# DMOSYS: DEFECT MONITORING SYSTEM FOR BUILDING MAINTENANCE AT POLYTECHNIC

ZUL-ATFI BIN ISMAIL

A thesis submitted in
fulfilment of the requirement for the award of the
Master of Science in Technology Management by research

Faculty of Technology Management and Business

Universiti Tun Hussein Onn Malaysia

NOVEMBER 2013

# ABSTRACT

Maintenance management could be a complex subject if implementation and planning issues of the building facility are not handled properly. In this context, the current maintenance management method has affected the efficiency of the building facility management at Polytechnics. Many issues such as poor service delivery, inadequate finance, poor maintenance planning and maintenance backlogs were emerged due to the usage of conventional method application (paper-based form and unsystematic database). Therefore, this research is to review existing maintenance management practices, and subsequently develop a prototype system based on the stated problems related to the conventional method in improving the maintenance management processes.

Literature review and semi-structured interview was carried out to achieve the objectives. Eight Polytechnics are selected based on major problems of using conventional method in the comparison to investigate the maintenance management practices in each Polytechnic. There are around 32 Polytechnics in Malaysia and almost are using conventional methods. The number is considered very big indicating that the use of modern Information and Communication Technology (ICT) is still very limited compared to other institutions of higher learning in Malaysia. The results revealed that the practice of maintenance management at Polytechnics needs to be improved and a computerised system was proposed based on the requirements of a maintenance management system identified through the case studies.

The framework was encapsulated in a computer-based prototype system based on Microsoft Visual Basic.Net as a graphical user-interface while for the database design, the Microsoft Access is used to deploy the information for maintenance management processes. The computerised system was developed using Data Flow Diagram (DFD) and

coding. Subsequently, the prototype system was tested by running it until the critical problems were fixed and its functional requirements work correctly. This system will help with the building diagnosis and decision making process approaches. It will assist staff in facilitating the maintenance identification, assessment, planning and execution in relation to building facility. In conclusion, the developed prototype system can improve the maintenance management practices effectiveness for building facility to provide high-quality building facility for safe and healthy environment.

# ABSTRAK

Pengurusan penyelenggaraan merupakan satu subjek yang rumit jika isu perancangan dan pelaksanaan untuk fasiliti bangunan tidak ditangani dengan tepat. Dalam konteks ini, kaedah pengurusan penyelenggaraan memberi kesan pada keberkesanan pengurusan fasiliti bangunan di Politeknik. Isu seperti kelemahan penghantaran aduan, kekangan peruntukan kewangan, kelemahan pengurusan perancangan dan tunggakan penyelenggaraan timbul disebabkan oleh penggunaan kaedah secara konvensional (seperti borang berasaskan kertas dan pangkalan data yang tidak sistematik). Oleh itu, penyelidikan ini dijalankan adalah untuk menilai kaedah pengurusan penyelenggaran sedia ada, dan seterusnya membangunkan sebuah prototaip sistem berdasarkan kenyataan masalah pada kaedah konvensional dalam menambahbaikan proses-proses pengurusan penyelenggaraan. Kajian literatur dan temu bual semi-struktur telah dilaksanakan untuk mencapai objektif-objektif tersebut. Lapan buah Politeknik dipilih berdasarkan masalah major menggunakan kaedah konvensional dalam pembandingan untuk menyiasat amalan pengurusan penyelenggaraan di setiap Politeknik. Terdapat kira-kira 32 Politeknik di Malaysia dan hampir kesemuanya menggunakan kaedah konvensional. Bilangan ini dianggap sangat besar yang menunjukkan bahawa penggunaan Teknologi Maklumat dan Komunikasi (ICT) moden yang masih sangat terhad berbanding dengan institusi pengajian tinggi lain di Malaysia. Hasil kajian menunjukkan amalan pengurusan penyelenggaraan di Politeknik perlu dibaiki dan sistem berkomputer telah dicadangkan berdasarkan pada keperluan sistem pengurusan penyelenggaraan yang telah dikenal pasti melalui kajian kes. Rangka kerja terkandung dalam satu prototaip sistem berasaskan komputer berdasarkan Microsoft Visual Basic.Net sebagai pengantara muka grafik pengguna manakala bagi reka bentuk pangkalan data, Microsoft Access digunakan untuk

menempatkan maklumat untuk proses-proses pengurusan penyelenggaraan. Sistem berkomputer ini telah dibangunkan dengan Gambarajah Aliran Data (GAD) dan kod program perisian. Seterusnya, prototaip sistem telah diuji dengan menjalankan sistem tersebut sehingga masalah yang kritikal dapat diatasi dengan keperluan fungsi bekerja dengan betul. Sistem baru ini dapat meningkatkan teknik dalam pendekatan pemeriksaan diagnosis dan proses membuat keputusan. Ia dapat membantu staf dalam proses mengesan kerosakan, penilaian, perancangan dan pelaksanaan pengurusan penyelenggaraan dalam fasiliti bangunan. Kesimpulannya, pembangunan sistem prototaip ini dapat menambahbaik kerja pengurusan penyelenggaraan dengan lebih efektif untuk fasiliti bangunan dalam menyediakan fasiliti bangunan yang berkualiti untuk persekitaran yang lebih menjamin keselamatan dan kesihatan.

# TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| *AHP* | - | Analytic Hierarchy Process |
| *AS-IS* | - | Current Value Chain Model |
| *BIM* | - | Building Information Modelling |
| *BIMFM* | - | BIM-Based Facility Management |
| *BLK* | - | Borang Laporan Kerosakan |
| *BMS* | - | Building Management System |
| *CAD* | - | Computer-Aided Design |
| *CAFM* | - | Computer-Aided Facility Management |
| *CBM* | - | Condition Based Maintenance |
| *CBR* | - | Case-Based Reasoning |
| *CIMMS* | - | Centralised Information Maintenance Management System |
| *CM* | - | Corrective Maintenance |
| *CMMS* | - | Computerised Maintenance Management System |
| *COMOLOS* | - | Condition Monitoring of Low Speed Machinery |
| *CRM* | - | Customer Relationship Management |
| *C&S* | - | Civil and Structure |
| *CSP* | - | Condition Survey Protocol |
| *DFD* | - | Data Flow Diagram |
| *DLP* | - | Defect Liability Period |
| *DMOSYS* | - | Defect Monitoring System |
| *EAM* | - | Enterprise Asset Management |
| *E-FORM* | - | Electronic Form |

| | | |
|---|---|---|
| *ERP* | - | Enterprise Resource Planning |
| *E-MRO* | - | Maintenance, Repair and Operating Materials |
| *FBM* | - | Failure-Based Maintenance |
| *FMECA* | - | Failures, Modes, Effects and Criticality Analysis |
| *FMIS* | - | Facility Management Information System |
| *GIS* | - | Geographical Information System |
| *GPS* | - | Global Positioning System |
| *GUI* | - | Graphical User Interfaces |
| *HVAC* | - | Heating, Ventilation and Air Conditioning |
| *ICT* | - | Information and Communication Technology |
| *IR* | - | Infrared |
| *IS* | - | Information System |
| *ITOBO* | - | Information and Communication Technology for Sustainable and Optimised Building Operation |
| *IWMS* | - | Integrated Workplace Management System |
| *KKR* | - | Ministry of Works Malaysia |
| *MAMPU* | - | Malaysian Administrative Modernisation and Management Planning Unit |
| *MANR* | - | Assessment Method for Building Rehabilitation Needs |
| *M&E* | - | Mechanical and Electrical |
| *MMS* | - | Maintenance Management System |
| *M-RFIDMM* | - | Mobile RFID-Based Instruments Maintenance Management |
| *MS Access* | - | Microsoft Access |
| *NDT* | - | Non-Destructive Testing |
| *OBS* | - | Organisational Breakdown Structure |
| *OCC* | - | Online Customer Complaint |
| *PBS* | - | Banting Polytechnic |
| *PDA* | - | Personal Digital Assistant |
| *PETRONAS* | - | Petroliam Nasional Berhad |

| | | |
|---|---|---|
| *PIS* | - | Ibrahim Sultan Polytechnic |
| *PM* | - | Preventive Maintenance |
| *PMJ* | - | Mersing Polytechnic |
| *PMK* | - | Melaka Polytechnic |
| *PMM* | - | Merlimau Polytechnic |
| *PMMS* | - | PETRONAS Maintenance Management System |
| *PNS* | - | Nilai Polytechnic |
| *PPD* | - | Port Dickson Polytechnic |
| *PROMETHEE* | - | Preference Ranking Organisation Method for Enrichment Evaluation |
| *PS* | - | Prioritisation System |
| *PSA* | - | Sultan Salahudin Abdul Aziz Shah Polytechnic |
| *PWD* | - | Public Work Department |
| *RAD* | - | Rapid Application Development |
| *RCM* | - | Reliability Centered Maintenance |
| *ROIIM* | - | Return on Investment in Maintenance |
| *RFID* | - | Radio Frequency Identification |
| *RPI* | - | Rensselaer Polytechnic Institute |
| *SCADA* | - | Supervisory Control and Data Acquisition |
| *SDLC* | - | System Development Life Cycle |
| *SPSS* | - | Statistical Package for the Social Sciences |
| *SPSU* | - | Southern Polytechnic State University |
| *TO-BE* | - | Modified Value Chain Model |
| *TPM* | - | Total Productive Maintenance |
| *TQM* | - | Total Quality Management |
| *UPP* | - | Maintenance and Development Unit |
| *UPPF* | - | Facility Management and Development Unit |
| *VB.Net* | - | Visual Basic.Net |
| *3-D* | - | Three-Dimensional |

## APPENDICES

# CHAPTER 1

# INTRODUCTION

This chapter presents the context for this research. It starts with a brief background of the research, and then the need for the research is justified. It also states the aim and objectives of the research and the adopted methodology. Lastly, it describes the structure of the thesis.

## 1.1 Background of Research

Lately, Maintenance management is an essential issue in the construction industry. This issue is related to the disastrous defects as the roof collapsed at Stadium Terengganu (Wyn, 2010) and the collapsed building at Jaya Supermarket in Petaling Jaya (Sagayam, 2009). The reasons for those collapses are the deficiency of technical and administrative services in maintenance management. Ismail (2012) states that, the reasons for maintenance management deficiencies are delay of action taken, inefficient steps toward decision making processes and other related factors of staff weakness. Effective maintenance management has significant value on running cost of particular building and infrastructure throughout its operation. Another identified issue of maintenance management is lack of completed system that helps to plan, implement, control and measure the maintenance performance of the facilities (Chanter and Swallow, 2007).

Although there are many systems related to maintenance management, a system that can diagnose the real situation of building and infrastructure maintenance defect is still not available (Ahmad *et al*., 2011). Therefore, there is a need to treat the defect for heritage or old building structure over 25 years age from being collapsed abruptly.

Presently, most organisations are still implementing conventional method rather than computerised systems to manage the maintenance of building facilities and infrastructure (Supramani, 2005). The conventional method such as using paper-based form and unsystematic database are apparently not able to capture long term business targets (Hassan, 2010). The problems emerged as a result of the need to manage huge and complicated data, for instance, data loss caused by unsuitable places for file storage, excessive retrieval time in the data files recovery and not supported with maintenance decision making.

The preservation of Polytechnic is another issue in maintenance management. Polytechnic has a department to coordinate maintenance and repair of equipment, buildings, infrastructure and facilities related work, including supporting services. However, the management system implemented by this department faced many problems of reporting the defect. All reports regarding facilities defect must use "Faulty Report Form", where students and staff have to fill up the paper-based form and send it to the related department. Students and staff are not motivated to report defect due to many forms required. There is also a risk of report being lost before reaching the related department. Moreover, the student and staff have to resubmit the form in case of incomplete information and other related factors. As complainers, staff and students also have the difficulty to identify their complaint status whereby they have to call or send an email for action progress. In addition, the teaching and learning process cannot be carried out smoothly and bother the lecture sessions because of this ineffective complaint system (Lazim & Samad, 2011).

As a result of the inherent weaknesses in maintenance management at Polytechnic, an alternate maintenance management model is proposed, namely, Computerised Maintenance Management System (CMMS). This model is designed by integrating causes and reasons from shortcomings in the conventional process through the "constructability concept". The CMMS model is engaged in the new system to

improve the characteristic element with the decision making process. The significant factor to select a CMMS is much more advantageous than just a way to schedule maintenance management processes and able to perform the task needed without stressing the budget (Kullolli, 2008). The CMMS does not make decision, rather it provides the maintenance manager with the best information which affects the operational efficiency of a facility (Sharma and Govindaraju, 2010). Therefore, this research focuses on the deployment of new system with the decision making process to improve maintenance identification, assessing and planning activity.

## 1.2 Problem Statement

The problems of paper-based and unsystematic database have occurred for a long time without effective action. According to the survey conducted by Wahab (2005), that problems cause the low quality in maintenance management and time gap of building repairs manpower in order to resolve the problems.

Port Dickson Polytechnic is among the Polytechnics in Malaysia which faced problems related to paper-based and unsystematic database. Port Dickson Polytechnic gradual increase of intakes every year indirectly contributes the building and infrastructure development with the conventional maintenance management system. The conventional processes are mainly corrective and cyclical. These approaches to maintenance have been criticised for various inadequacies. They lead to maintenance backlogs and poor user satisfaction (Ismail and Kasim, 2012). The inadequacies with the system maintenance also involved the Premiere Polytechnics such as Ungku Omar Polytechnic, Ibrahim Sultan Polytechnic and Sultan Salahuddin Abdul Aziz Shah Polytechnic (Yusof, 2010).

The application of paper-based form and unsystematic database are also included in preventive maintenance such as facilities services and disposed, supplier, contractor list and for statistical data. The maintenance management staff facing difficulty to update the instantly recorded data and contributed to the negligent of management such

as misplaces and mishandlings due to the huge amounts of data (Lateef, Khamidi and Idrus, 2010a).

Normally, the official working hours is on Mondays to Fridays at 8.00 am to 5.00 pm. All defects complaint on Saturdays and Sundays are attended on the next working day. Complaints received after 5:00 pm will be treated on the following working day. Therefore, there is no dedicated maintenance management system to manage the complaint in the whole days. Besides, complaints on defect are lodged through the warden of each of the hostels while complaints concerning the other building facilities and infrastructures are lodged through the technicians in the control room by the person concerned (i.e. lecturer and laboratory attendant) (Lateef, Khamidi and Idrus, 2010b). The management of complaint should be centralised for hostel and other facilities at Polytechnic to facilitate maintenance operation effectively.

Meanwhile, the existing database is based on paper form in order to record the defects. Sometimes, the maintenance management staff do not find the related data correctly in the database because of misplaced and unhanded paper report. Therefore, unsystematic database in maintenance management processes led to the difficulty for maintenance management staff to analyse the defect data accurately (Lazim & Samad, 2011). In addition, the application of Microsoft Excel and Microsoft Word database turns to be limited in operation when handling complex data (Lecorche & Senecal, 2002). The staff also require extensive time to recover and this potentially turns into devastating time in managing the huge amounts of data effectively. The poor accessibility of data collection affects the criticality to assign the problems on facilities condition and assessment at polytechnic.

Essentially, the maintenance management system should have decision making process by using Information and Communication Technology (ICT) to improve the decision in assessing defect and prioritising maintenance plan (Razali, Halim and Jusoff, 2011). The application of conventional method such as paper-based form and unsystematic database will not be able to include information management tool, for instance, enterprise information system and knowledge system. The staff will have difficulty to provide accurate decisions based on previous analysis of defect report. For example, the water seepage at pipe joint happens for many times in one month (Yusof,

2010). This indicated the system weakness to asses the facility performance due to downtime and frequency of failures. Thus, the building and infrastructure maintenance management process should be improved by integrating ICT where decision making process cannot be put into the system.

CMMS software was seen first around 1976 and today, it is widely used in maintenance management all over the world. CMMS provides inventory activity for facility assessment to reduce maintenance problems (O'Donoghue and Prendergast, 2004). This application covers the wide spectrum of building and infrastructure components such as specifying work location, labour, material and equipment needed as well as desired completion date (Hassanain *et al*., 2003). CMMS also supports the maintenance management budget and long term financial commitment to attain returns benefits of financial management. Nevertheless, CMMS does not support decision making process in the system (Ahmad *et al*., 2011). This is due to deficiency of defect diagnosis to prove the real situation of maintained buildings (Tomlingson, 1998). The lack of decision support also affects the efficiency and systematic maintenance in prioritising the maintenance plan and preventive action to the building facility (Labib, 2004). Therefore, the development of a new system with supported decision making process is expected to improve the conventional method at Malaysian Polytechnics.

## 1.3 Research Questions

This research is carried out to answer the following research questions (RQ):

i. RQ1: What are the existing processes on maintenance management in the building maintenance?
ii. RQ2: What are the current practices in maintenance management processes for building maintenance at Polytechnics?
iii. RQ3: What are the requirements for integrating maintenance management processes and information database (e.g. decision support) in the maintenance management system?
iv. RQ4: How to develop a prototype system for integrating maintenance management processes and information database?

## 1.4 Research Objectives

This research concentrates on the development of a new system towards its maintenance management issues. Specifically, the objectives for this research are as follows:

i. To review the existing literature on the processes of maintenance management in the building maintenance.
ii. To identify the current practices in maintenance management processes for building maintenance at Polytechnics.
iii. To establish the requirement for integrating maintenance management processes and information database in the maintenance management system.
iv. To develop a prototype system for integrating processes of maintenance management and information database.

## 1.5 Scope of Research

The scope of research will involve:

i. This research is focused towards maintenance management processes at Port Dickson Polytechnic, Ibrahim Sultan Polytechnic, Melaka Polytechnic, Merlimau Polytechnic, Nilai Polytechnic, Mersing Polytechnic, Banting Polytechnic and Sultan Salahuddin Abdul Aziz Shah Polytechnic that consisted of three types of Polytechnic, namely, 'New Polytechnic', 'Old Polytechnic' and 'Premier Polytechnic'.

ii. This research involved experts views (i.e. engineer and assistant engineer) from eight Polytechnics due to their exposure to the major problems and challenges in managing maintenance such as poor service delivery, inadequate financial, poor maintenance planning and maintenance backlogs using conventional method.

iii. This research is in regard to condition assessment, defect identification and maintenance planning of building facility at Polytechnic.

iv. This research is conducted to identify the different system approach that is equipped with decision making processes.

## 1.6 Research Methodology

In this study, the research process generally consisted of literature review, case study, and system development as illustrated in Figure 1.1. The following is the research process and the approach used for this research, such as:

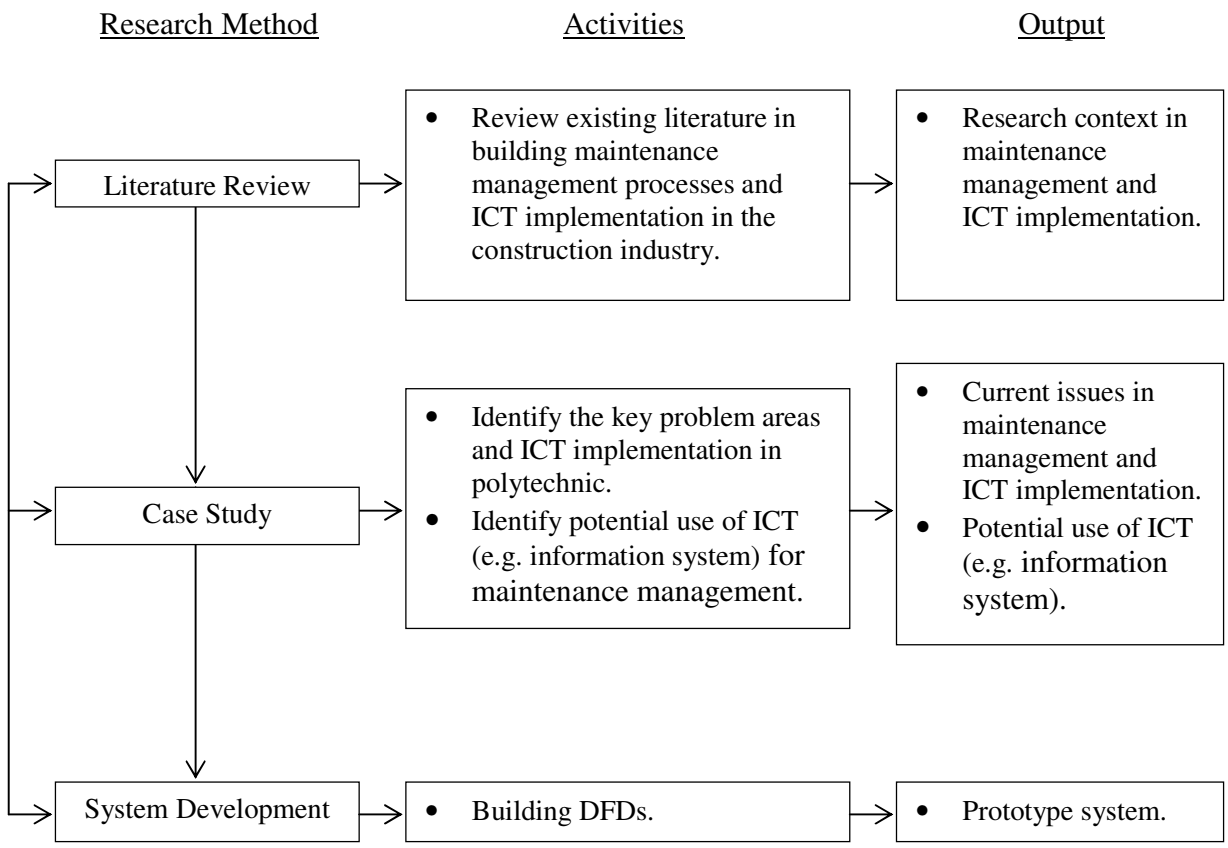


Figure 1.1: Research Flow Processes

*a) Literature Review*

The literature review is constructed through reviewing existing literature on maintenance management in the construction industry together with the implementation of ICT to support maintenance management practices in the construction industry. The literature review is important to find the gap of the research based on the variety of findings and criticism. The aim of the literature review is to identify problems and aspects of maintenance management practices that can be improved, and to examine the implementation of ICT. It will then be

referred to design the structural interview questions for the purpose of case study in the next phase.

*b) Case Study*

Case Studies were undertaken to review the current industrial practice in maintenance management to establish key problem areas and elements of good practices. They were also essential to identify how ICT is being used to facilitate maintenance management processes. Eight Polytechnics were selected for the case studies. Analysis of the obtained data from the case studies was used as a foundation for developing a new system to integrate maintenance management process and information system. The case studies were undertaken as the following process below.

- *Identification of organizations*

The identification of the Polytechnics focuses on premier, old and new Polytechnic, which attempted to implement new technologies (such as information system) for maintenance management. The selection of polytechnic was based on the willingness of staffs within the organizations to participate and share their experiences.

- *Data Collection*

Data collection involved semi-structured interviews, which is recorded on tape and transcribed verbatim. This method was used to identify current maintenance management problems, the causes, how to address the problems, and how ICT is used to facilitate maintenance management practices. The questions were organized under broad headings including: (1) Maintenance Management Problems, (2) Approaches to Address Problems, (3) ICT Implementation, and (4) Maintenance Management System.

- *Data analysis*

Data analysis was concerned with gathering information on the problems of the current practices of maintenance management, current approaches to address problems, ICT implementation, the use of emerging technologies, and current maintenance management system. Results from the analysis were used to support the development of a new system.

c) *Systems Development*

Prototyping is a process of building the complete set of user needs and information system requirement in order to develop the initial prototype rapidly with the functional design. The generality of the prototype depends on the prototyping tools and the naturalness of the system that being built. The development of a prototype was made on a personal computer (PC) and working environment, Microsoft Visual Basic.NET. There were a few steps in developing the prototype as below:

- *Identify the user's requirements*

The results from the literature review and case study findings were used to create the basic requirements for improving maintenance management practices. The process model has been used to discover the procedures, information and strategy of the preliminary design for developing the framework system such as data flow diagram (DFD).

- *Develop and initial prototype*

An operational prototype was developed using Microsoft Visual Basic.NET programming language. There was also the combination of the selected software such as MS Access (for database system).

## 1.7 Structure of the Thesis

This research is divided into six chapters. The explanation of each chapter is as follows:

***Chapter 1: Introduction***

Chapter 1 presents an overview of maintenance management. This chapter also introduces the context of the research and briefly discusses the background. It explains the need for the research, aim and objectives, scope of research and research methodology.

***Chapter 2: Literature Review***

Chapter 2 describes the current maintenance management practices in the construction industry followed by a discussion on the maintenance management process by describing four main components such as identification, assessing, planning and execution. It also discusses the current problems that occur in maintenance management practices, followed by a discussion on the implementation of the current technologies.

***Chapter 3: Research Methodology***

Chapter 3 reviews the research methodology, the methodological consideration for this study, and justification for the adoption of the specific research method. Basically, this research consists of four main research activities, such as literature review, case study, prototype design and prototype development.

***Chapter 4: Maintenance Management Practices at Polytechnic***

Chapter 4 presents the findings from eight case studies. The findings are used to reveal the maintenance management problems, approaches to addressing problems, ICT implementation and maintenance management system. This chapter concludes with suggestion on the conceptual framework to establish the

requirement for integrating maintenance management processes and information database (e.g. decision support).

***Chapter 5: The Development of a Prototype System of DMOSYS***

Chapter 5 describes the choice of a development environment and system architecture for the prototype system. It also explains the generic approach on the contents and features of the prototype system by integrating maintenance management processes and information database which are Microsoft Access 2010 and Visual Basic.NET 2010. The development of a new system is followed by the operation and testing of the prototype system.

***Chapter 6: Conclusions and Recommendations***

The last chapter highlights the conclusion of the thesis including the findings, the conclusions of the research, limitations and provides recommendations for future research.

## 1.8 Summary

This chapter has presented the issues of maintenance management as well as a justification for the need for the research. There are many issues in maintenance management and this research will be focusing on the inefficiency management in the defect identification, assessing, planning and execution for building due to conventional process at the Polytechnics selected. This problem has attributed to the poor service delivery, inadequate financial, poor maintenance plan and maintenance backlogs. This chapter has also presented the aim and objectives of the research, followed by the scope of research, the outline of research methodology and the structure of the thesis. The next chapter focuses on the maintenance management of processes and technologies applied in this study.

# CHAPTER 2

# MAINTENANCE MANAGEMENT: PROCESSES AND TECHNOLOGIES

## 2.1 Introduction

This chapter reviews maintenance management practices at Polytechnics. The overview of the maintenance management is described in the first section based on the research approaches on the current building maintenance management. Secondly, it discusses the maintenance processes, current issues in the method implementation and the approaches to address these problems. Then, this chapter presents the implementation of the current technologies, advantages and the limitations, and finally reviews the application of Information System (IS) in maintenance management.

## 2.2 Maintenance Management

This section gives the overviews of maintenance management as well as reviews of maintenance management in Polytechnic.

### 2.2.1 Overview of Maintenance Management

Maintenance management can be divided into various activities such as procurement process, schedule maintenance and project management that comprise of multi-faceted services and depend on the orientation of the organisation. The most prominent area in maintenance is building and infrastructure that contains three basic elements of civil, electrical and mechanical engineering. Maintenance management function is to generate decision and action to control and upkeep the building and infrastructure for sustainability (Sullivan *et al*., 2010). Thus, competent engineer is required to ensure the effectiveness in managing maintenance of any building and infrastructure facility.

Maintenance management is conducted in the post-construction process and is practiced at Polytechnic institutions around the world (Hamid & Alshawi, 2005). Polytechnic is an education institution and incline to produce the graduate that is knowledgeable in technical and vocational skills. Therefore, quality teaching and learning is emphasised at Polytechnics. In addition, the engineer has the responsibility to improve the maintenance management of the building and infrastructure or otherwise, the unexpected accident appears burdening the staff for their negligent in maintenance management. There are many issues related to maintenance management problems by using conventional method at Polytechnic (Arman, 2005).

The over application of paper-based form is among the problems which required extensive time to recover data collection. The file information is not handled properly, recorded in improper database and difficult to edit and to update because the data are hand written. As a result, the maintenance management staff are not able to improve the maintenance management performance such as building diagnosis on budget control at the Polytechnic. Meanwhile, Microsoft Excel and Microsoft Word database are not convenient and should be altered for more security and using ICT (Lazim & Samad, 2011).

Computerised Maintenance Management System (CMMS) is the most common software package that enables staff to trace the maintenance work status on building facility and monitor the labour, material and machineries for maintenance management.

The data are tabulated into tables and are ranked based on the priorities maintenance to handle the critical building like old structured building. According to Labib (2004), maintenance management at Polytechnic becomes better by improving CMMS with the decision making process to produce new effective system. Therefore, the new system could assist the maintenance management staff to perform better on the building defect identification, assessing and prioritising the maintenance. This research focuses on the deployment of a new system to improve the decision making process and building defects diagnosis in managing building maintenance at the Polytechnics.

### 2.2.2 Maintenance Management at Polytechnic

Polytechnic is a leading institution in the technical and vocational training such as for engineering technology, commerce and services. This institution aims to provide students with skills and technical knowledge required in the working environments.

Building and infrastructure at Polytechnic need to be maintained in order to improve the building services and good working environments that meet the student needs (Awang *et al*., 2011). Conventional method (i.e. paper based form) is normally used for building and infrastructure maintenance at Polytechnic and yet to be reviewed. Technical and managerial defects are the main problems in the conventional method in maintenance management. The technical defect is defined as the lack of technical expert to operate and monitor the building and infrastructure with new approaches. This is related to the knowledge exposed to the ICT application. Presently, CMMS is widely used in the maintenance management processes of building facility. CMMS can reduce the negligent management due to problems emerging as a result of the need to manage huge and complicated maintenance record data (Ismail, 2012). The technical defects are also because of less application technology in the equipment and machineries (Zulkarnain *et al*., 2011). As an illustration, the use of sky lift instead of staging for building maintenance assists labours to carry out painting works on the wall exterior effectively.

The managerial defect consists of project management defect, resource management defect and economical and financial defects (Saghatforoush *et al*., 2011). The project management defects at Polytechnic are related to improper planning of works, insufficient system operation to record data, failure to identify the potential defect causes and to specify the correct remedial work. Report of defects by using paper-based form is also haphazardly completed. Often, one could find defect report issued for work done in January preceded by those issued in March. As a matter of fact, the docket information is not reliable due to not all the works are implemented. Therefore, it is difficult to assess decision making for remedial works (Razali *et al*., 2011).

The resource management defect is related to the human resources problem which is poor workmanship. The technicians should be equipped with the technical knowledge to complete the tasks efficiently. The competency of the technicians will ensure the quality of maintenance management provided at Polytechnic and can produce the better feedback derived from the students (Zulkarnain *et al*., 2011).

The economical and financial defects are defined as the budget uncertainty to conduct maintenance management in the organisation. The maintenance cannot be blamed but it is the conventional method that should be blamed. For instance, even if all the work is carried out correctively, it still requires more systematic system and cost-effective approaches than those currently used at Malaysian Polytechnics.

Maintenance management at Polytechnic is still not benefiting from potential improvement as it still uses conventional method through paper-based application in managing huge amount of data and customer complaints. Thus, new system is proposed in order to improve the conventional method that tends to be cumbersome at Polytechnics (Ismail, 2012). Essentially, the new system has the potential to transform maintenance management processes into one of the most successful technology to foster the professionalism and excellent working culture for the transformation agenda.

## 2.3 Maintenance Management Processes

The processes involved in maintenance management consist of four stages; identification, assessing, planning and execution of an asset. Each stage is clarified into detail in order to design the actual process in maintenance management practiced in most organisations such as at Polytechnics.

### 2.3.1 Identification

Defects and damages are common phenomenon to building facility and infrastructure. Defects can be referred as fault on something that detract from perfection, whilst building damage can be seen when any structure, material, equipment and also element of the building is not fully functional (Watt, 2007; Khalid and Mydin, 2012). Defect identification consists of detecting the occurrence of defect, localising the defect areas and estimating the extent of defect in the various defect areas (Moaveni *et al.,* 2010). Identification of defects is also referred as the identification of the equipment, description of the failure, inspection and data gathering of an asset such as building facility and infrastructure to provide database of asset specification located at certain workplace (Glover, 2003; Lehtonen and Ala-Risku, 2005).

There are five mediums of defect identification which are visual, concealed object, dampness, stress and strain survey. The visual identification deals with the facilities that can be seen while the concealed object identification is refers to the facilities inside the structure, for instance, piping and steel reinforcement. The dampness identification is to measure the level of building humidity such as by using the excessive mould spore growth or remote sensing system as well as stress strain survey, on the other hand, is to capture the source of bending, elastic, crack and displacement of the component or the building structure (Singh, 2000; Ramly, 2004).

In the defect identification process, the dilapidation survey is among the current approaches to record the building facility and infrastructure defects. The photographic and digital documentation are used prior to any maintenance work to investigate the existing building conditions and defects. Besides, the causes and reasons of the building defects are examined to provide the appropriate techniques of building maintenance and as the reference for the construction materials to the clients, consultants and project contractors (Ahmad, 2004). The dilapidation survey is also integrated with the information technology to produce the detailed elucidation of data, the scientific studies and tests that concerned in the maintenance project through the means of pertinent graphics presentation. Identification of these assets poses the significant advantages especially for managing the largest area of building facility and infrastructure of around 100 acres. The other methods for recording on-site information for identification process are as in Table 2.1.

Table 2.1: Current Identification Technologies

| No. | Type of System/ Technology | Function |
|---|---|---|
| 1 | PDA/ RFID | To perform the defect identification and inventory management such as site history, parts and customer information (Anonymous, 2004 Hoxley, 2002; Hamblen, 2005; Dong, Maher and Daruwala, 2006). |
| 2 | Aerial photographs/ Global positioning system (GPS)/ Satellite images and Thermal infrared images | To record the building defect interpretation in the large area on a map and to determine the overall defect distribution (Ogawa and Yamazaki, 2000; Yamazaki, Yano and Matsuoka, 2003; Townsend, 2004; Parape and Tamura, 2011; Corban *et al.,* 2011; Hanada, Suzuki and Yamazaki, 2012). |
| 3 | Laser scanners data processing system | To highlight the defect issue early for the maintenance work (Boukamp and Akinci, 2004). |
| 4 | Vibration test and modal techniques technology (Non-Destructive Test) | To estimate the displacement and shake of the component especially the reinforced concrete structure (Niousha and Motosaka, 2007; Moaveni *et al.,* 2010). |
| 5 | Reality capture technologies (e.g. 3-D as built models and wireless embedded sensing) | • To record the data identification, manage and limit the impact of the facility defect (Gordon *et al.*, 2003).<br>• To generate the superimposed building maintenance information in the CAD images through augmented reality (AR) (Dong, Maher and Daruwala, 2006; Kamat and Tawil, 2007).<br>• To provide the obvious latent defects identification by using the computer-generated graphic and relevant location of the defect using a position locating technology such as GPS (Dong, Maher and Daruwala, 2006; Kamat and Tawil, 2007). |

Most of the latent defects appear only during the occupancy stage and hard to detect in the early construction or maintenance work. In addition, developing the decision framework in the proposed database using AR can help to simplify the process of identifying defective designs and is prepared over when the facility is elevated into the new ones or treated for demolition (Chong and Low, 2006; Bernold and AbouRizk, 2010). There are other advantages for the facility identification practiced in the maintenance management processes such as:

i. Provide adequate information such as scale of damage, strength of the facilities and cost estimation for maintenance planning (Hollis and Gibson, 2000).
ii. Prevent emergency breakdown of any element or system in the building facility and infrastructure (Hollis and Gibson, 2000).
iii. Save time in terms of man power to locate unidentified asset (Hoxley, 2002).
iv. Improve the maintenance identification which involved in the biggest area (Hamada *et al.,* 2012).
v. Security advancement for an asset (Moaveni *et al.,* 2010).

Indeed, the asset identification assists maintenance staff to locate the inventory asset quickly to improve the management of asset in the organisation.

### 2.3.2 Assessing

Assessment of asset depends on investigation or defect diagnosis processes in order to classify the level of performance and risk of failure for the facility services. Normally, the maintenance staff that consist of technical and vocational skills which are considered as competent staff will be hired to monitor and repair the asset such as building facility and infrastructure. Information on certain facility is collected based on the reported defect from the customers and sometimes through initiative of head of the department to instruct their staff to investigate the facility defects by zone and defect risk of area

(Mohamad and Annuar, 2011). The docket carried out by the maintenance management staff is to ensure the risks asset can be repaired on time without delay. The docket contents are, name of asset, location in detail, date including the defect notices from complainer.

According to Nielsen, Hansen and Aagaard (2009), the defects are assessed by their buildability concept of consequences based on risk levels which are risk for lives and health, risk for large economic losses and risk for small economic losses. The risk for life and health is prescribed in building regulations which normally refers to policies and standards while the risk for large economic losses is associated to the costs consequences (Nielsen *et al.,* 2009). The risk for small economic losses covers many types of defects from small damages including an aesthetic problem and the technical performance evaluation.

In addition, defect assessment is categorised by the source (e.g. design, workmanship, material and lack of protection) and the origin (e.g. change, error and omission) (Josephson and Hammarlund, 1999; Love and Sohal, 2003; Georgiou, 2010). The building is also assessed by the severity of the defects utilising Defect Index Method. The components of the buildings are disaggregated into functional elements such as walls and beam and assessed relative to four categories scale: very slight, minor, medium or severe (Aye, Karki and Schulz, 2006). The maintenance work, for instance, whether a minor or major repair is determined through the result from that scale categories (Pedro *et al.,* 2011; Fauzi, Yusof and Abidin, 2011).

There are many tools and systems to asses the building facility and infrastructure defects and among them are either by performing the laboratory testing or in-situ testing. Both of them are practiced in the material condition survey to asses the deficiencies of the building structure component and to propose the average index for the building defect contentment level (Mohamad and Annuar, 2011). The Dilapidation survey is a familiar approach to assist defect assessment process in order to provide the adequate information and documentation to identify the building defect, causes as well as the maintenance repairs using photograph (Glover, 2003; Ramly, 2004).

Furthermore, the Bayesian Networks and Failures, Modes, Effects and Criticality Analysis (FMECA) are the decision tools used in relation to the major construction

assessment. These tools involve the systematic approaches utilising the decision graphs, grading scale, demographic information and proposed the defect criticality index for an engineering judgement of a complicated problem such as the repetition of defects concerning the defects cost consequences for the different alternatives (Jensen and Nelsen, 2007; Talon, Boissier and Lair, 2007). FMECA has been regarded as most suitable for building maintainability with easily understandable, systematic method for failure classification and capable to determine any design-related changes or provisions that can prevent failure or mitigate its effects (Talon *et al.,* 2008; Das and Chew, 2011).

Presently, there are other frameworks to improve the assessment techniques from using conventional method into computerised system. The frameworks from the previous research are illustrated in Table 2.2.

Table 2.2: Various Assessment Techniques Framework

| No. | Type of System | Function |
|---|---|---|
| 1 | Assessment of Existing Buildings | For examining both the building underlying structure and its external shell respectively (ASCE, 2000) |
| 2 | Listing Defects Method | For building defect rating assessment (Liu, 2003) |
| 3 | Infrared (IR) Thermography and Global positioning system (GPS) | To identify and measures near surface defects by detecting the temperature gradient on the surface of a target object to its geographic location (e.g. a concrete wall) (Lo and Choi, 2004). |
| 4 | Building Damage Risk-Assessment | For evaluating buildings condition during deep excavations and tunnelling works (Aye, Karki and Schulz, 2006) |
| 5 | Arguably methods (Due Diligence Evaluation) | For discovering any apparent structural deficiencies using three separate levels: hands on, visual and testing (Peraza, 2006) |
| 6 | Arguably methods (General Structural Integrity Assessment) | For identifying any maintenance or repair items, as well as any imminent hazards using three separate levels: hands on, visual and testing (Peraza, 2006) |
| 7 | Reality capture technologies using sensor technologies application | To identify the deviation based on related construction specifications that constitutes a construction defect (spatial defect) (Gordon *et al*., 2003; Akinci *et al*., 2006). |
| 8 | Northern Ireland House Condition Method | For building defect rating assessment (Frey, Jahnet and Russell, 2007) |
| 9 | Standardise Subjective Rating Method | For building defect rating assessment (Rindfuss *et al.,* 2007) |
| 10 | Defects Index Method | For building defect rating assessment (Pedro, 2008) |
| 11 | Multi-Parallel Condition Assessment Scale /FEMA 154/ ATC-20 | For evaluating intensive structure including pre- and post-earthquake evaluation using crack damage scale and digital photography (Burland, 1995; Rojahn, 2002; Laefer *et al.,* 2008) |
| 12 | Priority Ranking Method | For building defect rating assessment (Che-Ani *et al.,* 2009) |

Table 2.2: Various Assessment Techniques Framework (continued)

| | | |
|---|---|---|
| 13 | Assessment Method for Building Rehabilitation Needs (MANR) and Geographical Information System (GIS) | To define the different parameters (e.g. main defects and severity of defects) in carrying out the defect mapping for buildings condition (Pedro *et al*., 2008; Straub, 2009; Vilhena and Pedro, 2010). |
| 14 | Grid Survey and System Code | To investigate and classify the latent defect or the defect in part of the difficult captured level into grid location (Ishak *et al.*, 2007; Johar *et al.,* 2011). |
| 15 | Fuzzy Logic Modelling to Hazard Assessment | For evaluating the damage of buildings based on different parameters of sewer pipeline failure (Emarah *et al.,* 2011) |
| 16 | Automatic Failure Diagnosis | To take the symptoms of defects and provide the probable failure reason using the decision making process (Zackariasson and Wilson, 2004; Ahmad *et al.,* 2011). |
| 17 | Non-Destructive Testing (NDT) | To assess the properties of a material, component or system without causing the damage (Ishak *et al*., 2007; Khalid and Mydin, 2012). |
| 18 | Condition Survey Protocol (CSP) 1 Matrix | To assess the condition of building carefully and entirety through visual inspection, scoring, photos and layout plan tag (Hamzah *et al*., 2010; Che-Ani, Tazilan and Kosman, 2011; Ismail *et al*., 2012; Othman *et al*., 2012). |
| 19 | Vulnerable Assessment | For searching and prioritising vulnerability assessment in building emergencies (Leite and Akinci, 2013) |

These diagnosis frameworks and instruments are to assist staff to minimise their time in managing defect investigation and to gather the definite information from a certain defect. The combination between an information system and application instrument of defect diagnosis is expected to improve the existing system of using paper or verbal literate from the customer report. Amongst the improvement toward customers and staff are (Gordon *et al.,* 2003; Akinci *et al.,* 2006):

i. Persistent of defect information
ii. Paperless
iii. Decrease negligent management
iv. Increase the staff skill level of technology in defect diagnosis
v. Able to inspect the defect for the sophisticated building facility and infrastructure quickly

Therefore, the improvement of defect assessment is necessary for the organisation as a back-up plan toward competence services for job inspection of an asset.

### 2.3.3 Planning

There are many discussions about the designation of the maintenance planning. According to Babor and Plian (2008), the maintenance planning requires the stage of an understanding of the specific architectural character of the building. This element of character is used to explain the historic reliability of the building such as building conditions, materials and repairs in order to intend the good maintenance planning and to prevent ad-hoc accident. This also includes the building type, age, usage and user details (Mclean, 2009).

Basically, the components of the maintenance planning involved the maintenance priorities, inspection, life cycle costing, building regulations, health hazards, fire and life safety (Babor and Plian, 2008). The maintenance priorities are concerned to the special considerations of the building and inspection that derived from the maintenance scheduling. The life cycle costing is to control the economical factor for the materials and maintenance services while the building regulations, health hazards, fire and life safety is to provide the building and human protection from the hazards situations.

The principle of planning in maintenance management is entailed by two methods namely unplanned maintenance and planned maintenance. The unplanned maintenance is divided into reactive and predictive maintenance while planned maintenance category can be divided into cyclical and preventive maintenance. In certain cases, there is available for condition-based maintenance that similar to the predictive maintenance (Chanter and Swallow, 2007; Mclean, 2009).

The reactive or corrective maintenance may be defined as the remedial action carried out due to failure or deficiencies discovered during preventive maintenance, to repair equipment to its operational state whether immediately or deferred to a later date in the maintenance plan. Corrective maintenance is also so called as ad-hoc maintenance due to unpredictable situation of asset defect (Badr, Malapert and Brown, 2010). Predictive maintenance is to treat continuously or intermittently before the total failure potential to occur and requires replacing or repairing the product after it has achieved a

useful life span (Lehtonen and Ala-Risku, 2005). The advantages of corrective maintenance are (Zulkarnain *et al.,* 2011):

i. It reduces the holistic failures of an asset
ii. It reduces the demand for frequent repairs that depended on the capacity of usage
iii. It is able to avoid the possible damage by refurbishment during on time

The preventive maintenance is to extend the life span of the equipment (Saranga, 2002). The preventive maintenance is executed to evade the danger impact to the customer such as fire extinguisher and to evade customer dissatisfaction, such as air conditioning utility and replaced the equipment when a certain condition is observed. Cyclical maintenance is defined as schedule or time-based maintenance. The asset for maintenance is classified as mostly on mechanical and electrical utilities whereby the need for the maintenance usage-based is scheduled (Hill, 2000). The cyclical maintenance in the planned maintenance is regularly periodic service (thereby tasks are performed at a fixed time) (Saranga: 2002; Dhillon, 2002).

Another classification of maintenance planning is deferred maintenance. Deferred maintenance is the postponing maintenance activities such as repairs on a major facility that need to meet budget funding levels or sometimes to realign available budget monies (Lazarus and Hauptfleisch, 2010). According to Lind and Muyingo (2012), there is a new concept of maintenance plan called as opportunistic maintenance. The opportunistic maintenance is to carry out the maintenance activity in the cost-effective way by using the predictive time to asses the performance deterioration under uncertainty of equipment including the expected time of future failure for the time-based maintenance with the interaction of the sophisticated technology, globalisation and change of economy (Horner, El-Haram and Munns, 1997). Chanter and Swallow (2007) suggest the use of decision-based type of maintenance with a similar concept to the opportunistic maintenance in order to overcome the limited budget and to provide the back-up plans in dealing with uncertainties cases of building defects.

The development of system to enhance building maintenance scheduling is illustrated in Table 2.3:

## REFERENCES


Adebayo, S. O. *A Study of the Maintenance Management of Public Buildings in Nigeria.* Ph.D. Thesis. University of Lagos, Lagos, Nigeria; 1991.

Adenuga, O. A. Labour Composition for Maintenance Works in Public Hospital Built Environment in South-West, Nigeria. *Journal of Building Performance.* 2010. 1(1): 83-97.

Adenuga, O. A., Dosumu, O. S. Assessment of Procurement Methods used for Executing Maintenance Works in Lagos State. *Ethiopian Journal of Environmental Studies and Management (EJESM).* 2012. 5(4): 477-483.

Afify, E. A. E. A. E., Hegazy, A. E. A., El-Sayed, M. A. K. A Model for Customer Complaint Management System using SOA. *Proceedings of the 15th WSEAS International Conference on Computers.* 15.7.2011. Corfu Island, Greece: WSEAS. 2011. pp. 291-296.

Ahmad, M. A. H., Salimah, M., Ani, A .I. C., Ramly, A. Pembangunan Model Sistem Maklumat Pemeriksaan dan Diagnosis Bangunan untuk Kerja-Kerja Penyenggaraan Bangunan. *The Malaysian Surveyor.* 2011. 46(2): 21-27.

Ahmad, A. G. Understanding Common Building Defects: The Dilapidation Survey Report. *Majalah Arkitek.* 2004. 16(1): 19-21.

Ahuja, I. P. S., Khamba, J. S. Total Productive Maintenance: Literature Review and Directions. *International Journal of Quality and Reliability Management.* 2008. 25(7): 709-756.

Akasah, Z. A., Shamsuddin, S. H., Rahman, I. A., Alias M. School Building Maintenance Strategy: A New Management Approach. *Malaysian Technical Universities Conference on Engineering and Technology (MUCEET 2009).* Pahang: Universiti Malaysia Pahang. 2009. pp. 1-5.

Akcamete, A., Akinci, B., Garrett, J. H. Potential Utilization of Building Information Models for Planning Activties. *In Computing in Civil and Building Engineering, Proceedings of the Intenrnational Conference.* 30.6.2010. Nottingham, UK: Nottingham University Press. 2010. pp. 151-157.

Akinci, B., Boukamp, F., Gordon, C., Huber, D., Lyons, C., Park, K. A Formalism for Utilization of Sensor Systems and Integrated Project Models for Active Construction Quality Control. *Journal of Automation in Construction.* 2006. 15(2): 124-138.

Akinsola, O. E., Fapohunda, J. A., Ogunsanmi, O. E., Fatokun, A. O. Evaluation of the Scenarios of Facilities Maintenance Management of Sport Complexes in South West Nigeria. *Journal of Sustainable Development.* 2012. 5(4): 99-115.

Albright, B. Come See the Software Side of Sears. *Frontline Solutions.* 2000. 1(11): 36.

Aldridge, A., Levine, K. *Surveying the Social World: Principles and Practice in Survey Research.* Buckingham: Open University Press. 2001.

Ali, A.S., Kamaruzzaman, S. N., Sulaiman, R., Peng, Y. C. Factors Affecting Housing Maintenance Cost in Malaysia. Journal of Facilities Management. 2010. 8(4): 285-298.

Ali, K. N., Sun, M., Petley, G., Barrett, P. Improving the Business Process of Reactive Maintenance Projects. *Journal of Facilities.* 2002. 20(7): 251-261.

Almarshad, A., Motawa, I., Ogunlana, S. O. Knowledge Management for Public Building Maintenance in Kuwait. *Proceedings of the 26th Annual ARCOM Conference.* 6.9.2010. Leeds, UK: Associations of Researchers in Construction Management. 2010. pp. 877-886.

Anonymous Source One Healthcare Opts for Field Centrix Wireless Workflow Software. *Wireless News*. 2004. 1.

Arbnor, I., Bjerke, B. *Methodology for Creating Business Knowledge.* London: SAGE Publications, Inc. 1997.

Archibus (2013). *Archibus Facilities and Real Estate Management Software has been the Industry Standard for over 30 years.* Retrieved on March 25, 2013, from http://www.archibus.com

Aripin, S. B. *Database Management Inventory System.* Master Thesis. UniversitiTeknologi Malaysia; 2006.

Arman, N. Web-Enabled Computer Maintenance Management Application: PPU E-Maintenance Management System. *Proceedings of the 5th International Business Information Management Conference.* Cairo, Egypt: Internet and Information Technology in Modern Organizations. 2005. pp. 1-5.

ASCE. *Guideline for structural condition assessment of existing buildings. ASCE Standard*. Reston, VA. 11-99: 52. 2000.

Atkins, A., Zhang, L., Yu, H. Applications of RFID and Mobile Technology in Tracking of Equipment for Maintenance in Mining Industry. *10th Underground Coal Operator's Conference.* Australia: University of Wollongong & the Australasian Institute of Mining and Metallurgy. 2010. 350-358.

Avan, B. I., White, F. Why a Research Study Needs a Design? *Journal of Pakistan Medical Association (JPMA).* 2001. 51(5): 197-201.

Awang, M. B., Mohammed, A. H. B., Abdullah, S. I. B., Shukor F. S. B. A. Facilities Management Competency Imperatives to Realize Polytechnic Transformation Goals. *Proceeding of the International Conference On Management (ICM 2011).* Skudai, Johor Bharu: Universiti Teknologi Malaysia. 2011. pp. 480-496.

Aye, Z. Z., Karki, D., Schulz, C. Ground Movement Prediction and Building Damage Risk-Assessment for the Deep Excavations and Tunneling Works in Bangkok Subsoil. *International Symposium on Underground Excavation and Tunneling.* 2.2.2006. Thailand: SEAFCO. 2006. 281-297.

Babor, D., Plian, D. Maintenance Planning for Historic Buildings. *Buletin of the Polytechnic Institute of Jassy.Constructions Architecture Section.* 2008. LVIII(3): 33-44.

Badr, A. M., Malapert, A., Brown, K. N. Modeling a Maintenance Scheduling Problem with Alternative Resources. *The 9th International Workshop on Constraint Modeling and Reformulation (CP10).* 6.9.2010. St Andrews: Royaume-Uni. 2010. pp. 1-15.

Baker, C. D., Johnson, G. Interview Talk as Professional Practice. *Language and Education.* 1998. 12(4): 229-242.

Barrett, P., Baldry, D. *Facilities Management towards Best Practice.* US: John Wiley and Sons Ltd. 2009.

Bernold, L. E., AbouRizk, S. M. *Managing Performance in Construction.* Hoboken, New Jersey: Jonh Wiley and Sons, Inc. 2010.

Blakeley, F., Bozkaya, B., Cao, B., Hall, W., Knolmajer, J. Optimizing Periodic Maintenance Operations for Schindler Elevator Corporation. *Interfaces.* 2003. 33(1): 67-80.

Blance, M. T., Durrheim, K., Painter, D. *Research in Practice: Applied Methods for the Social Sciences.* 2nd Ed. Cape Town: University of Cape Town Press (Pty) Ltd. 2006.

Blaxter, L., Hughes, C., Tight, M. *How to Research.* 3rd Ed. UK: Open University Press. 2006.

Boukamp, F., Akinci, B. Towards Automated Defect Detection: Object-Oriented Modeling of Construction Specifications. *International Conference on Computing in Civil and Building Engineering (ICCCBE).* 25.10.2004. Weimar, Germany: Bauhaus-Universitat Weimar. 2004. pp. 1-12.

Bowling, A. *Research Method in Health: Investigating Health and Health Services.* 2nd Ed. Buckingham: Open University Press. 2002.

Burhanuddin, M. A., Halawani, S. M., Ahmad, A. R., Tahir, Z. Failure-based Maintenance Decision Support System using Analytical Hierarchical Process. *International Journal of Advanced Computer Science.* 2011. 1(1): 1-9.

Burland, J. B. Assessment of Damage to Buildings due to Tunneling and Excavation. Invited special lecturer to IS-Tokyo. *First International Conference on Earthquake Geotechnical Engineering.* 1995. pp.14.

Burns, R. B. *Introduction to Research Methods.* 4th Ed. Australia: Pearson Education Australia (Pty) Limited. 2000.

Buys, F., Nkado, R. A Survey of Maintenance Management Systems in South African Tertiary Educational Institutions. *Journal of Construction Management and Economics.* 2006. 24(10): 997-1005.

Campos, J., Jantunen, E., Prakash, Om. A Mobile Maintenance Decision Support System. *Maintenance and Asset Management Journal.* 2008. 23(2): 42-48.

Capterra (2013). *AMPRO by AMPRO Software.* Retrieved on March 25, 2013, from http://www.capterra.com

Cardellino, P., Finch, E. Mapping IT Innovation in Facilities Management. *Journal of Information Technology in Construction (ITcon).* 2006. 11: 673-684.

Centric Maintenance Systems (2013). *API Pro CMMS/ EAM Introduction.* Retrieved on March 25, 2013, from http://www.centricmaintenance.com

Chang, C., Chang, Y., Huang, S. Prioritization System for Building Maintenance Application in Public Universities. *21st International Symposium on Automation and Robotics in Construction.* Jeju, South Korea: IAARC. 2004. pp. 713-718.

Chanter, B., Swallow, P. *Building Maintenance Management.* 2nd Ed. Oxford: Blackwell Science, Ltd. 2007.

Che-Ani, A. I., Tazilan, A. S. M., Kosman, K. A. The Development of Condition Survey Protocol Matrix. *Journal of Structural Survey.* 2011. 29(1): 35-45.

Che-Ani, A. I., Zaharim, A., Zain, M. F. M., Mohd-Tawil, N., Surat, M. Timber Defects in Building: a Study of Telapak Naning, Malacca, Malaysia. *WSEAS Transaction on Environment and Development.* 2009. 1(5): 109-118.

Chen, N. S., Huang, S. Y. Applying Evolutionary Prototyping Model in Developing Stream-Based Lecturing Systems. *Journal of Interactive Educational Multimedia.* 2002. 4: 62-75.

Cheng, M., Lien, L, Tsai, M., Chen, W. Open-Building Maintenance Management using RFID Technology. *24th International Symposium on Automation and Robotics in Construction (ISARC).* Kochi, India: IAARC. 2007. pp. 41-46.

Cho, Y., Im, I., Hiltz, R., Fjermestad, J. An Analysis of Online Customer Complaints: Implications for Web Complaint Management. *Proceedings of the 35th Hawaii International Conference on System Sciences.* 7.1.2002. Hawaii: IEEE. 2002. pp. 2308-2317.

Chong, W. K., Low, S. P. Latent Building Defects: Causes and Design; Strategies to prevent them. *Journal of Performance of Constructed Facilities.* 2006. 20(3): pp. 213-221.

Chowdhury, S., Akram, A. E-Maintenance: Oppurtinities and Challenges. *Proceedings of IRIS 2011.* 16.8.2011. Turku, Finland: TUCS. 2011. pp. 68-81.

Christensen, L. T. Corporate Communication: The Challenge of Transparency. *Corporate Communications: An International Journal.* 2002. 7(3): 162-168.

Clowes, A. Barriers to Information Sharing in the Construction Supply Chain. *Proceedings of the Brisbane 2000 CIB International Symposium on Facilities Management and Maintenance.* Brisbane: Queensland University of Technology. 2000. pp. 153-160.

Cohen, L., Manion, L., Morrison, K. *Research Methods Education.* New York: Routledge Taylor and Francis Group. 2007.

Cole, G. G., Waltz, M. E. Jr. How long will it last? Condition Assessment of the Building Envelope. *Proceedings of the 13th Structures Congress*. 1995. 1(2): 642-657.

Corban, C., Saito, K., Dell'oro, L., Bjorgo, E., Gill, S., Lemoine, G., Kemper, T., Piard, B., Huyck, C. K., Spence, R., Shankar, R., Senegas, O., Ghesquire, F., Lallemant, D., Evans, G., Gartley, R. A., Toro, J., Ghosh, S., Svekla, W. D., Adams, B. J., Eguchi, R. T. A Comprehensive Analysis of Building Damage in the January 12, 2010 $M_w$ 7 Haiti Earthquake using High Resolution Satellite and Aerial Imagery. *Photogrammetric Engineering and Remote Sensing Journal.* 2011. 77(10): 997-1009.

Costello P. J. M. *Action Research.* London: Continuum. 2003.

Creswell, J. W. *Qualitative Inquiry and Research Design.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2012.

Crotty, M. *The Foundations of Social Research: Meaning and Perspective in the Research Process.* 4th Ed. London: SAGE Publications, Inc. 2005.

Cworks (2008). *What works for CWorks works for all.* Retrieved on March 25, 2013, from http://www.cworks.com.my

Das, S., Chew, M. Y. L. Generic Method of Grading Building Defects using FMECA to Improve Maintainability Decisions. *ASCE Journal of Performance of Constructed Facilities.* 2011. 25(6): 522-533.

Davies C., Greenough, R. M. The Use of Information Systems in Fault Diagnosis. Advances in Manufacturing Technology-Conference. United Kingdom: Taylor and Francis Ltd. 2000. pp. 383-388.

Davila, I., Davis, N., Rodriguez, W. G., Ziavras, E. *Improving Work Flow at the National Science Foundation.* Degree Thesis. Worcester Polytechnic Institute; 2012.

Dennis, C., Harris, L. *Marketing the E-Business.* 2nd Ed. UK: Routledge Taylor and Francis Group. 2007.

Denzin, N. K., Lincoln Y. S. *The SAGE Handbook of Qualitative Research.* 4th Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2011.

Deraman, R., Salleh, H., Beksin, A. M., Alashwal, A. M., Abdullahi, B. C., Abdullah, A. A. The Roles of Information and Communication Technology (ICT) Systems in Construction Supply Chain Management and Barriers to their Implementation. *African Journal of Business Management.* 2012. 6(7): 2403-2411.

Design Maintenance Systems Inc. (2011). *Press Release: New MAINTelligence™ 4.5 Release Adds Predictive Maintenance and Internet Portal Capabilities.* Retrieved on March 25, 2013, from http://www.desmaint.com

Dhillon, B. S., *Engineering Maintenance: A Modern Approach.* Florida: CRC Press LLC. 2002.

Djebarni, R., Al-Abed, A. Housing Adequacy in Yemen: An Investigation into Physical Quality. *Journal of Property Management.* 1998. 16(1): 16-23.

Dong, A., Maher, M. L., Daruwala, Y. Construction Defect Reporting using Mobile and Digital Workbench Technologies. *Joint International Conference on Computing and Decision Making in Civil and Building Engineering.* 14.6.2006. USA: INFORMS. 2006. pp. 3597-3606.

Dukic, D., Trivunic, M., Curcin, A. S. Computer-Aided Building Maintenance with "BASE-FM" Program. *Journal of Automation in Construction*. 2013. 30(2013): 57-69.

Egbu, C., Vines, M., Tookey, J. The Role of Knowledge Management in E-Procurement Initiatives for Constructions Organisations. *ARCOM Proceedings Twentieth Annual Conference 2004.* 1.9.2004. Edinburgh, UK: Association of Researchers in Construction Management. 2004. pp. 661-671.

El-Haram, M. A., Horner, M. W. Factors Affecting Housing Maintenance Cost. *Journal of Quality in Maintenance Engineering*. 2002. 8(2): 115-123.

Emaint (2013). *Things you should consider when choosing a CMMS?* Retrieved on March 26, 2013, from http://www.emaint.com

Emarah, D. A., Hussein, M. M., Mousa, H. M., Akl, A. Y. The Application of Fuzzy Modelling to Hazard Assessment for Reinforced Concrete Building Structure due to Pipeline Failure. *Life Science Journal.* 2011. 8(4): 595-608.

Eti, M. C., Uche, O., Odiowei, S. O. Micro-Process Maintenance Systems in Electric Power Industry. *International Journal of Research in Engineering, IT and Social Sciences (IJREISS).* 2012. 2(5): 43-76.

Faiz, R. B., Edirisinghe, E. A. Decision Making for Predictive Maintenance in Asset Information Management. *Interdisciplinary Journal of Information, Knowledge and Management.* 2009. 4: 23-36.

Fauzi, S. N. F. M., Yusof, N., Abidin, N. Z. Evaluation of Housing Defects in Build-Then-Sell Houses: A Study of Six Residential Areas. *World Academy of Science, Engineering and Technology.* 2011. 113(58): 554-560.

Fawcett, W., Palmer, J. *Good Practice Guidance for Refurbishing Occupied Buildings.* London, UK: CIRIA. 2004.

Fellows, R., Liu, A. *Research Methods for Construction.* 3rd Ed. UK: Blackwell Science Ltd. 2009.

Fernandez O., Labib A. W., Walmsley R., Petty D. J. A Decision Support Maintenance Management System: Development and Implementation. *International Journal of Quality and Reliability Management.* 2003. 20(8): 965-979.

Fetterman, D. M. *Ethnography: Step by Step.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2010.

Flick, U. *An Introduction to Qualitative Research.* 4th Ed. London: SAGE Publications, Inc. 2009.

Fraenkel, J. R., Wallen N. E., Hyun H. H. *How to Design and Evaluate Research in Education.* 8th Ed. New York: McGraw-Hill Companies, Inc. 2012.

Freebody, P. *Qualitative Research in Education: Interaction and Practice.* London: SAGE Publications, Inc. 2003.

Frey, J., Jahnet, B., Russel, K. Northern Ireland house condition survey 2006. *Final Report from Ireland Housing Executive*. 2007.

Gabbar, H. A., Yamashita, H., Suzuki, K., Shimada, Y. Computer-Aided RCM-Based Plant Maintenance Management System. *Journal of Robotics and Computer-Integrated Manufacturing.* 2003. 19(5): pp. 449-458.

Gane, C., Sarson, T. *Structured Systems Analysis: Tools and Techniques.* USA: Prentice-Hall. 1979.

Georgiou, J. Verification of a Building Defect Classification System for Housing. *Journal of Structural Survey.* 2010. 28(5): 370-383.

Gillham, B. *Case Study Research Methods.* London. Continuum. 2000.

Glaser, B. G., Strauss, A. L. *The Discovery of Grounded Theory: Strategies for Qualitative Research.* 7th Ed. New Jersey: Transaction Publishers. 2012.

Glover, P. *Building Surveys.* 5th Ed. Oxford: Butterworth- Heinemann. 2003.

Gordon, C., Boukamp, F., Huber, D., Latimer, E., Park, K., Akinci, B. Combining Reality Capture Technologies for Construction Defect Detection: A Case Study. *E-Activities and Intelligent Support in Design and the Built Environment, 9th Europia International Conference.* Istanbul, Turkey: Europia Productions. 2003. pp. 99-108.

Greenwood, D. J., Levin, M. *Introduction to Action Research: Social Research for Social Change.* 2nd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2007.

Grix, J. *Demystifying Postgraduate Research: from MA to PhD.* Birmingham: University of Birmingham Press. 2001.

Guba G. E., Lincoln, Y. S. Paradigmatic Controversies, Contradictions and Emerging Confluence. In: Denzin, N. K., Lincoln Y. S.. *The SAGE Handbook of Qualitative Research.* 4th Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2005.

Haider, A., Koronios, A. E-Prognostics: A Step towards E-Maintenance of Engineering Assets. *Journal of Theoretical and Applied Electronic Commerce Research (JTAER).* 2006. 1(1): 42-55.

Hallberg, D. *System for Predictive Life Cycle Management of Building and Infrastructures.* PhD Thesis. University West; 2009.

Hamblen, M. Mobile apps may boost revenue. *Computerworld.* 2005. 39(25): 5.

Hamid, I. Z. A., Alshawi, M. Role of Information Technology in Facility Management. *Buletin Ingenieur.* Board of Engineers Malaysia (BEM). 2005.

Hamza, R. M. A., Al-Mohdaf, T. A. Enhancement of Maintenance System Performance by Using Computerized Maintenance Management System (CMMS) at Private Hospital. *Journal of Global Perspective on Engineering Management.* 2012. 1(1): pp. 1-6.

Hamzah, N., Mahli, M., Che-Ani, A. I., Tahir, M. M., Abdullah, N. A. G., Tawil, N. M. The Development of Smart School Condition Assessment Based on Condition Survey Protocol (CSP) 1 Matrix: A Literature Review. *World Academy of Science, Engineering and Technology Journal.* 2010. 114(47): 620-625.

Han, T., Yang, B. Development of an E-Maintenance System Integrating Advanced Techniques. *Computers in Industry.* 2006. 57(6): 569-580.

Hanada, D., Suzuki, K., Yamazaki, F.. Damage detection of the May 6, 2012 tornado in Tsukuba, Japan using Aerial Thermal Infrared Images. *Proceeding 33rd Asian Conference on Remote Sensing.* Pattaya Beach, Thailand: AARS, GISTDA and MOST. 2012. pp. 1-9.

Hancock, D. R., Algozzine D. B., Algozzine R. *Doing Case Study Research: A Practical Guide for Beginning Researchers.* 2nd Ed. New York: Teachers College Press. 2011.

Hart, E., Bond, M. *Action Research for Health and Social Care: A Guide to Practice.* California: Open University Press. 1995.

Hassan, S. *Developing Online Help Desk For Politeknik Tuanku Sultanah Bahiyah.* Master Thesis. Universiti Utara Malaysia; 2010.

Hassan, M. Modeling an Oil Drilling Rig Total Productive Maintenance System Using Causal Loop Diagram Simulation. *International Journal of Technology.* 2012. 2(2): 17-26.

Hassanain M. A., Froese T. M., Vanier D.J. A Framework Model for Asset Maintenance Management. *Journal of Performance of Constructed Facilities*. 2003. 17(1): 51-64.

Hertlein, K. M., Lambert-Shute, J., Benson, K. Postmodern Influenced in Family Therapy Research: Reflections of Graduate Students. *The Qualitative Report.* 2004. 9(3): 538-561.

Hill, T. *Operations Management: Strategic Context and Managerial Analysis.* Basingtoke, England. MacMillan Business. 2000.

Hollis, M., Gibson, C. *Surveying Buildings.* 4th Ed. Coventry: RICS Books Imprint. 2000. Horner, R. M. W., El-Haram, M. A, Munns, A. K. Building Maintenance Strategy: A new management Approach. *Journal of Quality in Maintenance Engineering.* 1997. 3(4): 273-280.

Hoxley, M. Conditions Inspections of Residential Property: A Procedural Framework. *Journal of Structural Survey.* 2002. 20(1): 31-35.

Hua, G. H., Sher, W., Pheng, L. S. Factors Affecting Effective Communication between Building Clients and Maintenance Contractors. *Corporate Communications: An International Journal.* 2005. 10(3): 240-251.

Hussain, S., Gabbar, H. A. Non-Destructive Testing of Machines to Reduce Maintenance Time and Cost. *Annual Reliability and Maintainability Symposium (RAMS) 2012 Proceedings.* 23.1.2012. Nevada: IEEE. 2012. pp. 1-6.

Ibrahim, R., Yen, S. Y. Formalization of the Data Flow Diagram Rules for Consistency Check. *International Journal of Software Engineering and Application (IJSEA).* 2010. 1(4): 95-111.

Idhammar (2010). *Idhammar Whitepaper-Benefits of Implementing a CMMS.* Retrieved on April 2, 2013, from http://www.idhammarsystems.com

Ishak, N. H., Ali, Z. M., Omar, Y., Hashim, H. A. Case Studies on Timber Defects of Selected Traditional Houses in Malacca. *Journal of Design and Built Environment.* 2007. 3(1): 81-90.

Ismail, I., Che-Ani, A. I., Tawil, N. M., Yahaya, H., Abd-Razak M. Z. Housing Defect of Newly Completed House: An Analysis Using Condition Survey Protocol (CSP) 1 Matrix. *World Academy of Science, Engineering and Technology Journal.* 2012. 114(67): 620-623.

Ismail, Z. *Maintenance Management System to Support Facilities Management at Polytechnic.* Degree Thesis. Universiti Teknologi Malaysia; 2012.

Ismail, Z., Kasim, N. Improving Maintenance Management Practices on Conventional Method at Malaysian Polytechnic. *International Conference on Technology Management, Business and Entrepreneurship 2012 (ICTMBE 2012).* Batu Pahat, Johor: Universiti Tun Hussein Onn Malaysia. 2012. pp. 432-438.

Ismail, Z., Kasim, N. Maintenance Management Practices for Building Facility: A Case Study. *International Journal of Engineering Research and Applications (IJERA).* 2013. 3(4): 487-497.

Irigaray, A. A., Gilabert, E., Jantunen, E., Adgar, A. Ubiquitous Computing for Dynamic Condition Based Maintenance. *Journal of Quality in Maintenance Engineering.* 2009. 15(2): 151-166.

Iwmsnews (2010). *6 Aspects about IWMS that Everybody Ought to Know.* Retrieved on March 25, 2013, from http://www.iwmsnews.com

Jabatan Pengajian Politeknik (2013). *Senarai Politeknik KPT.* Retrieved on August 22, 2013, from http://www.politeknik.edu.my/portalbpp/index.asp?pg=poli

Jajac, N., Knezic, S., Marovic, I. Decision Support System to Urban Infrastructure Maintenance Management. *Organization, Technology and Management in Construction: An International Journal.* 2009. 1(2): 72-79.

Jajac, N., Bilic, I., Ajduk, A. Decision Support Concept to Management of Construction Projects-Problem of Construction Site Selection. *Croatian Operational Research Review.* 2013. 4(1): 235-246.

Jan, B., Jaroslav, O. Quality Tools in Building Maintenance and Monitoring. *Improving Vocational Education Conference (IMVOCED).* 20.10.2003. Luton, UK: University of Luton. 2003. pp. 9-16.

Jantunen, E., Emmanouilidis, C., Arnaiz, A., Gilabert, E. E-Maintenance: Trends, Challenges and Oppurnities for Modern Industry. *World Congress.* 2011. 18(1): 453-458.

Jardine, A. K. S., Lin, D., Banjevic, D. A Review on Machinery Diagnostics and Prognostics Implementing Condition-based Maintenance. *Mechanical Systems and Signal Processing.* 2006. 20(7): 1483-1510.

Jensen, F. V., Nielsen, T. D. *Bayesian Networks and Decision Graphs.* 2nd Ed. New York: Springer. 2007.

Johar, S., Ahmad, A. G., Che-Ani, A. I., Tawil, N. M., Utaberta, N. Penyiasatan Kerosakan terhadap Bangunan Kayu Lama: Kajian Kes Masjid Lama Mulong, Kelantan. *The Professional Journal of the Institution of Surveyors.* 2011. 46(1): 20-24.

Johnson, B., Christensen, L. *Educational Research: Quantitative, Qualitative and Mixed Approaches.* 2nd Ed. USA.: Pearson Education, Inc. 2004.

Josephson, P. E., Hammarlund, Y. The Causes and Costs of Defects in Construction: A Study of Seven Building Projects. *Journal of Automation in Construction.* 1999. 8(6): 681-687.

Julta, D., Craig, J., Bodorik, P. Enabling and Measuring Electronic Customer Relationship Management Readiness. *Proceedings of the 34th Hawaii International Conference on System Sciences.* Hawaii: IEEE. 2001. pp. 7023-7033.

Kamat, V. R., Tawil, S. E. Evaluation of Augmented Reality for Rapid Assessment of Earthquake-Induced Building Damage. *Journal of Computing in Civil Engineering.* 2007. 21(5): pp. 303-310.

Kans, M. The Advancement of Maintenance Information Technology: A Literature Review. *Journal of Quality in Maintenance Engineering.* 2009. 15(1): 5-16.

Kans, M., Williamsson, I. Maintenance IT Practices in Swedish Industry. *The 1st International Workshop and Congress on eMaintenance 2010.* 22.6.2010. Lulea, Sweden: Lulea University of Technology. 2010. pp. 127-132.

Kementerian Kerja Raya (2011) *Direktori Sistem Aplikasi Kementerian Kerja Raya.* Retrieved on April 13, 2013, from http://www.kkr.gov.my

Khalid, M., Mydin, M. A. O. Building Condition Assessment and Defect Analysis on Heritage Shophouses in Penang, Malaysia: Case Studies. *International Journal of Engineering.* 2012. 77(3): 441-444.

Knudsen D. Aligning Corporate Strategy, Procurement Strategy and E-Procurement Tools. *International Journal of Physical Distribution & Logistics Management.* 2003. 33(8): 720-734.

Ko, C. H. RFID-based building maintenance system. *Automation in Construction.* 2009. 18(3): 275-284.

Ko, C., Kuo, J. Enhancing Building Maintenance using RFID Technology. *International Conference on Engineering, Project and Production Management.* 14.10.2010. Pingtung, Taiwan: EPPM. 2010. pp. 51-60.

Kordon, F., Luqi. An Introduction to Rapid System Prototyping. *IEEE Transaction on Software Engineering.* 2002. 28(9): 817-821.

Kothari, C. R. *Research Methodology: Methods and Techniques.* 2nd Ed. New Delhi: New Age International. 2009.

Kroenke, D. M. *Using MIS.* 5th Ed. Indiana, USA: Prentice Hall PTR. 2012.

Kullolli, I. Selecting a Computerized Maintenance Management System. *Clinical Engineering Management*. Biomedical Instrumentation & Technology. 2008.

Labib A. W. A Decision Analysis Model for Maintenance Policy Selection Using a CMMS. *Journal of Quality in Maintenance Engineering*. 2004. 10(3): 191-202.

Labib, A. W. Next Generation Maintenance Systems (NGMS): Emerging Educational and Training Needs to Support An Adaptive Approach to Maintenance Planning and Improve Decision Support. *Proceedings of the 5th International Conference on Condition Monitoring and Machinery Failure Prevention Technologies (CM and MFPT).* 15.7.2008. Edinburgh, UK: The British Institute of Non-Destructive Testing and Coxmoor Publishing. 2008. pp. 1-9.

Laefer, D. F., Conry, B., Murphy, D., Ceribasi, S. A New Multi-Parallel Condition Assessment Scale for Estimating Tunnel-Induced Damage. *Development of Urban Areas and Geotechnical Engineering.* 16.6.2008. Ireland: University College Dublin. 2008. pp. 1-6.

Lam, E. W. M., Chan, A. P. C., Chan, D. W. M. Qualitative Survey on Managing Building Maintenance Projects. *World Academy of Science, Engineering and Technology Journal.* 2010. 35(41): 232-236.

Lateef, O. A. Case for Alternative Approach to Building Maintenance Management of Public Universities. *Journal of Building Appraisal.* 2009. 5(3): 201-212.

Lateef, O. A., Khamidi, M. F., Idrus, A. Building Maintenance Management in a Malaysian University Campus: A Case Study. *Australasian Journal of Construction Economics and Building*. 2010a. 1(2): 76-89.

Lateef, O. A., Khamidi, M. F., Idrus, A. *Development of a Value Maintenanance Management Model for Malaysian University Campuses*. CIB World Congress. Salford: Machester, UK, 2010b.

Lateef, O. A. A., Khamidi, M. F., Idrus, A. Appraisal of the Building Maintenance Management Practices of Malaysian University. *Journal of Building Appraisal.* 2011. 6(3/4): 261-275.

Latif, L. A., Bahroom, R., Fard, Y. Improving Accessibility and Responsiveness in a Complaints Management System. *E-leader Conference.* Singapore: Chinese American Scholars Association Inc. 2010. pp. 1-12.

Lavy, S., Bilbo, D. L. Facilities Maintenance Management Practices in Large Public Schools, Texas. *Journal of Facilities.* 2009. 27(1/2): 5-20.

Laws, S., Harper, C., Marcus, R. *Research for Development: A Practical Guide.* London: SAGE Publications, Inc. 2003.

Lazarus, S. J., Hauptfleisch, A. C. The Application of Facilities Maintenance within the Public Sector: An Exploratory Study. *The Fifth Built Environment Conference.* Belville, South Africa: Association of Schools of Construction of Southern Africa (ASOCSA). 2010. pp. 301-313.

Lazim, M. H. M., Samad, N. A. A. *Masalah Melaporkan Kerosakan Komputer di Jabatan Teknologi Maklumat dan Komunikasi, Politeknik Tuanku Syed Sirajuddin.* Politeknik Tuanku Syed Sirajuddin Digest (PTSS Digest). 2011.

Leake, A. (2006, April) *Definition Database.* Retrieved on June 5, 2012, from http://searchsqlserver.techtarget.com/definition/database

Lebar, O. *Penyelidikan Kualitatif: Pengenalan kepada Teori dan Metod.* Tanjung Malim: Universiti Pendidikan Sultan Idris. 2007.

Lecorche, E., Senecal, G. *Installation of a CMMS Piece of Software Aiming to Improve the Maintenance Sstrategy at Ganil*. 1st Accelerator Reliability Workshop (ESRF), 2002.

Lee, J., Lee, M., Lee, S., Oh, S., Kim, B., Nam, S., Jang, J. Development of Computerized Facility Maintenance Management System Based on Reality Centered Maintenance and Automated Data Gathering. *International Journal of Control and Automation.* 2013. 6(1): 1-12.

Lee, R., Wordsworth, P. *Building Maintenance Management.* 4th Ed. Malden, Massachusetts: Blackwell Science. 2000.

Lehtonen, O., Ala-Risku, Timo. Enhancing On-Site Maintenance Execution with ICT-A Case Study. *Proceedings of the Fifth International Conference on Electronic Business.* 5.12.2005. New York, USA: ACM Press. 2005. pp.882-895.

Leite, F., Akinci, B. Reasoning about Building Systems and Content to Support Vulnerability Assessment in Building Emergencies. *Journal of Computing in Civil Engineering.* 2013. 27(2): 118-128.

Leonard-Barton, D. A Dual Methodology for Case Studies: Synergistic Use of a Longitudinal Single Site with Replicated Multiple Sites. *Journal of Organizational Science.* 1990. 1(3): 248-266.

Li, C-S., Guo, S-J., Life Cycle Cost Analysis of Maintenance Costs and Budgets for University Buildings in Taiwan. *Journal of Asian Architecture and Building Engineering.* 2002. 11(1): 97-94.

Li, N., Becerik-Gerber, B. Exploring the Use of Wireless Sensor Networks in Building Management. *In Computing in Civil and Building Engineering, Proceedings of the International Conference.* 30.6.2010. Nottingham, UK: Nottingham University Press. 2010. pp. 91-97.

Lim, T. M., Lee, S. P. A Persistence Framework for Object-To-Relational and Multidimensional DBMSS. *Malaysian Journal of Computer Science.* 2004. 17(1): 74-82.

Lin, T. R., Tan, A. C. C., Howard, I., Pan, J., Crosby, P., Mathew, J. Development of a Diagnostic Tool for Condition Monitoring of Rotating Machinery. *ICOMS Asset Management Conference Proceedings.* Queensland, Australia: Asset Management Council Limited. 2011. pp.1-9.

Lind, H., Muyingo, H. Building Maintenance Strategies: Planning Under Uncertainty. *Journal of Property Management.* 2012. 30(1): 14-28.

Liu, A. M. M. The Quest for Quality in Public Housing Projects: a Behaviour-to-Outcome Paradigm. *Construction Management and Economics.* 2003. 21: 147-158.

Liu, Y. *A Forecasting Model for Maintenance and Repairs Costs for Office Buildings.* Master Thesis. Concordia University; 2006.

Lo, T. Y., Choi, K. T. W. Building Defects Diagnosis by Infrared Thermography. *Journal of Structural Survey.* 2004. 22(5): 259-263.

Love, P. E. D., Sohal, A. S. Capturing Rework Costs in Projects. *Managerial Auditing Journal.* 2003. 18(4): 329-339.

Lounis, Z., Vanier, D. J. A Multiobjective and Stochastic System for Building Maintenance Management. *Journal of Computer-Aided Civil and Infrastructure Engineering.* 2000. 15(5): 320-329.

Lung, B., Levrat, E., Marquez, C., Erbe, M. Conceptual Framework for E-Maintenance: Ilustration by E-Maintenance Technologies and Platforms. *Annuals Reviews in Control.* 2009. 33: 220-229.

Mahmood, W. H. W., Rahman, M .N. A., Mazli, H., Deros, B. M. Maintenance Management System for Upstream Operations in Oil and Gas Industry: Case Study. *World Academy of Science, Engineering and Technology.* 2009. 68(36): 413-419.

Mantra (2012). *Free Maintenance Management Software.* Retrieved on March 25, 2013, from http://www.bmstc.uku.co.uk/mantra/

Marquez, A. C., Leon, P. M. D., Fernandez, J. F. G., Marquez, C. P., Campos, M. L. The Maintenance Management Framework: A Practical View to Maintenance Management. *Journal of Quality in Maintenance Engineering.* 2009. 15(2): 167-178.

Marquez, A. C., Lung, B. A Review of E-Maintenance Capabilities and Challenges. *Journal on Systemics, Cybernetics and Informatics.* 2008. 6(1): 62-66.

Mason, J. *Qualitative Researching.* 2nd Ed. London: SAGE Publications, Inc. 2002. McMillan, J. H., Schumacher, S. *Research in Education: Evidence-Based Inquiry.* 6th Ed. USA: Pearson Education, Inc. 2006.

Mathew, A., Zhang, S., Ma, L., Earle, T., Hargreaves, D. Reducing Maintenance Cost Through Effective Prediction Analysis and Process Integration. *Advances in Vibration Engineering.* 2006. 5(2): 87-96.

Matusheski, B. Using Information Technology to Optimize Maintenance Operations. *Plant Engineering.* 2001. 55(5): 22-26.

Mclean, S. Why does Maintenance Planning require a Bespoke Approach? *Journal of Building Appraisal.* 2009. 5(1): 1-5.

Merriam, S. B. *Qualitative Research: A Guide to Design and Implementation.* San Francisco, CA: John Wiley and Sons, Inc. 2009.

Microwest Software Systems Inc. (2013). *AMMS Maintenance Management.* Retrieved on March 25, 2013, from http://www.microwestsoftware.com

Mikkelsen, B. *Methods for Development Work and Research: A New Guide for Practitioners.* 2nd Ed. New Delhi: SAGE Publications, Inc. 2005.

Ming, L. C., Mydin, M. A. O. Case Studies on Construction Defects on Different Types of Walling System for Building. *International Journal of Cement and Concrete Composites.* 2012. 50(2012): 10354-10357.

Moaveni, B., Xianfei, H., Jose, R., Jole, P. C. Damage Identification Study of a Seven-Story Full-Scale Building Slice Tested on the UCSD-NEES Shake Table. *Journal of Structural Safety.* 2010. 32(5): 347-356.

Mohamad, S. B. H. S., Annuar, W. F. H. W. Engineering Approach System to Assess Defect and Deteriorations of Building Structures. *International Seminar on the Application of Science & Mathematics 2011 (ISASM 2011).* 1.11.2011. Batu Pahat, Johor: UTHM Holdings Sdn. Bhd. 2011. pp. 1-8.

Moore, W. J., Starr, A. G. An Intelligent Maintenance System for Continuous Cost-Based Prioritisation of Maintenance Activities. *Computers in Industry.* 2006. 57(6): 595-606.

Morello, B. C., Karray, M. H., Zerhouni, N. New Persepctives of Maintenance Systems: "Towards S-Maintenance". *Proceedings from the IMS2020 Summer School on Sustainable Manufacturing.* 26.5.2010. Trondheim, Norway: IMS & Tapir Academic Press. 2010. pp. 223-236.

Morton-Cooper, A. *Action Research in Health Care.* Oxford: Blackwell Science Ltd. 2000.

Muffatto, M., Payaro, A. Integration of Web-Based Procurement and Fulfillment: A Comparison of Case Studies. *International Journal of Information Management: The Journal for Information Professionals.* 2004. 24(4): 295-311.

Muijs, D. *Doing Quantitative Research in Education with SPSS.* London: SAGE Publications, Inc. 2004.

Mukattash, A., Fouad, R. H., Kitan, H., Samhouri, M. Computer-Aided Maintenance Planning System for Industrial Companies. *Jordan Journal of Mechanical and Industrial Engineering.* 2011. 5(3): 227-234.

Mukelas, M. F. M., Zawawi, E. M. A., Kamaruzzaman, S. N., Ithnin, Z., Zulkarnain, S. H. A Review of Critical Success Factors in Building Maintenance Management of Local Authority in Malaysia. *2012 IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA).* 23.9.2012. Bandung, Indonesia: IEEE. 2012. pp. 653-657.

Muller, A., Marquez, A. C., Lung, B. On the Concept of E-Maintenance: Review and Current Research. *Reliability Engineering and System Safety.* 2007. 93(8): 1165-1187.

Nasir, A. R. M., Che-Ani, A. I., Surat, M., Tawil, N. M., Abdullah, N. A. G. Common Toilet Defect in Higher Education Institution: Building Condition Analysis using CSP1 Matrix. *Journal of Building Performance.* 2010. 1(1): 80-93.

Nawi, M. N. M., Kamar, K. A. M., Abdullah, M. R., Haron, A. T., Lee, A., Arif, M. Enhancement of Constructability Concept: An Experience in Offsite Malaysia Construction Industry. *CIB International Conference, Changing Roles New Roles; New Challenges.* 5-9.10.2009. Rotterdam, Nederland: Delft University of Technology. 2009. pp. 1-13.

Nielsen, J., Hansen, E. J. D. P., Aagaard, N. J. Buildability as Tool for Optimisation of Building Defects. *CIB Joint International Symposium 2009.* 29.9.2009. Croatia: University of Zagreb. 2009. pp. 1003-1012.

Niousha, A., Motosaka, M. System Identification and Damage Assessment of an Existing Building before and after Retrofit. *Journal of Structural Engineering.* 2007. 53B: 297-304.

Ogawa, N., Yamazaki, F. Photo-Interpretation of Building Damage due to Earthquakes using Aerial Photographs.*12th World Conference on Earthquake Engineering (12WCEE).* Auckland, New Zealand: Upper Hutt. 2000. pp. 1-8.

Oakley, A. *The Ann Oakley Reader: Gender, Women and Social Science.* UK: The Policy Press. 2005.

O'Donoghue, C.D., Prendergast, J.G. Implementation and Benefits of Introducing a Computerised Maintenance Management System Into a Textile Manufacturing Company. *Journal of Materials Proceeding Technology*. 2004. 153-154(2004): 226-232.

Olanrewaju, A. A. Quantitative Analysis of Criteria in University Building Maintenance in Malaysia. *Journal of Construction Economics and Building.* 2010. 10(3): 51-61.

Olanrewaju, A. L., Idrus, A., Khamidi, M. F. Investigating Building Maintenance Practices in Malaysia: A Case Study. *Journal of Structural Survey.* 2011. 29(5): 397-410.

Olubodun, F. A. Multivariate Approach to the Prediction of Maintenance Needs in Public Housing: The Tenant Dimension. *Journal of Structural Survey.* 2001. 19(2): 133-141.

Othman, N., Halim, A. A., Halim, A. Z. A., Radzuan, N. A. M. Analysis of Building Defect for Wooden Houses at Flooded Area in Kota Bharu, Kelantan. *Journal of Design and Built.* 2012. 5(1): 1-5.

Otis (2013). *Otis Maintenance Management System (OMMS).* Retrieved on March 25, 2013, from http://www.otis.com

Oyegoke, A. S. UK and US Construction Management Contracting Procedures and Practices: A Comparative Study. *Journal of Construction, Engineering and Architectural Management.* 2001. 9(5/6): 403-417.

Panneerselvam, R. *Research Methodology.* 3rd Ed. New Delhi: Prentice-Hall of India Private Limited. 2004.

Parape, C. D., Tamura, M. Identifying Damaged Buildings from High-Resolution Satellite Imagery in Hazardous Area using Morphological Operators. *Geoscience and Remote Sensing IEEE International Symposium (IGARSS).* Sendai, Japan: IEEE GRSS, IEICE and Science Council of Japan. 2011. pp. 1898-1901.

Patton, M. Q. *Qualitative Research and Evaluation Methods.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2002.

Pedro, J. B., Paiva, J. V., Vilhena, A. Portuguese Method for Building Condition Assessment. *Journal of Structural Survey.* 2008. 26(4): 322-335.

Pedro, J. B., Vilhena, A., Coelho, A. B., Paiva, J. V., Cruz, C. Main Spatial Defects of Illegal Residential Buildings: The Case of Alto da Cova da Moura District. *International Conference on Durability of Building Materials and Components.* 12.4.2011. Netherlands: Delft University of Technology. 2011. pp. 1-8.

Peraza, D. B. Condition Assessment of Buildings. *Proceedings of the Structures Congress 2006*. ASCE, Reston, VA. 2006.

Pheng, T. H. *Development of Information System for Government Chinese Primary School (Case Study: SJK(C) Convent Datuk Keramat).* Master Thesis. Universiti Teknologi Malaysia; 2009.

Politeknik Seberang Perai (2009) *eAplikasi (Internet).* Retrieved on April 13, 2013, from http://www.psp.edu.my

Punch, K. F. *Introduction to Social Research: Quantitative and Qualitative Approaches.* 2nd Ed. London: SAGE Publications, Inc. 2005.

Rahman, M. A. A., Akasah, Z. A., Abdullah, M. S., Musa, M. K. Issues and Problems Affecting the Implementation and Effectiveness of Heritage Buildings Maintenance. *International Conference on Civil and Environmental Engineering Sustainability (IConCEES 2012).* Batu Pahat, Johor. Universiti Tun Hussein Onn Malaysia. 2012. pp. 1-5.

Ramli, A., Akasah, Z. A., Masirin, M. I. M., Building Safety and Health Modelling Framework for Polytechnic Buildings in Malaysia. *International Conference on Civil and Environmental Engineering Sustainability (IConCEES 2012).* Batu Pahat, Johor. Universiti Tun Hussein Onn Malaysia. 2012. pp. 1-9.

Ramly, A. *Guideline of Building Defects Inspection Work.* Selangor: Hizi Print Sdn. Bhd. 2004.

Rashidi, M., Lemass, B. A Decision Support Methodology for Remediation Planning of Concrete Bridges. *KICEM Journal of Construction Engineering and Project Management.* 2011. 1(2): 1-10.

Razali, R., Halim, K. N. A., Jusoff, K. Quality Improvement of Services in Universiti Teknologi Mara Pahang from a Management Perspective. *Journal of Management Science and Engineering.* 2011. 5(1): 71-80.

Razali, R., Jaafar, J. Complaint Handling Theoretical Framework. *2012 International Conference on Computer and Information Science (ICCIS).* 12.6.2012. Kuala Lumpur, Malaysia: IEEE. 2012. pp. 382-385.

Razali, M. N., Manaf, Z. The Role of Facilities Management Information System (FMIS) in Construction Project Management. *4th Annual Conference of Management Construction Researchers Association (MICRA).* Kuala Lumpur: Universiti Malaya. 2005. pp. 1-10.

Rensselaer Polytechnic Institute (2013). *Administration Division.* Retrieved on April 13, 2013, from http://www.rpi.edu/

Rindfuss, R. R., Piotrowski, M., Thongthai, V., Prasartkul, P. Measuring Housing Quality in the Absence of a Monetized Real Estate Market. *Population Studies.* 2007. 61(1): 35-52.

Rojahn, C. *Rapid Visual Screening of Buildings for Potential Seismic Hazards, A Handbook, FEMA 154*. 2nd Ed. Redwood City, CA. Applied Technology Council, National Earthquakes Hazards Reduction Program. 2002.

Sagayam, A. (2009, May 29). *Jaya Supermarket Collapse: 4 Dead, Search On For 3.* Retrieved on August 11, 2012, from http://thestar.com.my/news/story.asp?file=/2009/5/29/nation/20090529101559&sec=nation

Saghatforoush, E., Trigunarsyah, B., Too, E., Heravitorbati, A. Extending Constructability Concept to include Operation and Maintenance Issues. *International Construction Business & Management Symposium (ICBMS 2011) Proceeding.* Queensland, Australia: Queensland University of Technology, 2011. pp. 1-10.

Saharkhiz, E., Bagherpour, M., Feylizadeh, M. R., Afsari, A. Software Performance Evaluation of a Computerized Maintenance Management System: A Statistical Based Comparison. *Maintenance and Reliability.* 2012. 14(1): 77-83.

Sapsford, R. *Survey Research.* 2nd Ed. London: SAGE Publications, Inc. 2007.

Saranga, H. Relevant Condition-Parameter Strategy for an Effective Condition-Based Maintenance. *Journal of Quality in Maintenance Engineering.* 2002. 8(1): 92-105.

Satzinger, W., Jackson, R. B., Burd, S. D. *Systems Analysis and Design in a Changing World.* 5th Ed. USA: Cengage Learning. 2008.

Senger, T. (2005, April) *Electronic Form (E-Form).* Retrieved on June 6, 2012, from http://searchcio.techtarget.com/definition/e-form

Shafie, F., Yusoff, W. W. Z., Sidi, S. N. S., and Facilities Management Helpdesk in Universiti Tun Hussein Onn Malaysia (UTHM). *Proceeding of the International Conference on Social Science, Economics and Art.* Putrajaya, Malaysia: International Scientific Conference. 2011. pp. 139-143.

Shamsuddin, N. H. A. *Development of Complaint Management System for Pejabat Pengurusan Fasiliti UiTM Shah Alam*. Degree Thesis. Universiti Teknologi Mara; 2006.

Shareghi, M., Faieza, A. A. Service Oriented Architecture and Advancement of Maintenance Management Information System: A Review. *Scientific Research and Essays.* 2011. 6(15): 3182-3188.

Sharma, R., Govindaraju, N. Intelligent Support System a Maintenance Planning Activity. *International Conference of Chemical, Biological and Environmental Engineering.* 2.11.2010. Cairo, Egypt. IEEE. 2010. 331-335.

Sharma, R. K., Kumar, D., Kumar, P. FLM to Select Suitable Maintenance Strategy in Process Industries using MISO Model. *Journal of Quality in Maintenance Engineering.* 2005. 11(4): 359-374.

Sherwin, D. A Review of Overall Models for Maintenance Management. *Journal of Quality in Maintenance Engineering.* 2000. 6(3): 138-164.

Shohet, I. M., Perelstein, E. Decision Support Model for the Allocation of Resources in Rehabilitation Projects. *Journal of Construction Engineering and Management.* 2004. 130(2): 249-257.

Shreve D.H. *Integrated Condition Monitoring Technologies*. IRD Balancing LLC. 2003.

Singh, J. Fungal Problems in Historic Buildings. *Journal of Architectural Conservation.* 2000. 6(1): 17-37.

Sodangi, M., Idrus, A., Khamidi, M. F. Examining the Maintenance Management Practices for Conservation of Heritage Buildings in Malaysia. *National Postgraduate Conference 2011 (NPC 2011).* 19.9.2011. Tronoh, Perak: Universiti Teknologi Petronas. 2011. pp. 1-7.

Sooriyarachchi, M. P., Gayani, K. Information Technology Usage in Building Operation and Maintenance Management. *International Research Conference on Management and Finance (IRCMF).* Sri Lanka: University of Colombo. 2010. pp. 9-18.

Southern Polytechnic State University (2012) *Welcome to SPSU Facilities Division.* Retrieved on April 13, 2013, from http://www.spsu.edu/facilities/

Stack, P., Menzel, K., Flynn, D., Ahmed, A. A Cloud-based Platform for Energy and Maintenance Management. *4th International Conference on Computing in Civil and Building Engineering (14th ICCCBE).* 27.6.2012. Moscow, Russia: Moscow State University of Civil Engineering (MSUCE). 2012. pp. 1-8.

Stack, P., Ryan, J., Walsh, B., Quinlan, J., Menzel, K. Context-Sensitive Maintenance Management using Mobile Tools. *Second International Conference on Advances in Engineering and Technology 2011 (AET 2011).* Noida, India: ACEEE. 2011. pp. 374-381.

Stake, R. *Multiple Case Study Analysis.* New York: Guilford Press. 2005.

Straub, A. Dutch Standard for Condition Assessment of Buildings. *Journal of Structural Survey.* 2009. 27(1): 23-35.

Strauss, A., Corbin, J. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2008.

Su, Y. C., Lee, Y. C., Lin, Y. C. Enhancing Maintenance Management using Building Information Modeling in Facilities Management. *2011 Proceedings of the 28th International Symposium on Automation and Robotics in Construction (ISARC).* Seoul, Korea: IAARC. 2011. pp. 752-757.

Sullivan, G. P., Pugh, R., Melendez, A. P., Hunt, W. D. *Operation and Maintenance Best Practice A Guide to Achieving Operational Efficiency.* 3rd Ed. United States of America: Department of Energy's Federal Energy Management Program (FEMP). 2010.

Supramani T. *Development of Computerised Maintenance Management System (CMMS) for Ready Mix Concrete Plant Production Facilities.* Master Thesis. Universiti Teknologi Malaysia; 2005.

Suter, W. N. *Introduction to Educational Research: A Critical Thinking Approach.* 2nd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2012.

Tahir, Z. Maintenance Decision Support Fuzzy System in Small and Medium Industries using Decision Making Grid. *International Conference on Advanced Computer Theory and Engineering 2008 (ICACTE '08).* 20.12.2008. Phuket, Thailand: IEEE. 2008. pp. 680-684.

Tahir, Z., Burhanuddin, M. A. Ahmad, A. R., Halawani, S. M., Arif, F. Improvement of Decision Making Grid Model for Maintenance Management in Small and Medium Industries. *Fourth International Conference on Industrial and Information Systems (ICIIS 2009).* 28.12.2009. Sri Lanka: IEEE. 2009. 598-603.

Tainton, B. E. The Unit of Analysis 'Problem' in Educational Research. *Queensland Journal of Educational Research.* 1990. 6(1): 4-19.

Talon, A., Boissier, D., Lair, J. Service Life Assessment of Building Components: Application of Evidence Theory. *Canadian Journal of Civil Engineering.* 2007. 35(3): pp. 66-70.

Talon, A., Boissier, D., Hans, J., Lacasse, M. A., Chorier, J. FMECA and Management of Building Components. *11th International Conference on the Durability of Building Materials and Components.* 11.5.2008. Canada: National Research Council Canada (NRCC). 2008. pp. 1-9.

Tesch, R. Computer Programs that assist in the analysis of qualitative data: An Overview. *Qualitative Health Research.* 1991. 1(3): 309-325.

Thimbleby, H. Interaction Walkthrough: Evaluation of Safety Critical Interactive Systems. In: Doherty, G., Blanford, A. *Interactive System: Design, Specification and Verification.* Jerman: Springer Berlin Heidelberg. pp. 52-66; 2007.

Tmasystems (2011). *About Us: Maintenance Management Software - CMMS.* Retrieved on March 25, 2013, from http://www.tmasystems.com

Tomlingson, P. D. *Effective Maintenance, The Key to Profitability: A Manager's Guide to Effective Industrial Maintenance Management*. Indiana: Wiley, Inc. 1998. pp. 22, 66-67.

Townsend, B., Widener, Ken. Southern Dispatch Succeeds With Laptops in the Field. *Transmission & Distribution World.* 2004. 56(8): 66.

Trappey, A. J. C., Hsiao, D. W., Ma, L. Maintenance Chain Integration Using Petri-Net Enabled Multi-Agent System Modeling and Implementation Approach. *IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews.* 2011. 41(3): 306-315.

Trimmer. G., Kidston, N. *Assessing Procurement*. London: Trimmer CS and the Housing Corporation. 2003.

Ucar, M., Qiu, R. G. E-Maintenance in Support of E-Automated Manufacturing Systems. *Journal of the Chinese Institute of Industrial Engineers.* 2005. 22(1): 1-10.

Underwood, J., Alshawi, M. Forecasting Building Element Maintenance within an Integrated Construction Environment. *Automation in Construction.* 2000. 9: 169-184.

Uysal, F., Tosun, O. Fuzzy TOPSIS-based Computerized Maintenance Management System Selection. *Journal of Manufacturing Technology Management.* 2012. 23(2): 212-228.

Vilhena, A., Pedro, J. B. Assessment Method for Building's Rehabilitation Needs: Development and Application. *Proceeding 2010 CIB World Congress-Building a Better World.* 10.5.2010. Salford, UK: CIB 2010 World Congress. 2010. pp. 1-12.

Wahab, M. B. A. *A Study to Ascertain Customer's Satisfaction on Building Performance and Facilities provided in Polytechnic Kulim.* Master Thesis. Universiti Teknologi Malaysia; 2005.

Wang, J. F., Tse, P. W., He, L. S., Yeung, R. W. Remote Sensing, diagnosis and collaborative maintenance with Web-Enabled Virtual Instruments and Mini-Servers. *International Journal of Advanced Manufacturing Technology.* 2004. 24(9-10): 764-772.

Wang, Z. A Data Mining based Maintenance Decision Support System for Electric Utilities. *2004 IEEE Pes Power Systems Conference and Exposition.* 10.10.2004. New York: IEEE. 2004. pp. 1-3.

Watt, D. *Building Pathology: Principles and Practices.* 2nd Ed. Oxford: Blackwell Publishing, Ltd. 2007.

Wyn, L. J. (2010, January 07) *Report on Stadium Roof Collapse Out.* Retrieved on June 6, 2012, from http://www.theedgemalaysia.com/business-news/157029-report-on-stadium-roof collapse-out.html

Xing, X., Xiao, Y., Chang, W., Zhao, L., Cao, J. The Establishment of a Preventive Maintenance Period Optimum Model. *IEEE 18th International Conference on Industrial Engineering and Engineering Management (IE&EM).* 3.9.2011. Changchun, China: IEEE. 2011. 1169-1172.

Yahya, M. R., Ibrahim, M. N. Building Maintenance Policy Issues in High Rise Commercial Buildings. *The 2nd International Conference on Public Policy & Social Sicences 2011 (ICoPS 2011).* 31.10.2011. Selayang, Selangor: International Islamic University Malaysia. 2011. pp. 1-6.

Yahya, M. R., Ibrahim, M. N. Effective Communication System between Building Occupants and Maintenance Management: A Study in High Rise Office Building, Klang Valley, Malaysia. *International Journal of Sustainable Development.* 2012. 4(6): 77-84.

Yam, R. C. M., Tse, P. W., Li, L., Tu, P. Intelligent Predictive Decision Support System for Condition-Based Maintenance. *The International Journal of Advanced Manufacturing Technology.* 2001. 17: 383-391.

Yamazaki, F., Yano, Y., Matsuoka, M. Visual Damage Interpretation of Buildings in Bam City using QuickBird Images Following the 2003, Bam, Iran, Earthquake. *Earthquake Engineering Research Institute Journal.* 2003. 21(S1): S329-S336.

Yau, C., Baglee, D. The Development of a Mobile E-Maintenance System Utilizing RFID and PDA Technologies. *Proceedings of the 4th World Congress on Engineering Asset Management (WCEAM 2009).* 28.9.2009. London: Springer. 2009. pp. 679-687.

Yin, R. K. *Case Study Research: Design and Methods.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, Inc. 2003.

Yunus, M. Z. B. M., Ramli, M. Z. B., Mesir, B. B.. *Civil Engineering Information System.* 12th Ed. Skudai, Johor: Universiti Teknologi Malaysia. 2010.

Yusof, M. N. *Inspirasi Ke Arah Kampus Politeknik Lestari.* Degree Thesis. Universiti Teknologi Malaysia; 2010.

Zackariasson, P., Wilson, T. L. Internet Worked After-Sales Service. *Industrial Marketing Management.* 2004. 33(2): 75.

Zainudeen, N. A., Labib, A. Practical Application of the Decision Making Grid (DMG). *Journal of Quality in Maintenance Engineering.* 2011. 17(2): 138-149.

Zulkarnain, S.H., Zawawi, E. M. A., Rahman, M. Y. A., Mustafa, N. K. F. A Review of Critical Success Factor in Building Maintenance Management Practice for University Sector. *World Academy of Science, Engineering and Technology.* 2011. 34(53): 195-199.