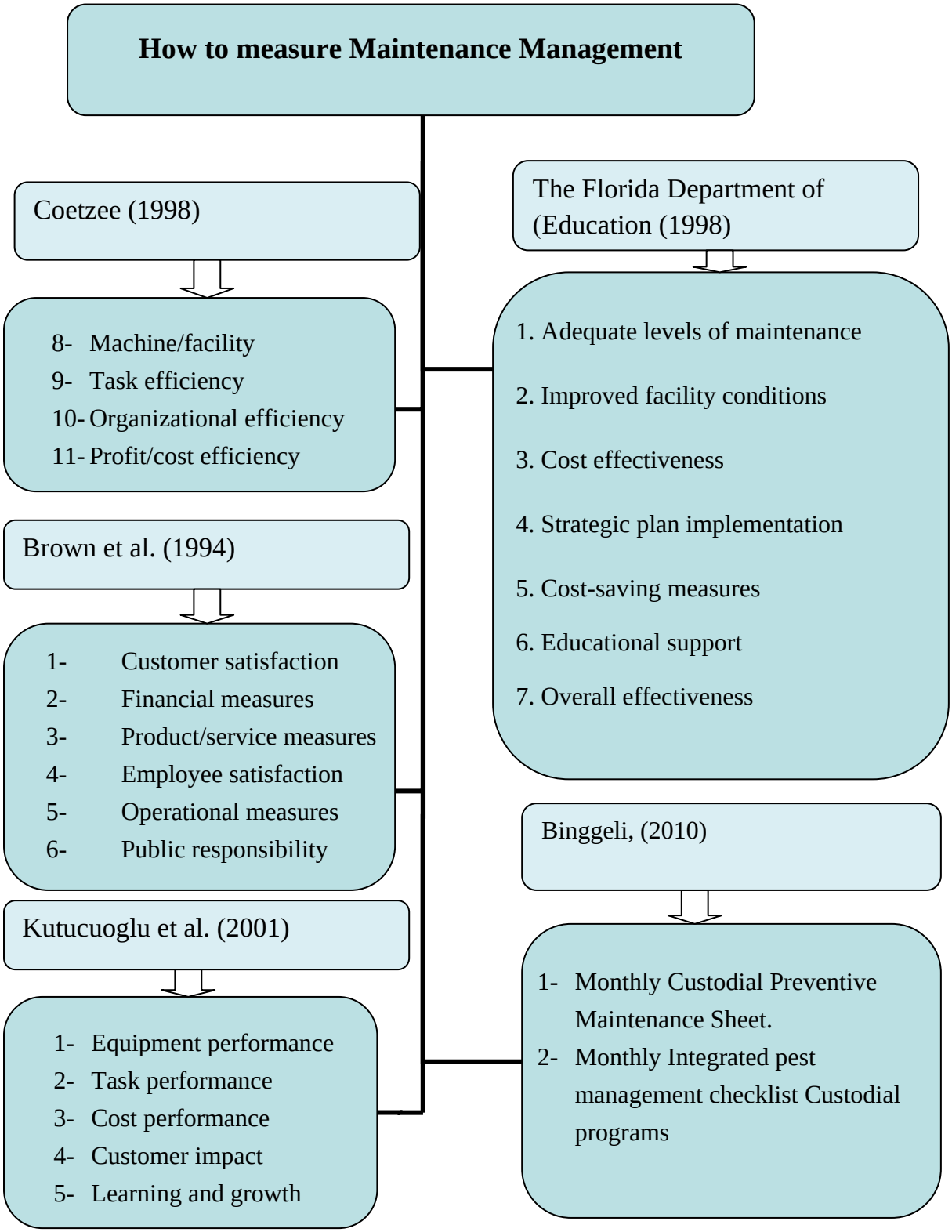

Figure 2-4 Maintenance Management Measurement Methodology

2.6 Identification of the Measurable Quality Criteria

In Saudi Arabia, research for maintenance management systems for school buildings necessitates the need to develop assessment tools for maintenance management. Based on the review of literature as indicated in sections 2.2- 2.5, sixty two elements under twenty measurable quality criteria have been identified. These criteria have been classified into four main categories in order to group the common criteria which address the same issue. These categories are as follows:

(1) Technical Category

(2) Functional Category

(3) Behavioural Category

(4) Managerial Category

The main and subcategories are shown in Figure 2-5. A wide scope review of literature in related areas indicates that there were variations between previous researches for defining these measurable quality criteria.

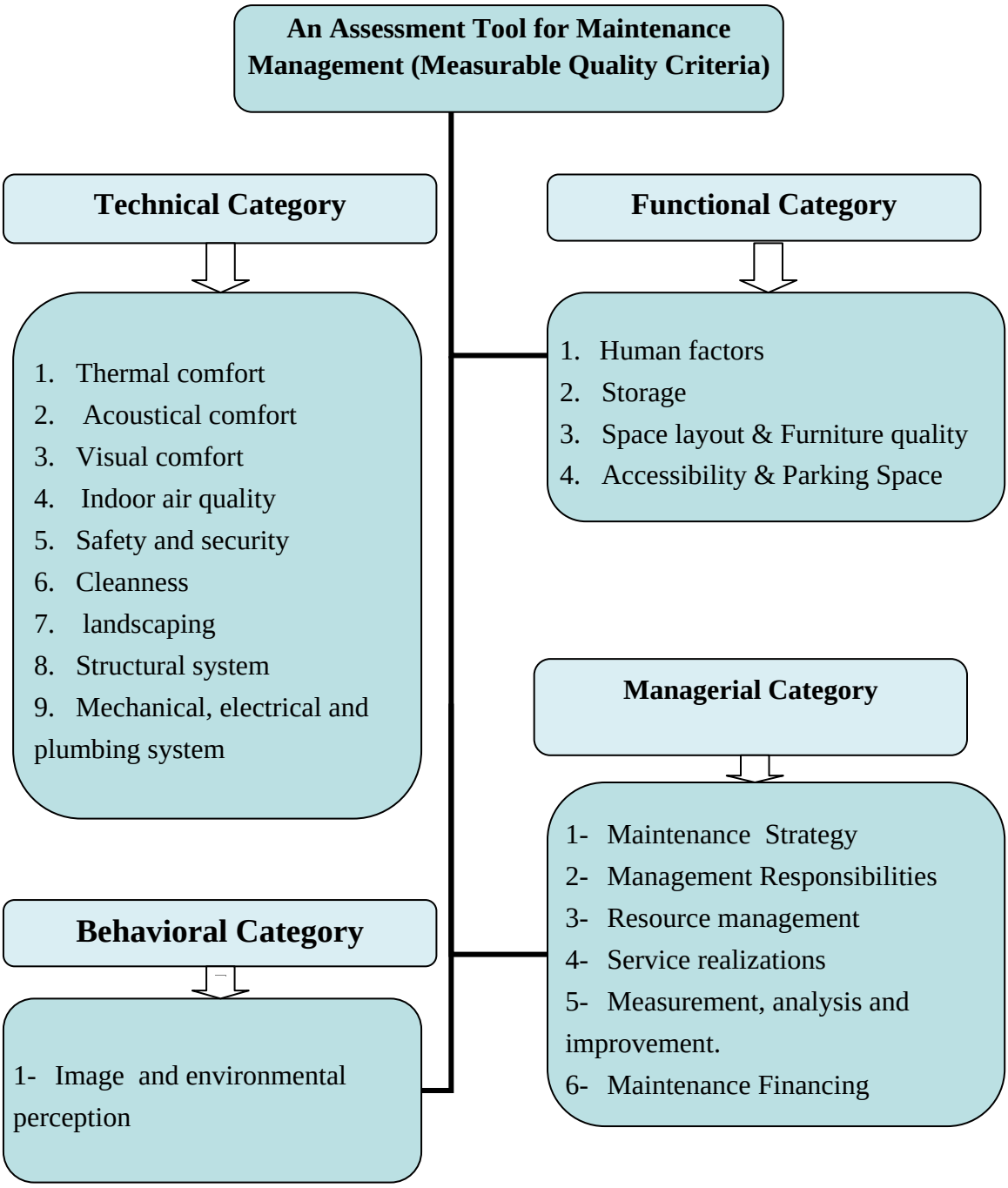

Figure 2-5 An Assessment Tool for Maintenance Management (Measurable Quality Criteria)

2.6.1 Technical Category

The technical category can be defined as issues dealing with the performance of the building systems and reflects the environmental background (Preiser, et al. 1988). The criteria in this category include the following:

2.6.1.1 Thermal Comfort

The thermal comfort criterion is considered as one of the main technical criteria that need to be taken into account when measuring the maintenance performance of public schools (ASHRAE, 2004; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). The reviewed research works showed the contradiction in definitions of this criterion as shown in Table 2-8. The "Thermal Comfort" criterion identified using the following different terms: "Servicing and repair of heating system" (Arkansas, 2009), "Troubleshooting of heating system'' (Binggeli, 2010), "Distribution of air within the optimum temperature" (Myeda et al., 2011), "Inspecting heating and cooling" (Minnesota, 2000) and "Thermal Comfort" (ASHRAE. ,2004; Indiana School Design Guidelines, 2009; Prakash, 2005 ; Steskens and Loomans, 2010 and LEED, 2008).Thermal comfort can be defined as "the state of mind in humans that expresses satisfaction with the surrounding environment" (ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy, 2007). The measurable quality criteria be classified into two elements which are:

1) Provision of comfortable temperature during summer throughout all spaces in the building (ASHRAE, 2004; Indiana School Design Guidelines, 2009; Prakash, 2005; and LEED, 2008). This can be assessed by measurement through devices such as the

Solomat Meter to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (22-27 ° C) as shown in Figure 2-6 and survey occupants that must meet comfort needs of the majority (at least 80%) of the occupants.

2) Provision of comfortable temperature during winter throughout all spaces in the building (ASHRAE, 2004; Indiana School Design Guidelines, 2009; Prakash, 2005; and LEED, 2008). Similarly, this can be implemented with the above mention method for the first element.

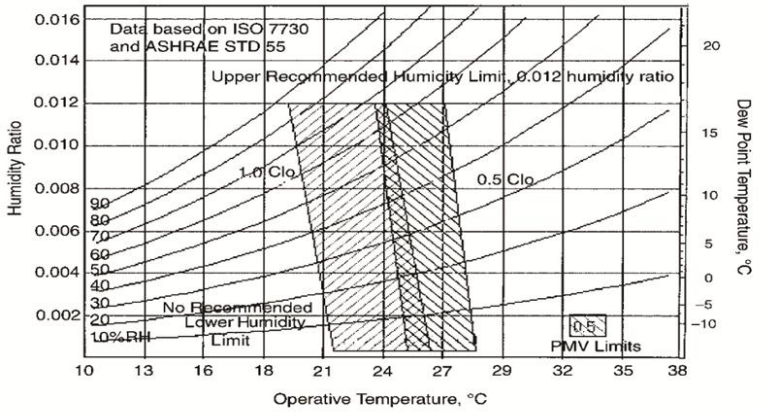

Figure 2-6 Acceptable Range of Thermal Comfort by ASHRAE Standard (55), 2004

2.6.1.2 Acoustical Comfort

The acoustical comfort criterion should be considered in the development of an assessment tool of maintenance management in public schools (ANSI, 2002; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). It is noticed that there is inconsistency in the definition of this criteria as

shown in Table 2-8. An "Acoustical Comfort" criterion was identified using the following different terms: "Vibration and noise" (Arkansas, 2009; Bruce, et al., 1998 and Kibert, 2005), "Noise Pollution or Vibration'' (Khalil and Nawawi, 2008) and "Acoustical comfort'' (ANSI, 2002; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). The acoustic comfort in a room can be defined as "providing acoustic conditions in a building that facilitate clear communication of speech between the users of the building'' (Steskens and Loomans, 2010). The measurable quality criteria can be classified into three elements which are:

1) Provision of acoustical comfort throughout all spaces in the building (ANSI, 2002; Indiana School Design Guidelines, 2009; Prakash, 2005; Arkansas, 2009 and LEED, 2008). This can be assessed by measurement through devices such as a Dosimeter as shown in Figure 2-7 or t Sound Level Meter to achieve the requirements of ANSI S12.60 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools standard (background sound pressure level 35-40 decibels (dB) as a maximum).

Figure 2-7 Dosimeter Device (Prakash, 2005)

2) Provision of a system for regularly evaluating the quality of acoustical comfort through all spaces in the building (Minnesota, 2000). This can be assessed by proof of a documented system for regularly evaluating the quality of acoustical comfort.
3) Implementation of noise control and speech privacy measures wherever needed (Khalil and Nawawi, 2008). This can be assessed by surveying occupants to assess their satisfaction with acoustical comfort.

Egan (1972) presents the range of approximate equivalent sound level (dBA) for specific types of rooms as shown in Table 2-4.

Table 2-4 Recommended Noise Criteria for Rooms (Egan, 1972)

Location	dBA
For excellent listening conditions – concert halls, recording studios	25-30
For sleeping, resting, relaxing	30-40
For good listening conditions – private offices, conference rooms	40-45
For fair listening conditions – reception areas, restaurants	45-50
For moderately fair listening conditions – lobbies, corridors	50-55
For poor listening conditions – kitchens, industrial shops, garages	55-65

2.6.1.3 Visual Comfort

The visual comfort criterion is considered as one of the main technical criteria that need to be taken into account for development of an assessment tool of maintenance management in public schools (IESNA, 2000; Khalil &Nawawi, 2008; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). The reviewed research works showed the contradiction in definitions of this criterion as shown in Table 2-8. A "Visual Comfort" criterion was identified by the following different terms: "Visual Comfort'' (IESNA, 2000; Khalil &Nawawi, 2008; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008), "All lighting in proper working order" (Binggeli, 2010) and "Inspection of interior and exterior lighting" (Arkansas, 2009). Visual comfort can be defined as a term which "represents a positive or neutral user/occupant evaluation of the lighting conditions in a space" (Indiana School Design Guidelines, 2009). Glare, which is a result of light source and reflector position, can cause discomfort, in some cases giving headaches to the occupants, and hinder in task performance (Kibert, 2005). The assessment tools to measure maintenance management of visual comfort can be classified into two elements:

1) Provision of good appearance and quality of lighting as per identified standards (IESNA., 2000; Khalil &Nawawi, 2008; Indiana School Design Guidelines, 2009; Prakash; Binggeli, 2010 and LEED, 2008). Figure 2-8 presents recommended illuminance levels for rooms with different functions as provided by the European Standard (BS EN 12464-1 Light and lighting - Lighting of work places, 2003).

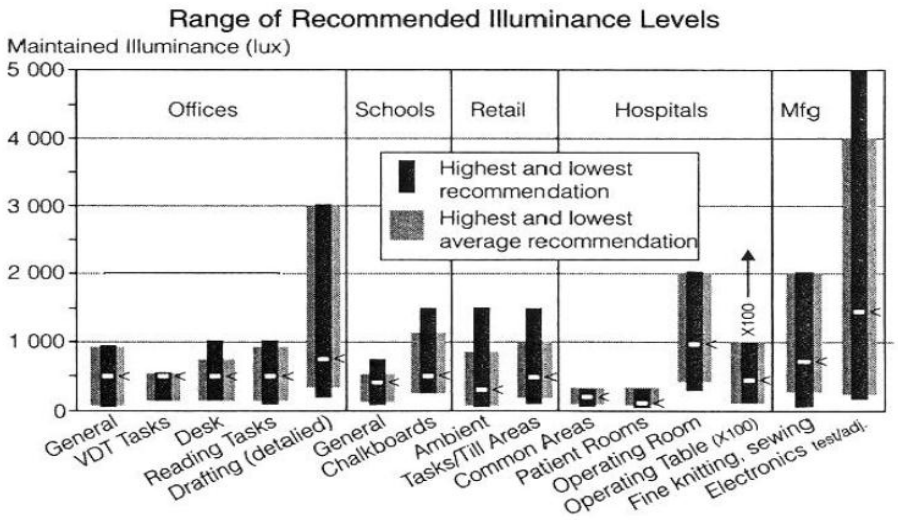

Figure 2-8 Rang of Recommended Illuminance levels (the European Standard, 2003)

This can be assessed by measurement through devices such as a light meter as shown in Figure 2-9 or Lux Meter to achieve the requirements of Illuminating Engineering Society of North America IESNA Lighting Handbook (typical classroom reading tasks is 30 foot-candles (FC) or European Standard (BS EN 12464-1 Light and lighting - Lighting of workplaces, 2003) illuminance levels for reading task (500-900 lux).

Figure 2-9 A light Meter Device (Prakash, 2005)

2) Provision of a system for regularly evaluating the quality of lighting throughout all spaces in the building (Arkansas, 2009). This can by assessed by proof of a documented system for regularly evaluating the quality of visual comfort.

2.6.1.4 Indoor Air Quality

One of the most important technical criteria that need to be considered for development of an assessment tool of maintenance management in public schools is the indoor air quality criterion (Myeda et al., 2011; Howard, 2006; Minnesota, 2000; Steskens and Loomans, 2010 and ASHRAE Standard 62.1, 2007). Based on a review of literature, there are different terminologies which define indoor air quality as shown in Table 2-8. The "Indoor Air Quality" criterion was identified using the following different terms: "Natural or mechanical ventilation levels'' (Binggeli, 2010), "Ventilation and air-conditioning system" (Arkansas, 2009) and "Indoor Air Quality" (Myeda et al., 2011; Howard, 2006; Minnesota, 2000; Steskens and Loomans, 2010 and ASHRAE Standard 62.1, 2007). Table 2-5 represents the minimum ventilation rate requirements by ASHRAE Standard 62.1-2007.

Table 2-5 Minimum Ventilation Rate Requirements by ASHRAE Standard 62.1-2007

Occupancy Category	People Outdoor Air Rate R_P		Area Outdoor Air Rate R_A	
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2
Correctional Facilities				
Cell	5	2.5	0.12	0.6
Day room	5	2.5	0.06	0.3
Guard stations	5	2.5	0.06	0.3
Booking/waiting	7.5	3.8	0.06	0.3
Educational Facilities				
Daycare (through age 4)	10	5	0.18	0.9
Classrooms (ages 5-8)	10	5	0.12	0.6
Classrooms (age 9 plus)	10	5	0.12	0.6
Lecture classroom	7.5	3.8	0.06	0.3
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3
Art classroom	10	5.0	0.18	0.9
Science laboratories	10	5.0	0.18	0.9

Regarding the ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality, acceptable indoor air quality can be defined as: “air in which there are no known contaminants at harmful concentrations”. The assessment tools to assess maintenance management of indoor air quality can be classified into two elements:

1) Implementation of periodical inspection of the HVAC system to comply with ASHRAE Standard 62.1(Myeda et al., 2011; Howard, 2006; Minnesota, 2000; Binggeli, 2010 and ASHRAE Standard 62.1, 2007). This can be assessed by measurement through devices to achieve the requirements of ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality (people outdoor air rate for classrooms 5 l/s per person). Also, it can be by measured by devices such as Co_2 Gas Monitor or IAQ monitor devices as shown in Figure 2-10 to achieve the requirements of ASTM D6245 - 12 Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation (Carbon dioxide < 1000 ppm).
2) Provision of a system for regularly evaluating indoor air quality throughout all spaces in the building including procedures for managing processes with potentially significant pollutant sources and procedures for responding to IAQ complaints (Arkansas, 2009 and Minnesota, 2000). This can be assessed by proof of a documented system for regularly evaluating indoor air quality.

Figure 2-10 IAQ Monitor Device (Prakash, 2005)

2.6.1.5 Safety and Security

The development of an assessment tool of maintenance management in public schools should consider safety and security criteria (Preiser, et al., 1988; Myeda et al., 2011; Baharum et al., 2009; Florida, 2010; Cholasuke and Bhardwa, 2004; Arkansas, 2009; Khalil and Nawawi, 2008; Alsyouf, 2009 and The Institute for Security and Open Methodologies (ISECOM)). It is noticed that there is no inconsistency in the definition of this criterion as shown in Table 2-8. Safety can be defined as "the control of recognized hazards to achieve an acceptable level of risk". Also, security can be defined as "a form of protection where a separation is created between the assets and the threat" (The Institute for Security and Open Methodologies (ISECOM). Three measurable quality criteria can be developed to assess this category which includes:

1) Proof of compliance with the local safety statutory requirements (Lam, 2001; Arkansas, 2009; and Ali and Wan Mohamad, 2009).
2) Provision of a checklist for regular upkeep of safety systems throughout all spaces in the building as well as the playgrounds (Preiser, et al., 1988; Myeda et al., 2011; Baharum et al., 2009; Florida, 2010; Cholasuke and Bhardwa, 2004); Arkansas, 2009; Khalil and Nawawi, 2008; and Alsyouf, 2009).
3) Proof of an evacuation drill at least once a year (Binggeli, 2010 and Arkansas, 2009).

The Saudi Civil Defense provided preventive requirements for the protection against fire in educational buildings; Table 2-6 shows the general requirements of ways to escape (emergency exits).

Table 2-6 General Requirements of Ways to Escape (Emergency Exits), Source http://www.998.gov.sa/English/safety/SafetyInstructionList/Pages/SafetyInstForEduBuilding

General requirements of ways to escape (emergency exits)	
3-1	Ways to escape (emergency exits:(Ways to escape (emergency exits) are (passage) or more safe passages to allow the people who are found in the building from escaping through any starting point in the building to reach the outside of the building directly. Or to a safe place from fire, which in its turn leads to the outside of the building where it is away from fire.
3-1/1	Adequate ways to escape (emergency exits) must be provided in the buildings, facilities and shops, in order to find a way out to evacuate the users and occupants of the building, and to keep them away from the fire sector, in order to protect them and their lives from injury and fire.
3-1/2	Ways of escape (emergency doors) is consisted from different parts such as passage, stairs, balconies, bridges, slopes, doors, exits, and others. It consist totally a whole unit (emergency doors) ways to escape).
3-1/3	All of the facilities, buildings, and shops under the license civil defense Must be equipped with fire-fighting equipment and warning alarms and appropriate prevention in accordance with these conditions.
3-1/4	You may not make any amendments or additions to the building which could breach these conditions, as well as you may not change the nature of the exploitation of the building unless the ways of escape are modified (emergency exits) to suit the new exploitation conditions.
3-1/5	Civil Defense the right to set conditions as it deems appropriate for special cases and in which there was no text set, or in which he sees that there is an unusual risk of fire.

2.6.1.6 Cleanness

The cleanness criterion is one of the most important technical criteria that need to be considered in the development of an assessment tool of maintenance management in public schools (Arkansas, 2009; Binggeli, 2010; Baharum et al., 2009; Khalil and Nawawi (2008); Shamsuddin et al. (2006); and Tucker and Pitt, 2010). Based on a review of literature, there are different terminologies which define cleanness as shown in Table 2-8. The "Cleanness" criterion was identified using as the following different terms: "Caring for cleanliness and tidy working environment" (Myeda et al., 2011 and; Arkansas, 2009); "Custodial Standards'' (Binggeli, 2010) and "Cleanliness" (Arkansas, 2009; Binggeli, 2010; Baharum et al., 2009; Khalil and Nawawi (2008); Shamsuddin et al. (2006); and Tucker and Pitt, 2010). Cleanness can be defined as "routine and renovation cleaning activities related to daily operations and upkeep of facilities, including related supervisory and management activities" (Arkansas, 2009). The assessment tools to measure maintenance management of cleanness can be classified into five elements:

1) Implementation of preventive maintenance plan for cleanliness (Arkansas,2009; Binggeli, 2010 ; Baharum et al. ,2009 ;Myeda et (2011) ; Khalil &Nawawi (2008) ; Shamsuddin et al. (2006) and Tucker and Pitt, 2010).
2) Ensuring the overall cleanliness throughout all spaces in the building (Binggeli, 2010; Shamsuddin et al., 2006; Myeda et al., 2011; Arkansas, 2009 and Custodial Standards, 2010).
3) Supporting a recycling program during the cleanliness process (Binggeli, 2010).

4) Ensuring the overall cleanliness of laboratories including removal of foreign materials (Binggeli, 2010).
5) Provision of a system for regularly evaluating the quality of cleanliness and custodial programs throughout all spaces (including bathrooms) in the building (Binggeli, 2010 and Arkansas, 2009).

These measurable criteria can be assessed by walkthrough inspection including evidence of implementing a recycle program, proof of a document system for regularly evaluating the quality of cleanliness and custodial programs, and conducting a survey of occupants to assess their satisfaction with cleanness. Binggeli (2010) developed a custodial service cleanliness evaluation checklist, as shown in Figure 2-11.

Custodial Service Cleanliness Evaluation

Your room was ***PROFESSIONALLY*** cleaned last night by _____. Please take the time and look around your room, workstation, and restroom areas. I would appreciate any comments or recommendations that you make.

- Trash receptacles empty and cleaned? _____
- Workstation (desk) dusted? _____
- Shelves cleaned and dusted? _____
- File cabinets dusted? _____
- Carpet vacuumed? _____
- Stains removed? _____
- Floor has luster? _____
- Floor cleaned? _____
- Restrooms cleaned and stocked? _____
- Baseboards cleaned? _____
- Windows cleaned and cobweb free? _____
- Ledges cleaned and dusted? _____

- **Comments:**_____

Figure 2-11 Custodial Service Cleanliness Evaluation (Binggeli, 2010)

2.6.1.7 Maintaining Landscaping

Maintaining the landscaping criterion should be considered in measuring the maintenance performance of public schools (Myeda et al, 2011; Arkansas, 2009 and Binggeli, 2010). It is noticed that there is inconsistency in the definition of this criteria as shown in Table 2-8. The "Landscaping" criterion was identifying using as the following different terms: "Landscaping'' (Binggeli, 2010), "Indoor and outdoor plants" (Myeda et al., 2011) and "Playground inspections" (Arkansas, 2009). Landscaping can be defined as "any activity that modifies the visible features of an area of land" (http://en.wikipedia.org/wiki/Landscaping). Two measurable quality criteria were identified to assess this category which includes:

1) Implementation of periodical checking for both indoor and outdoor plants (Myeda et al, 2011; Arkansas, 2009 and Binggeli, 2010).This can be implemented by walk-through inspections to ensure the periodical checking of both indoor and outdoor plants.
2) Provision of a system for regularly evaluating the quality of landscaping throughout all spaces in the building (Binggeli, 2010 and Arkansas, 2009). This can be assessed by proof of a document system for regularly evaluating the quality of landscaping and by conducting a survey of the occupants survey to ensure their satisfaction.

2.6.1.8 Maintain Structural Systems

The maintenance of structural systems criterion is considered as one of the main technical criteria that need to be taken into account in measuring the maintenance performance of public schools (Khalil and Nawawi, 2008; Binggeli, 2010; Cripps, 1984 and Baharum et al., 2009). It is noticed that there is a contradiction in definitions of this criterion as shown in Table 2-8. The "Structural Systems" criterion was identified using the following different terms: "Structural Systems'' (Khalil and Nawawi, 2008; Binggeli, 2010; Cripps, 1984 and Baharum et al., 2009), "Early diagnosing of various cracks, scratches and corrosion and their causes" (Preiser, et al., 1988) and "Inspection and repair of masonry and concrete building exteriors" (Arkansas, 2009). Maintaining Structural Systems can be defined as "regular maintenance of the structure of a building, including walls, floors, roofs, windows, doors, sanitary fittings and plumbing, drains, fire escapes, yard, roads and cleaning, and restoration of elevation" (Cripps,1984). The assessment tools to assess maintenance management of structural systems can be classified into three elements that include:

1) Implementation of periodical checking of structural systems in the building as well as removal of any overload (Preiser, et al., 1988; Binggeli, 2010; Khalil and Nawawi, 2008 and Baharum et al., 2009). This can be measured by walkthrough inspections to assure the periodical checking of the structural systems of a building, as well as the removal of any overload.
2) Provision of a system for regularly evaluating the quality of maintaining structural systems throughout all spaces in the building (Arkansas, 2009). This can be

implemented by proof of a document system for regularly evaluating the quality for maintaining structural systems.

2.6.1.9 Mechanical, Electrical and Plumbing Systems

The development of an assessment tool of maintenance management in public schools should consider mechanical, electrical and plumbing systems criteria (Myeda et al., 2011; Khalil &Nawawi, 2008; Alsyouf and Tucker & Pitt, 2010; Binggeli, 2010 and Arkansas, 2009). It is noticed that there is no inconsistency in the definition of this criteria as shown in Table 2-8. Based on the literature reviewed as shown below, four performance measures were included as follows:

1) Implementation of preventive maintenance of the mechanical and electrical systems (Myeda et al., 2011; Khalil &Nawawi, 2008; Alsyouf and Tucker & Pitt, 2010 and Arkansas, 2009).
2) Implementation of a periodical inspection of the water supply / sanitary systems (Myeda et al., 2011; Khalil &Nawawi, 2008; Alsyouf, 2009; Binggeli, 2010 and Arkansas, 2009).
3) Provision of a system for regularly checking the availability of spare parts required and their efficient use (Lwarere and lawal, 2011).
4) Provision of a system for regularly evaluating the quality of drinking water (Myeda et al., 2011; Khalil &Nawawi 2008; and Arkansas, 2009).

These measurable criteria can be assessed by proof of a documented system of preventive maintenance for mechanical, electrical and plumbing systems and proof of a documented system of monitoring spare parts and their efficient use.

2.6.2 Functional Category

According to Preiser, et al. (1988), the functional category can be defined as criteria that deal with the following "support the activities within the building, and they must be responsive to the specific needs of the organization and occupants, both quantitatively and qualitatively".

2.6.2.1 Human Factors

The human criterion is considered as one of the main functional criteria that need to be considered in measuring the maintenance performance of public schools (Preiser, et al., 1988; Peggy, 1999 and Myeda et al., 2011). It is noticed that there is no inconsistency in the definition of this criteria as shown in Table 2-8. According to Preiser, et al. (1988) human factors can be defined as "factors concerned with the dimensions and configurations of the designed environment, often the near environment, to match building occupants' physiological needs and physical dimensions". Two measurable quality criteria have been determined to assess this category:

1) Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process (Peggy, 1999). This can be assessed by proof

of a documented system to instruct maintenance staff to minimize the interruption of the educational process.

2) Availability of maintenance staff to provide any assistance required and eases of contacting them and their comprehension of user's requirements (Myeda et al., 2011 and Peggy, 1999). This can be measured by surveying occupants to assess their satisfaction with staff response.

2.6.2.2 Storage

One of the most important functional criteria that need to be considered for development of an assessment tool of maintenance management in public schools is the storage criterion (The City of Casselberry, 2010, Arkansas, 2009 and Binggeli, 2010). It is noticed that there is no inconsistency in the definition of this criteria as shown in Table 2-8. Two measurable quality criteria can be developed to assess this category which includes:

1) Provision of enough storage space for maintenance supplies/spare parts as well as required inventory (The City of Casselberry, 2010, Arkansas, 2009 and Binggeli, 2010).
2) Provision of sealable, labeled containers for the storage of chemical products and supplies (The city of Casselberry, 2010).

These measurable quality criteria can be implemented by walkthrough inspections to assure that there is enough storage space for maintenance supplies/spare parts, as well as

by conducting an inventory and a survey of occupants to assess their satisfaction with the storage of chemical products and supplies.

2.6.2.3 Space Layout and Furniture Quality

The development of an assessment tool of maintenance management in public schools should consider space layout and furniture quality criteria (Preiser, et al., 1988; Fink, 1992 and Hassanain, 2008). It is noticed that there is no inconsistency in the definition of this criterion as shown in Table 2-8. Space layout can be defined as "The process of establishing, sizing, and locating the appropriate production and support activities within a new or existing structure" (Fink, 1992). This category deals with the arrangement of furniture. Four measurable quality criteria have been determined to assess this category and they are:

1) Implementation of periodical checking of the availability of teaching tools and making sure that they are ready to be used (AL-Maged, 2012).
2) Implementation of a periodical checking system of furniture arrangement in the classrooms and making sure that they are sufficient for students and teachers, especially at the beginning of each semester (AL-Qrni, 2012).
3) Implementation of periodical checking of the adequacy and capacity of teachers' offices and computer laboratories (Preiser, et al., 1988 and Hassanain, 2008).
4) Provision of a system for regularly evaluating the arrangement of furniture in classrooms and teachers' offices (AL-Maged, 2012).

These measurable quality criteria can be implemented by walkthrough inspections to ensure the arrangement of furniture and teaching tools that are ready to be used,

providing proof of a document system for regularly evaluating the arrangement of furniture and a survey of occupants to assess their satisfaction with the space layout and furniture quality.

2.6.2.4 Accessibility and Parking Space

The development of an assessment tool of maintenance management in public school should consider accessibility and parking space criteria (Myeda et al., 2011; Preiser, et al., 1988; Hassanain, 2008 Arkansas, 2009 and Baharum et al., 2009). It is noticed that there is no inconsistency in the definition of this criteria as shown in Table 2-8. Accessibility can be defined as "Ease with which a facility or location can be reached from other locations" (http://www.businessdictionary). Eight measurable quality criteria have been determined to assess this category which are:

1) Implementation of the periodical checking of the function and position of all signage (Myeda et al., 2011 and Baharum et al., 2009).
2) Implementation of the periodical checking of the ease of identifying and reaching the building's main entrance (Myeda et al., 2011).
3) Implementation of the periodical checking of the ease by which visitors can locate rooms in the building (Preiser, et al., 1988 and Hassanain, 2008).
4) Implementation of the periodical checking of the availability of emergency signage (Myeda et al., 2011).
5) Proximity of the building to car parking spaces (Preiser, et al., 1988 and

Hassanain, 2008).

6) Sufficient number of car parking spaces (Myeda et al., 2011; Arkansas, 2009 and Baharum et al., 2009).
7) Availability of ease of access for the handicapped (AL-Hammad, 2012).
8) Provision of a system for regularly evaluating the quality of the accessibility function (AL-Qrni, 2012).

These measurable quality criteria can be implemented by walkthrough inspection to ensure the quality of the accessibility function (including availability of emergency signage and ease of access for the handicapped), proof of a documented system for regularly evaluating the quality of the accessibility function and a survey of occupants to assess their satisfaction with the quality of the accessibility function.

2.6.3 Behavioral Category

According to Preiser, et al. (1988), behavioral category can be defined as the criteria that "deal with the perceptions and psychological needs of the building users and how they interact with the facility image and environmental perception".

2.6.3.1 Image and Environmental Perception

The most important behavioral criteria that need to be considered for development of an assessment tool of maintenance management in public schools are image and

environmental perception criteria (Preiser, et al., 1988; Khalil and Nawawi, 2008; Myeda et al., 2011 and Baharum et al., 2009). Based on a review of literature, there are different terminologies which define management responsibilities as shown in Table 2-8. The "Image and Environmental Perception" criterion was identifying the following different terms: "Image and Environmental Perception" (Preiser, et al., 1988; Khalil and Nawawi, 2008; Myeda et al., 2011 and Baharum et al., 2009) and "Interior and exterior finishes" (Binggeli, 2010).According to Preiser, et al. (1988); image and environmental perception can be defined as "the significant effect of the building design on their occupant's or visitors' perception". The measurable quality criteria in this category can be classified into two elements which include:

1) Implementation of periodical checking for the quality of interior and exterior finishing throughout all spaces in the building (Khalil and Nawawi, 2008; Baharum et al., 2009 and Myeda et al., 2011).
2) Provision of a system for regularly evaluating the quality of interior and exterior finishing throughout all spaces in the building (Binggeli, 2010).

Image and environmental perception can be measured by walkthrough inspections to ensure the quality of interior and exterior finishing, proof of a document system for regularly evaluating interior and exterior finishing and a survey of occupants to assess their satisfaction with the quality of interior and exterior finishing.

2.6.4 Managerial Category

The managerial category deals with any administrative action which is referred to in the definition of maintenance by British Standard Glossary of Terms (3811:1993) that defines maintenance as "the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function". Legat and Jurca (2004) developed a model of maintenance management using a quality management system approach, as shown in Figure 2-12.

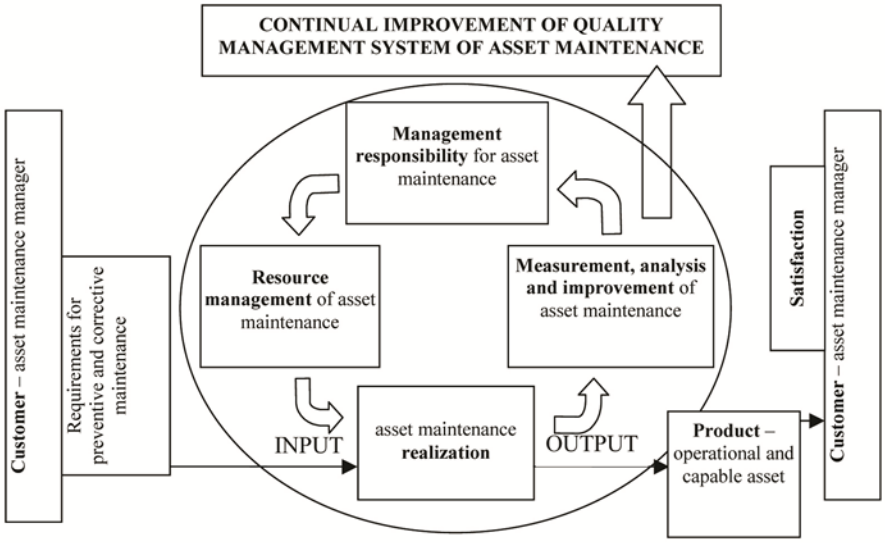

Figure 2-12 Maintenance Management Using Quality Approach (Legat and Jurca, 2004)

2.6.4.1 Maintenance Strategy

The maintenance strategy criterion is considered as one of the main managerial criteria that need to be considered for development of an assessment tool of maintenance management in public schools (Howard, 2006 and Wireman, 2005). It is noticed that there is inconsistency in the definition of this criteria as shown in Table 2-8. "Maintenance Strategy" criterion was identified using the following different terms: "Plan strategically'' (Minnesota, 2000) and "Maintenance Strategy" (Howard, 2006 and Wireman, 2005). Maintenance strategy can be defined as "a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function" (http://www.kwaliteg.co.za). According to ISO 9001:2008 and different references as shown below, assessment tools to assess the implementation of a maintenance strategy in the maintenance management department can be classified into three elements that include:

1) The maintenance department must have a process for identifying the most effective maintenance strategy/tasks (ISO 9001:2008; Minnesota, 2000 and Howard, 2006). This can be assessed by proof of a documented system for maintenance strategy, quality policy, objective, operation procedures and control procedures.
2) The maintenance management department has a quality manual that documents maintenance quality policy, objectives and controls and operation procedures (ISO 9001:2008).

3) The maintenance department must have a comprehensive database for each school including building systems and equipment with information such as location, warranty information, and replacement parts (Minnesota, 2000).

These elements can be assessed by providing proof of a documented system for maintenance strategy, a quality policy, objectives, an operation procedure and control procedures, proof of a documented system for a buildings database and a staff opinion survey (focus groups samples of managers, supervisors and staffs) to assess availability, implementation and effectiveness of the maintenance strategy. Wireman, (2005) developed a comprehensive maintenance asset management strategy as shown in Figure 2-13.

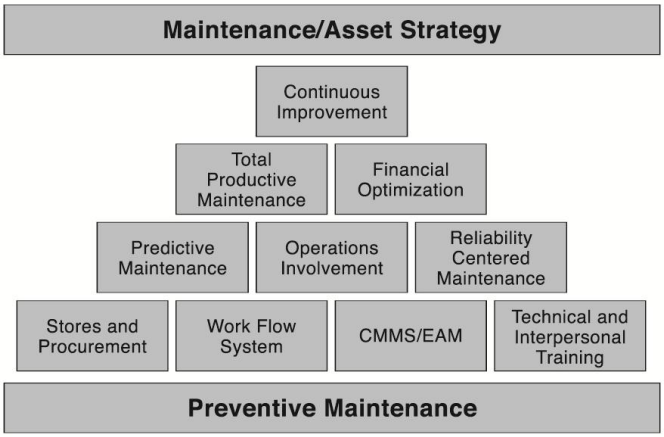

Figure 2-13 Comprehensive Maintenance Asset Management Strategy (Wireman, 2005)

2.6.4.2 Management Responsibilities

The development of an assessment tool of maintenance management in public schools should consider management responsibilities criteria (ISO 9001:2008 and Howard, 2006). Based on a review of literature, there are different terminologies which define management responsibilities as shown in Table 2-8. "Management Responsibilities" criterion was identified using the following different terms: "Organization Structure" (Cholasuke and Bhardwa, 2004); "Leadership role'' (Binggeli, 2010) and "Management Responsibilities" (ISO 9001:2008 and Howard, 2006). According to ISO 9001:2008 Management Responsibilities can be defined as "Different tasks of top management that provides evidence of its commitment to the development and implementation of the QMS and continually improving its effectiveness". Three measurable quality criteria were identified to assess this category:

1) Maintenance mission stated and known to everyone in the organization (Ali and Wan Mohamad, 2009 and Cholasuke and Bhardwa, 2004).
2) Existence of clear organization structure (Ali and Wan Mohamad, 2009 and Cholasuke and Bhardwa, 2004).
3) Top management must check that responsibilities and authorities are identified by all staff (Ali and Wan Mohamad, 2009).

The above elements can be measured by providing proof of a documented system for maintenance mission, staff responsibilities and organization structure and a staff opinion survey to assess their realizations of the maintenance mission, responsibilities and

organization structure. The Florida Department of Education (1998) identified different staff positions as shown in Table 2-7.

Table 2-7 Staff Positions for Maintenance and Operations Departments in School Districts (Florida Department of Education, 1998

Personnel	**General Job Description**
Department administrator/director	Chief administrative and budget officer of the maintenance and operations organization and is responsible for establishing departmental policies and procedures, implementing a range of required services, and ongoing stewardship of educational facilities.
Assistant department administrator/director	Second administrative officer for the department is primary liaison with area/zone supervisors and responsible for coordinating overall work effort and other priority services.
Area/zone supervisors	Mid-level managers responsible for administering maintenance and operations functions for a specified number of school facilities within a defined geographic area.
Custodial, and grounds supervisors	Mid-level managers responsible for coordinating trades, custodial, and grounds personnel, as well as routine and work order services.
Trades, shift supervisors, and foremen	First-line staff managers responsible for supervising maintenance and operations work crews on a daily basis.
Trades people, engineers,	Staff persons responsible for completing various types of maintenance, operations, and grounds related tasks.
Administrative staff	Staff persons responsible for coordinating a variety of administrative and office-related duties central to departmental operations.
Specialized/technical personnel	Staff persons responsible for specialized tasks associated with such functions as procurement, vehicle maintenance, security, technical services, etc.

2.6.4.3 Resource Management

The resource management criterion is considered as one of the main managerial criteria that need to be taken into account in measuring the maintenance performance of public schools (ISO 9001:2008; Shamsuddin et al., 2006; Arkansas, 2009). It is noticed that there is inconsistency in the definition of this criteria as shown in Table 2-8. "Resource Management" criterion was identified using the following different terms: "Resource Management'' (ISO 9001:2008; Shamsuddin et al., 2006; Arkansas, 2009), "Human Resource Management" (Cholasuke and Bhardwa, 2004), "Customer Service Training" (Myeda et al., 2011) and "Resources Planning" (Ali and Wan Mohamad, 2009). Resource management can be defined as "the process of using a company's resources in the most efficient way possible. These resources can include tangible resources such as goods and equipment, financial resources, and labor resources such as employees" (http://www.businessdictionary.com/definition/resource-management.).Three measurable quality criteria were identified to assess implementation of resource management in the maintenance department and these include:

1) The maintenance department identifies the resources needed to support the maintenance effectiveness and achieve customer satisfaction (ISO 9001:2008).
2) Staff who are expected to provide the services must be competent, with good skills, education, training, experience and be in sufficient number (ISO 9001:2008; Myeda et al., 2011; Shamsuddin et al., 2006; Arkansas, 2009 and Cholasuke and Bhardwa.2004).

3) The maintenance department must provide an appropriate infrastructure for maintenance staff to carry out the required services (ISO 9001:2008 and Ali and Wan Mohamad, 2009).

The above elements can be implemented by providing proof of a documented system for the resources needed to support maintenance effectiveness including an appropriate infrastructure, achieving the training requirements of the U.S. Occupational Safety and Health Act (OSHA) and Minnesota OSHA for activities maintenance workers, review of weekly, monthly reports and a staff opinion survey (focus groups samples of managers, supervisors and staff) to assess availability, implementation and effectiveness of the resources needed.

2.6.4.4 Service Realizations

The development of an assessment tool of maintenance management in public schools should consider service realizations criteria (Howard, 2006; Minnesota, 2000 and Binggeli, 2010). Based on a review of literature, there are different terminologies which define service realizations as shown in Table 2-8. "Service Realizations" criterion was identified using the following different terms: "Task Planning and Scheduling" (Cholasuke and Bhardwa, 2004); "Work Order System'' (Howard, 2006), "High Reliability of Services'' (Lam, 2001) and "Service Realizations" (ISO 9001:2008). Service realizations can be defined as "Plan and develop the processes needed for service realization" (ISO 9001:2008). Six measurable quality criteria were identified to assess service realizations in the maintenance department and include:

1) The maintenance department must have a planning function for delivering the required services (ISO 9001:2008).
2) The maintenance department must identify service requirements which include specified customer requirements, regulatory requirements, and any other necessary requirements (ISO 9001:2008).
4) The maintenance department must have a clear process for delivering services and their traceability (ISO 9001:2008 and Lam, 2001).
5) Implementation of a work order system that provides high reliability and quality of services (Howard, 2006; Minnesota, 2000 and Binggeli, 2010).
6) The maintenance department must have a plan to reduce deferred maintenance that includes a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog (Minnesota, 2000 and Cholasuke and Bhardwa, 2004).

These measurable quality criteria can be implemented by providing proof of a documented system for a plan for delivering the required services, a review of weekly, monthly reports, a work order sample and a survey of occupants to assess their satisfaction of required services.

2.6.4.5 Measurement, Analysis and Improvement

The development of an assessment tool of maintenance management in public schools should consider measurement, analysis and improvement criteria (ISO 9001:2008 and Cholasuke and Bhardwa, 2004). It is noticed that there is inconsistency in the definition of this criteria as shown in Table 2-8. "Measurement, analysis and improvement"

criterion was identified using the following different terms: “Measurement, analysis and improvement’’ (ISO 9001:2008 and Cholasuke and Bhardwa, 2004), “On-going improvement” (Legát and Jurča, 2004; and Pheng and Shiua, 2000) and “Information management and CMMs” (Ali and Wan Mohamad, 2009). Measurement, analysis and improvement can be defined as “Plan and implement the monitoring, measurement, analysis and improvement processes needed” (ISO 9001:2008). According to ISO 9001:2008 and different references as shown below, assessment tools to assess the implementation of measurement, analysis and improvement in the maintenance management department can be classified into four elements that include:

1) Implementation of IT support including CMMs to handle information related to customer requirements or perceptions such as customer satisfaction surveys (Myeda et al., 2011; Legat and Jurca, 2004; Howard, 2006 and Cholasuke and Bhardwa, 2004 and Ali and Wan Mohamad, 2009).
2) The maintenance department must have a system for maintenance performance measurement that has a maintenance response time and a measurement of it (ISO 9001:2008).
3) The maintenance department must have internal audits using its criteria and documented methods (ISO 9001:2008).
4) On-going improvement through established quality policy, and analyses of data and management reviews (ISO 9001:2008; Legát & Jurča, 2004; Pheng & Shiua, 2000; Peggy, 1999; Cholasuke and Bhardwa, 2004 and Ali and Wan Mohamad, 2009).

These measurable quality criteria can be implemented by providing proof of implementing IT support including CMMs to handle information related to customer requirements, proof of a documented system for maintenance performance measurement systems, internal audits, and a staff opinion survey (focus groups samples of managers, supervisors and staff) to assess availability, implementation and effectiveness of the maintenance performance measurement system.

2.6.4.6 Maintenance Financing

One of the most important managerial criteria that need to be considered for development of an assessment tool of maintenance management in public schools is the maintenance financing criterion (Cholasuke and Bhardwa, 2004 and Lee, 1987). The reviewed research works showed the contradiction in definitions of this criterion as shown in Table 2-8. "Maintenance Financing" criterion was identified using the following different terms: "Maintenance Financing" (Cholasuke and Bhardwa, 2004 and Lee, 1987), "Maintenance Financing'' (Binggeli, 2010), "Budget Control" (Howard, 2006), and "Maintenance Cost" (Bin Hashim, 2006). Maintenance Financing can be defined as "The variable sum based on the costs of some primary activity or replacement value, or taken from the fixed sum based on historic costs or an analysis of anticipated benefits" (Lee, 1987). Two measurable quality criteria were identified to assess maintenance financing of maintenance management department:

1) Implementation of good budgetary planning and control (Howard, 2006 and Cholasuke and Bhardwa, 2004).

2) Ability to select adequate and effective outsourcing contracts and effectively the contractors (Legat and Jurca, 2004; Arkansas, 2009 and The Florida Department of Education, 1998).

These measurable quality criteria can be implemented by providing proof of a documented system of implementation, good budgetary planning and control, including economic analysis of cost and a staff opinion survey (focus groups samples of managers, supervisors and staff) to assess the selection of effective outsourcing contracts.

Table 2-8 An Assessment Tool for Maintenance Management Terminologies Variation

An Assessment Tool for Maintenance Management of public schools	Criteria Terminologies
Technical Category	
Thermal Comfort	- Thermal comfort (ASHRAE ,2004; Indiana School Design Guidelines, 2009; Prakash, 2005 ; Steskens and Loomans, 2010 and LEED, 2008). - Servicing and repair of heating system (Arkansas, 2009). -Troubleshooting of heating system (Binggeli, 2010). - Distribution of air within the optimum temperature (Myeda et al.,2011). - Inspecting heating and cooling (Minnesota, 2000).
Acoustical Comfort	- Acoustical comfort (ANSI, 2002; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). -Vibration and noise (Arkansas, 2009; Bruce, et al., 1998 and Kibert, 2005). - Noise Pollution or Vibration (Khalil and Nawawi, 2008).
Visual Comfort	- Visual Comfort (IESNA, 2000; Khalil &Nawawi, 2008; Indiana School Design Guidelines, 2009; Prakash, 2005; Steskens and Loomans, 2010 and LEED, 2008). - All lighting in proper working order (Binggeli, 2010). - Inspection of interior and exterior lighting (Arkansas, 2009).

Indoor Air Quality	- Indoor Air Quality (Myeda et al., 2011; Howard, 2006; Minnesota, 2000; Steskens and Loomans, 2010 and ASHRAE Standard 62.1, 2007). - Natural or mechanical ventilation levels (Binggeli, 2010). - Ventilation and air-conditioning system (Arkansas, 2009).
Safety and Security	- Compliance with statutory requirements. (Lam (2001); Arkansas, 2009; and Ali and Wan Mohamad, 2009). - Safety and security (Preiser, et al., 1988; Myeda et al. (2011); Baharum et al., 2009; Florida, 2010; Cholasuke and Bhardwa, 2004; Arkansas, 2009; Khalil &Nawawi, 2008; and Alsyouf, 2009). - Evacuation plan (Arkansas, 2009 and Binggeli, 2010)
Cleanness	- Cleanliness (Arkansas, 2009; Binggeli, 2010; Baharum et al., 2009; Khalil and Nawawi, 2008; Shamsuddin et al. 2006 and Tucker and Pitt, 2010). - Caring for cleanliness and tidy working environment (Myeda et al., 2011 and; Arkansas, 2009). - Custodial Standards (Binggeli, 2010)
Landscaping	- Landscaping (Binggeli, 2010) - Indoor and outdoor plants (Myeda et al, 2011). - Playground inspections (Arkansas, 2009).
Structural Systems	- Structural Systems (Khalil and Nawawi, 2008; Binggeli, 2010; Cripps, 1984 and Baharum et al., 2009). -Early diagnosing of various cracks, scratches and corrosion and their causes (Preiser, et al., 1988). Inspection and repair of masonry and concrete building exteriors (Arkansas, 2009).

Mechanical, Electrical and Plumbing Systems	- Mechanical and electrical systems. (Myeda et al., 2011; Khalil and Nawawi, 2008; Alsyouf; Binggeli, 2010; Arkansas, 2009 and Tucker and Pitt, 2010).
Functional Category	
Human Factors	Human Factors (Preiser, et al., 1988; Peggy, 1999 and Myeda et al., 2011).
Storage	Storage (The city of Casselberry, 2010; Arkansas, 2009 and Binggeli, 2010).
Space Layout and Furniture Quality	Space Layout and Furniture Quality (Preiser, et al., 1988; Fink, 1992 and Hassanain, 2008).
Accessibility and Parking Space	Accessibility and Parking Space (Myeda et al., 2011; Preiser, et al., 1988; Hassanain, 2008 Arkansas, 2009 and Baharum et al., 2009).
Behavioral criteria	
Image and Environmental Perception	Image and Environmental Perception (Preiser, et al., 1988; Khalil and Nawawi, 2008; Myeda et al., 2011 and Baharum et al., 2009). Interior and exterior finishes (Binggeli, 2010).
Managerial Category	
Maintenance Strategy	- Maintenance strategy (Howard,2006 and Wireman, 2005) - Plan strategically (Minnesota, 2000) - Organization Strategy (ISO 9001:2008).
Management Responsibilities	Management responsibilities (ISO 9001:2008 and Howard, 2006) Organization structure (Cholasuke and Bhardwa,2004) Leadership role (Ali and Wan Mohamad , 2009 and Arkansas, 2009)

Resource Management	Resources management (ISO 9001:2008; Shamsuddin et al., 2006; Arkansas, 2009). - Human resource management (Cholasuke and Bhardwa, 2004). - Customer service training.(Myeda et al.,2011). - Resources planning (Ali and Wan Mohamad ,2009).
Service Realizations	- Service Realizations (ISO 9001:2008). - High Reliability of Services (Lam, 2001). - Work-Order System (Howard, 2006). - Task Planning and Scheduling (Cholasuke and Bhardwa, 2004).
Measurement, Analysis and Improvement	- Information management and CMMs (Ali and Wan Mohamad , 2009).
	Measurement, analysis and improvement (ISO 9001:2008 and Cholasuke and Bhardwa, 2004).
	- On-going improvement (Legát and Jurča; and Pheng and Shiua, 2000).
Maintenance Financing	- Maintenance Financing (Cholasuke and Bhardwa, 2004 and Lee, 1987). Budget Control (Howard, 2006). Maintenance Cost (Bin Hashim,2006).

2.7 Summary and Discussion

Based on the above presented literature as indicated in section 2.6, it is evident that previous research has not addressed a holistic approach for developing the required quality criteria for generic maintenance management and there were variations in classifying maintenance management measurement for public schools and its measurement methods. Table 2-9 presents summary of definitions and measurements for the identified criteria which were concluded from review of literature.

Table 2-9 Definitions and Measurements for the Identified Criteria

Technical Category		
Criteria	Definition	Measurement
Thermal Comfort	"The state of mind in humans that expresses satisfaction with the surrounding environment" (ASHRAE Standard (55), 2004).	- ASHRAE Standard (55), 2004 temperature range (22-27 ° C) and Satisfy 80 % of occupants. - Surveying Occupants
Acoustical Comfort	"Providing acoustic conditions in a building that facilitate clear communication of speech between the users of the building'' (Steskens and Loomans, 2010).	- ANSI S12.60 Standard, 2002 background sound pressure level (35-40 decibels (dBA). - Surveying Occupants
Visual Comfort	"represents a positive or neutral user/occupant evaluation of the lighting conditions in a space" (Indiana School Design Guidelines, 2009)	- BS EN 12464-1,2003 illuminance levels for reading task (500-900 lux) - IESNA, 2000 a typical classroom reading task is 30 foot-Candles. - Surveying Occupants
Indoor Air Quality	"air in which there are no known contaminants at harmful concentrations" (ASHRAE Standard 62.1, 2007)	- ASHRAE Standard 62.1, 2007- people outdoor air rate for classrooms (5 L/S person). - ASTM D6245 – 12 - Carbon

		dioxide (< 1000 ppm). - Surveying Occupants
Safety and Security	"the control of recognized hazards to achieve an acceptable level of risk" (The Institute for Security and Open Methodologies (ISECOM)	- Proof of a documented system (compliance with the local safety statutory requirements). - Surveying occupants.
Cleanness	"both the abstract state of being clean and free from dirt, and the process of achieving and maintaining that state" http://www.answers.com/topic/cleanliness	- Walkthrough inspection. - Proof of a documented system. - Survey Occupants
Maintaining Landscaping	"Any activity that modifies the visible features of an area of land" (http://en.wikipedia.org/wiki/Landscaping)	- Walkthrough inspection - Proof of a documented system - Surveying Occupants
Maintaining Structural Systems	"Regular maintenance of the structure of building, including walls, floors, roofs, windows, doors, sanitary fittings and plumbing, drains, fire escapes, yard, roads and cleaning, and restoration of elevation" (Cripps,1984).	- Walkthrough inspection - Proof of a documented system
Mechanical, Electrical and Plumbing Systems	"Any activity that improve quality of Mechanical, Electrical and Plumbing Systems".	- Proof of a documented system of implementation preventive maintenance and spare parts for mechanical, electrical and plumbing systems.
Functional Category		
Human Factors	"Factors concerned with the dimensions and configurations of the designed environment, often the near environment, to match building occupants' physiological needs and physical dimensions" (Preiser, et al.,1988)	- Proof of a documented system to instruct maintenance staff - Surveying Occupants
Storage	"The act of storing goods or the	- Walkthrough inspection to

	state of being stored'' (http://www.thefreedictionary.com/ storage).	assure that there are enough storage space. - Surveying Occupants.
Space layout and Furniture Quality	"The process of establishing, sizing, and locating the appropriate production and support activities within a new or existing structure" (Fink, 1992)	- Walkthrough inspection to assure the arrangements of furniture and teaching tool. - Proof of a documented system for regularly evaluating the arrangements of furniture. - Surveying Occupants.
Accessibility and Parking Space	"Ease with which a facility or location can be reached from other locations" http://www.businessdictionary.	- Walkthrough inspection to assure the quality of accessibility function. - Proof of a documented system. - Surveying Occupants.
Behavioural Category		
Image and Environmental Perception	"The significant effect of the building design on their occupants or visitors perception" (Preiser, et al., 1988).	- Walkthrough inspection to assure the quality of interior and exterior finishing. - Proof of a documented system. - Surveying Occupants.
Managerial Category		
Maintenance Strategy	"A long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function" (http://www.kwaliteg.co.za).	- Proof of a documented system for maintenance strategy, quality policy, objective, operation procedures and control procedures. - Proof of a documented system for buildings database. - Staff Opinion Survey
Management Responsibilities	"Different task of top management that provide evidence of its commitment to the development and	- Proof of a documented system for maintenance mission, staffs responsibilities and organization

	implementation of the QMS and continually improving its effectiveness" (ISO 9001:2008).	structure. - Staff Opinion Survey to assess their realizations of maintenance mission, responsibilities and organization structure.
Resource Management	"The process of using a company's resources in the most efficient way possible. These resources can include tangible resources such as goods and equipment, financial resources, and labour resources such as employees" http://www.businessdictionary	- Proof of a documented system for the resources needed. - Achieve the training requirements by the U.S. Occupational Safety and Health Act (OSHA) and Minnesota OSHA for activities maintenance workers. - Review of weekly, monthly reports and Staff Opinion Survey.
Service Realizations	"Plan and develop the processes needed for service realization" (ISO 9001:2008).	- Proof of a documented system for a plan for delivering the required services. - Review of weekly, monthly reports and work order sample. - Occupancy survey to assess their satisfactions for delivering the required services.
Measurement, Analysis and Improvement	"Plan and implement the monitoring, measurement, analysis and improvement processes needed" (ISO 9001:2008).	- Proof of an evidence of implementing IT support including CMMs to handle information related to customer requirement. - Proof of a documented system for maintenance performance measurement system and internal audit.
Maintenance Financing	"The variable sum based on the costs of some primary activity or replacement value, or taken from fixed sum based on historic costs or an analysis of anticipated benefits" (Lee, 1987).	- Proof of a documented system of implementing a good budgetary planning and control including economic analysis of cost. - Staff opinion survey.

CHAPTER 3

DEVELOPMENT OF AN ASSESSMENT TOOL

3.1 Introduction

This chapter analyzes the results of the survey conducted. Sixty-two elements under twenty measurable quality criteria that have been developed in chapter two were assessed through developing, testing and administering of the questionnaire survey. It presents the degree of important for these measurable quality criteria as described as follows:

3.2 Pilot Test of the Questionnaire Survey

Before the final distribution of the questionnaire survey, a pilot testing was conducted by five maintenance experts who are working in the Eastern Province of Saudi Arabia for the purposes of:

- Testing the adequacy of the questions.
- Incorporating additional possible measurable quality criteria.
- Assessing the significance of these measurable quality criteria.

3.3 Development of Questionnaire Survey

The purpose of this survey is to identify these measurable quality criteria and assess their significance by maintenance experts. The structure of the survey questionnaire is divided into three parts which include (see Appendix I):

Part One - Respondent Information.

Part Two: Development of an Assessment Tool for Maintenance Management in Public Schools in Saudi Arabia.

Part Three: Maintenance Management measurement methods.

3.4 Distribution of the Tested Questionnaire

At this step, the tested questionnaire survey was distributed to maintenance experts in the Eastern Province of Saudi Arabia to assess the importance of the sixty-two identified measurable quality elements. The respondents to the questionnaire survey were asked to mark their perceived relative degree of importance for each of the identified measurable quality criteria through selection one of five evaluation terms; "**Extremely Important**", "**Important**", "**Moderately Important**", "**Not Important**" and "**Extremely Unimportant**".

3.5 Identification of the Sample Size

According to (Kish, 1995) the following equations was used to calculate the sample size.

$$\mathbf{n_o} = (p*q)/\mathrm{v}2$$
$$\mathrm{n} = \mathbf{n_o} / [1+ (\mathbf{n_o} /\mathrm{N})]$$

Where:

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**.

The population size (N) is 815 as obtained from the Chambers of Commerce in the Eastern Province of Saudi Arabia. The sample sizes are calculated as follows:

Sample size (n) = 25/ [1+ (25/815)] = **25**

3.6 Data Analysis

This chapter presents the analysis of the data received from the 40 maintenance experts who completed the questionnaire survey. The sample size which was determined by using equations is 25. However, the distribution survey was 56 and received was 40 which filled by maintenance experts who are working in the Eastern Province of Saudi Arabia in different organizations that are related to maintenance management for public schools as shown in the Table below:

Table 3-1 Data Collection

Organizations	Surveys distributed	Surveys received
Saudi Aramco Government Built School	16	12
General Administration of Education in the Eastern Province (boys) – Construction Department	14	10
General Administration of Education in the Eastern Province (girls) - Construction Department	12	8
King Fahd University of Petroleum and Minerals (Maintenance Department)	10	6
Royal Commission for Jubail and Yanbu (RCJY)	6	4
Total	56	40

3.6.1 Part One: Respondents' General Information

This part presents the general information of the respondents which includes their position, the experience that they have in this field, the nature of their organization, the types of project that they have mainly worked on and the number of employees that their organization has. Analysis of the data received was carried out using simple descriptive statistical techniques including simple graphics, percentages and simple summaries of the findings.

Respondents' Roles in their Organization

The maintenance experts were asked to identify their roles in their organizations. It was found that 11.7% of them were working as maintenance managers, 16.5% as facility managers, and 71.8% as engineers or architects as illustrated in Figure 3-1.

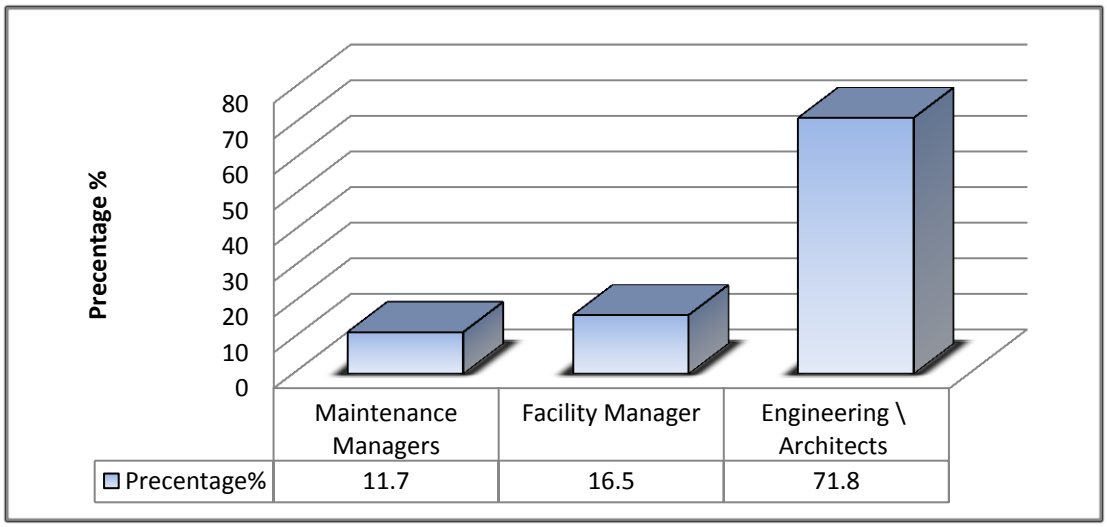

Figure 3-1 Respondents' Roles in their Organizations

Respondents' Experience

The maintenance experts were asked to determine the years of their experience which were classified into four categories: less than five years, five to ten years, ten to twenty years, more than twenty years. The results showed that 6.25% of them had over 20 years' experience, 18.75% 10-20 years' experience, 56.2 % 5-10 years' experience, and 18.75% less than 5 years' experience as illustrated in Figure 3-2.

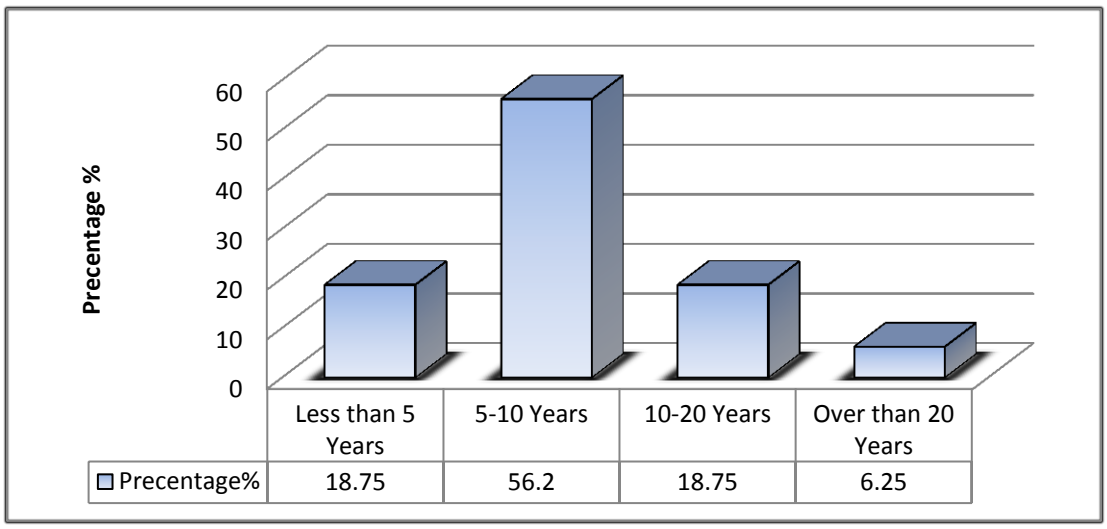

Figure 3-2 Respondent's Experience

Types of Projects Carried out by the Respondents

The maintenance experts were asked to determine the types of projects that they mainly worked on. Project types which had been determined include educational, offices, residential, recreational, sports and commercial buildings. The results indicated that 64 respondents worked on educational buildings projects, about 6.2% on the residential buildings projects, 7 % on the office buildings projects, 4.85% respondents on the sports

buildings projects and 6.2% of the respondents on the commercial buildings projects as illustrated in Figure 3-3.

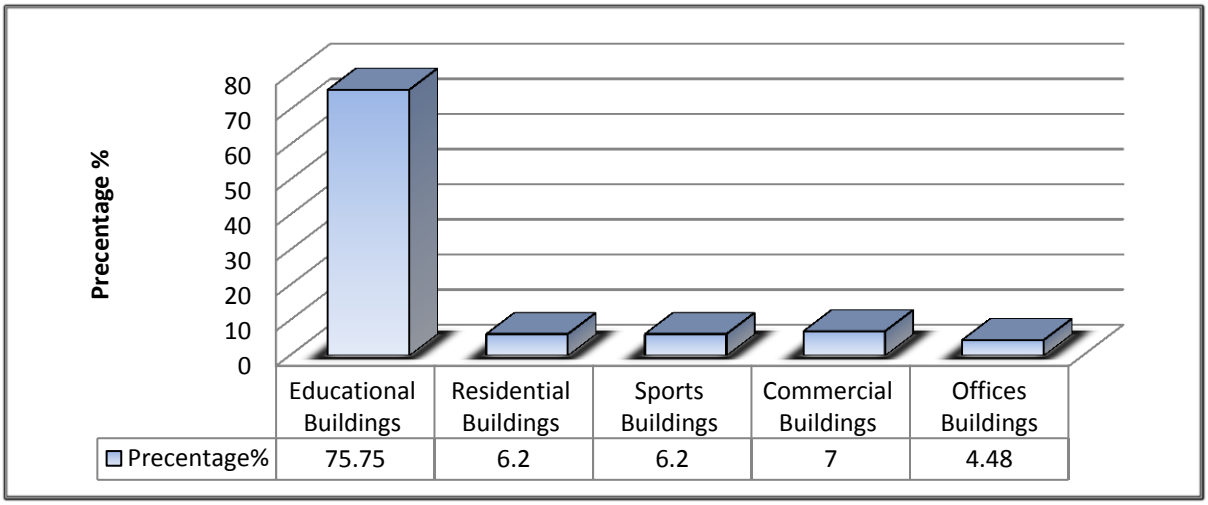

Figure 3-3 Types of Projects Carried out by the Respondents

The Nature of the Organization

The maintenance experts were asked to determine the nature of the organizations that they mainly worked in. The results indicated that all of them worked in maintenance departments of public organizations as illustrated in Figure 3-4.

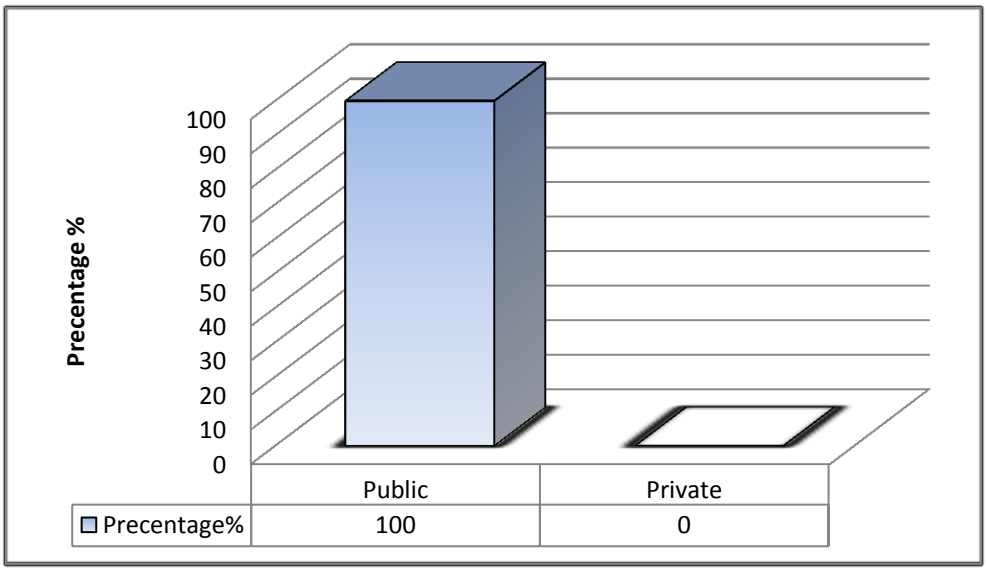

Figure 3-4 The Nature of the Maintenance Expert's Organization

The Number of Employees in the Organization

The maintenance experts were asked to determine the nature of employees in their organizations that they mainly worked in. The results indicated that about 45% of these organizations have 50 -100 employees, 20% 1- 50employees, 20% of them 1- 50 employees and only 15 % have more than 150 employees as illustrated in Figure 3-5.

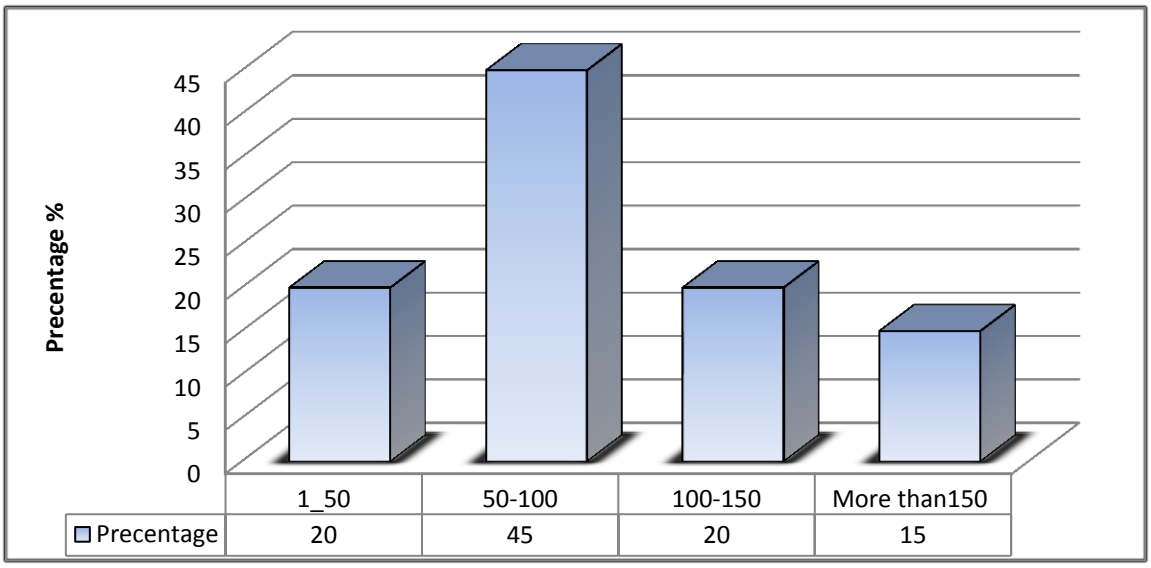

Figure 3-5 The Number of Employees in the Maintenance Expert's Organization

3.6.2 Calculation of the Importance Indexes and Determination of the Rates of Importance:

According to Dominowski (1980) the importance index for each factor has been calculated

using the following formula:

Importance index I = $\sum_{i=0}^{4}$ aixi $*$ $100/4\sum$xi

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 as illustrated in the following:

X0 = frequency of "Extremely Important" response corresponding to a0 = 4.

X1 = frequency of “Very Important” response corresponding to a1 = 3.

X2 = frequency of “Important” response corresponding to a2 = 2.

X3= frequency of “Somewhat Important” response corresponding to a3 = 1.

X4 = frequency of “Not Important” response corresponding to a4 = 0.

To reflect the scale of the respondents’ answers to the questionnaire, the importance index is classified as the following:

0- <12.5% is categorized as ‘‘Extremely Not Important’’ (ENI);

12.5–<37.5% is categorized as ‘‘Not Important’’ (NI);

37.5–<62.5% is categorized as ‘‘Moderately Important’’ (MI);

62.5–<87.5% is categorized as ‘‘Important’’ (I); and

87.5–100% is categorized as ‘‘Extremely Important’’ (EI).

3.7 Discussion of Results

3.7.1 An Assessment Tool for Maintenance Management (Technical Category)

Thermal Comfort

This is an assessment tool which includes two elements, namely provision of comfortable temperature during summer throughout all spaces in the building and provision of comfortable temperature during winter throughout all spaces in the building. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Extremely Important" with an overall average of important index of 89 % for this criterion as indicated in Table 3-2.

Table 3-2 Rate of Important for Measurable Criteria (Thermal Comfort)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Thermal Comfort		Overall average					4.4	**89.0**	**EI**
1.	Provision of comfortable temperature during summer throughout all spaces in the building.	26	10	2	2	0	4.5	**90.0**	**EI**
2.	Provision of comfortable temperature during winter throughout all spaces in the building.	20	16	4	0	0	4.4	**88.0**	**EI**

Acoustical Comfort

There were two elements in this criterion. These were provision of acoustical comfort throughout all spaces in the building, provision of a system for regularly evaluating the quality of acoustical comfort through all spaces in the building and implementation of noise control and speech privacy measures wherever needed. The mean response indicated that these elements were perceived to be "Important" with an overall average of important index of 80 % for this criterion as indicated in Table 3-3.

Table 3-3 Rate of Important for Measurable Quality Criteria (Acoustical Comfort)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Acoustical Comfort		Overall average					4.0	**80.0**	**I**
1.	Provision of acoustical comfort throughout all spaces in the building.	20	6	10	4	0	4.1	**81.0**	**I**
2.	Provision of a system for regularly evaluating the quality of acoustical comfort through all spaces in the building.	20	6	8	4	2	4.0	**79.0**	**I**
3.	Implementation of noise control and speech privacy measures wherever needed.	20	4	16	2	0	4.0	**80.0**	**I**

Visual Comfort

Two performance measures were included in this criterion. These measures were provision of good appearance and quality of lighting as per identified standards and provision of a system for regularly evaluating the quality of lighting throughout all spaces in the building. The results of the assessment according to the respondents indicate that these factors were perceived to be “Extremely Important” and “Important” respectively with an overall average of important index of 85 % for this criterion as indicated in Table 3-4.

Table 3-4 Rate of Important for Measurable Quality Criteria (Visual Comfort)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Visual Comfort		Overall average					4.5	**85.0**	**EI**
1.	Provision of good appearance and quality of lighting as per identified standards.	28	4	6	2	0	4.5	**89.0**	**EI**
2.	Provision of a system for regularly evaluating the quality of lighting throughout all spaces in the building.	14	14	8	4	0	4.0	**79.0**	**I**

Indoor Air Quality

Two elements were evaluated in this assessment criterion, namely implementation of periodical inspection of the HVAC system to comply with ASHRAE Standard 62.1and provision of a system for regularly evaluating indoor air quality throughout all spaces in the building, including procedures for managing processes with potentially significant pollutant sources and procedures for responding to IAQ complaints. The mean response indicated that these elements rated either "Extremely Important" or "Important" with an overall average of important index of 85 % for this criterion as indicated in Table (3-5).

Table 3-5 Rate of Important for Measurable Quality Criteria (Indoor Air Quality)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Indoor Air Quality		Overall average					4.2	**85.0**	**I**
1.	Implementation of periodical inspection of the HVAC system to comply with ASHRAE Standard 62.1.	24	10	4	2	0	4.4	**88.0**	**EI**
2.	Provision of a system for regularly evaluating indoor air quality throughout all spaces in the building including procedures for managing processes with potentially significant pollutant sources and procedures for responding to IAQ complaints.	20	6	10	4	0	4.1	**81.0**	**I**

Safety and Security

This assessment tool included three elements, namely proof of compliance with the local safety statutory requirements, provision of a checklist for regular upkeep of safety systems throughout all spaces in the building as well as the playgrounds and proof of an evacuation drill at least once a year. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be either "Extremely Important" or "Important" with an overall average of important index of 86.7 % for this criterion as indicated in Table 3-6.

Table 3-6 Rate of Important for Measurable Quality Criteria (Safety and Security)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Safety and Security		Overall average					4.3	**86.7**	**I**
1.	Proof of compliance with the local safety statutory requirements.	24	16	0	0	0	4.6	**92.0**	**EI**
2.	Provision of a checklist for regular upkeep of safety systems throughout all spaces in the building as well as the playgrounds.	18	12	6	4	0	4.1	**82.0**	**I**
3.	Proof of evacuation drill at least once a year.	16	12	6	0	0	4.3	**85.9**	**I**

Cleanness

Five performance measures were included in this criterion. These measures were implementation of a preventive maintenance plan for cleanness, ensure the overall cleanness throughout all spaces in the building, support of a recycling program during the cleanness process, ensuring the overall cleanness of laboratories including removal of foreign materials and provision of a system for regularly evaluating the quality of cleanness and custodial programs throughout all spaces (including bathrooms) in the building. The mean response indicated that these assessment tool were perceived to be "Important" with an overall average of important index of 85.9 % as shown in Table 3-7.

Table 3-7 Rate of Important for Measurable Quality Criteria (Cleanness)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Cleanness		Overall average					4.3	**85.9**	**I**
1.	Implementation of preventive maintenance plan for cleanness.	26	4	12	0	0	4.3	**86.7**	**I**
2.	Ensure the overall cleanness throughout all spaces in the building.	20	12	6	2	0	4.3	**85.0**	**I**
3.	Support a recycling program during cleanness process.	14	12	8	6	0	3.9	**77.0**	**I**
4.	Ensure the overall cleanness of laboratories including removal foreign materials.	18	10	10	0	2	4.1	**81.0**	**I**
5.	Provision of a system for regularly evaluating the quality of cleanness and custodial programs throughout all spaces (including bathrooms) in the building.	16	10	8	2	2	3.9	**78.9**	**I**

Landscaping

There were two elements in this criterion. These were implementation of periodical checking for both indoor and outdoor plants and provision of a system for regularly evaluating the quality of landscaping throughout all spaces in the building. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Important" with an overall average of important index of 79 % for this criterion as indicated in Table 3-8.

Table 3-8 Rate of Important for Measurable Quality Criteria (Landscaping)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Landscaping		Overall average					3.9	**79.0**	**I**
1.	Implementation of periodical checking for both indoor and outdoor plants.	24	8	8	4	2	4	**80.9**	**I**
2.	Provision of a system for regularly evaluating the quality of landscaping throughout all spaces in the building.	16	10	12	2	2	3.9	**77.1**	**I**

Structural Systems

Two elements were evaluated in this assessment criterion, namely implementation of periodical checking of structural systems in the building as well as removal of any overload and provision of a system for regularly evaluating the quality of maintaining structural systems throughout all spaces in the building. The mean response indicated that these assessment tools were perceived to be "Extremely important" and "Important" with an overall average of important index of 88 % for this criterion as indicated in Table 3-9.

Table 3-9 Rate of Important for Measurable Quality Criteria (Structural Systems)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Structural Systems		Overall average					4.4	**88.0**	**EI**
1.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.	28	6	2	4	0	4.5	**89.0**	**EI**
2.	Provision of a system for regularly evaluating the quality of maintaining structural systems throughout all spaces in the building.	24	10	2	2	2	4.3	**86.0**	**I**

Mechanical, Electrical and Plumbing Systems

Five performance measures were included in this criterion. These measures were implementation of preventive maintenance of the mechanical and electrical systems, implementation of periodical inspection of the water supply / sanitary systems, provision of a system for regularly checking the availability of spare parts required and its efficient

use and Provision of a system for regularly evaluating the quality of drinking water. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that most of these elements were perceived to be “Extremely Important” with an overall average of important index of 89 % for this criterion as indicated in Table 3-10.

Table 3-10 Rate of Important for Measurable Quality Criteria (Mechanical, Electrical and Plumbing Systems)

An Assessment Tool for Maintenance Management **Technical Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Mechanical, Electrical and Plumbing Systems		Overall average					4.5	**89.0**	**EI**
1.	Implementation of preventive maintenance of the mechanical and electrical systems.	30	4	4	2	0	4.6	**91.0**	**EI**
2.	Implementation of periodical inspection of the water supply / sanitary systems.	30	8	0	2	0	4.7	**93.0**	**EI**
3.	Provision of a system for regularly checking the availability of spare parts required and its efficient use.	24	6	10	0	0	4.4	**87.0**	**I**
4.	Provision of a system for regularly evaluating the quality of drinking water.	32	4	4	0	0	4.7	**94.0**	**EI**

3.7.2 An Assessment Tool for Maintenance Management (Functional Category)

Human Factors

This an assessment tool which included two elements, namely implementation of guidelines to instruct maintenance staff to minimize interruption of the educational process and availability of maintenance staff to provide any assistance required and ease of contacting them and their comprehension of user's requirements. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Important" with an overall average of important index of 86.7 % for this criterion as indicated in Table 3-11.

Table 3-11 Rate of Important for Measurable Criteria (Human Factors)

An Assessment Tool for Maintenance Management Functional Category		EI	I	MI	NI	ENI	E(X)	SI %	MR
Human Factors		Overall average					4.3	**86.7**	**I**
1.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.	16	14	6	4	0	4.1	**81.0**	**I**
2.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.	22	10	8	0	0	4.4	**87.0**	**I**

Storage

Two elements were evaluated in this assessment criterion, namely provision of enough storage space for maintenance supplies/spare parts as well as a required inventory and provision of sealable, labeled containers for storage of chemical products and supplies. The mean response indicated that these assessment tools were perceived to be "Important" with an overall average of important index of 80.7 % for this criterion as indicated in Table (3-12).

Table 3-12 3-12 Rate of Important for Measurable Criteria (Storage)

An Assessment Tool for Maintenance Management **Functional Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Storage		Overall average					4.0	**80.9**	**I**
1.	Provision of enough storage space for maintenance supplies/spare parts as well as required inventory.	16	12	6	8	0	3.9	**77.1**	**I**
2.	Provision of sealable, labeled containers for storage chemical products and supplies.	24	4	8	6	0	4.1	**81.9**	**I**

Space Layout and Furniture Quality

Four performance measures were included in this criterion. These measures are implementation of periodical checking of the availability of teaching tools and making sure that they are ready for use, implementation of periodical checking of the furniture arrangement in the classrooms and making sure that it is sufficient for students and teachers especially at the beginning of every semester, implementation of periodical checking of the adequacy and capacity of teachers' offices and computer laboratories and provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teachers' office as shown in Table 3-13.

Table 3-13 Rate of Important for Measurable Criteria (Space Layout and Furniture Quality)

An Assessment Tool for Maintenance Management **Functional Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Space Layout and Furniture Quality		Overall average					4.1	**79.5**	**I**
1.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	18	10	6	4	0	4.1	**82.1**	**I**
2.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.	20	10	6	2	2	4.1	**82.0**	**I**
3.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	18	6	6	8	2	3.8	**75.0**	**I**
4.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.	18	8	6	8	0	3.9	**78.0**	**I**

The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be “Important” with the listed assessment tools with an overall average of important index of 79.5 % for this criterion.

Accessibility and Parking Space

Eight elements were evaluated in this assessment criterion, namely implementation of periodical checking of the function and position of all signage, implementation of periodical checking of the ease of identifying and reaching the building’s main entrance, implementation of periodical checking of the ease by which visitors can locate rooms in the building, implementation of periodical checking of the availability of emergency signage, proximity of the building to car parking spaces, sufficiency of car parking spaces, availability of ease of access for the handicapped and provision of a system for regularly evaluating the quality of accessibility function. The mean response indicated that most of these assessment tools were perceived to be “Important” with an overall average of important index of 78.2 % for this criterion as indicated in Table 3-14.

Table 3-14 Rate of Important for Measurable Criteria (Accessibility & Parking Space)

An Assessment Tool for Maintenance Management Functional Category		EI	I	MI	NI	ENI	E(X)	SI %	MR
Accessibility and Parking Space		Overall average					3.9	**78.2**	**I**
1	Implementation of periodical checking of the function and position of all signage.	16	6	10	4	2	3.8	**75.8**	**I**
2	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	16	4	12	4	2	3.7	**74.7**	**I**
3	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.	14	2	14	10	0	3.5	**70.0**	**I**
4	Implementation of periodical checking of the availability of emergency signage.	18	10	10	2	0	4.1	**82.0**	**I**
5	Proximity of the building to car parking spaces.	20	4	14	2	2	3.9	**78.1**	**I**
6	Sufficiency of car parking spaces.	20	8	12	0	0	4.2	**84.0**	**I**
7	Availability of ease of access to handicaps.	24	6	8	2	0	4.3	**86.0**	**I**
8	Provision of a system for regularly evaluating the quality of accessibility function.	18	2	12	6	0	3.8	**76.8**	**I**

3.7.3 An Assessment Tool for Maintenance Management (Behavioral Category)

Image and Environmental Perception

This measurable quality criterion consists of two elements, namely implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building and provision of a system for regularly evaluating the quality of interior and exterior finishing throughout all spaces in the building. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Important" with an overall average of important index of 81% for this criterion as indicated in Table 3-15.

Table 3-15 Rate of Important for Measurable Criteria (Image and Environmental Perception)

An Assessment Tool for Maintenance Management Functional Category		EI	I	MI	NI	ENI	E(X)	SI %	MR
Image and Environmental Perception		Overall average					4.0	**81.0**	**I**
1.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	20	10	8	0	2	4.2	**83.0**	**I**
2.	Provision of a system for regularly evaluating the quality of interior and exterior finishing throughout all spaces in the building.	18	8	8	4	2	3.9	**78.0**	**I**

3.7.4 An Assessment Tool for Maintenance Management (Managerial Category)

Maintenance Strategy

Three performance measures were included in this criterion. These measures were the need for the maintenance department to have a process for identifying the most effective maintenance strategy/tasks, the need for the maintenance department to have a quality manual that documents maintenance quality policy, objective and control and operation procedures and the need for the maintenance department to have a comprehensive database for each school including building systems and equipment with information such as location, warranty information, and replacement parts as shown in Table 3-16 .

Table 3-16 Rate of Important for Measurable Criteria (Maintenance Strategy)

An Assessment Tool for Maintenance Management Managerial Category		EI	I	MI	NI	ENI	E(X)	SI %	MR
Maintenance Strategy		Overall average					4.1	**83.6**	**I**
1.	The maintenance department must have a process for identifying the most effective maintenance strategy\tasks.	22	8	6	4	0	4.2	**84.0**	**I**
2.	The maintenance management department has a quality manual that documented maintenance quality policy, objective and control and operation procedures.	20	10	4	6	0	4.1	**82.0**	**I**
3.	The maintenance department must have a comprehensive database for each school including building systems and equipment with information such as location, warranty information, and replacement parts.	26	8	0	4	2	4.3	**86.0**	**I**

The mean response indicated that these assessment tools were perceived to be "Important" with the listed assessment tools with an overall average of important index of 83.6% for this criterion.

Management Responsibilities

Three elements were evaluated in this assessment criterion, namely the statement of maintenance mission and its dissemination to everyone in the organization, the existence of a clear organization structure and the necessity of top management to check that responsibilities and authorities are identified to all staff members. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Important" with an overall average of important index of 84.6% for this criterion as indicated in Table 3-17.

Table 3-17 Rate of Important for Measurable Criteria (Management Responsibilities)

An Assessment Tool for Maintenance Management **Managerial Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Management Responsibilities		Overall average					4.2	**84.6**	**I**
1.	Maintenance mission stated and known to everyone in the organization.	16	16	4	2	0	4.2	**84.2**	**I**
2.	Existence of clear organization structure.	22	8	4	6	0	4.2	**83.0**	**I**
3.	Top management must check that responsibilities and authorities are identified to all staffs.	24	10	2	2	2	4.3	**86.0**	**I**

Resource Management

This measurable quality criterion consists of two elements, namely the identification by the maintenance department of the resources needed to support the maintenance effectiveness and achieve customer satisfaction and the necessity of staff tasked with the provision of the services being competent, with good skills, education, training, and experience and also being sufficient in numbers and capable of providing an appropriate infrastructure for maintenance staff to carry out the required services. The mean response indicated that these assessment tools were perceived to be either "Important" or "Extremely Important" with an overall average of important index of 85% for this criterion as indicated in Table 3-18.

Table 3-18 Rate of Important for Measurable Criteria (Resource Management)

An Assessment Tool for Maintenance Management **Managerial Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Resource Management		Overall average					4.3	**85**	**I**
1.	The maintenance department identified the resources needed to support the maintenance effectiveness and achieve customer satisfaction.	20	10	8	2	0	4.2	**84**	**I**
2.	Staffs who related to provide the services must be competent with good skills, education, training, and experience and sufficient in with numbers.	26	6	6	2	0	4.4	**88**	**E I**
3.	The maintenance department must provide an appropriate infrastructure for maintenance staff to carry out the required services.	22	10	4	4	0	4.3	**85**	**I**

Service Realizations

This an assessment tool which included five elements, namely the necessity of the maintenance department having a planning function for delivering the required services, the necessity of the department to identify service requirements which include specified customer requirements, regulatory requirements, and any other necessary requirements, the maintenance department must have a clear process for delivering services and its traceability, implementation of a work-order system that provided high reliability and quality of services and the maintenance department must have a plan to reduce deferred maintenance that include a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be “Important” with the listed assessment tools as with an overall average of important index of 80.4% for this criterion as indicated in Table 3-19.

Table 3-19 Rate of Important for Measurable Criteria (Service Realizations)

An Assessment Tool for Maintenance Management Managerial Category		EI	I	MI	NI	ENI	E(X)	SI %	MR
Service Realizations		Overall average					4.0	**80.4**	**I**
1.	The maintenance department must have a planning function for delivering the required services.	22	8	10	0	0	4.3	**86.0**	**I**
2.	The maintenance department must identify service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.	18	8	12	4	0	4.0	**79.0**	**I**
3.	The maintenance department must have a clear process for delivering services and its traceability.	20	8	10	6	0	4.0	**79.1**	**I**
4.	Implementation of a work-order system that provided high reliability and quality of services.	20	4	8	8	0	3.9	**78.0**	**I**
5.	The maintenance department must have a plan to reduce deferred maintenance that includes a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog.	16	8	14	4	0	3.9	**77.1**	**I**

Measurement, Analysis and Improvement

This criterion included four elements, namely implementation of IT support including CMMs to handle information related to customer requirement or perception such as customer satisfaction surveys, the need for the maintenance department to have a system

for maintenance performance measurement that has maintenance response time and its measures, the need for the maintenance department to have internal audits with their criteria and methods and on-going improvement through established quality policy, analysis of data and management review. The mean response indicated that these assessment tools were perceived to be "Important" with an overall average of important index of 82% for this criterion as indicated in Table 3-20.

Table 3-20 Rate of Important for Measurable Criteria (Measurement, Analysis and Improvement)

An Assessment Tool for Maintenance Management **Managerial Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Measurement, Analysis and Improvement		Overall average					4.1	**82.0**	**I**
1.	Implementation of IT support including CMMs to handle information related to customer requirement or perception such as customer satisfaction surveys.	20	6	6	8	0	4.0	**79.0**	**I**
2.	The maintenance department must have a system for maintenance performance measurement that has maintenance respond time and its measures.	20	4	16	2	0	4.0	**80.0**	**I**
3.	The maintenance department must have internal audits with its criteria and methods.	20	4	14	2	0	4.1	**81.0**	**I**
4.	On-going improvement through established quality policy, analyze data and management review.	22	6	4	8	0	4.1	**81.0**	**I**

Maintenance Financing

Two performance measures were included in this criterion. These measures were implementation of a good budgetary planning and control and ability to select adequate and effective outsourcing contracts and effectively coordinate with them. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that these elements were perceived to be "Extremely Important" with an overall average of important index of 87.5% for this criterion as indicated in Table 3-21.

Table 3-21 Rate of Important for Measurable Criteria (Measurement, Analysis and Improvement)

An Assessment Tool for Maintenance Management **Managerial Category**		**EI**	**I**	**MI**	**NI**	**ENI**	**E(X)**	**SI %**	**MR**
Maintenance Financing		Overall average					4.3	**87.5**	**EI**
1.	Implementation of a good budgetary planning and control.	24	10	4	2	0	4.4	**88.0**	**EI**
2.	Ability to select adequate and effective outsourcing contracts and effectively coordinate with them.	26	10	4	4	0	4.3	**86.4**	**EI**

During the distribution of the survey and interviews with maintenance experts, it was established that some criteria should be added to the development of the assessment tool and these included:

- The Maintenance Management Department must completely define the facility to its employees and instruct them how to deal with the building and to maintain it.

- Studying ways and procedures to reduce the vandalisation of the facility in cooperation with educational authorities.
- Setting standards of viability of building maintenance and continuity in service and/or demolition and rebuilding of the building according to periodic maintenance costs and the lifespan of the building.
- Creating a consultative unit to determine the terms and amounts of maintenance and rehabilitation and to decide how to implement them.

3.8 Maintenance Management Measurement Methods

In this part the different measurement methods for each criterion were evaluated by maintenance experts to determine the best method \ methods which could be used whilst conducting the three case studies to demonstrate the applicability and validity of the developed assessment tools for maintenance management. The measurement methods have been developed according to the nature of the identified measurable quality criteria which include:

- Measurement Methods of Technical Category
- Measurement Methods of Functional Category
- Measurement Methods of Behavioural Category
- Measurement Methods of Managerial Category

3.8.1 Measurement Methods of Technical Category

Thermal Comfort

Three measurement methods were identified in this criterion. These methods were measured by devices to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (22-27°C), a survey of occupants to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (must be comfortable for at least an 80% majority). The maintenance experts were asked to indicate which measurement method is best to measure this criterion; the results show that 74% of them preferred to use all of the identified measurement methods to measure, as illustrated in Figure 3-6.

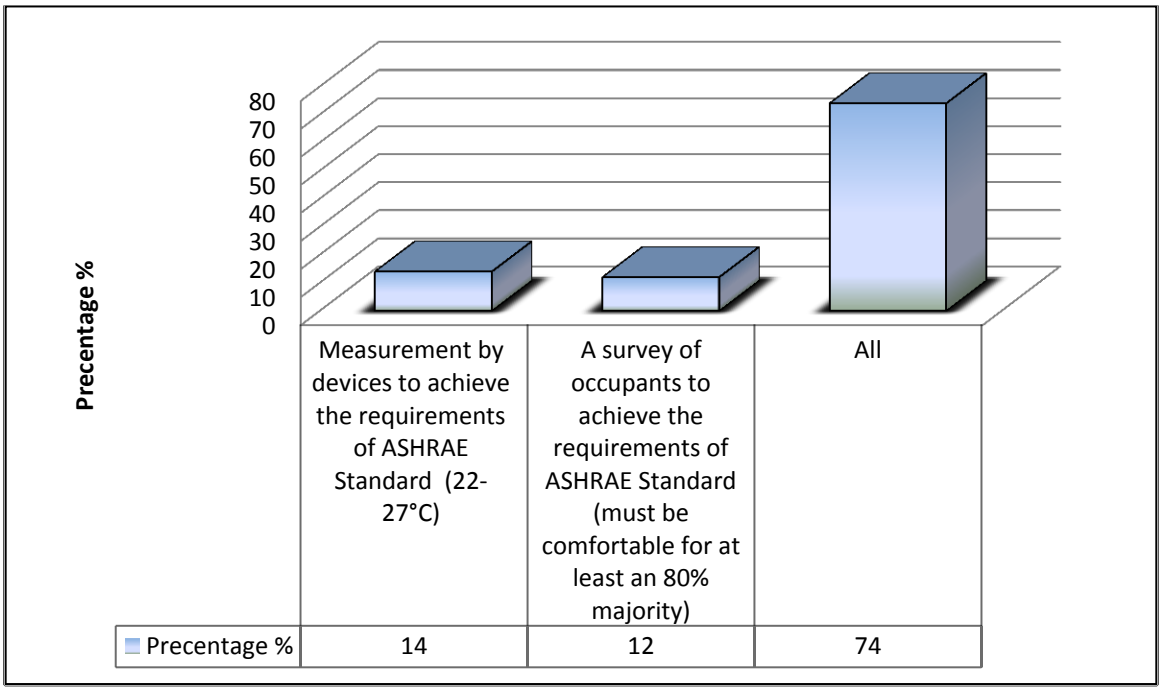

Figure 3-6 Measurement Methods to Assess Maintenance Management of Thermal Comfort

Acoustical comfort

Two measurement methods were evaluated in this assessment criterion, namely measurement by devices to achieve the requirements of ANSI S12.60 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools Standard (background sound pressure level 35-40 decibels (dB) as a maximum) and a survey of occupants to assess their satisfaction with acoustical comfort. Any or all of these methods can be applied.

The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 87% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-7.

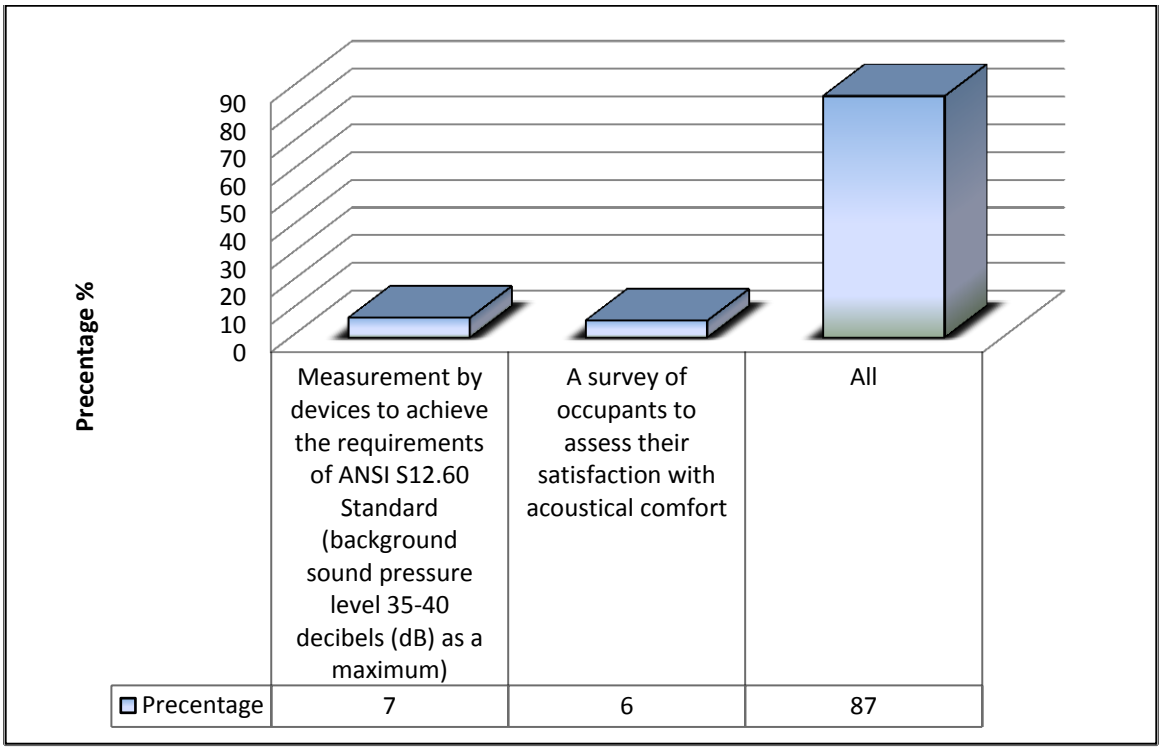

Figure 3-7 Measurement Methods to Assess Maintenance Management of Acoustical comfort

Visual Comfort

The measurement methods of this criterion are three, namely measurement by devices to achieve the requirements of the Illuminating Engineering Society of North America IESNA Lighting Handbook (typical classroom reading tasks is 30 foot-candles (FC) and a survey occupants to assess their satisfaction with visual comfort. Any or all of these methods can be applied. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 71% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-8.

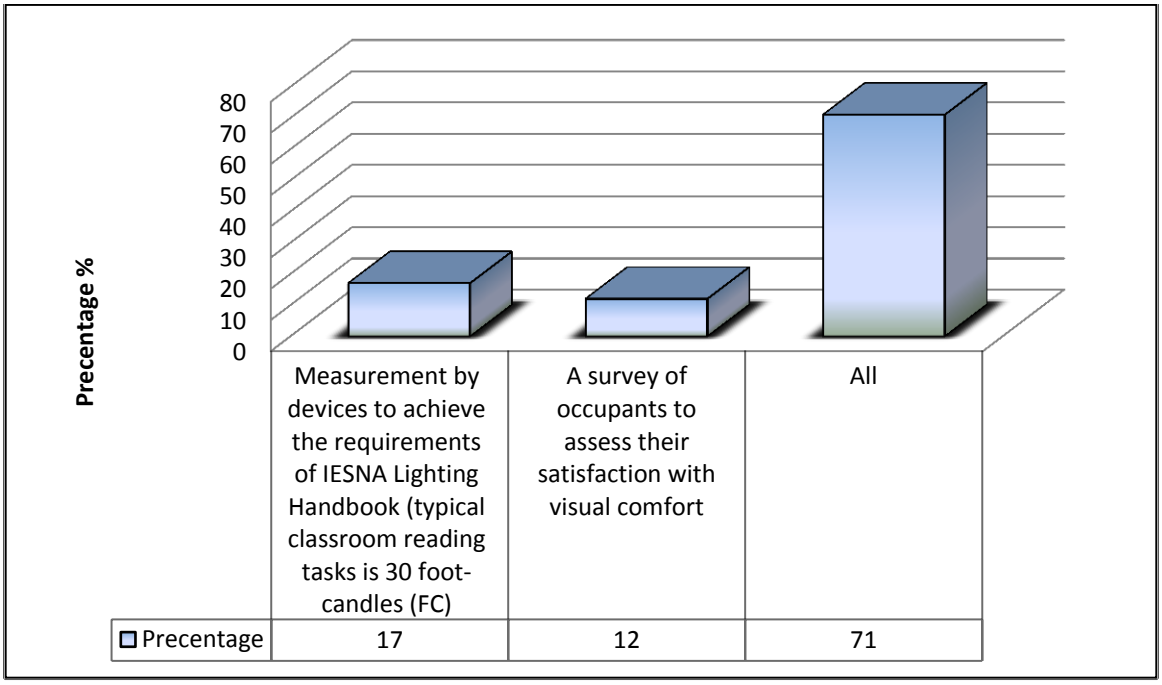

Figure 3-8 Measurement Methods to Assess Maintenance Management of Visual Comfort

Indoor Air Quality

Three measurement methods were evaluated in this assessment criterion, namely measurement by devices to achieve the requirements of ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality, Measurement by devices to achieve the requirements of ASTM D6245 - 12 Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation and a survey of occupants to achieve the requirements of ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality that must be comfortable for the majority (at least 80%) . The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 65% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-9.

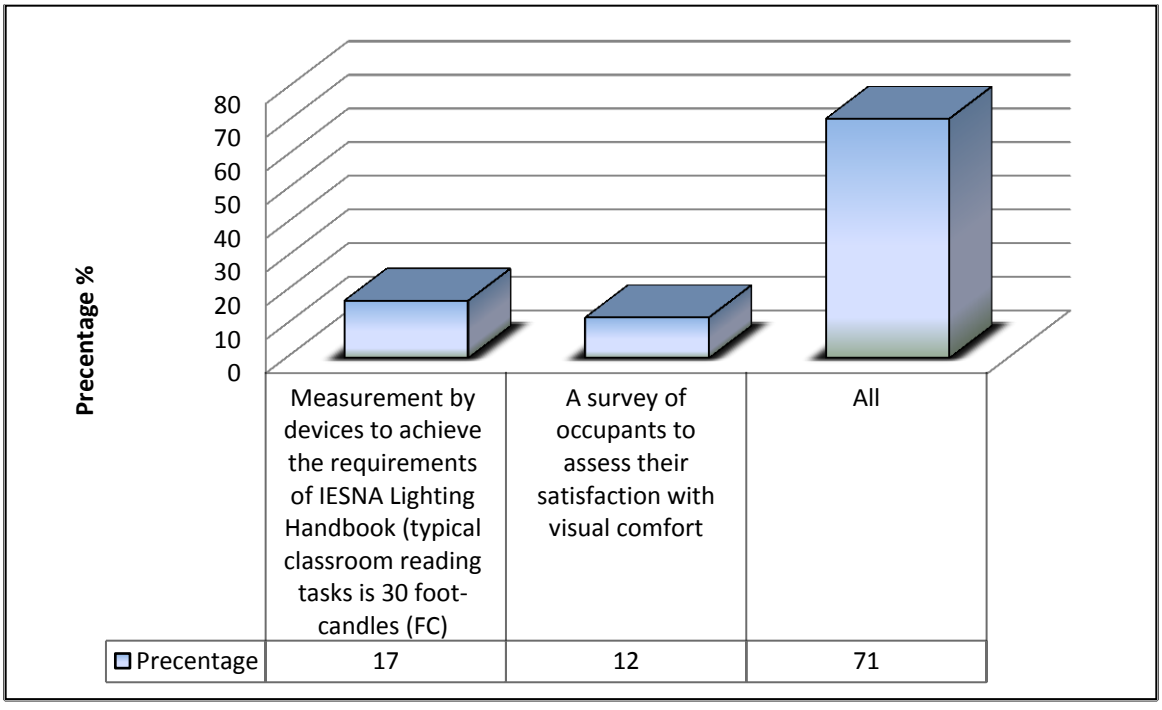

Figure 3-9 Measurement Methods to Assess Maintenance Management of Indoor Air Quality

Safety and Security

The measurement methods of this criterion are three. These methods are proof of compliance with the local safety statutory requirements, proof of a documented checklist for regular upkeep of safety systems, and a survey of occupants to assess their satisfactions with safety and security. Any or all of these methods can be applied. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 84% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-10.

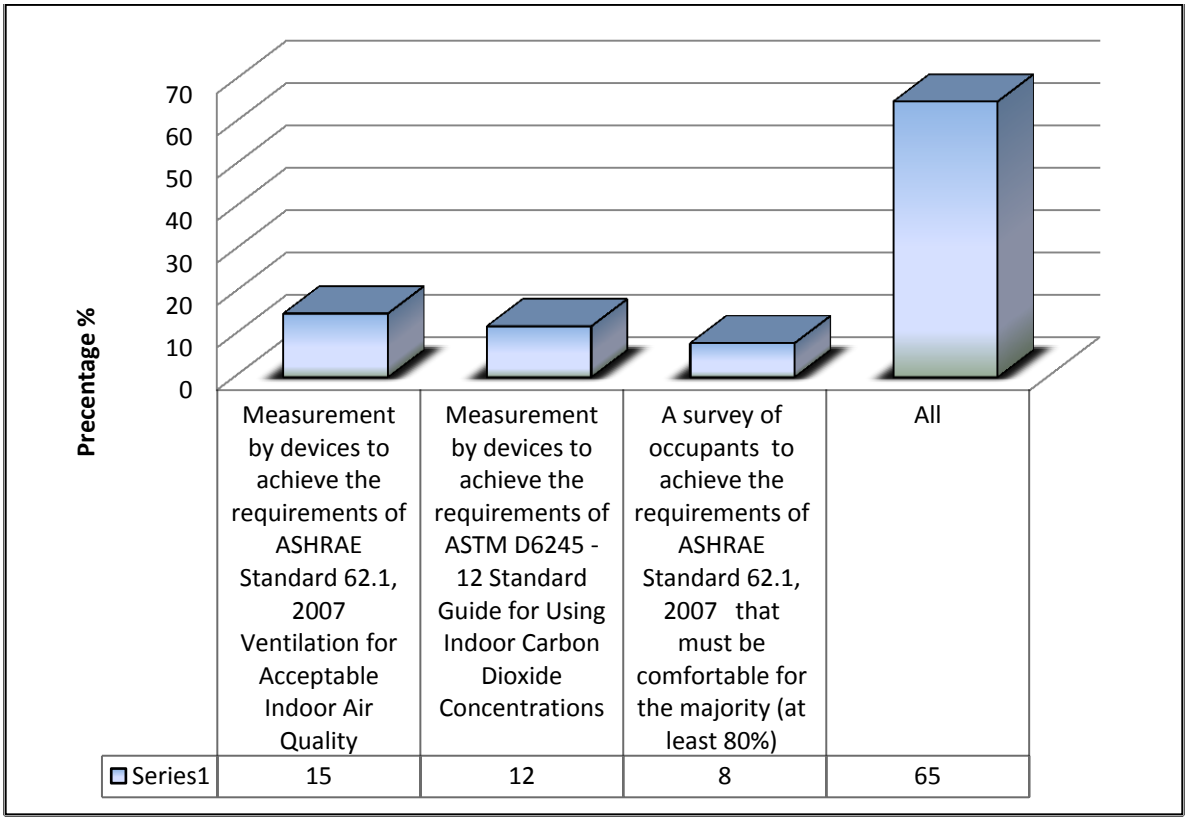

Figure 3-10 Measurement Methods to Assess Maintenance Management of Safety and Security

Cleanness

In this assessment criterion, four measurement methods were evaluated. These methods are walkthrough inspection, including evidence of implementing a recycling program, proof of a documented system for regularly evaluating the quality of cleanness and custodial programs and a survey of occupants to assess their satisfaction with cleanness. Any or all of these methods can be applied. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 54% of them preferred to use all of identified measurement methods to measure this criterion as illustrated in Figure 3-11.

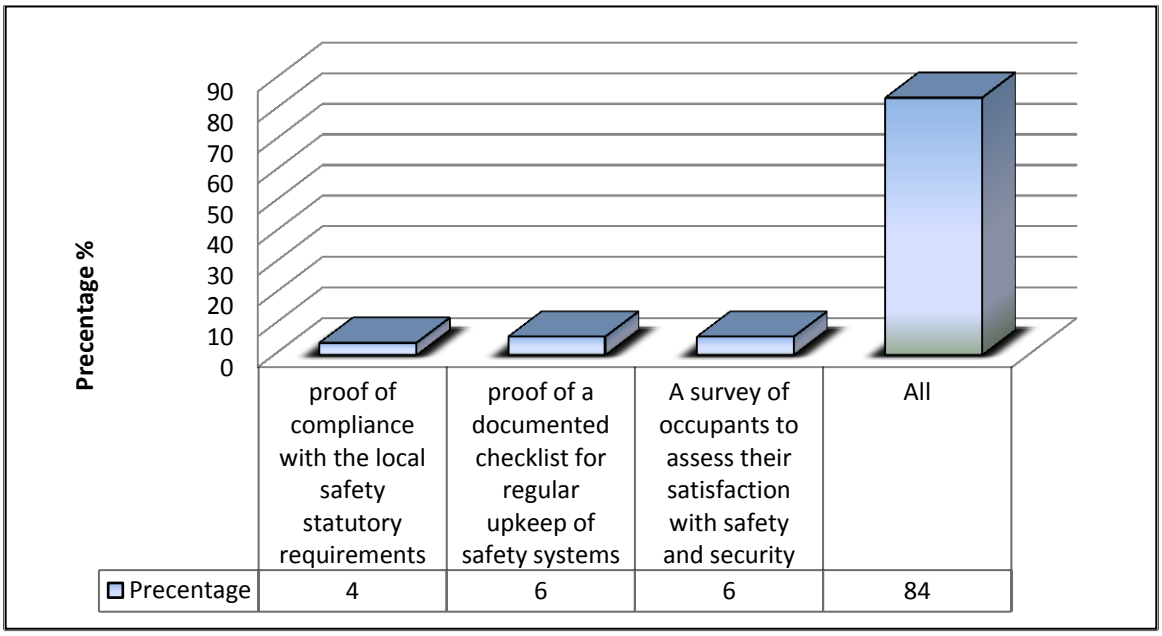

Figure 3-11 Measurement Methods to Assess Maintenance Management of Cleanness

Landscaping

The measurement methods of this criterion are three, namely walkthrough inspection to assure periodical checking for both indoor and outdoor plants, proof of a documented system for regularly evaluating the quality of landscaping and a survey of occupants to assess their satisfactions with landscaping. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 54% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-12.

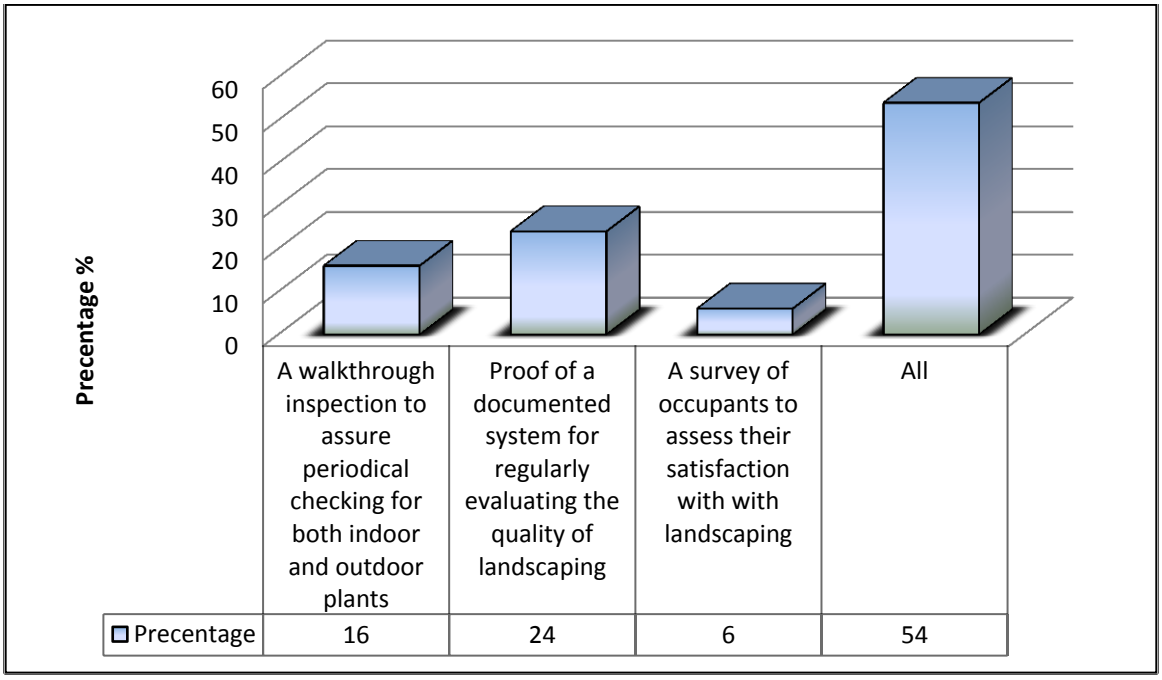

Figure 3-12 Measurement Methods to Assess Maintenance Management of Landscaping

Structural Systems

In this criterion, three measurement methods were developed which include walkthrough inspection to assure periodical checking of structural systems in the building as well as removal of any overload and proof of a documented system for regularly evaluating the quality of maintaining structural systems. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 64% of them preferred to use the first of the identified measurement methods to measure this criterion as illustrated in Figure 3-13.

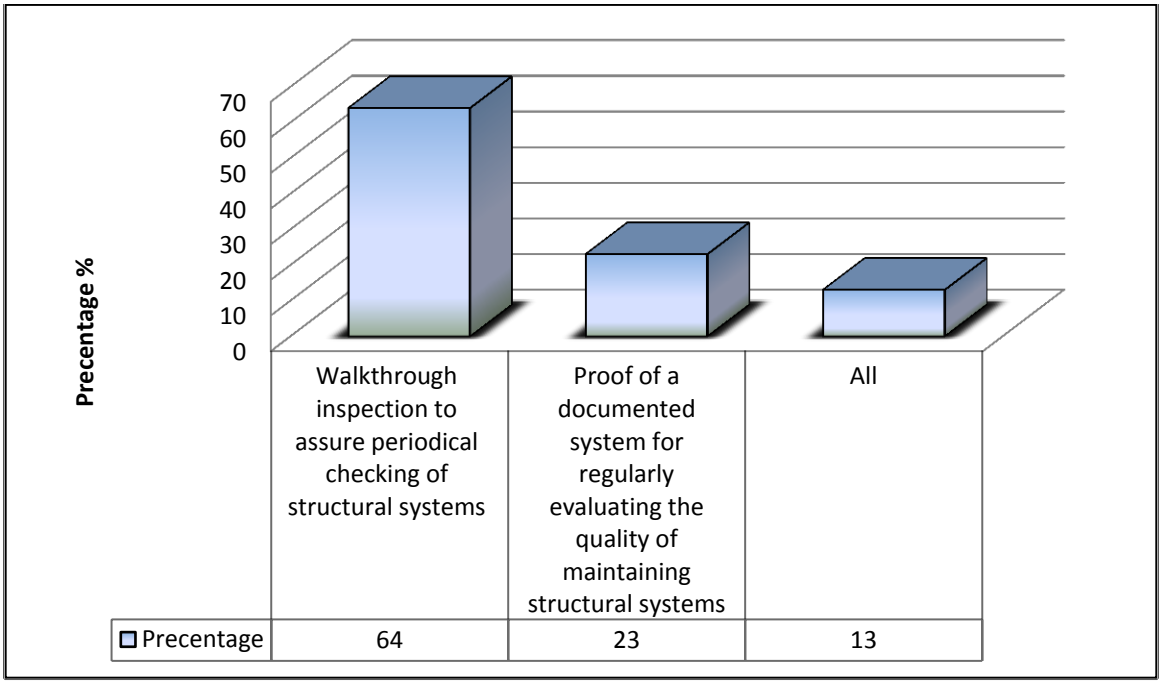

Figure 3-13 Measurement Methods to Assess Maintenance Management of Structural Systems

Mechanical, Electrical and Plumbing Systems

Two measurement methods were evaluated in this assessment criterion, namely proof of a documented system of implementation of preventive maintenance for mechanical, electrical and plumbing systems and proof of a documented system of monitoring spare parts and their efficient use. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 79% of them preferred use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-14.

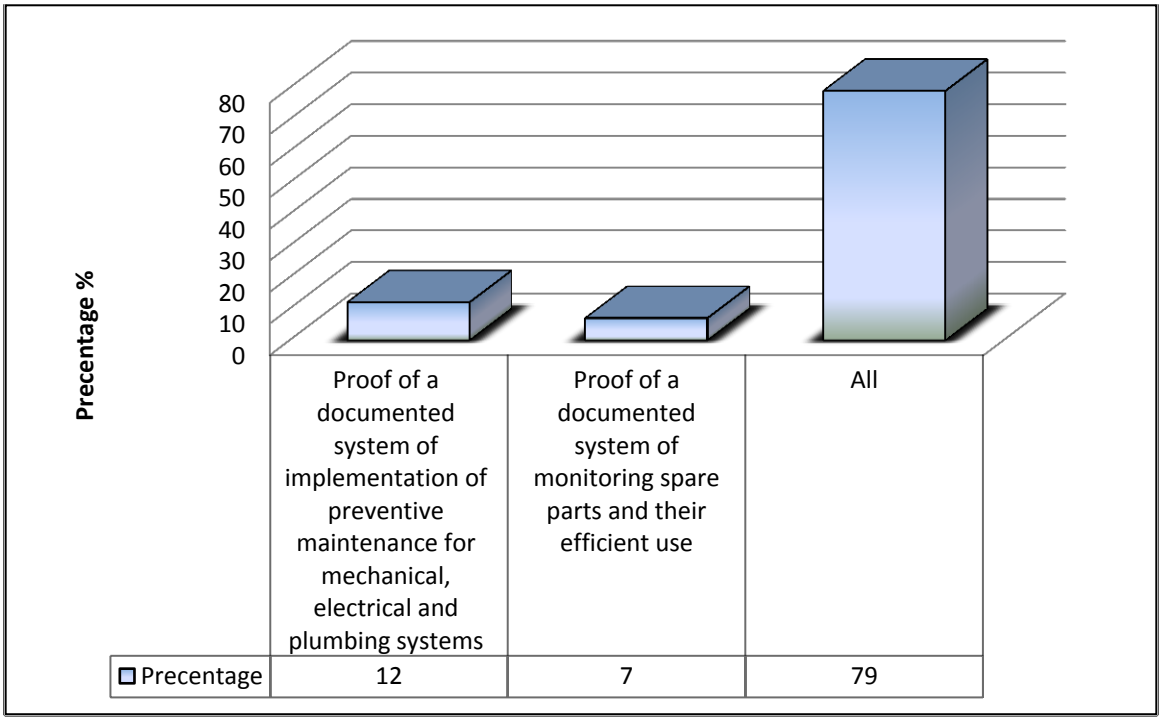

Figure 3-14 Measurement Methods to Assess Maintenance Management of Mechanical, Electrical and Plumbing Systems

3.8.2 Measurement Methods of Functional Category

Human Factors

This measurable criterion can be implemented by providing proof of a documented system to instruct maintenance staff to minimize the interruption of the educational process and by conducting a survey of occupants to assess their satisfaction with staffs response. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 62% of them preferred use the second method of the identified measurement methods "survey occupants to assess their satisfactions with staffs respond" to measure this criterion as illustrated in Figure 4-15.

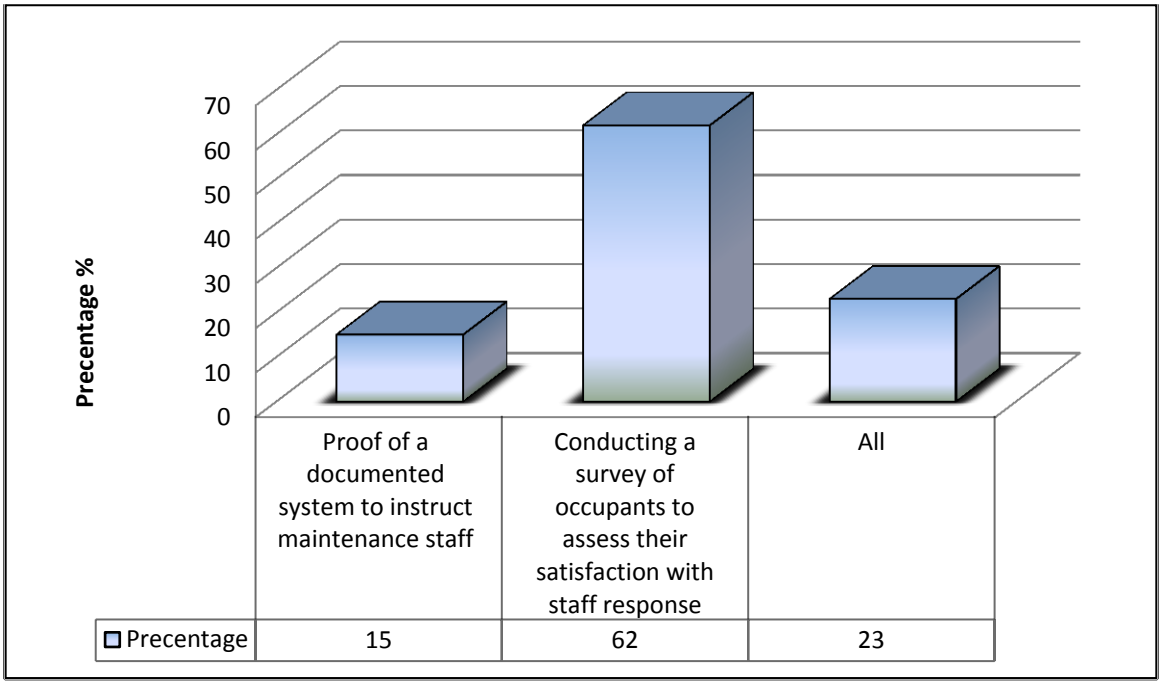

Figure 3-15 Measurement Methods to Assess Maintenance Management of Human Factors

Storage

To measure this criterion, two methods were identified. These methods were walkthrough inspection to assure that there is enough storage space for maintenance supplies/spare parts as well as a required inventory and a survey of occupants to assess their satisfaction with storage chemical products and supplies. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that they preferred to use all of the measurement methods to measure this criterion as illustrated in Figure 4-16.

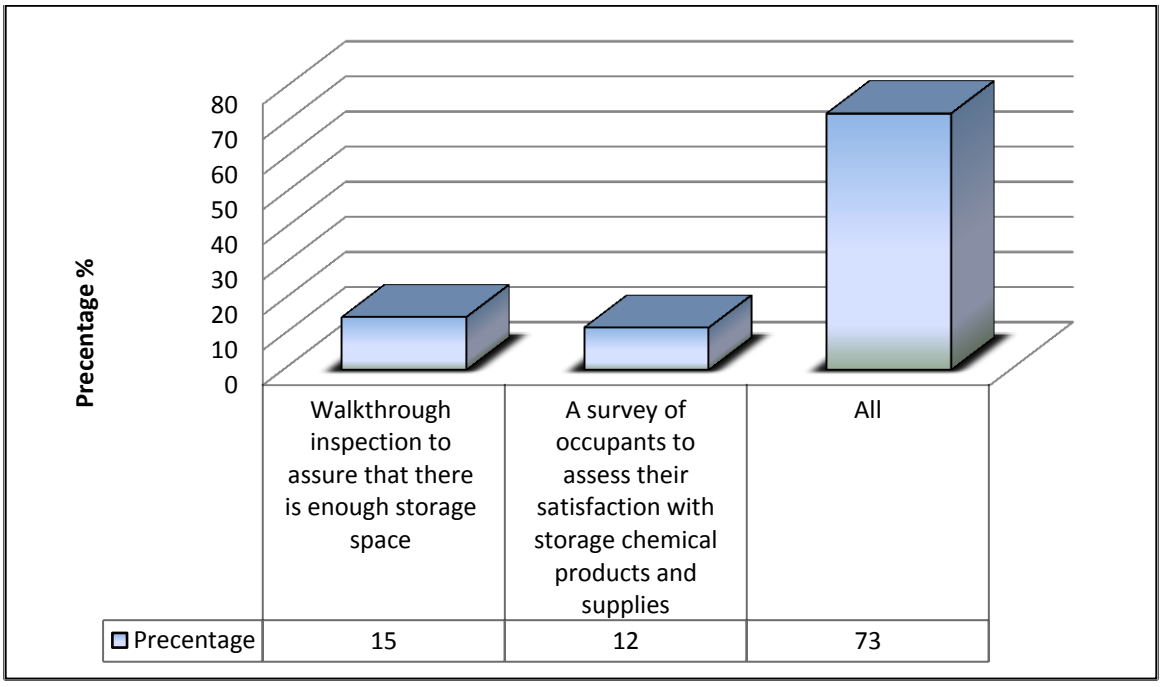

Figure 3-16 Measurement Methods to Assess Maintenance Management of Storage

Space Layout and Furniture Quality

This criterion can be evaluated through a walkthrough inspection to assure the arrangement of furniture and teaching tools, proof of a documented system for regularly evaluating the arrangement of furniture and a survey of occupants to assess their satisfaction with space layout and furniture quality. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 84% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-17.

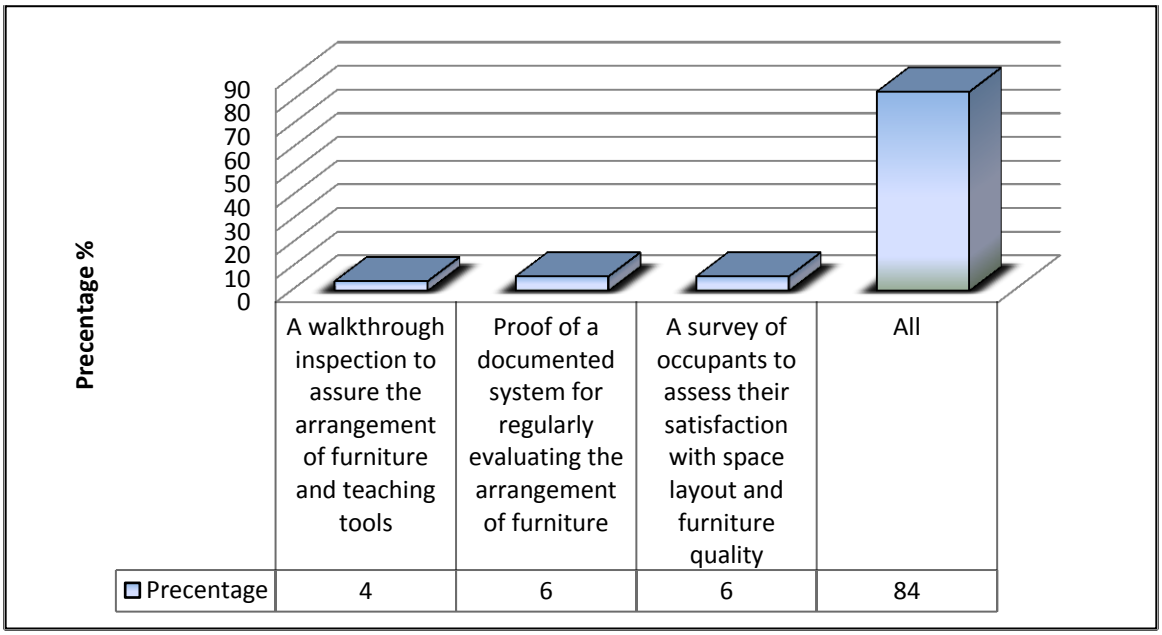

Figure 3-17 Measurement Methods to Assess Maintenance Management of Space Layout and Furniture Quality

Accessibility and Parking Space

Three measurement methods were evaluated in this assessment criterion, namely a walkthrough inspection to assure the quality of the accessibility function (including availability of emergency signage and ease of access to handicaps), proof of a documented system for regularly evaluating the quality of accessibility function and a survey of occupants to assess their satisfaction with the quality of the accessibility function. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 42% of them preferred use the first method and 35% of them preferred to use the second one of the identified measurement methods to measure this criterion as illustrated in Figure 3-18.

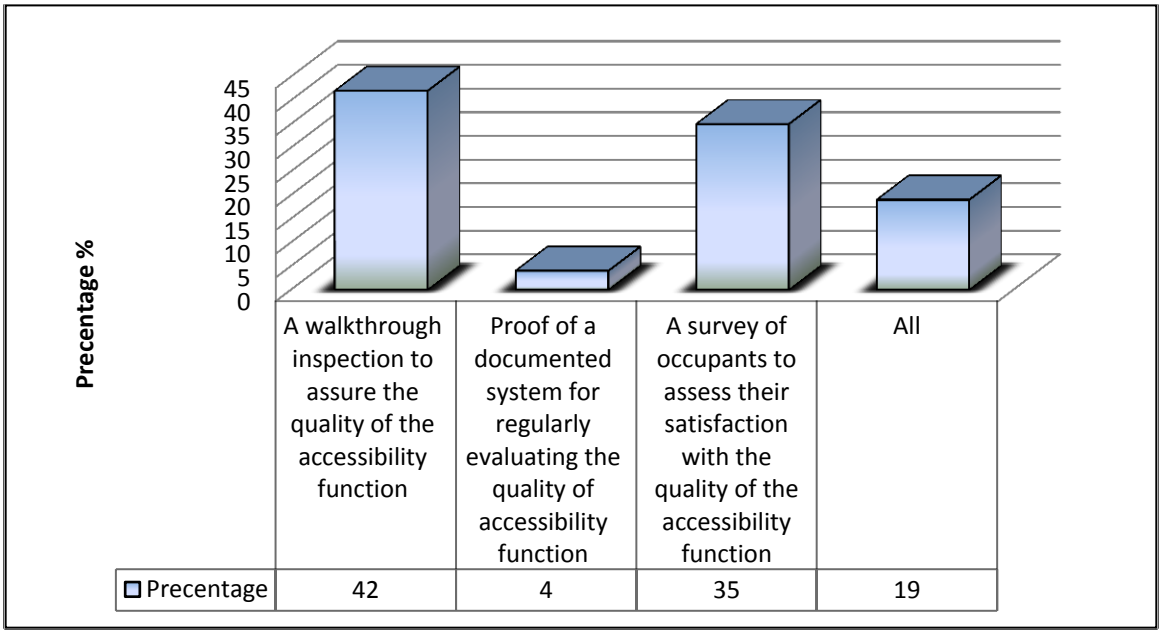

Figure 3-18 Measurement Methods to Assess Maintenance Management of Accessibility & Parking Space

3.8.3 Measurement Methods of Behavioral Category

Image and Environmental Perception

This measurable criterion can be implemented by a walkthrough inspection to assure the quality of interior and exterior finishing, proof of a documented system for regularly evaluating interior and exterior finishing and a survey of occupants to assess their satisfaction with the quality of interior and exterior finishing. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 66% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-19.

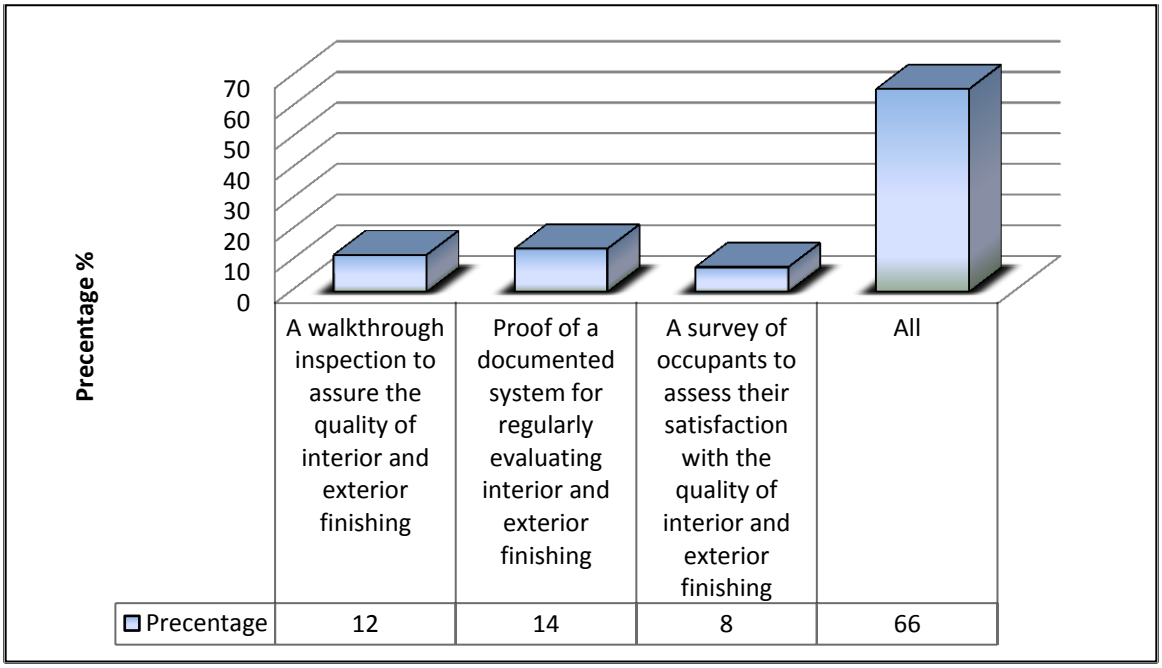

Figure 3-19 Measurement Methods to Assess Maintenance Management of Image and Environmental Perception

3.8.4 Measurement Methods of Managerial Category

Maintenance Strategy

Three methods were selected to measure this criterion. These methods were proof of a documented system for maintenance strategy, a quality policy, objective, operational and control procedures, proof of a documented system for the building's database and a staff opinion survey (Sample focus group of managers, supervisors and staff) to assess availability, implementation and effectiveness of the maintenance strategy. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 45% of them preferred to use the first method and 35% of them preferred to use the second one of the identified measurement methods to measure this criterion as illustrated in Figure 3-20.

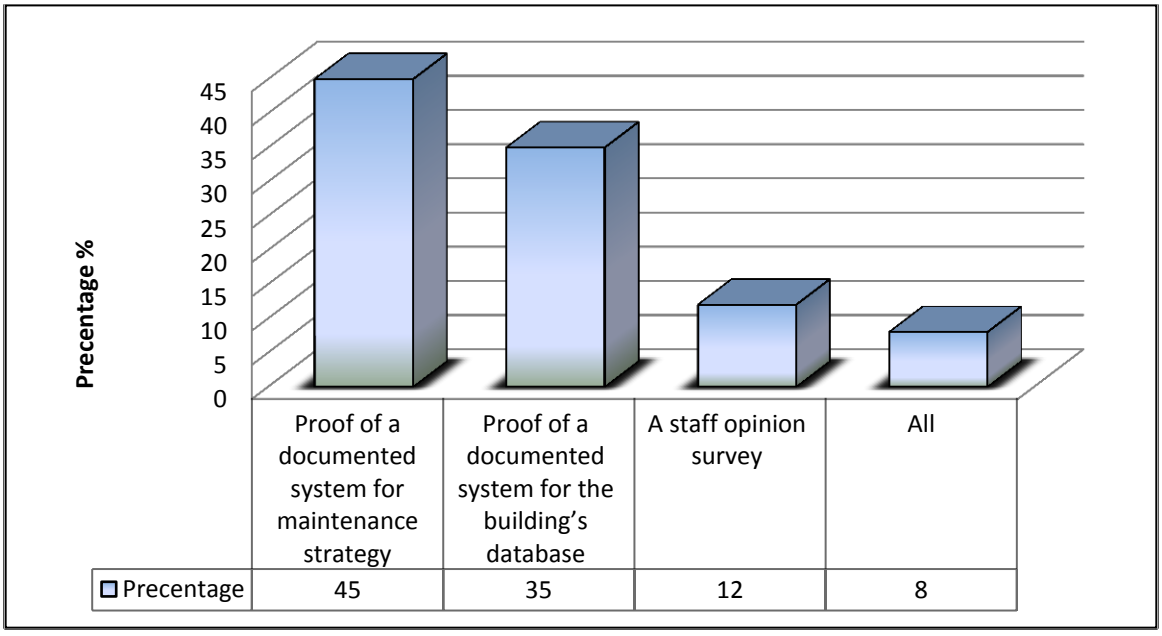

Figure 3-20 Measurement Methods to Assess Maintenance Management of Maintenance Strategy

Management Responsibilities

To implement this criterion, three methods were determined, namely proof of a documented system for the maintenance mission, staff responsibilities and organization structure and a staff opinion survey to assess their realizations of the maintenance mission, responsibilities and organization structure. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 74% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-21.

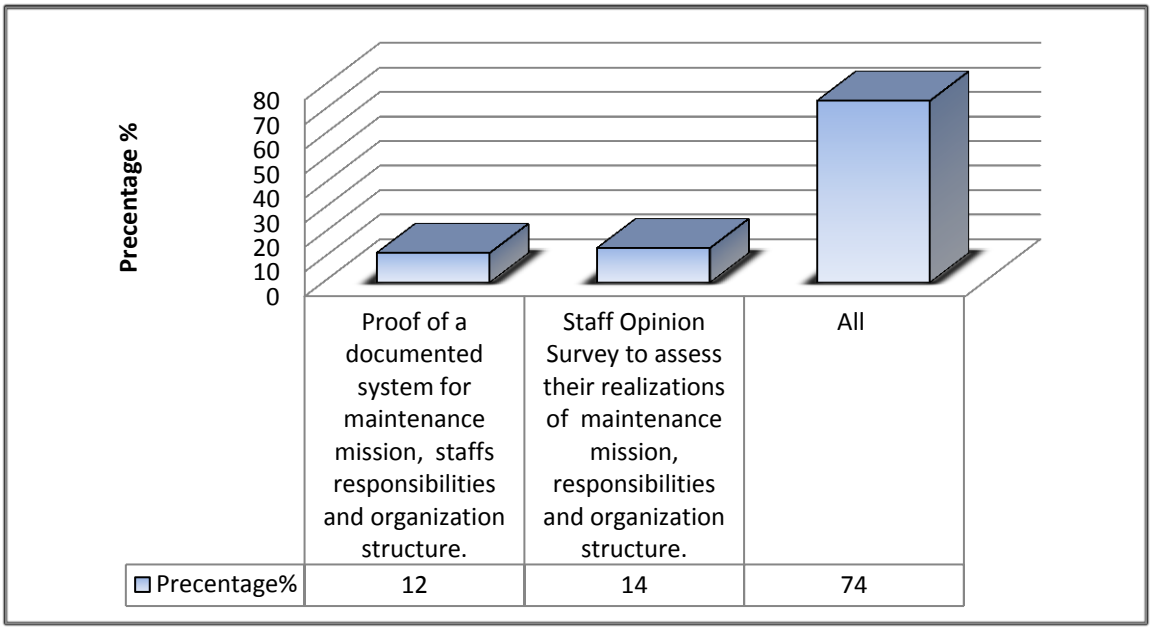

Figure 3-21 Measurement Methods to Assess Maintenance Management of Management Responsibilities

Resource Management

Four measurement methods were evaluated in this assessment criterion, namely proof of a documented system for the resources needed to support the maintenance effectiveness including an appropriate infrastructure, the achievement of the training requirements of the U.S. Occupational Safety and Health Act (OSHA) and Minnesota OSHA for activities of maintenance workers, a review of weekly and monthly reports and a staff opinion survey (Sample focus group of managers, supervisors and staff) to assess availability, implementation and effectiveness of the resources needed. The results of the assessment according to the respondents' discipline indicated that 22%, 24%, 20%, 19%, and 15% of them respectively preferred to use the identified measurement methods as illustrated in Figure 3-22.

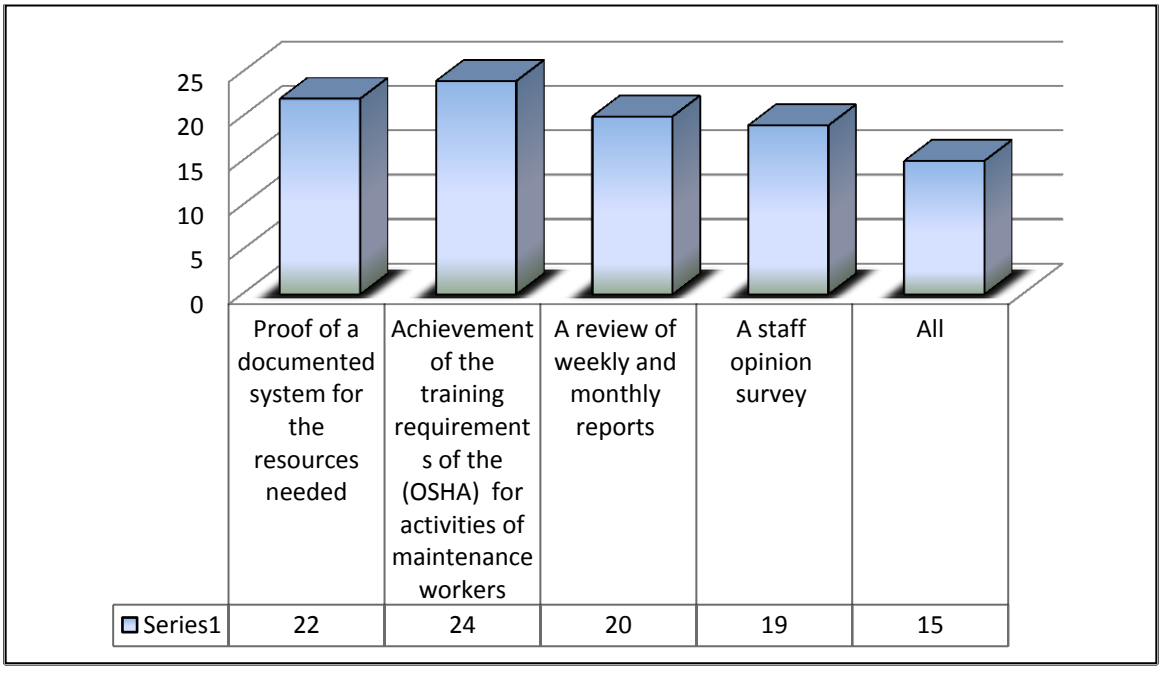

Figure 3-22 Measurement Methods to assess Maintenance Management of Resource Management

Service Realizations

This criterion can be evaluated through proof of a documented system for a plan for delivering the required services, review of weekly and monthly reports and work order sample and a survey of occupants to assess their satisfaction with the delivery of the required services. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 57% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-24.

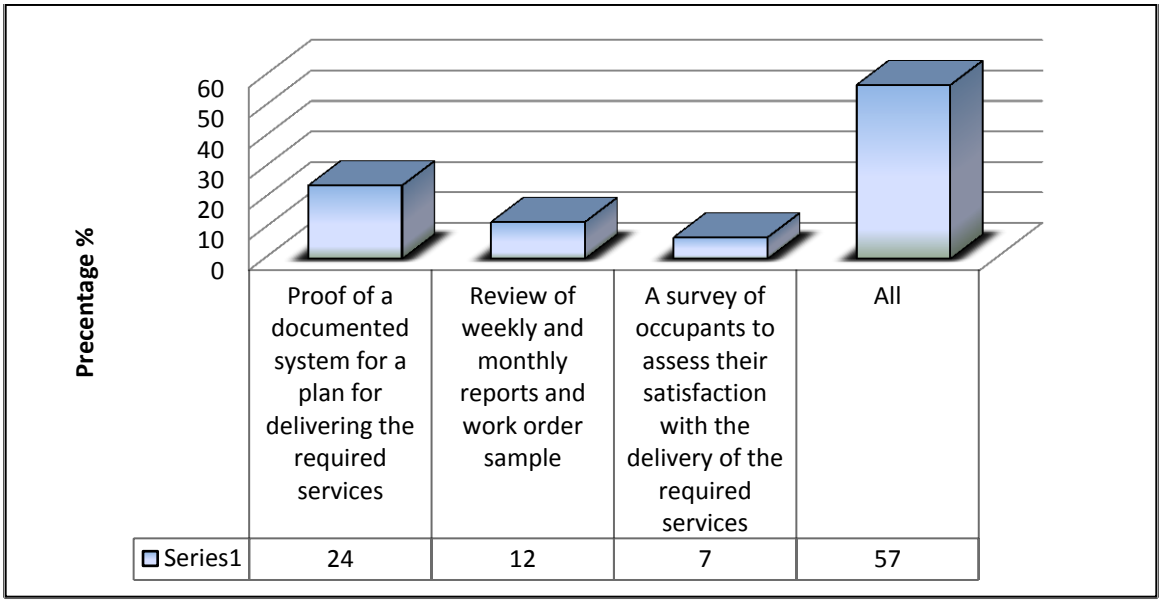

Figure 3-23 Measurement Methods to assess Maintenance Management of Service Realizations

Measurement, Analysis and Improvement

This measurable criterion can be implemented by proof of the implementation of IT support including CMMs to handle information related to customer requirements, proof of a documented system for the measurement of maintenance performance system, an internal audit and a staff opinion survey (Sample focus group of managers, supervisors and staff) to assess availability, implementation and effectiveness of the maintenance

performance measurement system. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 56% of them preferred to use all of the identified measurement methods to measure this criterion as illustrated in Figure 3-24.

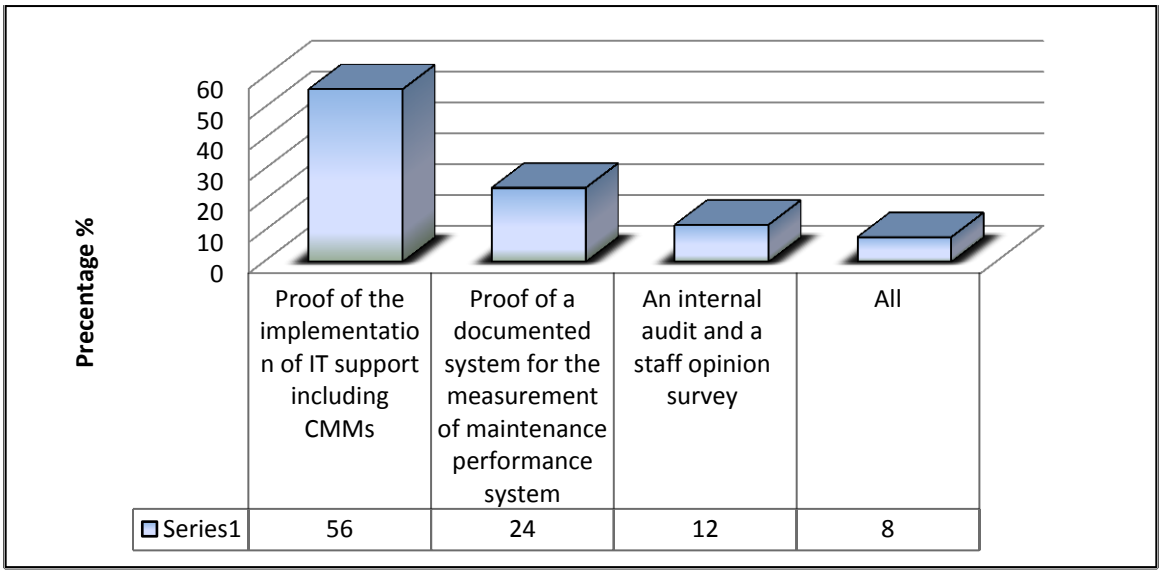

Figure 3-24 Measurement Methods to Assess Maintenance Management of Measurement, Analysis and Improvement

Maintenance Financing

Two methods were selected to measure this criterion. These methods were proof of a documented system of implementing a good budgetary planning and control including economic analysis of cost and a staff opinion survey (Sample focus group of managers, supervisors and staff) to assess the selection of effective outsourcing contracts. The mean response from the 40 maintenance experts who completed the questionnaire survey indicated that 88% of them preferred to use the first of the identified measurement methods to measure this criterion as illustrated in Figure 3-25.

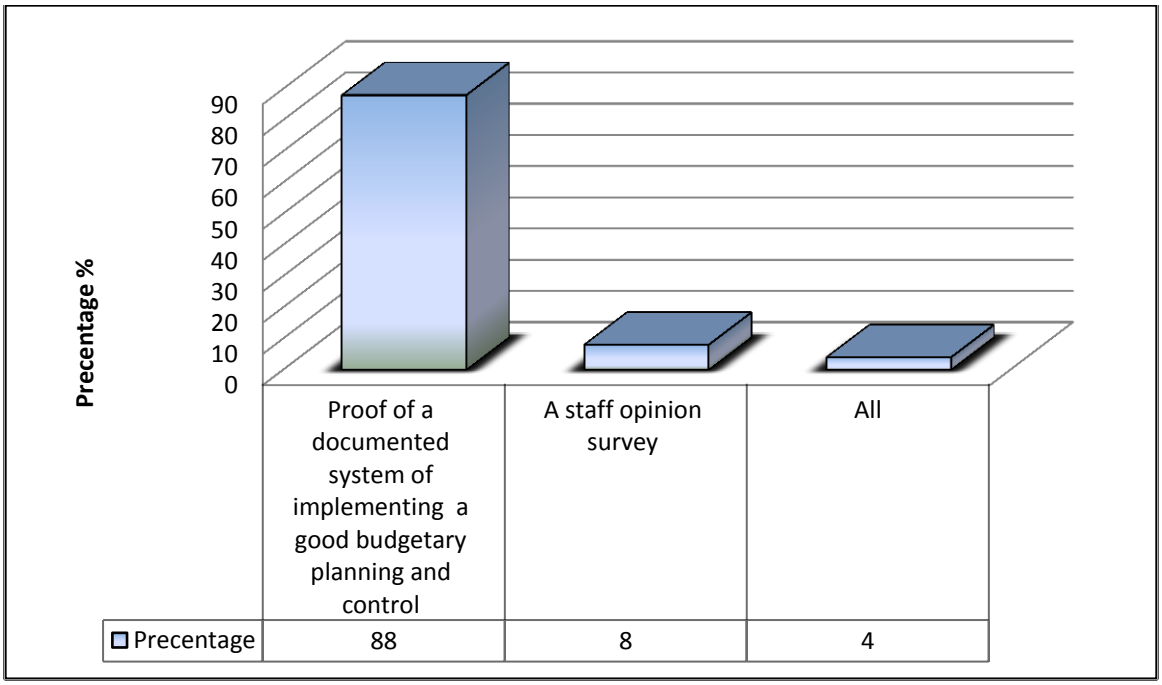

Figure 3-25 Measurement Methods to assess Maintenance Management of Maintenance Financing

3.9 Development of an Assessment Tool for Maintenance Management in Public Schools in Saudi Arabia

Based on the results obtained from the questionnaire survey, an assessment tool for maintenance management for facilities of public schools in Saudi Arabia have been developed and validated by three maintenance experts who are working in the Eastern Province of Saudi Arabia, these are:

An assessment Tool Implemented Through the use of Devices as shown in Table 3-22

An assessment Tool Measured by Walkthrough Inspection as shown in Table 3-23

An assessment Tool Measured by User Satisfaction Survey as shown in Table 3-24

An assessment Tool Measured by Staff Opinion Survey as shown in Table 3-25

An assessment Tool Measured by provision of a documented system as shown in Table 3-26

Table 3-22 An Assessment Tool Implemented Through the use of Devices

An assessment Tool Implemented Through the Use of Devices		***Achieved***	***Not Achieved***
Thermal Comfort			
01.	Measured Air Temperature Inside (°C) by devices to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (22-27°C)		
Acoustical Comfort			
01.	Measured Sound Pressure Level by devices to achieve the requirements of ANSI S12.60 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools standard (background sound pressure level 35-40 decibels (dB) as a maximum).		
Visual Comfort			
01.	Measured Illumance Level by devices to achieve the requirements of European Standard (BS EN 12464-1 Light and lighting - Lighting of work places, 2003) Reading tasks (500- 1000 Lux).		
Indoor Air Quality			
01.	Measured Indoor Carbon Dioxide Concentrations CO2 (ppm) by devices to achieve the requirements of ASTM D6245 - 12 Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation. (< 1000 ppm)		

Table 3-23 An Assessment Tool Implemented through Walkthrough Inspection

An assessment Tool Implemented Through Walkthrough Inspection		Adequate	Deficient
Cleanness			
01.	Ensure the overall cleanness throughout all spaces in the building.		
02.	Support a recycling program during cleanness process.		
03.	Ensure the overall cleanness of laboratories including removal foreign materials.		
Landscaping			
01.	Implementation of periodical checking for both indoor and outdoor plants.		
Structural Systems			
01.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.		
Storage			
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.		
02.	Provision of sealable, labeled containers for storage chemical products and supplies.		
Space Layout and Furniture Quality			
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.		
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.		
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.		
04.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.		
Accessibility & Parking Space			
01.	Implementation of periodical checking of the function and position of all signage.		
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.		
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.		
04.	Implementation of periodical checking of the availability of emergency signage.		
05.	Proximity of the building to car parking spaces.		
06.	Sufficiency of car parking spaces.		
07.	Availability of ease of access to handicaps.		
08.	Provision of a system for regularly evaluating the quality of accessibility function.		
Image and Environmental Perception			
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.		

Table 3-24 An Assessment Tool Implemented through User Satisfaction Survey

	An assessment Tool Implemented Through User Satisfaction Survey	**Strongly Satisfied**	**Satisfied**	**Dissatisfied**	**Strongly Dissatisfied**
Thermal Comfort					
01.	Provision of comfortable temperature during summer throughout all spaces in the building.				
02.	Provision of comfortable temperature during winter throughout all spaces in the building.				
Acoustical Comfort					
01.	Provision of acoustical comfort throughout all spaces in the building.				
Visual Comfort					
01.	Provision of good appearance and quality of lighting as per identified standards.				
Indoor Air Quality					
01.	Implementation of periodical inspection of the HVAC system				
Cleanness					
02.	Ensure the overall cleanness throughout all spaces in the building.				
Landscaping					
01.	Implementation of periodical checking for both indoor and outdoor plants.				
Human Factors					
01.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.				
02.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.				
Storage					
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.				
02.	Provision of sealable, labeled containers for storage chemical products and supplies.				
Space Layout and Furniture Quality					
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.				
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.				
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.				
Accessibility & Parking Space					
01.	Implementation of periodical checking of the function and position of all signage.				
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.				
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.				
04.	Implementation of periodical checking of the availability of emergency signage.				
05.	Proximity of the building to car parking spaces.				

06.	Sufficiency of car parking spaces.				
07.	Availability of ease of access to handicaps.				
Image and Environmental Perception					
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.				
Service Realizations					
01.	The maintenance department has a planning function for delivering the required services.				
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.				
03.	The maintenance department has a clear process for delivering services and its traceability.				
04.	Implementation of a work-order system that provided high reliability and quality of services.				

Table 3-25 An Assessment Tool Implemented through Staff Opinion Survey

An assessment Tool Implemented Through Staff Opinion Survey		***Strongly Agree***	***Agree***	***Disagree***	***Strongly Disagree***
Management Responsibilities					
01.	Maintenance mission stated and known to everyone in the organization.				
02.	Existence of clear organization structure.				
03.	Top management checks that responsibilities and authorities are identified to all staffs.				
Resource Management					
01.	The maintenance department identified the resources needed to support the maintenance effectiveness and achieve customer satisfaction.				
02.	Staffs who related to provide the services must be competent with good skills, education, training, and experience and sufficient in with numbers.				
03.	The maintenance department must provide an appropriate infrastructure for maintenance staff to carry out the required services.				
Service Realizations					
01.	The maintenance department has a planning function for delivering the required services.				
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.				
03.	The maintenance department has a clear process for delivering services and its traceability.				
04.	Implementation of a work-order system that provided high reliability and quality of services.				
05.	The maintenance department has a plan to reduce deferred maintenance that includes a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog.				

Table 3-26 An Assessment Tool Implemented through the Provision of a Documented System

An assessment Tool Implemented Through the Provision of a Documented System		*Yes*	*No*
Safety and Security			
01.	Proof of compliance with the local safety statutory requirements.		
02.	Proof of a documented checklist for regular upkeep of safety systems.		
Cleanness			
01.	Proof of a documented system for regularly evaluating the quality of cleanness and custodial programs.		
Landscaping			
01.	Proof of a documented system for regularly evaluating the quality of landscaping.		
Mechanical, Electrical and Plumbing Systems			
01.	Proof of a documented system of implementation preventive maintenance for mechanical, electrical and plumbing systems.		
02.	Provision of a system for regularly checking the availability of spare parts required and its efficient use.		
Space Layout and Furniture Quality			
01.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.		
Image and Environmental Perception			
01.	Provision of a system for regularly evaluating the quality of interior and exterior finishing throughout all spaces in the building.		
Maintenance Strategy			
01.	Proof of a documented system for maintenance strategy, quality policy, objective, operation procedures and control procedures.		
02.	Proof of a documented system for buildings databases.		
Management Responsibilities			
01.	Proof of a documented system for maintenance mission, staffs responsibilities and organization structure.		
02.	Proof of a documented system for the resources needed to support the maintenance effectiveness including an appropriate infrastructure.		
Resource Management			
01.	Proof of a documented system for the resources needed to support the maintenance effectiveness including an appropriate infrastructure.		
02	Review of weekly, monthly reports		
Service Realizations			
01.	Proof of a documented system for a plan for delivering the required services.		
02.	Review of weekly, monthly reports and work order sample.		
Measurement, Analysis and Improvement			
01.	Proof of an evidence of implementing IT support including CMMs to handle information related to customer requirement.		
Maintenance Financing			
01.	Proof of a documented system of implementing a good budgetary planning and control including economic analysis of cost.		

CHAPTER 4

IMPLEMENTATION OF THE DEVELOPED ASSESSMENT TOOL

4.1 Maintenance Management Current Practice

Information gathered in an interview with several engineers in the Office of the Ministry of Education in the Eastern Province established that maintenance work in public school occurs during impromptu visits to schools or at the school director's request. Also, there is no predictive maintenance program and they do not have buildings maintenance databases or maintenance management systems to evaluate their work.

On the other hand, according to interviews with the directors of the Aramco schools and engineers in the Saudi Aramco Government Built School's maintenance department, it appears that there is a maintenance management system and they have a predictive maintenance program, for example, maintenance procedures are implemented as follows:

• Maintenance requests are submitted online to the maintenance department of Saudi Aramco Schools Government Built according to the needs of the school which are grouped and classified into four categories which include office services, A\C servicing, cleaning services and construction services.

• Urgent and non-urgent maintenance requests can be made urgently and normally by the directors of the schools and there is a quick response to maintenance problems.

• There are periodical evaluations of the maintenance and safety requirements by a team from the maintenance department of Saudi Aramco Schools Government Built.

• There is a regular daily team of cleaners operating from 07:00 to 22:00.

4.2 Implementation of the Developed Assessment Tool for Maintenance Management

In this part, the developed assessment tool for maintenance management was applied at three public schools in the Eastern Province of Saudi Arabia to evaluate and assess the existing maintenance management practices and to provide validation for them by checking the consistency between the outcomes of the assessment tools and the maintenance management practices. Furthermore, additional quality criteria were identified during the conduct of the three case studies which have been selected randomly, these are:

Cast study 1: Abdurrahman Binalqasem School

Cast study 2: Saudi School

Cast study 3: Al-khobar Secondary School

4.2.1 Implementation of the Developed Assessment Tool for Maintenance Management: A case study (Abdurrahman Binalqasem School)

This study was conducted on the Abdurrahman Binalqasem School (as shown in figure 4-1) which is located in the Althigba District, Eastern Province of Saudi Arabia. The school can accommodate up to 500 students. The case study was conducted towards the beginning of winter semester.

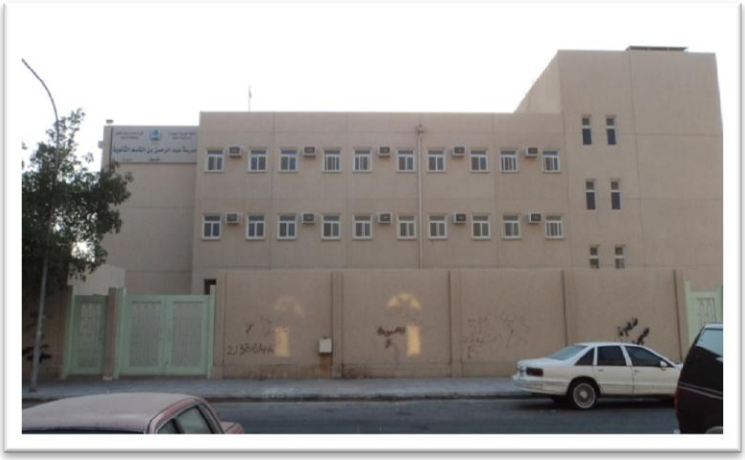

Figure 4-1 Abdurrahman Binalqasem School

Measurement Method by Devices

The devices which are available in the ARE laboratory were used to measure some parameters that are related to some criteria which include thermal comfort, acoustical comfort, visual comfort and indoor air quality.

Physical Environment

The IEQ elements, namely interior air temperature, humidity, sound pressure level, luminance, and carbon dioxide levels were measured in the selected classrooms and teachers' offices. The outdoor weather conditions were similar during measurements at 84.7°F and 61.12% relative humidity. Temperature was within the permissible level of 22-27°C, with the average in classrooms at 26.3°C, but teachers' offices at 31.1°C were not. Similarly, relative humidity (standard is between 30-60%) was at 38.8% in classrooms and 30 % in teachers' offices. The noise level in classrooms was 77 dbA and 73 dbA in teachers' offices. The standard for noise levels is 35dbA, proving that both classrooms and teachers' offices exceed recommended noise levels. Similarly, luminance level (standard for classroom is 538.2 lux) was 755 in classrooms and 790 in teachers' offices. Finally indoor carbon dioxide concentrations were within the permissible level (< 1000 ppm) as shown in Table 4-1.

Table 4-1 Average of Physical Environment Measurements in the Abdurrahman Binalqasem School Compared to Standards

Parameters	Standard	Classroom	Teacher office
Air Temperature Inside (°C)	22-27°C	26.3	31.1
Humidity (%)	30-60 %	38.8	30
Sound Pressure Level (A weighted decibel)	35-50	77	73
Illumance (lux)	538.2	755	790
Indoor Carbon Dioxide Concentrations CO2(ppm)	(< 1000 ppm)	269	156

Walkthrough Inspection

Walkthrough Inspection is one of the most important methods to implement several measurable quality criteria in the developed assessment tool. It reflects the current state related to certain criteria, such as cleanness, landscaping, storage, space layout, furniture quality, accessibility and parking space. During a walkthrough inspection in the school, it was noted that some of the criteria and requirements of assessment tools were met. These criteria as shown in table 4-2 include adequacy and capacity of teachers' offices and computer laboratories, availability of teaching tools and their readiness for use, ease of location of rooms in the building by visitors and the high quality of interior and exterior finishing. However, it was observed that the school suffered from some problems, such as the poor level of overall cleanliness throughout all spaces in the building and the lack of support for a recycling program. Also, there were no plants in the school. Furthermore, there were no notices to show the occupants or visitors the emergency exits, thus making it difficult to locate them. Also, it was difficult to identify and reach the fire alarm system as shown in Figures 4, 2-5. Walk through inspection have been done based on recommended standard (see Appendix II). For example, walk through inspection to assess maintain landscaping according to Custodial Standards, 2010 based and not limited to:

1- Sidewalks will be kept free of weeds.
2- Planters will be maintained in an aesthetic condition by removing trash and unwanted vegetation.
3- Tree limbs will not hang below a height of 7 feet in student travel areas.
4- Exterior surfaces will be washed annually.

5- Exterior painted surfaces will be maintained in an aesthetic condition.

Figure 4-2 Abdlrhmuan Binalqasem Schoolyard

Figure 4-3 Abdlrhmuan Binalqasem School -Teacher Office

Figure 4-4 Abdlrhmuan Binalqasem School - Unneeded Furniture

Figure 4-5 Abdlrhmuan Binalqasem School – Plumbing System

Table 4-2 Walkthrough Inspection Results on the Abdlrhmuan Binalqasem School

An Assessment Tool for Maintenance Management Measured by Walkthrough Inspection		*Adequate*	*Deficient*
Cleanness			
01.	Ensure the overall cleanness throughout all spaces in the building.		☒
02.	Support a recycling program during cleanness process.		☒
03.	Ensure the overall cleanness of laboratories including removal foreign materials.		☒
Landscaping			
01.	Implementation of periodical checking for both indoor and outdoor plants.		☒
Structural Systems			
01.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.	☒	
Storage			
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.		☒
02.	Provision of sealable, labeled containers for storage chemical products and supplies.		☒
Space Layout and Furniture Quality			
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	☒	
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.		☒
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	☒	
04.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.		☒
Accessibility & Parking Space			
01.	Implementation of periodical checking of the function and position of all signage.		
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	☒	
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.		☒
04.	Implementation of periodical checking of the availability of emergency signage.		☒
05.	Proximity of the building to car parking spaces.		☒
06.	Sufficiency of car parking spaces.		
07.	Availability of ease of access to handicaps.		☒
08.	Provision of a system for regularly evaluating the quality of accessibility function.		☒
Image and Environmental Perception			
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	☒	

Occupants' Perceptions

To implement the developed assessment tools, we were required to measure user satisfaction. The occupants' assessment of the building could provide valuable information about its performance and satisfaction levels. A total of 50 participants were expected and 42 responded. The questionnaire survey consisted of 24 questions. At the same time, as the survey was distributed to the students, a survey was also distributed to the teachers.

The respondents to the questionnaire were required to comment on their degree of satisfaction (how do they feel) with the listed elements of performance by selecting one of four evaluation terms provided. The evaluation terms used, along with their corresponding weight, were "Strongly Satisfied" with 4 points, "Satisfied" with 3 points, "Dissatisfied" with 2 points, and "Strongly Dissatisfied" with 1 point. The mean response for each element of performance was calculated as follows:

Step 1: The number of responses for each evaluation term will be multiplied by the corresponding weight of that evaluation term.

Step 2: The sum of the products of multiplication from Step 1 will be divided by the number of persons responding to the questionnaire survey.

To be able to quantify the degree of satisfaction for each element of performance, the author has adopted the following calibration:

. If the mean response is below 1.49, then the respondents are "Strongly Dissatisfied".

. If the mean response is between 1.50 and 2.49, then the respondents are "Dissatisfied".

. If the mean response is between 2.50 and 3.49, then the respondents are “Satisfied”.

. If the satisfaction index is above 3.50, the respondents are “Strongly Satisfied”.

The mean response from the student and teachers who completed the survey indicated that they were “Dissatisfied” with five out of the six performance elements listed as shown in Table 4-3. Some of the most noteworthy trends in the Table which received a complete negative response, “Strongly Dissatisfied”, were observed in the categories of periodical checking for both indoor and outdoor plants, the availability of maintenance staff to provide assistance when required, difficulty of contacting them and inability to understand the users’ requirements, provision of enough storage space for maintenance supplies/spare parts as well as a required inventory, provision of sealable, labeled containers for storage of chemical products and supplies, ease of identifying and reaching the building’s main entrance, availability of emergency signage, sufficiency of car parking spaces, availability of ease of access for the handicapped and provision of high quality and reliable maintenance services required.

Table 4-3 Satisfaction Survey for Abdurrahman Binalqasem School Occupants

An Assessment Tool for Maintenance Management Measured by User Satisfaction Survey		*SS*	*S*	*DS*	*SD*	*EX*	*Mean Responses*
Thermal Comfort							
01.	Provision of comfortable temperature during summer throughout all spaces in the building.	0	15	17	17	2.0	**D**
02.	Provision of comfortable temperature during winter throughout all spaces in the building.	0	28	21	0	2.6	**D**
Acoustical Comfort							
01.	Provision of acoustical comfort throughout all spaces in the building.	4	14	21	10	2.2	**D**
Visual Comfort							
01.	Provision of good appearance and quality of lighting as per identified standards.	10	14	17	1	2.8	**S**
Indoor Air Quality							
01.	Implementation of periodical inspection of the HVAC system	7	10	17	7	2.4	**D**
Cleanness							
02.	Ensure the overall cleanness throughout all spaces in the building.	14	16	6	7	2.9	**S**
Landscaping							
01.	Implementation of periodical checking for both indoor and outdoor plants.	0	2	8	32	1.3	SD
Human Factors							
01.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.	0	2	7	33	1.3	**SD**
02.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.	0	7	7	35	1.4	**SD**
Storage							
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.	0	4	10	28	1.4	**SD**
02.	Provision of sealable, labeled containers for storage chemical products and supplies.	0	2	7	33	1.3	**SD**
Space Layout and Furniture Quality							
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	7	35	7	7	2.8	**S**
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.	0	28	21	0	2.6	**S**
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	0	21	21	0	2.5	**S**
Accessibility & Parking Space							
01.	Implementation of periodical checking of the function and position of all signage.	21	21	14	0	3.1	**D**
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	2	2	8	30	1.4	**SD**
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.	7	35	7	7	2.8	**S**
04.	Implementation of periodical checking of the availability of emergency signage.	0	2	11	29	1.4	**SD**
05.	Proximity of the building to car parking spaces.	8	10	7	21	2.1	**D**
06.	Sufficiency of car parking spaces.	2	3	3	33	1.4	**SD**
07.	Availability of ease of access to handicaps.	0	2	9	31	1.3	**SD**

Image and Environmental Perception							
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	7	28	14	0	2.9	**S**
Service Realizations							
01.	The maintenance department has a planning function for delivering the required services.	2	3	3	33	1.4	**SD**
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.	8	10	7	21	2.1	**D**
03.	The maintenance department has a clear process for delivering	2	3	3	33	1.4	**SD**
04.	services and its traceability.						
	Implementation of a work-order system that provided high reliability and quality of services.	0	2	9	31	1.3	**SD**

Staff Opinion Survey

The school is administrated by the General Administration of Education in the Eastern Province (Boys) Construction Department. The developed questionnaire was administered to the engineers who were working there. 10 responses to the questionnaire survey were obtained. The respondents to the questionnaire survey were asked to assess the existing practice of maintenance management with the listed elements of performance, through selecting one of four evaluation terms provided. The questionnaire survey included 20 identified elements of performance. These elements were classified under six performance categories, which included maintenance strategy, management responsibilities, resource management, service realizations, measurement, analysis and improvement, and maintenance financing. The evaluation terms used, along with their corresponding weight, were “Strongly agree” with 4 points, “Agree” with 3 points, “Disagree” with 2 points, and “Strongly Disagree” with 1 point. The mean response for each element of performance was calculated as follows:

Step 1: The number of responses for each evaluation term will be multiplied by the corresponding weight of that evaluation term.

Step 2: The sum of the products of multiplication from Step 1 will be divided by the number of persons responding to the questionnaire survey.

To be able to quantify the degree for each element of performance, the author has adopted the following calibration:

If the mean response is below 1.49, then the respondents “Strongly Disagree”.

If the mean response is between 1.50 and 2.49, then the respondents “Disagree”.

If the mean response is between 2.50 and 3.49, then the respondents “Agree”.

If the mean response is above3.5, then the respondents “Strongly Agree”.

The most noteworthy trends in the results show that most engineers who are working in the General Administration of Education in the Eastern Province ether disagreed or strongly disagreed with the performance of elements as discussed below:

Management Responsibilities

Three elements were evaluated in this assessment category. These elements were the statement of maintenance mission and evidence of its dissemination to everyone in the organization, existence of clear organization structure and top management check that responsibilities and authorities are identified to all staff. The mean response from 10

engineers who completed the survey indicated that they opted for “Disagree” with the listed performance elements as indicated in Table 4-4.

Resource Management

Three performance measures were included in this category. These measures were the identification by the maintenance department of the resources needed to support the maintenance effectiveness and to achieve customer satisfaction, ensuring that staff who members responsible for the provision of the services are competent with good skills, education, training, and experience and sufficient in number and the provision by the maintenance department of an appropriate infrastructure for maintenance staff to carry out the required services. The mean response from 10 engineers who completed the survey indicated that they opted for “Disagree” with the listed performance elements as indicated in Table 4-4.

Service Realizations

The engineers were asked to evaluate five elements in this assessment category. These elements were the necessity of the maintenance department to have a planning function for delivering the required services, and to identify service requirements which include specified customer requirements, regulatory requirements, and any other necessary requirements. Additionally the maintenance department must have a clear and transparent process for delivering services, an implementation of a work order system that provided

high reliability and quality of services and a plan to reduce deferred maintenance that included a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog. The mean response from 10 engineers who completed the survey indicated that they opted for "Strongly Disagree" with the main listed performance elements as indicated in Table 4-4.

Table 4-4 Staff Opinion Survey in the General Administration of Education in the Eastern Province (boys) – Construction Department

	An Assessment Tool for Maintenance Management	*Strongly agree*	*Agree*	*Disagree*	*Strongly disagree*	*E(X)*	MR
Management Responsibilities							
01.	Maintenance mission stated and known to everyone in the organization.	1	1	6	2	**2.10**	**D**
02.	Existence of clear organization structure.	0	2	4	4	**1.80**	**D**
03.	Top management check that responsibilities and authorities are identified to all staffs.	1	3	3	4	**2.09**	**D**
Resource Management							
01.	The maintenance department identified the resources needed to support the maintenance effectiveness and achieve customer satisfaction.	1	1	2	8	**1.58**	**D**
02.	Staffs who related to provide the services must be competent with good skills, education, training, and experience and sufficient in with numbers.	0	0	5	5	**1.50**	**D**
03.	The maintenance department provides an appropriate infrastructure for maintenance staff to carry out the required services.	0	1	7	2	**1.90**	**D**

Service Realizations							
01.	The maintenance department has a planning function for delivering the required services.	0	0	4	6	**1.40**	**SD**
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.	0	0	4	6	**1.40**	**SD**
03.	The maintenance department has a clear process for delivering services and its traceability.	0	2	2	6	**1.60**	**D**
04.	Implementation of a work-order system that provided high reliability and quality of services.	0	1	3	7	**1.45**	**SD**
05.	The maintenance department has a plan to reduce deferred maintenance that includes a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog.	0	0	4	6	**1.40**	**SD**

Proof of Documented Systems

In this part, to implement the developed assessment tool, the maintenance management department requires to provide documented systems as shown in Table 3-5. However, the school is administrated by the General Administration of Education in the Eastern Province (Boys) Construction Department. According to interviews with engineers who are working there, there were no documented systems for maintenance in the department.

4.2.2 Implementation of the Developed Assessment Tool for Maintenance Management: A case study (Saudi School)

This study was conducted in Saudi School (as shown in figure 4-6) which is located in Abha Street, Althigba District, and Eastern Province of Saudi Arabia. The school can accommodate up to 500 students. The case study was conducted towards the beginning of winter semester.

Figure 4-4 Saudia School

Physical Environment

Temperature was within the permissible level of 22-27°C, with an average in classrooms of 26.3°C, but teachers' offices were at 27. 08 °C. Similarly, relative humidity (standard is between 30-60%) was at 47.7% in classrooms and 42.9 % in teachers' offices.The noise levels in classrooms were at 85.5 dbA and 61.2 dbA in teacher offices. The standard for noise levels is 35dbA, proving that both classrooms and teachers' offices

exceeded recommended noise levels. Similarly, the lluminance level (standard for classroom is 538.2 lux) was 550 in classrooms and 241 in teachers' offices. Finally indoor carbon dioxide concentrations were within the permissible level (< 1000 ppm) as shown in Table 4-5.

Table 4-5 Average of Physical Environment Measurements in the Saudia School Compared to Standards

Parameters	**Standard**	**Classroom**	**Teacher office**
Air Temperature Inside (F)	22-27°C	27.3	27.08
Humidity(%)	30-60 %	47.7	42.9
Sound Pressure Level (A weighted decibel)	35-50	85.5	61.2
Illumance (Lux)	30	550	241
Indoor Carbon Dioxide Concentrations CO2(ppm)	(< 1000 ppm)	70	115

Walkthrough Inspection Checklist

During the walkthrough inside the building, it was noted that the school suffered from many maintenance problems. The overall cleanness throughout all spaces in the building was poor because there were no regular cleaners. It was observed that many of the walls, especially in the toilets had graffiti on them. Furthermore, there was no support for a recycling program during the cleanness process. The school does not have indoor or

outdoor plants. It was noted that there was a lack of regular maintenance of the structure systems of the building. Many of the doors and windows were broken. Furniture and seating arrangements were very poor and it was observed that several chairs and tables were broken. Also, it was noted that some air conditioning units did not work well and some of them were broken as shown in Table 4-6 and Figures 4-7 and 4-8.

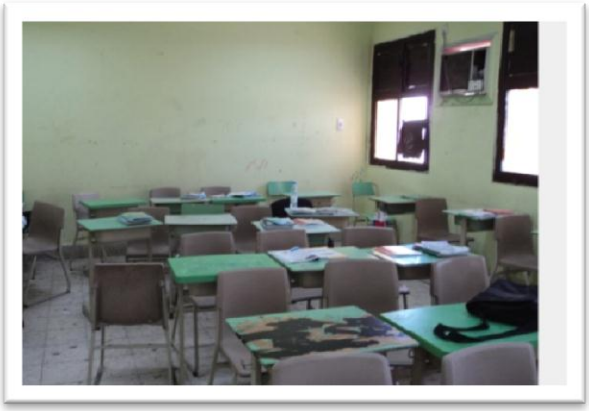

Figure 4-7 Saudia School - Classrooms

Figure 4-8 Saudia School - Low Quality of Furniture

There were no signs to show the occupants and visitors the emergency exits, so the location of emergency exits occupants and visitors was very difficult. Also, it was difficult to identify and reach fire alarm systems. Those were some of the reasons that brought the satisfaction level with these elements down.

Table 4-6 Walkthrough Inspection Results on the Saudia School

	An Assessment Tool for Maintenance Management Measured by Walkthrough Inspection	*Adequate*	*Deficient*
Cleanness			
01.	Ensure the overall cleanness throughout all spaces in the building.		☒
02.	Support a recycling program during cleanness process.		☒
03.	Ensure the overall cleanness of laboratories including removal foreign materials.		☒
Landscaping			
01.	Implementation of periodical checking for both indoor and outdoor plants.		☒
Structural Systems			
01.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.	☒	
Storage			
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.		☒
02.	Provision of sealable, labeled containers for storage chemical products and supplies.		☒
Space Layout and Furniture Quality			
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	☒	
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.		☒
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	☒	
04.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.		☒
Accessibility & Parking Space			
01.	Implementation of periodical checking of the function and position of all signage.		
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	☒	
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.		☒
04.	Implementation of periodical checking of the availability of emergency signage.		☒
05.	Proximity of the building to car parking spaces.		☒
06.	Sufficiency of car parking spaces.		
07.	Availability of ease of access to handicaps.		☒
08.	Provision of a system for regularly evaluating the quality of accessibility function.		☒
Image and Environmental Perception			
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	☒	

Occupants' Perceptions

The same survey and analyses conducted in this case study. However, the results were different compared to the previous one. The mean response from the student and teachers who completed the survey indicated that they were either "Dissatisfied" or "Strongly Dissatisfied" with the main performance elements listed as shown in Table 4-7. Some of the most noteworthy trends in the Table which earned the completely negative response "Strongly Dissatisfied" were observed in the categories of periodical checking for both indoor and outdoor plants, availability of maintenance staff to provide any assistance required and ease to contacting them and their comprehension of users' requirements, provision of enough storage space for maintenance supplies/spare parts as well as a required inventory, provision of sealable, labeled containers for storage chemical products and supplies, ease of identifying and reaching the building's main entrance, availability of emergency signage, sufficiency of car parking spaces, availability of ease of access for the handicapped and provision of high reliability and quality of maintenance services required.

Table 4-7 User Satisfaction Survey for Saudia School Occupants

	An Assessment Tool for Maintenance Management Measured by User Satisfaction Survey	*SS*	*S*	*DS*	*SD*	*EX*	*MR*
Thermal Comfort							
01.	Provision of comfortable temperature during summer throughout all spaces in the building.	0	15	17	17	2.0	**D**
02.	Provision of comfortable temperature during winter throughout all spaces in the building.	0	14	28	7	2.1	**D**
Acoustical Comfort							
01.	Provision of acoustical comfort throughout all spaces in the building.	4	14	21	10	2.2	**D**
Visual Comfort							
01.	Provision of good appearance and quality of lighting as per identified standards.	0	14	28	7	2.1	**D**
Indoor Air Quality							
01.	Implementation of periodical inspection of the HVAC system	7	10	17	7	2.4	**D**
Cleanness							
02.	Ensure the overall cleanness throughout all spaces in the building.	0	2	9	31	1.3	**SD**
Landscaping							
01.	Implementation of periodical checking for both indoor and outdoor plants.	0	2	8	32	1.3	**SD**
Human Factors							
01.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.	0	2	7	33	1.3	**SD**
02.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.	0	7	7	35	1.4	**SD**
Storage							
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.	0	4	10	28	1.4	**SD**
02.	Provision of sealable, labeled containers for storage chemical products and supplies.	0	2	7	33	1.3	**SD**
Space Layout and Furniture Quality							
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	0	2	7	33	1.3	**SD**
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.	0	28	21	0	2.6	**D**
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	0	21	21	0	2.5	**S**
Accessibility & Parking Space							
01.	Implementation of periodical checking of the function and position of all signage.	21	21	14	0	3.1	**D**
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	2	2	8	30	1.4	**SD**
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.	7	35	7	7	2.8	**S**

04.	Implementation of periodical checking of the availability of emergency signage.	0	2	11	29	1.4	**SD**
05.	Proximity of the building to car parking spaces.	8	10	7	21	2.1	**D**
06.	Sufficiency of car parking spaces.	2	3	3	33	1.4	**SD**
07.	Availability of ease of access to handicaps.	0	2	9	31	1.3	**SD**
Image and Environmental Perception							
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	7	28	14	0	2.9	**S**
Service Realizations							
01.	The maintenance department has a planning function for delivering the required services.	0	2	11	29	1.4	**SD**
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.	8	10	7	21	2.1	**D**
03.	The maintenance department has a clear process for delivering services and its traceability.	2	3	3	33	1.4	**SD**
04.	Implementation of a work-order system that provided high reliability and quality of services.	0	2	9	31	1.3	**SD**

Staff Opinion and Proof of Documented Systems

This school is also administrated by General Administration of Education in the Eastern Province (Boys) Construction Department, so the same results in the previous case study apply to it.

4.2.3 Implementation of the Developed Assessment Tool for Maintenance Management: A case study (Al-khobar Secondary School)

The building is located in Prince Muqrin Street, Al-Khobar, Saudi Arabia. The building consists of two floors and can accommodate up to 800 students (as shown in figure 4-9). It was built by the Saudi Aramco company in 1992 according to the agreement between the government and the company which built 139 schools in the Eastern Province, Saudi Arabia until 2005, and agreed to conduct ongoing maintenance and restoration of these buildings. The case study was conducted towards the beginning of winter semester.

Figure 4-9 Alkhobar Secondary School

Physical Environment

Temperature was within the permissible level of 22-27°C, with the average in classrooms of 26.3°C, but in teachers' offices it was at 22. 3°C. Similarly, relative humidity (standard is between 30-60%) was at 53.5% in classrooms and 58.3 % in teachers' offices. The

noise levels in classrooms were at 49.7 dbA and 66.7 dbA in teachers' offices. The standard for noise levels is 35dbA, proving that both classrooms and teachers' offices exceeded the recommended noise levels. Similarly, the illuminance level (standard for classroom is 538.2 lux) was 1160 in classrooms and 1253 in teachers' offices. Finally indoor carbon dioxide concentrations were within the permissible level (< 1000 ppm) as shown in Table 4-8.

Table 4-8 Average of Physical Environment Measurements in Alkhobar Secondary School Compared to Standards

Parameters	Standard	Classroom	Teacher office
Air Temperature Inside (F)	22-27°C	23.6	22.3
Humidity (%)	30-60 %	53.5	58.3
Sound Pressure Level (A weighted decibel)	35-50	49.7	66.7
Illumance (Lux)	538.2	1160	1253
Indoor Carbon Dioxide Concentrations CO2(ppm)	(< 1000 ppm)	100	99

Walkthrough Inspection

During the walkthrough inside the building, it was noted that the maintenance system in the school was perfect and we can say that most of maintenance standards that have developed can be applicable to this school. The overall cleanness throughout all spaces in the building was excellent and there was support for a recycling program during the cleanness process. Also, it was observed that there was a periodical checking of structural

systems, both indoor and outdoor plants and interior and exterior finishes. Furthermore, there was enough storage space for maintenance supplies/spare parts as well as a required inventory and adequate and capacity of teachers' offices and computer laboratories. Furniture and seating arrangements were prefect. There were signs to show the occupants and visitors the emergency exits, so the identification of the location of emergency exits for occupants and visitors was very easy. Also, it was easy to identify and reach fire alarm system. Those were some of the reasons that praised the satisfaction level with these elements as shown in Table 4-9 and Figures 4-10 and 4-11.

Figure 4-10 Corridors

Figure 4-11 Laundry Area

Table 4-9 Walkthrough Inspection Results on the Alkhobar Secondary School

An Assessment Tool for Maintenance Management Measured by Walkthrough Inspection		*Adequate*	*Deficient*
Cleanness			
01.	Ensure the overall cleanness throughout all spaces in the building.	☒	
02.	Support a recycling program during cleanness process.		
03.	Ensure the overall cleanness of laboratories including removal foreign materials.	☒	
Landscaping			
01.	Implementation of periodical checking for both indoor and outdoor plants.	☒	
Structural Systems			
01.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.	☒	
Storage			
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.	☒	
02.	Provision of sealable, labeled containers for storage chemical products and supplies.	☒	
Space Layout and Furniture Quality			
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	☒	
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.	☒	
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	☒	
04.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.	☒	
Accessibility & Parking Space			
01.	Implementation of periodical checking of the function and position of all signage.	☒	
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	☒	
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.	☒	
04.	Implementation of periodical checking of the availability of emergency signage.	☒	
05.	Proximity of the building to car parking spaces.	☒	
06.	Sufficiency of car parking spaces.		☒
07.	Availability of ease of access to handicaps.	☒	
08.	Provision of a system for regularly evaluating the quality of accessibility function.	☒	
Image and Environmental Perception			
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	☒	

Occupants' Perceptions

The same survey and analyses were conducted in this case study. However the results were completely different compared to the previous two case studies. The mean response from the student and teachers who completed the survey indicated that they were either "Satisfied" or "Strongly Satisfied" with the main performance elements listed Table 4-10. Some of the most noteworthy trends in the Table which earned the completely positive response "Strongly Satisfied" were observed in some criteria such as provision of acoustical comfort throughout all spaces in the building, provision of good appearance and quality of lighting, and adequacy of fire safety systems in the building (fire extinguishers, smoke detectors, etc.).

Table 4-10 User Satisfaction Survey for Alkhobar School Occupants

An Assessment Tool for Maintenance Management Measured by User Satisfaction Survey		*SS*	*S*	*DS*	*SD*	*EX*	*Mean Responses*
Thermal Comfort							
01.	Provision of comfortable temperature during summer throughout all spaces in the building.	12	15	12	1	2.5	**S**
02.	Provision of comfortable temperature during winter throughout all spaces in the building.	24	15	1	0	3.6	**SS**
Acoustical Comfort							
01.	Provision of acoustical comfort throughout all spaces in the building.	36	4	0	0	3.9	**SS**
Visual Comfort							
01.	Provision of good appearance and quality of lighting as per identified standards.	24	10	6	0	3.3	**S**
Indoor Air Quality							
01.	Implementation of periodical inspection of the HVAC system	24	12	4	0	3.3	**S**
Cleanness							
02.	Ensure the overall cleanness throughout all spaces in the building.	24	12	4	0	3.4	**S**
Landscaping							
01.	Implementation of periodical checking for both indoor and outdoor plants.	22	5	13	1	2.7	**S**
Human Factors							
01.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.	19	12	9	0	3.0	**S**
02.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.	12	20	8	0	2.8	**S**
Storage							
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.	0	30	4	6	2.5	**S**
02.	Provision of sealable, labeled containers for storage chemical products and supplies.	19	12	9	0	3.0	**S**
Space Layout and Furniture Quality							
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.	6	30	4	0	3.0	**S**
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.	26	12	2	2	3.6	**S**
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.	19	12	9	0	3.0	**S**
Accessibility & Parking Space							
01.	Implementation of periodical checking of the function and position of all signage.	12	15	12	1	2.5	**S**
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.	16	15	9	0	2.9	**S**
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.	12	10	16	2	2.2	**S**
04.	Implementation of periodical checking of the availability of emergency signage.	6	30	4	0	2.9	**S**
05.	Proximity of the building to car parking spaces.	12	15	12	1	2.5	**S**
06.	Sufficiency of car parking spaces.	6	12	20	2	1.8	**D**
07.	Availability of ease of access to handicaps.	12	15	12	1	2.5	**S**
Image and Environmental Perception							

01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.	18	20	2	0	3.4	**S**
Service Realizations							
01.	The maintenance department has a planning function for delivering the required services.	12	15	12	1	2.5	**S**
02.	The maintenance department identifies service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.	16	15	9	0	2.9	**S**
03.	The maintenance department has a clear process for delivering services and its traceability.	12	10	16	2	2.2	**S**
04	Implementation of a work-order system that provided high reliability and quality of services.	6	30	4	0	2.9	**S**

4.2.4 Discussion

While applying the assessment tools to the three case studies to test their applicability, some criteria have been highlighted and these include:

- Provision of awareness lectures for students about cleanliness, safety and evacuation training.
- The Ministry of Education, in cooperation with the Civil Defense, should conduct a periodical field survey to assess the maintenance and safety requirements in schools, especially schools buildings that are rented.

It was noticed that there is a consistency between the outcomes of the different methods that have been used to implement the developed assessment tool. For example, in Saudi school (Aramco School), the devices results refer to some problems related to thermal comfort and acoustical comfort. Also, the walkthrough inspection results indicate that schools suffered from many maintenance problems related to several measurable quality criteria such as cleanness level, landscaping, structural system and safety system. This was reflected in the occupants' perceptions which demonstrated dissatisfaction with most

performance elements in the occupants' survey. On the other hand, in Al-khobar Secondary School (Aramco School), the results from the measurement devices and walkthrough inspection results indicate that most of the criteria requirements of the developed assessment tools were met and the mean response indicated that the students and teachers were "Satisfied" with most performance elements. Also, it is noticed that there is a consistency between the outcomes of the assessment tools and the current maintenance management practices.

The developed assessment tool was tested through its implementation in three case studies in the Eastern Province of Saudi Arabia which demonstrate the applicability and validity of the developed assessment tools for maintenance management in public schools.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this research, an assessment tool for maintenance management for facilities at public schools in Saudi Arabia was developed and this assessment tool was applied to three case studies to demonstrate its applicability and validity. In this chapter, a summary of the research is discussed, followed by conclusions derived from the research and recommendations are made for possible future studies.

5.2 Summary of Study

The main objectives of this research were to formalize the development of an assessment tool for maintenance management for facilities of public schools in Saudi Arabia. An assessment tool is a set of clauses (quality criteria) that must be met in maintaining public schools to ensure that the functionality of facilities is continued as was originally designed and demanded by users.

The methodology consists of five phases. First, the research focused on identifying the main elements of the assessment tools for maintenance management (measurable quality criteria). The research focused on acquiring the knowledge through an extensive literature review including ISO 9001:2000.

Then, the measurable quality criteria were identified; resulting in the list of sixty-two sub-elements under twenty measurable quality criteria. These criteria have been classified into four main categories in order to group the common criteria which address the same issue. This phase was carried out through surveying and synthesizing various knowledge areas on maintenance management documented in international literature sources.

Next, a pilot study was conducted through interviews with five maintenance management experts of large public organizations, with at least 10 years of experience, to assess the proposed quality criteria to be used for assessment tools for maintenance management.

Then, the identified 62 factors were assessed to investigate their applicability and determining the level of importance for each factor of the assessment tools in Saudi Arabia. This phase was carried out through the development of the questionnaire survey. The questionnaire was developed, tested and distributed and then collected from 40 maintenance experts in the Eastern Province of Saudi Arabia. The received responses were analyzed by five likert scale. The analysis resulted in determining the level of importance for each factor.

Finally, three case studies were conducted to demonstrate the applicability and validity of the developed assessment tools for maintenance management, and then a set of conclusions and recommendations was developed. Areas of future research are also highlighted.

5.3 Conclusion

The following conclusions were reached based on this research:

1. Surveying and synthesizing various knowledge areas on maintenance management documented in international literature sources and ISO standard 9001:2000 resulted in identifying sixty-two elements under twenty measurable quality criteria classified and grouped under four main categories, namely technical, functional, behavioral and managerial.

2. A questionnaire survey was developed, for the purpose of the assessment of the identified measurable quality criteria. The sample size which was determined by using equations is 25. However, the distribution survey was 56 and received was 40 which filled by maintenance experts who are working in six different organizations that related to maintenance management for public schools in the Eastern Province of Saudi Arabia. The findings revealed that 71.8% of the maintenance experts were working as engineering or architect, 56.2 % of them had over 5 years' experience, 75.5% of them worked on the educational buildings projects and all of them worked in maintenance department of public organization.

3. The assessment results illustrated that the sixty-two measurable quality criteria were assessed as "Extremely Important'' or "Important''. The assessment results indicated that the highest weight was given to the measurable quality criteria "thermal comfort'' with the important index of 89%. However, it was indicated that the lowest weight was given to the measurable quality criteria "Accessibility and Parking Space'' with the important index of 78.2%.

4. Based on the survey results, five maintenance management measurement methods have been used to implement the developed assessment tool, namely implementation through the use of devices, implementation through walkthrough inspection, implementation through user satisfaction survey, implementation through staff opinion survey and implementation through the provision of a documented system.

5. The survey results indicated that most of the measurable quality criteria can be implemented through user satisfaction survey method, which includes thermal comfort, acoustical comfort, visual comfort, indoor air quality, cleanness, landscaping, human factors, storage, space layout and furniture quality, accessibility and parking space, image and environmental perception and service realizations. However, the least methods have been used for implementation is the use of device method, only four measurable quality criteria implemented through it, namely thermal comfort, acoustical comfort, visual comfort and indoor air quality.

6. The developed assessment tool was tested by its implementation in three cases studies which have been selected randomly in the Eastern Province of Saudi Arabia which are: Abdurrahman Binalqasem School (Public School), Saudi School (Public School) and Al-khobar Secondary School (Aramco School). Information gathered in an interview with several engineers in the Office of the Ministry of Education in the Eastern Province established that maintenance work in public school occurs during impromptu visits to schools or at the school director's request. Also, there is no predictive maintenance program and they do not have buildings maintenance databases or maintenance management systems to evaluate their work. On the other hand, according to interviews with the directors of the Aramco schools and engineers in the Saudi Aramco Government

Built School's maintenance department, it appears that there is a maintenance management system and they have a predictive maintenance program.

7. During conducting the three case studies it was observed that public schools suffered from several maintenance problems related to thermal comfort, acoustical comfort, indoor air quality, cleanness, landscaping, human factors, storage, space layout and furniture quality, accessibility and parking space and service realizations. On the other hand, most of the requirements of the developed assessment tool were met in Armco School except some problems with accessibility and parking space as shown in Table 5-1.

Table 5-1 The Consistency between the Outcomes of the Different Measurement Methods

Public schools (Abdurrahman Binalqasem School and Saudi School)			
Measurable Quality Criteria	Weakness indictors by device	Weakness indictors by walkthrough inspection	Weakness indictors by user satisfaction survey
Thermal Comfort	✓	✓	✓
Acoustical Comfort	✓	✓	✓
Indoor Air Quality	✓	✓	✓
Cleanness		✓	✓
Landscaping		✓	✓
Human Factors		✓	✓
Storage		✓	✓
Space Layout and Furniture Quality		✓	✓
Service Realizations		✓	✓

Accessibility and Parking Space		✓	✓
Aramco school (Al-khobar Secondary School)			
Accessibility and Parking Space		✓	✓

8. The findings revealed that each measurable quality criteria can be implemented through at least two maintenance management measurement methods. It was noticed that there is a consistency between the outcomes of the different methods that have been used to implement the developed assessment tool as shown in Table 5-1. This will give a yardstick to ensure the reliability of the identified measurable quality criteria that need to be correct.

10. The assessment results illustrated that there is a consistency between the outcomes of the developed assessment tool and the current maintenance management practices as evidence from the public and Aramco schools in implementation of the maintenance management practice.

5.4 Recommendation

The following recommendations are developed from the research described in this thesis:

- The developed assessment tool should be implemented to assess maintenance management in public schools in the Kingdom.

- Further studies should be carried out to assess existing maintenance management practices in public schools as well as private schools in the Kingdom.
- The Ministry of Education in cooperation with the Civil Defense should conduct Short Training Courses for teachers and students about proper maintenance practice in schools especially in safety issues.
- The Ministry of Education should have a comprehensive database for each school including building systems and equipment with information such as location, warranty information, and replacement parts.
- Frequent arrangement of conferences on maintenance management to allow experts to exchange opinions should be encouraged.

5.5 Directions for Future Research

It has been observed that there is no research related to maintenance management standards in Saudi Arabia. There is a need therefore to conduct such research to improve the practice of maintenance management. Also, this research is limited to maintenance management in the Eastern Province of Saudi Arabia. Future studies might be conducted using a wider range to cover the main cities of Saudi Arabia and with different types of buildings.

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APPENDIX I

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

Dear Sir,
Subject: Development of an Assessment Tool for Maintenance Management in Public Schools in Saudi Arabia.

I am a master student in Architectural Engineering Department, at King Fahd University of Petroleum and Mineral. I am now undertaking my master thesis titled "Development of an assessment tool for Maintenance Management in Public Schools in Saudi Arabia". An assessment tool is a set of clauses (quality criteria) that must be met in maintaining public schools to ensure that the functionally of facilities is continued as was originally designed and demanded by users. The purpose of this survey is to identify these measurable quality criteria and assess their significance by maintenance experts. The structural of the survey questionnaire divided into two parts which include:

Part One: Respondent Information
Part Two: Development of an Assessment Tool for Maintenance Management in Public Schools in Saudi Arabia.
Part Three: Maintenance Management measurement methods

Please complete the attached survey within one week and return it to the address given below. I appreciate your help and support in this matter:

Architectural Engineering Department
King Fahd University of Petroleum and Minerals
Dhahran 31261
Saudi Arabia
E-mail: binlswad1234@gmail.com
Fax: 03-860-3785
Mobile: 0535101976

Thank you for your cooperation

Part One - Respondent Information

1) Respondent Information

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

2) What is your position in the organization?

Maintenance Manager	☐
Facility Manager	☐
Engineering\Architect	☐
Others please specify.....	

3) How many years of experience do you have in the maintenance work?

a) Less than **5** years	☐	c) **10-20** years	☐
b) **5-10** years	☐	d) Over **20** years.	☐

4) What is the nature of your organization?

a) Public	☐
b) Private	☐

5) What are the types of project that you mainly worked on?

a) Educational Buildings	☐	d) Office Buildings	☐
b) Residential Buildings	☐	e)Sports Buildings	☐
c) Commercial Buildings	☐	Others please specify…….	

6) What is the number of employees your organization have?

a) 1-50	☐	c) 100-150	☐
b) 50- 100	☐	d) More than150	☐

Part Two: Development of an Assessment Tool for Maintenance Management in Public Schools in Saudi Arabia.

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

Extremely Important (EI), Important (I), Moderately Important (MI), Not Important (NI) and Extremely Not Important (ENI)

An Assessment Tool for Maintenance Management		EI	I	MI	NI	ENI
Technical Criteria						
Thermal Comfort						
01.	Provision of comfortable temperature during summer throughout all spaces in the building.					
02.	Provision of comfortable temperature during winter throughout all spaces in the building.					
Acoustical Comfort						
01.	Provision of acoustical comfort throughout all spaces in the building.					
02.	Provision of a system for regularly evaluating the quality of acoustical comfort through all spaces in the building.					
03.	Implementation of noise control and speech privacy measures wherever needed.					
Visual Comfort						
01.	Provision of good appearance and quality of lighting as per identified standards.					
02.	Provision of a system for regularly evaluating the quality of lighting throughout all spaces in the building.					
Indoor Air Quality						
01.	Implementation of periodical inspection of the HVAC system to comply with ASHRAE Standard 62.1.					
02.	Provision of a system for regularly evaluating indoor air quality throughout all spaces in the building including procedures for managing processes with potentially significant pollutant sources and procedures for responding to IAQ complaints.					
Safety and Security						
01.	Proof of compliance with the local safety statutory requirements.					
02.	Provision of a checklist for regular upkeep of safety systems throughout all spaces in the building as well as the playgrounds.					
03.	Proof of evacuation drill at least once a year.					
Cleanness						
01.	Implementation of preventive maintenance plan for cleanness.					
02.	Ensure the overall cleanness throughout all spaces in the building.					
03.	Support a recycling program during cleanness process.					

04.	Ensure the overall cleanness of laboratories including removal foreign materials.					
05.	Provision of a system for regularly evaluating the quality of cleanness and custodial programs throughout all spaces (including bathrooms) in the building.					
Landscaping						
01.	Implementation of periodical checking for both indoor and outdoor plants.					
02.	Provision of a system for regularly evaluating the quality of landscaping throughout all spaces in the building.					
Structural Systems						
01.	Implementation of periodical checking of structural systems in the building as well as removal of any overload.					
02.	Provision of a system for regularly evaluating the quality of maintaining structural systems throughout all spaces in the building.					
Mechanical, Electrical and Plumbing Systems						
01.	Implementation of preventive maintenance of the mechanical and electrical systems.					
02.	Implementation of periodical inspection of the water supply / sanitary systems.					
03.	Provision of a system for regularly checking the availability of spare parts required and its efficient use.					
04.	Provision of a system for regularly evaluating the quality of drinking water.					
Functional Criteria						
Human Factors						
01.	Implementation of guidelines to instruct maintenance staff to minimize interruption of educational process.					
02.	Availability of maintenance staff to provide any assistance required and easy to contact them and they understand user's requirements.					
Storage						
01.	Provision of enough storage space for maintenance supplies \spare parts as well as required inventory.					
02.	Provision of sealable, labeled containers for storage chemical products and supplies.					
Space Layout and Furniture Quality						
01.	Implementation of periodical checking of the availability of teaching tools and making sure that it ready for use.					
02.	Implementation of periodical checking of the furniture arrangement in the classrooms and making sure that they are enough for students and teachers especially at the beginning of every semester.					
03.	Implementation of periodical checking of the adequacy and capacity of teacher's offices and computer laboratories.					
04.	Provision of a system for regularly evaluating the arrangements of furniture in the classrooms and teacher's office.					

Accessibility & Parking Space						
01.	Implementation of periodical checking of the function and position of all signage.					
02.	Implementation of periodical checking of the ease of identifying and reaching the building's main entrance.					
03.	Implementation of periodical checking of the ease by which visitors can locate rooms in the building.					
04.	Implementation of periodical checking of the availability of emergency signage.					
05.	Proximity of the building to car parking spaces.					
06.	Sufficiency of car parking spaces.					
07.	Availability of ease of access to handicaps.					
08.	Provision of a system for regularly evaluating the quality of accessibility function.					
Behavioral Criteria						
Image and Environmental Perception						
01.	Implementation of periodical checking for quality of interior and exterior finishing throughout all spaces in the building.					
02.	Provision of a system for regularly evaluating the quality of interior and exterior finishing throughout all spaces in the building.					
Managerial Criteria						
Maintenance Strategy						
01.	The maintenance department must have a process for identifying the most effective maintenance strategy\tasks.					
02.	The maintenance management department has a quality manual that documented maintenance quality policy, objective and control and operation procedures.					
03.	The maintenance department must have comprehensive databases for each school including building systems and equipment with information such as location, warranty information, and replacement parts.					
Management Responsibilities						
01.	Maintenance mission stated and known to everyone in the organization.					
02.	Existence of clear organization structure.					
03.	Top management must check that responsibilities and authorities are identified to all staffs.					
Resource Management						
01.	The maintenance department identified the resources needed to support the maintenance effectiveness and achieve customer satisfaction.					
02.	Staffs who related to provide the services must be competent with good skills, education, training, and experience and sufficient in with numbers.					
03.	The maintenance department must provide an appropriate infrastructure for maintenance staff to carry out the required services.					

Service Realizations						
01.	The maintenance department must have a planning function for delivering the required services.					
02.	The maintenance department must identify service requirements which include customer requirements specified, regulatory requirements, and any necessary requirements.					
03.	The maintenance department must have a clear process for delivering services and its traceability.					
04.	Implementation of a work-order system that provided high reliability and quality of services.					
05.	The maintenance department must have a plan to reduce deferred maintenance that includes a list of major deferred maintenance projects and estimates of the cost for reducing the existing backlog.					
Measurement, Analysis and Improvement						
01.	Implementation of IT support including CMMs to handle information related to customer requirement or perception such as customer satisfaction surveys.					
02.	The maintenance department must have a system for maintenance performance measurement that has maintenance respond time and its measures.					
03.	The maintenance department must have internal audits with its criteria and methods.					
04.	On-going improvement through established quality policy, analyze data and management review.					
Maintenance Financing						
01.	Implementation of a good budgetary planning and control.					
02.	Ability to select adequate and effective outsourcing contracts and effectively coordinate with them.					

Please add any criteria that you think are necessary:

Thank you for your cooperation.

Part Three: Maintenance Management measurement methods

Based on your experience, please indicate which measurement method is better to measure each of the following:

Technical Criteria	
1) Thermal Comfort	
a) Measured by devices to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (22-27°C).	☐
b) Survey Occupants to achieve the requirements of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy (must be comfortable for the majority at least 80%).	☐
c) All the above.	☐
d) Others, please specify……	
2) Acoustical comfort	
a) Measured by devices to achieve the requirements of ANSI S12.60 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools standard (background sound pressure level 35-40 decibels (dB) as a maximum). (E.g. with a dosimeter device).	☐
b) Survey Occupants to assess their satisfactions with acoustical comfort.	☐
c) All the above.	☐
d) Others, please specify……	
3) Visual Comfort	
a) Measured by devices to achieve the requirements of Illuminating Engineering Society of North America IESNA Lighting Handbook (typical classroom reading tasks is 30 foot-candles (FC). (E.g. with a light meter device).	☐
b) Survey occupants to assess their satisfactions with visual comfort.	☐
c) All the above.	☐
d) Others, please specify……	
4) Indoor Air Quality	
a) Measured by devices to achieve the requirements of ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality. (E.g. IAQ monitor device).	☐
b) Measured by devices to achieve the requirements of ASTM D6245 - 12 Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation (E.g. IAQ monitor device).	☐
c) Survey occupants to achieve the requirements of ASHRAE Standard 62.1, 2007 Ventilation for Acceptable Indoor Air Quality that must be comfortable for the majority (at least 80%).	☐
c) All the above.	☐
d) Others, please specify……	
5) Safety and Security	
a) Proof of compliance with the local safety statutory requirements.	☐
b) Proof of a documented checklists for regular upkeep of safety systems.	☐
c) Survey occupants to assess their satisfactions with safety and security.	☐
d) All the above.	☐
e) Others, please specify……	

6) **Cleanness**	
a) Walkthrough inspection including evidence of implementing a recycle program.	☐
b) Proof of a documented system for regularly evaluating the quality of cleanness and custodial programs.	☐
c) Survey Occupants for to assess their satisfactions with cleanness.	☐
d) All the above	☐
e) Others, please specify……	
7) **Landscaping**	
a) Walkthrough inspection to assure periodical checking for both indoor and outdoor plants.	☐
b) Proof of a documented system for regularly evaluating the quality of landscaping.	☐
c) Survey Occupants for to assess their satisfactions with landscaping .	☐
d) All the above.	☐
d) Others, please specify……	
8) **Structural Systems**	
a) Walkthrough inspection to assure periodical checking of structural systems in the building as well as removal of any overload.	☐
b) Proof of a documented system for regularly evaluating the quality of maintaining structural systems.	☐
c) All the above.	☐
d) Others, please specify……	
9) **Mechanical, Electrical and Plumbing Systems**	
a) Proof of a documented system of implementation preventive maintenance for mechanical, electrical and plumbing systems.	☐
b) Proof of a documented system of monitoring spare parts and its efficient use.	☐
c) All the above	☐
d) Others, please specify……	

Functional Criteria	
1) **Human Factors**	
b) Proof of a documented system to instruct maintenance staff to minimize interruption of educational process.	☐
b) Survey Occupants to assess their satisfactions with staffs respond.	☐
c) All the above.	☐
d) Others, please specify……	
2) **Storage**	
a) Walkthrough inspection to assure that there are enough storage space for maintenance supplies \spare parts as well as required inventory.	☐
b) Survey Occupants to assess their satisfactions with storage chemical products and supplies.	☐
c) All the above.	☐
d) Others, please specify……	
3) **Space Layout and Furniture Quality**	
a) Walkthrough inspection to assure the arrangements of furniture and teaching tool .	☐
b) Proof of a documented system for regularly evaluating the arrangements of furniture.	☐
c) Survey Occupants to assess their satisfactions with space layout and furniture quality.	☐
e) All the above.	☐
e) Others, please specify……	

4) **Accessibility & Parking Space**	
a) Walkthrough inspection to assure the quality of accessibility function (including availability of emergency signage and ease of access to handicaps).	☐
b) Proof of a documented system for regularly evaluating the quality of accessibility function.	☐
c) Survey Occupants to assess their satisfactions with the quality of accessibility function.	☐
e) All the above.	☐
e) Others, please specify……	

Behavioral Criteria	
Image and Environmental Perception	
a) Walkthrough inspection to assure the quality of interior and exterior finishing.	☐
b) Proof of a documented system for regularly evaluating interior and exterior finishing.	☐
c) Survey Occupants to assess their satisfactions with the quality of interior and exterior finishing.	☐
d) All the above.	☐
d) Others, please specify……	

Managerial Criteria	
1) **Maintenance Strategy**	
a) Proof of a documented system for maintenance strategy, quality policy, objective, operation procedures and control procedures.	☐
b) Proof of a documented system for buildings database.	☐
c) Staff Opinion Survey (focus groups samples of managers, supervisors and staffs) to assess availability, implementation and effectiveness of maintenance strategy.	☐
d) All the above.	☐
e) Others, please specify……	
2) **Management Responsibilities**	
a) Proof of a documented system for maintenance mission, staffs responsibilities and organization structure.	☐
b) Staff Opinion Survey to assess their realizations of maintenance mission, responsibilities and organization structure.	☐
c) All the above.	☐
d) Others, please specify……	
3) **Resource Management**	
a) Proof of a documented system for the resources needed to support the maintenance effectiveness including an appropriate infrastructure .	☐
b) Achieve the training requirements by the U.S. Occupational Safety and Health Act (OSHA) and Minnesota OSHA for activities maintenance workers.	☐
c) Review of weekly, monthly reports.	☐
d) Staff Opinion Survey (focus groups samples of managers, supervisors and staffs) to assess availability, implementation and effectiveness of the resources needed .	☐
e) Others, please specify……	

6) Service Realizations	
a) Proof of a documented system for a plan for delivering the required services.	☐
b) Review of weekly, monthly reports and work order sample.	☐
c) Occupancy Survey to assess their satisfactions for delivering the required services.	☐
d) All the above.	☐
e) Others, please specify….....	
4) Measurement, Analysis and Improvement	
a) Proof of an evidence of implementing IT support including CMMs to handle information related to customer requirement.	☐
c) Proof of a documented system for maintenance performance measurement system and internal audit.	☐
d) Staff Opinion Survey (focus groups samples of managers, supervisors and staffs) to assess availability, implementation and effectiveness of maintenance performance measurement system.	☐
e) All the above.	☐
f) Others, please specify….....	
5) Maintenance Financing	
a) Proof of a documented system of implementing a good budgetary planning and control including economic analysis of cost.	☐
b) Staff Opinion Survey (focus groups samples of managers, supervisors and staffs) to assess the selection of an effective outsourcing contracts.	☐
c) All the above.	☐
d) Others, please specify….....	

Please make any common that you think are necessary:

Thank you for your cooperation.

جامعة الملك فهد للبترول والمعادن
كلية تصاميم البيئة
قسم الهندسة المعمارية

السلام عليكم ورحمة الله وبركاته

الموضوع : تطوير أداه تقييميه لإدارة الصيانة بالمدارس العامة بالمملكة العربية السعودية

أنا طالب ماجستير بقسم الهندسة المعمارية – جامعة الملك فهد للبترول والمعادن - حاليا أقوم بإعداد رسالة الماجستير بعنوان تطوير أداه تقييميه لإدارة الصيانة بالمدارس العامة بالمملكة العربية السعودية . أداة تقييم الصيانة عبارة عن مجموعة من الشروط (معايير الجودة) التي يجب الوفاء بها في الحفاظ على المدارس الحكومية لضمان استمرار وظيفية هذه المرافق كما صممت في الأصل وحسب طلبات مستخدميها . الهدف من هذا الاستبيان هو تحديد معايير الجودة وتقييم أهميتها بواسطة خبراء الصيانة . هيكل هذا الاستبيان قسم إلى ثلاثة أقسام وهي :

القسم الأول : معلومات عن المستجيب

القسم الثاني : تطوير أداه تقييميه لإدارة الصيانة بالمدارس العامة بالمملكة العربية السعودية

القسم الثالث : طرق قياس معايير جودة الصيانة

ارجوا إكمال تعبئة الاستبيان خلال أسبوع من تاريخه وإعادته الى العنوان الموضح أدناه مع فائق امتناني لتعاونك ودعمك لهذا الموضوع

قسم الهندسة المعمارية
جامعة الملك فهد للبترول والمعادن
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شكرا لتعاونكم

الإستبيان

القسم الأول – معلومات عامة

الاسم (اختياري)	
اسم الشركة (اختياري)	
رقم الهاتف (اختياري)	
رقم الفاكس (اختياري)	
البريد الإلكتروني (اختياري)	
عنوان المكتب أو الشركة (اختياري)	

1) ماهو منصبك في الشركة أو المكتب ؟

مدير الصيانة	☐
مدير تشغيل المرافق	☐
مهندس معماري أو مهندس أخر	☐
أخرى (يرجى التحديد)	

2) كم عدد سنوات الخبرة لديك ؟

اقل من خمس سنوات	☐	من 10 إلى 20 سنة	☐
من خمس إلى عشر سنوات	☐	أكثر من عشرين سنه	☐

3) ماطبيعة المنظومة أو الشركة التي تعمل بها ؟

عامة	☐
خاصة	☐

4) مانوع المشاريع التي غالبا تعمل بها ؟

مباني مكتبية	☐	مباني تعليمية	☐
مباني رياضية	☐	مباني سكنية	☐
أخرى (يرجى التحديد)		مباني تجارية	☐

5) كم عدد الموظفين في المنظومة او الشركة التي تعمل بها؟

50-1	☐	150-100	☐
100-50	☐	أكثر من 150	☐

القسم الثاني : تطوير أداه تقييميه لإدارة الصيانة بالمدارس العامة بالمملكة العربية السعودية

فضلا حدد درجة الأهمية لكل من المعايير أدناه باختيار احد معايير التقييم وهي

مهم جدا بقوه ، مهم ، متوسط الأهمية ، مهم لحد ما ، غير مهم

معايير تقييم إدارة الصيانة		مهم جدا بقوه	مهم	متوسط الاهمية	مهم لحد ما	غير مهم
عوامل تقنية						
الراحة الحرارية						
01	توفير درجة حرارة مريحة خلال فصل الصيف في جميع الأماكن في المبنى .					
02	توفير درجة حرارة مريحة خلال فصل الشتاء في جميع الأماكن في المبنى .					
الراحة الصوتية						
01	توفير الراحة الصوتية في جميع الأماكن في المبنى.					
02	توفر نظام لتقييم منتظم لجودة الراحة الصوتية في جميع الأماكن في المبنى .					
03	تنفيذ مكافحة الضوضاء وتدابير خصوصية التحدث كلما تطلب الأمر ذلك.					
الراحة البصرية						
01	توفير مظهر جيد مع جودة الإضاءة وفقا لمعايير محددة.					
02	توفر نظام لتقييم منتظم لجودة الإضاءة في جميع الأماكن في المبنى .					
جودة الهواء الداخلي						
01	تنفيذ التفتيش الدوري على نظام التكييف للامتثال لمعيار الاشري الخاص بنظم التكييف .					
02	توفر نظام لتقييم منتظم لجودة الهواء الداخلي في جميع الأماكن في المبنى بما في ذلك إجراءات لإدارة العمليات مع مصادر الملوثات الهامة المحتملة وإجراءات الاستجابة لشكاوى جودة الهواء الداخلي.					
السلامة والأمن						
01	توفير دليل على الامتثال لمتطلبات السلامة المحلية القانونية .					
02	توفير قائمة مرجعية للإيفاء بشكل منتظم بنظام السلامة في جميع الأماكن في المبنى وكذا الملاعب .					
03	توفير دليل على عمليات الإخلاء على الأقل مرة في السنة.					
النظافة						
01	تنفيذ خطة صيانة وقائية للنظافة .					
02	التأكيد على النظافة الشاملة لجميع الأماكن في المبنى .					
03	دعم برنامج إعادة التدوير خلال أعمال النظافة .					
04	التأكيد على النظافة الشاملة في المختبرات مع إزالة مخلفات المواد .					
05	توفر نظام لتقييم منتظم لجودة النظافة في جميع الأماكن في المبنى .					
الطبوغرافية والمناظر الطبيعية						
01	تنفيذ فحص دوري للعناية بالنباتات داخل و خارج المبنى .					
02	توفر نظام لتقييم منتظم لجودة العناية بالطبوغرافية والمناظر الطبيعية في جميع الأماكن في المبنى .					

هيكل المبنى						
01	تنفيذ فحص دوري لأنظمة هيكل المبنى مع إزالة الأحمال الزائدة .					
02	توفر نظام لتقييم منتظم لجودة صيانة أنظمة هيكل المبنى في جميع فضاءات المبنى.					
النظم الميكانيكية والكهربائية وإمدادات المياه						
01	تنفيذ الصيانة الوقائية للنظم الميكانيكية والكهربائية .					
02	تنفيذ فحص دوري لإمدادات المياه وأنظمة الصرف الصحي .					
03	توفير نظام للتحقق بانتظام من توافر قطع الغيار اللازمة واستخدامها على نحو فعال.					
04	توفير نظام لتقييم منتظم لجودة مياه الشرب.					
عوامل وظيفية						
عوامل بشرية						
01	تنفيذ مبادئ توجيهية لإرشاد موظفي الصيانة للحد من الانقطاع في العملية التعليمية .					
02	توافر موظفي الصيانة لتقديم أي مساعدة مطلوبة مع سهولة الاتصال بهم وكذا تفهمهم لمتطلبات المستخدم .					
التخزين						
01	توفير مساحة تخزين ما يكفي من لوازم الصيانة\ قطع الغيار مع متطلبات الجرد .					
02	توفير الحاويات مغلقة بإحكام لتخزين المنتجات الكيماوية والمستلزمات .					
تخطيط الفضاء وجودة الأثاث						
01	تنفيذ فحص دوري لمدى توافر الوسائل التعليمية والتأكد من أنها جاهزة للاستخدام .					
02	تنفيذ تدقيق دوري لترتيب الأثاث في الفصول الدراسية والتأكد من أنها كافية للطلاب والمعلمين وخاصة في بداية كل فصل دراسي .					
03	تنفيذ تدقيق دوري لمدى كفاية وسعة مكاتب المعلمين والمختبرات .					
04	توفر نظام لتقييم منتظم لتجهيز الأثاث في الفصول الدراسية ومكاتب المعلمين .					
إمكانية الوصول ومواقف السيارات						
01	تنفيذ فحص دوري لوظيفة ووضعية كل اللافتات .					
02	تنفيذ تدقيق دوري لسهولة التعرف على والوصول إلى مدخل المبنى الرئيسي .					
03	تنفيذ فحص دوري للسهولة التي يمكن للزوار العثور على غرف المبنى .					
04	تنفيذ تدقيق دوري لمدى توافر لافتات في حالات الطوارئ .					
05	قرب المبنى من مواقف السيارات.					
06	كفاية مواقف السيارات.					
07	توفر سهولة الوصول للمعاقين .					
08	توفير نظام لتقييم منتظم إمكانية الوصول في جميع الأماكن في المبنى .					
معايير تصورية						
التصور والإدراك البيئي						
01	تنفيذ تدقيق دوري لجودة التشطيبات الداخلية والخارجية في جميع الأماكن في المبنى .					
02	توفير نظام لتقييم منتظم جودة التشطيبات الداخلية والخارجية في جميع الأماكن في المبنى .					
معايير إدارية						

إستراتيجية الصيانة						
01	قسم إدارة الصيانة لديه عمليات تحديد إستراتيجية ومهام الصيانة الأكثر فعالية .					
02	قسم إدارة الصيانة لديه دليل الجودة موثق سياسة جودة صيانة وموضوعية وعملية الرقابة والإجراءات .					
03	قسم إدارة الصيانة لديه قواعد بيانات شاملة لكل مدرسة بما في ذلك أنظمة البناء والمعدات مع معلومات مثل الموقع ومعلومات الضمان وقطع غيار دليل الجودة.					
مسؤوليات الإدارة						
01	مهام الصيانة معلنة ومعروفة للجميع في المنظمة .					
02	وجود هيكل تنظيمي واضح.					
03	يجب على الإدارة العليا التحقق من تحديد المسؤوليات والصلاحيات لجميع الموظفين .					
إدارة الموارد						
01	قسم إدارة الصيانة حدد الموارد اللازمة لدعم فعالية الصيانة وتحقيق رضا العملاء .					
02	الموظفين المختصين بتوفير الخدمات يكونوا من ذوي المهارات الحيدة والتعليم والتدريب والخبرة مع توفر عدد كاف منهم .					
03	قسم إدارة الصيانة يوفر بنية تحتية مناسبة لموظفي الصيانة لتنفيذ الخدمات المطلوبة.					
تصور وإدراك الخدمة						
01	قسم إدارة الصيانة يقوم بوظيفة التخطيط لتقديم الخدمات المطلوبة.					
02	قسم إدارة الصيانة يحدد متطلبات الخدمة والتي تشمل متطلبات العملاء المحددة والمتطلبات ألتنظيمية وأي شروط ضرورية .					
03	قسم إدارة الصيانة لديه عمليات واضحة لتقديم الخدمات وتتبع لها .					
04	تنفيذ نظام أوامر العمل التي توفر موثوقية عالية وجودة الخدمات .					
05	قسم إدارة الصيانة لديه خطة للحد من أعمال الصيانة المؤجلة والتي تشمل قائمة المشاريع الكبرى والصيانة المؤجلة وتقديرات التكلفة للحد من تراكم القائمة .					
القياس والتحليل والتطوير						
01	تنفيذ دعم تكنولوجيا المعلومات بما في ذلك (نظام حاسوبي لإدارة الصيانة) للتعامل مع المعلومات ذات الصلة بمتطلبات العملاء مثل استبيان قياس رضا العملاء .					
02	قسم إدارة الصيانة لديه نظام لقياس أداء الصيانة بمافي ذلك معدل زمن التجاوب وأدوات قياسه .					
03	قسم إدارة الصيانة لديه نظام فحص داخلي بمافي ذلك معاييره وطرقه .					
04	تطوير مستمر من خلال جودة السياسات المتبعة وتحليل البيانات ومراجعة الأساليب الإدارية .					
تكاليف الصيانة						
01	تنفيذ التخطيط الجيد في الميزانية والتحكم بها .					
02	القدرة على تحديد مقاولين خارجين مناسبين وفعالين والتنسيق الفعال معهم .					

أرجو إضافة أي معايير تعتقد أنها مهمة وضرورية:

القسم الثالث : طرق قياس جودة الصيانة

معايير تقنية	
الراحة الحرارية	
تقاس بواسطة أجهزة لتحقيق متطلبات الظروف البيئية الحرارية لشغل الإنسان(22-27) درجة مئوية	☐
مسح إستبياني لشاغلي المدرسة مريحة بالنسبة للأغلبية على الأقل 80 %	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
الراحة الصوتية	
تقاس بواسطة أجهزة لتحقيق متطلبات معايير الأداء الصوتي، متطلبات التصميم، والمبادئ بالمدارس (مستوى ضغط الصوت الخلفية 35-40 ديسيبل التوجيهية لمستوى الصوت (ديسيبل) كحد أقصى	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
الراحة البصرية	
تقاس بواسطة أجهزة لتحقيق متطلبات كتاب جمعية الإضاءة الهندسة شمال أمريكا (الإضاءة النموذجية لهمة القراءة30 فوت- كاندل	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
جودة الهواء الداخلي	
تقاس بواسطة أجهزة لتحقيق متطلبات التهوية لجودة الهواء الداخلي المقبول	☐
تقاس بواسطة أجهزة لقياس نسبة تركيز ثاني أكسيد الكربون بالهاء الداخلي	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
السلامة والأمن	
إثبات الامتثال لمتطلبات السلامة القانونية المحلية	☐
دليل على وجود قوائم مرجعية موثقة لصيانة العادية للأنظمة السلامة	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
النظافة	
نزول ميداني للمبنى مع توفر أدلة على وجود دعم لبرنامج إعادة التدوير	☐
دليل على وجود نظام موثق لتقييم منتظمة لنوعية النظافة وبرامج الحراسة	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	
الطبوغرافية والمناظر الطبيعية	
نزول ميداني للمبنى للتأكيد على وجود فحص دوري للنباتات داخل وخارج المبنى	☐
دليل على وجود نظام موثق لتقييم منتظم لجودة تنسيق الطبوغرافية	☐
مسح إستبياني لشاغلي المدرسة	☐
كل ماذكر أعلاه	☐
أخرى (يرجى التحديد)	

هيكل المبنى	
نزول ميداني للمبنى للتأكيد على وجود فحص دوري لهيكل المبنى مع إزالة الأحمال الزائدة	
دليل على وجود نظام موثق لتقييم منتظم لجودة هيكل المبنى	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
النظم الميكانيكية والكهربائية وإمدادات المياه	
دليل على وجود نظام موثق لوجود صيانة وقائية للنظم الميكانيكية والكهربائية وإمدادات المياه	
دليل على وجود نظام موثق لرصد قطع الغيار واستخدامها بكفاءة	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
معايير وظيفية	
عوامل بشرية	
دليل على وجود نظام موثق لتوجيه موظفي الصيانة لتقليل إنقطاع العملية التعليمية	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
التخزين	
نزول ميداني للمبنى للتأكيد على وجود مساحة تخزين كافية لتخزين لوازم الصيانة وقطع الغيار والسلع المخزونة	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
تخطيط الفضاء وجودة الأثاث	
نزول ميداني للمبنى للتأكيد على جودة ترتيب الأثاث والأدوات التعليمية	
دليل على وجود نظام موثق لتقييم منتظم لجودة ترتيب الأثاث	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
اخرى (يرجى التحديد)	
إمكانية الوصول ومواقف السيارات	
نزول ميداني للمبنى للتأكيد على سهولة إمكانية الوصول (مع توفر لوائح الطوارئ الإرشادية وسهول الوصول للمعاقين	
دليل على وجود نظام موثق لتقييم منتظم لسهولة إمكانية الوصول	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
معايير تصورية	
التصور والإدراك البيني	
نزول ميداني للمبنى للتأكيد على جودة التشطيبات الداخلية والخارجية	
دليل على وجود نظام موثق لتقييم منتظم لجودة التشطيبات الداخلية والخارجية	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	

معايير إدارية	
استراتيجية الصيانة	
دليل على وجود نظام موثق لإستراتيجية الصيانة، سياسة الجودة وموضوعية، وإجراءات عملية وإجراءات الرقابة.	
دليل على وجود نظام موثق يحتوي قاعدة بيانات للمدرسة	
مسح إستبياني لأراء موظفي الصيانة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
مسؤوليات الادارة	
دليل على وجود نظام موثق لمهام الصيانة – مسؤوليات الموظفين – هيكلة قسم الصيانة	
مسح إستبياني لأراء موظفي الصيانة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
إدارة الموارد	
دليل على وجود نظام موثق للموارد المحتاجة لدعم فاعلية الصيانة بمافي ذلك البنية التحتية المناسبة	
تحقيق متطلبات التدريب من قبل منظمة السلامة المهنية بالولايات المتحدة (OSHA)و قانون الصحة لفعاليات الصيانة	
مسح إستبياني لشاغلي المدرسة	
كل ماذكر أعلاه	
اخرى (يرجى التحديد)	
تصور وإدراك الخدمة	
دليل على وجود نظام موثق للتخطيط لتوصيل خدمات الصيانة المطلوبة	
إستعراض التقارير الأسبوعية والشهرية ونموذج لآلية ترتيب العمل	
مسح إستبياني لأراء موظفي الصيانة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
القياس والتحليل والتطوير	
دليل على توظيف تقنية المعلومات بمافي ذلك تقنية معلومات إدارة الصيانة لمعالجة المعلومات الخاصة بخدمة العميل	
دليل على وجود نظام موثق لقياس أداء الصيانة والفحص الداخلي	
مسح إستبياني لأراء موظفي الصيانة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	
تكاليف الصيانة	
دليل على وجود نظام موثق لاستخدام تخطيط وإدارة جيدة للميزانية بمافي ذلك التحليل الاقتصادي للكلفة	
مسح إستبياني لأراء موظفي الصيانة	
كل ماذكر أعلاه	
أخرى (يرجى التحديد)	

شكرا على تعاونكم

APPENDIX II

Cleanness (Custodial Standards 2009 / 2010)

Classrooms

Floor Coverings

1. The floor, including corners, will be free of all debris.
2. Carpeted floors will be vacuumed every other service day.
3. Vinyl, ceramic and terrazzo floors will be dust mopped every other service day with a dust inhibitor treated dust mop.
4. Spots and gum on all floor coverings will be removed upon discovery.
5. Floor moldings will be maintained in a dust free condition.
6. Vinyl, ceramic and terrazzo floors will be wet mopped weekly. Spots and stains will be removed daily.
7. Vinyl and terrazzo floors will be scrubbed and recoated as finish wears, allowing damage to floor covering. (Minimum semi-annually)
8. Vinyl and Terrazzo floors will have a burnishing program in place.
9. Ceramic tile will be swept every other service day and cleaned according to manufacturer's recommendations.
10. Walk off mats will be cleaned every other service day and be free from sand and debris. Mats should be inspected and removed from service when tattered or torn causing trip or other type hazards

Walls/Wall Coverings

1. Dust and remove all smudges and fingerprints.
2. Wall coverings will be dust free.
3. Chalk trays will be wiped down so large accumulations of chalk dust are not present.
4. Chalkboards will be maintained to meet the expectations of the instructional staff.
5. Pencil sharpeners will be emptied daily.
6. Any tape on walls will be removed daily.
7. Walls will be inspected when cleaned for any peeling or chipped paint. Any walls needing repair will be corrected at next FAST team visit. Head Custodian will take measures to assure chipped or peeled paint is removed until such service is provided.
8. Graffiti will be removed from walls daily. Obscenity and gang related material will be removed immediately.

Toilets

1. Bowl will be free of water deposits.
2. Water swirl holes will be free of deposits to allow proper water circulation.
3. Fixtures will be cleaned and polished daily to remove water deposits.
4. Entire toilet (including base and both sides of seat) will be wiped down daily with germicidal detergent.
5. Toilet seat will be maintained in a safe condition.

Grounds (Custodial Standards 2009 / 2010)

1. Sidewalks will be kept free of weeds and inspected monthly for dangerous conditions.
2. Planters will be maintained in an aesthetic condition by removing trash and unwanted vegetation.
3. Fence lines/backstops will be weed-free to maintain an aesthetic condition.
4. Tree limbs will not hang below a height of 7 feet in student travel areas.
5. Backstops will be maintained in a state of good repair.
6. Exterior surfaces will be washed annually.
8. Exterior painted surfaces will be maintained in an aesthetic condition.
9. All grass areas immediately surrounding the campus where tractors do not have access will be the responsibility of the custodial staff to include 10' from all obstructions, i.e., portables, backstops, and fence lines to include adjoining property. Also, property lines that border the site shall be weed whacked to allow spraying of herbicide. The grass areas are to be maintained in an aesthetic condition at all times.
10. Remove all trimmed/cut debris to the proper disposal area.
11. Grounds will be free of trash and associated debris.

Process and Procedures for Inspection and Repair of Masonry and Concrete Building Exteriors(Arkansas, 2009)

Masonry and concrete building exteriors shall be inspected bi-annually (spring and fall) for open expansion joints, cracking, spalling, and porosity. Cracked and open joints need to be repaired by using a urethane sealant (or as recommended by manufacturer). Mortar joints shall be repaired by tuck pointing. Surfaces may need washing at regular intervals to remove accumulated dirt, mildew, and stains from surface. It is recommended that a flood coat of an approved type of sealant be applied every three-to-five years to protect exterior surfaces from damage caused from moisture.

Process and Procedures for Inspection and Repair of Interior and Exterior Finishes (Arkansas, 2009)

Painting of facilities, interior and exterior, shall be performed or supervised by trained and experienced painters only. This ensures that the correct type of paint is used for the application and that all precautions to prevent health hazards to the students and staff have been taken. Proper ventilation is always required. Paints and solvents will be stored away from all student areas in a container authorized for "Flammable Material" and disposed of properly. Proper ventilation shall be utilized during painting operation.

VITAE

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Academic Background Saleh Ahmed Ben Lasod is a graduate student in Architectural Engineering department at King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. He received the B.Sc. degree in Architectural Engineering and Environmental Planning from Hadramout University of Science and Technology (HUST), Hadramout, Yemen in July, 2007.