IJEFI
INTERNATIONAL JOURNAL OF ECONOMICS AND FINANCIAL ISSUES
EJ EconJournals
ISSN: 2146-4138

International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

EconJournals

International Journal of Economics and Financial Issues, 2016, 6(S3) 28-35.

Special Issue for "Asia International Conference (AIC 205), 5-6 December 2015, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia"

A Case Study of Maintenance Management Systems in Malaysian Complex and High-rise Industrialized Building System Buildings

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ABSTRACT

The implementation of a maintenance management system faced many issues due to defect repetition and lack of proper structure management planning. A case study was undertaken among complex and high-rise industrialized building system (IBS) buildings in Malaysia to identify a key of problem areas and to establish elements of good practice. The study evaluated the performance of the existing maintenance management system used by complex and high-rise IBS buildings to determine whether there is a need to improve current maintenance management system. Results showed that existing performance is far below best practice standards and that the use of emerging technology such as building information modeling is very limited. This led to the development of a key feature of the maintenance management system using emerging technology to assist engineers at complex and high-rise IBS buildings to improve their existing approaches to maintenance management.

Keywords: Maintenance Management, Process, Malaysia, Industrialized Building System Buildings, Building Information Modeling
JEL Classifications: O1, O2, O4

1. INTRODUCTION

The selected of assessment or diagnosis tools on industrialized building system (IBS) building maintenance has the significant to affect the lifetime performance of building structures owing to the knowledge level of designer or contractor to determine the appropriate concepts and technologies in IBS building maintenance. In this situation, the absence of available defect diagnosis techniques and integration approaches on design and construction aspects of cooperation among particular parties create an additional cost to redesign the project when measuring the maintenance delivery in IBS building (Chen et al., 2010). The repairing method in maintenance through conventional method (paper-based reports/unsystematic database) restrict contractors and manufacturers from being involved in the knowledge sharing in improving project performance level, which often results in design changes and a corresponding maintenance and operation cost increase including materials cost, labor cost and maintenance duration (Yunus and Yang, 2012; Chang and Tsai, 2013). According to Kamaruddin et al. (2013) and Rahman and Omar (2006), the management level in Malaysia, defect identification (DI) process, repairing method and use of technology in building defect diagnosis of IBS buildings is far behind some developed countries. Compared with the relatively high level of IBS construction in the USA and Japan, the supporting technologies and large-scale production systems (such as supervision systems and matching construction technologies) are used to improve the maintainability of components and could diagnose the maintenance problems with safety monitoring process including the avoidance of conflicts involving the parties in the construction (e.g., the designer and contractor) undesirable from happening (Zhang et al., 2014). Less understanding of building defect level and limited technology supports such as technology in building defect diagnosis to help identify the defect problems of IBS components during building maintenance management process may cause great economic losses and personal casualty incidents due to the disaster building defect. For example, concrete roof of the Gong Badak stadium collapsed in Kuala Terengganu on June 2, 2009 (Kaos, 2013). The roof structure crash occurred under construction for SMK Taman Connaught in Kuala Lumpur and three labours were injured on Jan 15, 2010 (Isa, 2010). In addition, a few of ceilings at a Hospital Serdang in Selangor collapsed for a third time as a result of its structural failure (steel corrosion) on November 14, 2013 (Ramli, 2013). Based on the studies about inappropriate maintenance assessment through building collapse cases, there is a need for efficient maintenance management in IBS building construction projects by integration among relevant players. Inappropriate building defect level assessment method will affect the overall quality or productivity, budget and concept of the IBS building maintainability (defect repetition and delay). The effective maintenance management is also required to avoid related problem, such as process quality in making strategic decision for IBS building projects.

There are still cases where complex and high-rise building projects constructed using IBS contributes to poor productivity and maintenance quality due to defects problem and building deteriorates (Ahzahar et al., 2011; Qureshi et al., 2015). The inefficiency in decision making process has been found to be a major cause of aesthetic and functional faults (Chiu and Lin, 2014). The defects include cracks, blemishes, moisture penetration, water leakage due to improper jointing and poor thermal insulation (Onyeizu et al., 2011). Many factors stimulate ineffective decision support to provide the sufficient information of maintenance strategy with the extensive coordination on technical knowledge requirements and schedules prior to maintenance operations of project implementation, however poor maintenance management or inappropriate method in assessment and defect diagnosis can give a major impact to the IBS building maintenance decisions (Chiu and Lin, 2014; Qureshi et al., 2016). According to Chen et al. (2010), the main reasons for not optimum decision making on IBS building construction projects were lack of knowledge and exposure to IBS technology, since the resolution implementation were based on familiarity and personal preferences (e.g., experience of the design team) rather than rigorous data between team members through regular meetings. This is also supported by Bari et al. (2012), who agree with that the incorrect strategic decision at the initial project phase was a major cause of cost overrun and supply chain integration problem due to lack of comprehensive principles in the maintainability approach such as measuring convention, standardization, build ability score and open system practices among IBS building maintenance teams. The integrated decision making process with the maintenance strategy from the design stage to the installation of components is needed that can significantly improve the repairing method of IBS building maintenance projects (Wood, 2012).

The research is to develop an appropriate key feature of system for use by engineers of complex and high-rise IBS buildings to generate effective maintenance management approaches and to implement relevant process on system elements for best practice in maintenance management. This paper reports the research leading to the development of such a new key feature of maintenance system.

2. RESEARCH METHOD

A case study approach is helpful in providing large margin in-depth analyses of the problem and understanding numerous variables as well as their relationships having impact on the phenomenon (Kapoor and Saigal, 2013). This approach combines predefined questions with the topics, issues, and questions of other sources of information to gather systematic information about a set of central topics, while also allowing some exploration when new issues or topics emerge. The case study was undertaken to explore the precise topic and to inquire specific open-ended questions regarding the issues in IBS building maintenance management. The multiple case (embedded) designs have been chosen for this research based on the work of Flick (2014) to identify the replication on the various units of analysis and to decide the generalization approach on improvement of maintenance management practices between case studies. The multiple case studies involved eight IBS building maintenance projects as the unit of the analysis with embedded unit of the analysis for each of the eight IBS building maintenance projects (Cases A-H). The unit of analysis is the entity on which there are data and which will be subjected to statistical analysis (Tainton, 1990). The unit of analysis for this study was based on the embedded approach of the identified group of eight maintenance organizations. The "embedded units of analysis" adopted were maintenance management problems, approaches to address problems, information and communication technology (ICT) implementation, use of emerging technologies and maintenance management system.

The case studies on the eight IBS buildings were undertaken in order to obtain information relating to the maintenance identification, assessment, planning and execution processes. Eight maintenance clients/contractors are selected based on major problems of using conventional method in the comparison to investigate the maintenance management practices in each complex and high-rise IBS building. There are around 51 contractors of IBS building maintenance from a classification of precast concrete system have the highest of IBS building maintenance projects in Malaysia according to construction industry development board (CIDB) and almost are using conventional method and inadequately use of modern ICT tools. The number is considered very big indicating that the use of modern ICT is still very limited for precast concrete system classification in IBS building maintenance management in Malaysia and is presented in Tables 1-4 (CIDB, 2015a; CIDB, 2015b; Nawi et al., 2014).

The interviews consisted of two types of IBS building, namely, "residential" and "non-residential." The case study was based on eight cases (Case A-Case H) of IBS buildings in Malaysia. There were two case studies (Cases A and E) on "residential" due to housing maintenance operation such as the Putrajaya Quarters. In addition, six more case studies (Cases B-H) were classified as "non-residential" which manages the maintenance operation with fully equipped office buildings. The interviews reached a saturated point after the eighth interview session. The justifications for the selected case studies were according to the following main criteria: Exposed to the conventional method used and major problems, attempted to implement computerized technology and the willingness of staff to share their experiences in improving the maintenance management

Table 1: Statistic of active contractor for building maintenance (IBS precast concrete system)

Grade of IBS contractor	Active contractor for IBS building maintenance (IBS precast concrete system)	Maintenance management system	Case study
G7	29	Conventional	-
G6	3	Conventional	-
G5	2	Conventional	-
G4	9	Conventional	-
G3	8	Conventional	-
G2	0	Conventional	-
G1	0	Conventional	-
Total	51		

IBS: Industrialized building system

Table 2: Statistic of IBS building maintenance projects for building maintenance (IBS precast concrete system)

Grade of IBS contractor	IBS building maintenance projects		Maintenance management system	Case study
	Residential	Non-residential		
G7	14	65	Conventional	-
G6	3	1	Conventional	-
G5	6	1	Conventional	-
G4	15	14	Conventional	-
G3	3	10	Conventional	-
G2	0	0	Conventional	-
G1	0	0	Conventional	-
Total	41	91		

IBS: Industrialized building system

Table 3: Statistic of residential building maintenance

Residential	Grade of IBS contractor							Total
	G7	G6	G5	G4	G3	G2	G1	
Public house	4	0	0	9	2	0	0	15
Dormitory complex	7	0	0	1	0	0	0	8
Quarters	3	0	4	0	0	0	0	7
Apartment	1	2	2	1	0			6
Flat	0	1	0	5	1	0	0	6
Chalet	0	0	0	2	0	0	0	2

IBS: Industrialized building system

Table 4: Statistic of non-residential building maintenance

Non-residential	Grade of IBS contractor							Total
	G7	G6	G5	G4	G3	G2	G1	
Office complex	28	0	0	1	1	0	0	30
School	11	0	0	1	2	0	0	14
Mosque	5	0	0	1	2	0	0	8
Administration building	2	1	0	2	2	0	0	7
Shop office	6	0	0	0	0	0	0	6
Institutions	3	0	0	0	0	0	0	3
Hospital	1	0	0	2	0	0	0	3
Workshop	0	0	0	2	1	0	0	3
Prayer	0	0	0	2	1	0	0	3
University	2	0	0	0	0	0	0	2
Hall	1	0	0	0	1	0	0	2
Palace	2	0	0	0	0	0	0	2
Laboratory	2	0	0	0	0	0	0	2
Clinic	1	0	1	0	0	0	0	2
Arcade	1	0	0	0	0	0	0	1
Hotel	1	0	0	0	0	0	0	1

IBS: Industrialized building system

processes at the IBS building. The differences between the types of IBS building project provided an opportunity to explore variations in maintenance management issues for complex and high-rise IBS building projects. The type of IBS buildings under study for maintenance project were all varied from quarters to integration news center. The summary on the eight case studies is presented in Table 5.

The semi-structured interviews were conducted with the engineers who were responsible for the maintenance management of the entire IBS's building under the facility management and development unit (UPPF) and maintenance and development unit (UPS) including maintenance contractor. The interview sessions took around 5 h to accumulate the data on the maintenance processes including the demonstration of the current maintenance management system with the implementation of the ICT tools by the engineer. All the data from the interviews were recorded using video camera and transcribed verbatim.

3. KEY FINDINGS FROM CASE STUDIES

There are eight case studies involved in this research to identify the maintenance management problems, the approaches to address problems, ICT implementation, use of emerging technologies and the maintenance management system at the nominated IBS building to improve the maintenance management practices for building facility and infrastructure. The findings from the case studies are summarized and presented in Table 6 below. The discussions involved a cross-case analysis and have been grouped into five main "embedded units of analysis" that has been identified which is (1) maintenance management problems, (2) approaches to address problems, (3) ICT implementation, (4) use of emerging technologies and (5) maintenance management system.

4. RESULTS AND DISCUSSION

There were many problems related to the conventional method at the IBS building such as, defect repetition (leaking, jointing and cracking) and less competent contractor. The conventional method also led to inaccurate design and construction information, late updating of the required information, lack of coordination and integration (Ismail, 2014). The high quality of IBS building maintenance works level and the long life span of services required an efficient management to maintain the building structure and facility at the IBS building. Therefore, the transformation of the conventional process into the computer-based systems using emerging technologies is important to improve the maintenance management processes for complex projects, in the works of defect diagnosis and to reduce the defects for structural component especially during the post occupancy of a building.

In the case studies, the engineers of client/maintenance contractor revealed that a number of shortcomings in the conventional method. The building defect information record was insufficient to facilitate the maintenance management staff to handle the data analysis and

Table 5: List of case studies

Case A	
Type of IBS building project	Quarters
Type of building	Residential
Design of IBS building	High-rise
Grade of IBS contractor	G7
IBS component used	Precast concrete, blockwork system, formwork system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	10 years
Case B	
Type of IBS building project	Malaysian Institute of Pharmaceuticals and Nutraceuticals (IPHARM)
Type of building	Non-residential
Design of IBS building	High-rise
Grade of IBS contractor	G7
IBS component used	Blockwork system, formwork system, steel framing system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	20 years
Case C	
Type of IBS building project	National Youth Skills Institute (IKBN)
Type of building	Non-residential
Design of IBS building	Complex
Grade of IBS contractor	G7
IBS component used	Precast concrete system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	10 years
Case D	
Type of IBS Building Project	Anti-corruption agency office complex and housing
Type of building	Non-residential
Design of IBS building	Complex
Grade of IBS contractor	G7
IBS component used	Precast concrete system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	4-5 years

(contd)...

Table 5: *(Continued)*

Case E	
Type of IBS building project	Double storey super link house
Type of building	Residential
Design of IBS building	Complex
Grade of IBS contractor	G7
IBS component used	Precast concrete system, formwork system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	24 years
Case F	
Type of IBS building project	Inland Revenue Board of Malaysia Complex
Type of building	Non-residential
Design of IBS building	High-rise
Grade of IBS contractor	G7
IBS component used	Blockwork system, formwork system, steel framing system
Maintenance Management System	Conventional
Person interviewed	Engineer
Years of experience	21 years
Case G	
Type of IBS building project	National Audit Department Office
Type of Building	Non-residential
Design of IBS Building	Complex
Grade of IBS Contractor	G7
IBS component used	Precast concrete system, formwork system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	4-5 years
Case H	
Type of IBS building project	Integration news center
Type of building	Non-residential
Design of IBS building	High-rise
Grade of IBS contractor	G7
IBS component used	Precast concrete, blockwork system, formwork system
Maintenance management system	Conventional
Person interviewed	Engineer
Years of experience	10 years

IBS: Industrialized building system

diagnose the defects. The information record were also inaccurate in order to assess the size of work done and other decision making process. The repetition of defect was frequent at IBS building. The maintenance inspection and assessment was not able to address the building defect problems at the particular location due to the lack of knowledge transfer between all parties in maintenance management. Furthermore, the less competent contractor caused the maintenance faults to be increased to encourage the deterioration of the IBS building structure and facility.

5. THE IMPORTANCE OF HAVING AN EMERGING TECHNOLOGIES TO MANAGE MAINTENANCE EFFECTIVELY

The main function of computerized maintenance management system (CMMS) application for IBS building is to record, analyze and use specific information to particular maintenance activities. Although useful functions provided by this application, nevertheless, when there is a repetition defect or lack of proper structure management planning, engineers failed to address these problems effectively. The existing application has also lack the intelligent capabilities of linking defect diagnosis operations in maintenance affecting various building elements with IBS component defects knowledge. It can be seen that most of the existing prototype CMMS applications in the field of IBS concrete repair have been restricted to limited supports of diagnosis data in decision making process and have no facility for sophisticated diagnosis data management.

In this research, the modeling key feature of maintenance management system using emerging technologies was intended to improve the maintenance management problems at the IBS building which are:

Table 6: Cross-case analysis

Case	Element of analysis: Maintenance management problems
Case A	Lack of commitment for handling defect
	Report delay and undelivered
	Unsystematic database
	Less competent contractor staff
	Less engineer competency
	Technician's report is in general description
	Technician's failure to identify defect problem
	Defects repetition (surface cracking, leaking, scaling and jointing)
	Fault design
	Poor quality work by contractor
	Less material quality
	Poor build ability (M&E coordination)
	Lack coordination between design and maintenance team
	Poor maintainability
	Unspecific accessibility to the defect location
	Poor waterproofing
	Poor maintenance method
Case B	Poor quality work by contractor
	Low repair requirements of the structure component
	Lack of staff
	Lack of supervision
	Limited budgets
	Budget constraint
	Defects repetition (surface cracking and aircond belting)
	Lack of technician
	Less defect detection technologies
	Less competent contractor staff
	Less engineer/technician competency
Case C	Defects repetition (surface cracking, leaking and jointing)
	Low quality design control
	Surface cracks due to improper jointing
	Less quality of joint material
	Deep cracks due to settlement
	Less suitable soil
	Less competent contractor staff
	Less engineer/technician competency
Case D	Defects repetition (leaking and jointing)
	Design performance for concrete durability requirements
	Structural installation method
	Poor waterproofing
	Poor installation of the waterproof membrane
	Poor quality work by contractor
	Lack of uniform standard
	Poor material quality
	Less competent contractor staff
	Less engineer/technician competency
Case E	Defects repetition (surface cracking, leaking and jointing)
	Fault design
	Poor material quality
	Time gap of building repairs
	Poor plumbing fitting
	Plumbing installation method

(contd)...

Table 6: *(Continued)*

Case	Element of analysis: Maintenance management problems
Case F	Defects repetition (leaking and jointing)
	Design performance for concrete durability requirements
	Less competent contractor staff
	Less engineer/technician competency
Case G	Defects repetition (leaking, jointing and overload current trip)
	Fault design
	Contractor ethics issues-interested in making profits
Case H	Defects repetition (heavy leaking)
	Poor quality of design
	Less technician competency
	Deep cracking on structure
	Limited experience by engineer
	Poor maintenance method by contractor
	Less competent contractor staff
	Less engineer/technician competency
Case	**Element of analysis: Approaches to address problem**
Case A	Improve the maintenance assessment for the building works did by contractor
Case B	Provide more quality staff in managing the maintenance of critical defect
	To replace the conventional defect detection method (e.g., visual inspection) with the sophisticated ICT application (e.g., CMMS)
Case C	Improve the maintenance effectiveness for the building works did by contractor
Case D	Proper supervision of work for the building works did by contractor
Case E	Improve the building control for the building works did by main contractor
Case F	Critical plan on maintenance repairs
Case G	Conduct the maintenance assessment for evaluating the building works performance did by contractor
Case H	Conduct the maintenance assessment for evaluating the building works performance did by contractor
Case	**Element of analysis: ICT implementation**
Case A	mySPATA - Data inventory for immobile facilities (e.g., building)
	mySPA - Data inventory for mobile facilities (e.g., furniture)
	mySMS system-for managing complaints
Case B	Conventional (e.g., MS Word, MS Excel)
Case C	mySPATA-Data inventory for immobile facilities (e.g., building)
	mySPA-Data inventory for mobile facilities (e.g., furniture)
Case D	Conventional (e.g., MS Word, MS Excel)
Case E	Conventional (e.g., MS Word, MS Excel)
Case F	Conventional (e.g., MS Word, MS Excel)
Case G	Conventional (e.g., MS Word, MS Excel)
Case H	BAS-for detected building's heating, ventilation and air conditioning systems
	Supervisory control and data acquisition system (SCADA)-to ensure that the building systems (e.g. fire alarm) were in good condition
	E-Aduan-for managing complaints

(contd)...

Table 6: ***(Continued)...***

Case	Element of analysis: Maintenance management problems
Case	**Element of analysis: Use of emerging technologies**
Case A	No
Case B	No
Case C	No
Case D	No
Case E	No
Case F	No
Case G	No
Case H	No
Case	**Element of analysis: Maintenance management system**
Case A	Conventional (e.g., paper-based reports/unsystematic database)
Case B	Conventional (e.g., paper-based reports/unsystematic database)
Case C	Conventional (e.g., paper-based reports/unsystematic database)
Case D	Conventional (e.g., paper-based reports/unsystematic database)
Case E	Conventional (e.g., paper-based reports/unsystematic database)
Case F	Conventional (e.g., paper-based reports/unsystematic database)
Case G	Conventional (e.g., paper-based reports/unsystematic database)
Case H	Conventional (e.g., paper-based reports/unsystematic database)

ICT: Information and communication technology, CMMS: Computerized maintenance management system, BAS: Building automation system

a. Defect repetition due to failure to identify the actual reason of structure defect
b. Defect repetition (leaking, jointing and cracking) due to design defect; and
c. Less competent contractor due to lack of knowledge regarding with materials, method and design of structure repair.

6. THE EXTENT TO WHICH MAINTENANCE FUNCTIONS ARE COMPUTERIZED USING EMERGING TECHNOLOGIES

The main objective of research focuses on the development of an appropriate key feature of system to improve information storage of design and construction, diagnostic and defect risk assessments on IBS building through the integration of building information modeling (BIM). This research focuses on automatic bidirectional communications between expert system and BIM on a database level. An expert system is developed to automatically evaluate the defects and provide flexibility for different maintenance scenarios to gain better quality operation. BIM will be used during the construction phase and data collected from the expert system will be integrated and updated in real-time using Revit Application Programming Interface and Revit DB link for improving interoperability. Adoption of the approaches suggested in the research will enable the system to achieve the maintenance operation visualization, information automation and multi-collaborative participation, which can effectively promote the development of zero IBS building maintenance.

7. MODELING KEY FEATURES OF MAINTENANCE MANAGEMENT SYSTEM FOR COMPLEX AND HIGH-RISE IBS BUILDINGS USING BIM

The key feature of maintenance management are adopted into the maintenance management system to improve the maintenance management approach at the IBS buildings. The knowledge transfer support is the new approach of the new key feature of system that is provided with the diagnosis of problems and decision making for structural component based on the inputs and information supplied by the user for handling the maintenance on the IBS building. Besides, the new key feature of system can be accessed through portable devices such as tablet and notebook at the site location with the database provided (e.g. VB.net and MS Access) for each defects and locations in the report complaint and assessment. The safety database is used to protect the data entry and maintenance collection for the facilities at the IBS buildings. The BIM can be integrated into the new key feature of system with the BIM platform provided (Autodesk Revit) for each respond information results of defect components and cause in the model that facilitate the maintenance assessment process.

The data obtained in the case studies and literature review revealed that the IBS buildings are using the conventional method (paper-based reports/unsystematic database) in managing the maintenance processes for building structure and facility. This arise a problematic situation such as defects repetition (leaking, jointing and cracking) and less competent contractor that need sophisticated tools towards a solution. Presently, the implementation of emerging technologies in the new process is the better improvement to lead the tremendous saving in budget, time planning and to receive the precise data in handling the diagnosis and defect control. The integration of modern ICT tools such as BIM and expert system also facilitates the knowledge transfer for maintenance management processes in recommending the repair needed for the efficacy of the maintenance management practices. From the case studies findings, the involved key feature of maintenance management system are the DI, defect assessment (DA), BIM maintenance assessing (BMA), expert defect diagnosis (EDD), remedial measures (RM) and database control center (DCC) as the main stages in managing maintenance for building structure and facility. The platform used for the key feature of system is Autodesk Revit 2014, Visual Basic.Net 2010 and Microsoft Access 2014 and was designed based on case study findings among complex and high-rise IBS buildings in Malaysia.

8. DESCRIPTION OF KEY FEATURES OF SYSTEM

The key feature of system consisted of: (1) DI; (2) DA; (3) BMA; (4) EDD; (5) RM; and (6) DCC. The explanation of the key feature of maintenance management in the new system is as follows:

i. DI: The defect is examined through observation and reflection in services on the IBS building structure and facility determined by three major areas of building structure, finishes, mechanical and electrical engineering reported by the complainer. The defect is divided into two types of facilities which are the IBS component structures and non-IBS component facilities whereas the report of defect is limited to the uncritical defect for the entire structure and facilities at the IBS building which included the old and newly developed ones.
ii. DA: It is to identify and analyze the real defect that took place at the facility location based on the report received from the complainer. This report information also can be captured through the regular staff's inspection done twice every month at the particular location. The findings data such as the location, facility type, defect explanation and visual inspection such as physical condition category are recorded into the electronic form in the system to assess the cause-effect for the defect sequence on the building structure and facility at the certain duration. Besides, the classifying of defect such as "building design," "defect rating" and "maintenance approach" is appraised which is grounded by the current performance and condition of the structures and facilities. The feedback for the maintenance assessment is updated by the staff to conclude the defect solution before this form is submitted to the members of senior management for validating the required action.
iii. BMA: The different maintenance approaches based on the objective of the structure and facility repair are among the concerned factors in the BMA. Commonly, the IBS building structure, mechanical and electrical maintenance is associated with the record modeling of BIM model. Therefore, the record modeling such as design and specification information for the defect repair in the system is to facilitate the staff's job to assess the maintenance component on site for the complicated defect structures and facilities and are viewed as 3D model based on the facility locations and conditions which are the complex building component types with highly integrated building elements for the next step of the defect diagnosis execution.
iv. EDD: The knowledge base with the explanation of the defect for each of the structure details provided for the staff's defect diagnosis requirement. Meanwhile, the analysis of defect is determined through the structure history and condition data for that structure. This system process is to enable the tracking defect for the cause and reason between the comparable conditions for RM. The system result can be specified in detail when the maintenance repair is required for the certain IBS component of concrete structure.
v. RM: At this stage, the engineer evaluate defect diagnosis information of IBS building structure collected with the system to be decided by using RM electronic form. This stage also provides the right decision for the specific task for maintenance execution requirements.
vi. DCC: All data are sent into the main database associated with the particular network for facilitating staff in taking the recorded statistic of maintenance management processes. The range of networks is limited to the main office of Maintenance management department/unit at the IBS building and become as the DCC in locating the entire information related to the structures and facilities.

9. CONCLUSIONS

Maintenance management is one of the aspects neglected most by the top management of complex and high-rise IBS buildings. New key features of system development is a method whereby organizations can improve their maintenance management systems and making use of a new key feature of system approach can assist maintenance managers to deliver maintenance work effectively. "defect repetition" and "less competent contractor" was perceived to be the most maintenance management problems. By having regular assessment and diagnosis (by well-trained inspection staff) of the IBS building and all its structures facilities to identify defective work, maintenance work can be carried out before expensive corrective maintenance is required. If the maintenance management staffs of buildings are also made aware of the importance of ICT-based maintenance they can assist the organizations greatly by analyzing any defective items using emerging technology.

The performances of existing maintenance management system in complex and high-rise IBS buildings are all below practice standards; this amplifies the need for an improvement in maintenance management system. One-way of improving the whole maintenance management system is by using an emerging technology (BIM). The implementation of a BIM can assist maintenance managers greatly in managing all maintenance aspects. The advantages of using a BIM are well documented and it may be necessary that providers of BIM software should inform maintenance managers about the availability of the various software packages and their advantages. Organizations may realize that a BIM is needed, but do not know how to find the best approach that will improve the maintenance management processes of the organizations. Maintenance managers at complex and high-rise IBS buildings can confidently use the new key feature of maintenance system that has been developed to improve their existing maintenance management systems.

It is crucial that top management should take a serious look at how the maintenance of IBS buildings and is managed and realize the importance of maintaining their structure and facility to good standards, make sufficient provision for competent contractor and realize the adverse long-term effects of ignoring the importance of ICT-based maintenance using emerging technologies for managing defect repetition or other major maintenance problems.

10. ACKNOWLEDGMENT

This study was funded by the Ministry of Education, Malaysia, through the FRGS (FRGS/1/2015/TK01/UKM/02/4) and ERGS Grant Scheme (ERGS/1/2013/PK04/UKM/02/1).

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