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Research Article

Integrating Maintenance Management System in IBS Building Projects: A Qualitative Study

Zul-Atfi Ismail [a,*]

[a] *Universiti Malaysia Perlis, Faculty of Civil Engineering and Technology, Arau, Malaysia*

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Abstract
The IBS building plays a significant role in human life by providing safe, reliable, cost-effective services, which are environmental and drive economic growth. Significant decisions are taken at maintenance stage of IBS building projects which need effective tools to avoid rework and save time, cost, and increase work efficiency. Indeed, the continuous upgrading of this sector is needed to respond to technological advances, environmental change, and increased customer demands. Integrating Maintenance Management Systems (MMS) is promising since the scope of MMS usually does not extend beyond the footprint of the "defect"; it does not provide defect diagnosis data. Therefore, integrating MMS provides a complete picture of the project. However, this integration is challenging especially in IBS building projects as they are amongst the most complicated projects and numerous parties are involved in making important decisions. This paper reviews the case study regarding integrating MMS systematically, with the aim of analysing the need for this integration and its benefits. The paper highlights a lack of a clear solution for collaboration in the IBS building project lifecycle and indicates the need for research to focus on this issue as well as the possibility of applying integrated MMS as a potential solution to improve collaboration for better decision among project participants.

Keywords: Maintenance Management; Conventional Method; Maintenance Management System; Malaysian PC Building

1. Introduction

Maintenance management is paramount in ensuring the effective and efficient monitoring process of maintenance activities, and Information and Communication Technology (ICT) could play fundamental role in delivering that maintenance management. Precast Concrete (PC) building maintenance depends on the design type (e.g. complex and high-rise building), size and building usability that require quality maintenance in order to achieve life-span prolongation. Structural repairing practice in managing PC building maintenance activities has been a hot issue in recent years due to lack of progress in the area of computer-aided maintenance management and difficulties with accessing information and data in maintenance support systems such as Computerised Maintenance Management System (CMMS) and Computerised Aided Facility Management (CAFM) (Duran, 2011). Clients and contractors should use the high-quality building information from an emerging application of computerbased technology during the maintenance activities of the PC building's lifecycle. In response to the challenges of dynamic maintenance operations and the need for improving the quality of maintenance process in complex and high-rise structural building components, clients and contractors could change their method from conventional practices to more enabling technology to increase productivity and a new level of interoperability and collaboration. The conventional modus operandi (paper-based reports/unsystematic database), which is commonly being conducted in a sequential manner using CAFM and CMMS tools replaced to new business model which integrates various sources of data and knowledge such as CMMS with the Building Information Modelling (BIM) of the PC building in the maintenance activities (Espindola et al., 2013; Motamedi et al., 2014; Nawi et al., 2014).

Maintenance staff generally introduces ICT into PC building maintenance management for providing maintenance inspection records and results, including checklists, specification, and maintenance procedure by using software such as CMMS and CAFM. The CMMS and CAFM application provides various paper-based reports (such as inventory confirmation) related to maintenance and repair issues (Motamedi et al., 2014). Furthermore, the traditional 2D CAD technology is widely used for maintenance information illustration and even integrating related data for PC building construction design history purposes (Su et al., 2011). Despite the fact that the use of ICT solutions in assessing, planning or process execution takes place at a different scale and function, the emerging trend such as using sophisticated or innovative tools and techniques could improve productivity in PC building maintenance activities and have a great potential to redefine and re-engineer the conventional setting. The conventional method (paper-based reports/unsystematic database) is lack of knowledge support in coordination, maintenance monitoring, maintainability, automation and robot control systems.

*Corresponding author Email address: zulatfippkas@gmail.com

The PC building maintenance has different training or maintenance approach to address the issue of defects for particular component compared to the conventional building maintenance. The connection of PC component such as by using corbel and PCB need the expert knowledge to improve the quality and reliability of PC scheme in order to avoid any defect repetition in the long-term of life cycle building services. Failure to capture the data acquisition and monitor the defects effectively will influence the assessment process including maintenance planning and execution. This can contribute poor quality, productivity and performance in PC building construction projects (Vaha et al., 2013; Kamaruddin et al., 2013). There is also give problematic and inefficient in the handling of information and integration of data of maintenance components within a post-construction site activity (Babic et al., 2010).

Engineers will therefore have to produce strong and well-supported arguments if they wish maintenance to be given a higher performance in the IBS buildings for defect diagnosis and decision making process. The critical research question is to develop an appropriate solution for use by engineers of complex and high-rise IBS buildings to generate effective maintenance management approaches and to implement relevant solution on system elements for best practice in maintenance management. This paper reports the research leading to the development of such a new maintenance solution.

2. The Importance of having an Emerging Technologies

Current developments and trends in ICT software and tools have the potential to radically change the shape and practice of building maintenance management. The combined use of BIM, Computerised Maintenance Management System (CMMS) and modern ICT applications represents a very promising setting for the full-scale use of emerging technology capabilities to enhance maintenance decisions and activities in IBS building construction projects. For example, like BIM as a tool for construction quality control, avoiding errors and omissions to reduce maintenance costs and time by providing timely and relevant information to maintenance management as early as the design stage, including the use of 3D modelling for visualising, coordinating AEC (architecture, engineering and construction) work and efficient information utilization (Eadie et al., 2013; Chen and Luo, 2014). Other examples are the recording process and work control for maintenance components, the wide and rapid use of maintenance management software like CMMS according to a survey taken by Duran (2011), which found that 62% of the respondents changed their maintenance work process to fit the CMMS characteristics and 66% customised the CMMS to fit the work process for better prioritisation of work, scheduling, planning, backlog management, and resource allocation in buildings.

Introduction of ICTs in construction projects has prompted to yield a wide range of new computer-based tools to support the effective management of construction activities (Froese, 2010). This trend has challenged the industry to become more efficient, integrated and more attractive as well, with construction organisations investing a better service and projects that meet the client's requirements more meticulously (Chaphalkar and Patil, 2012; Chen et al., 2012). However, as ICTs and its positive impact in construction development have advanced, the use of strategies, tools and techniques to improvement in the delivery of services of building maintenance is still rare and are seen as "non-core" functions that provide "supportive" services in organisations (Waheed and Fernie, 2009; Espindola et al., 2013). Therefore, building maintenance requires more sophisticated technology solutions based on ICT in the future (such as BIM and CMMS integration) that increase the performance and productivity through the maintenance revolution. Several other industry projects worldwide, for example real estate, waste management, transportation, supply chain and facility management, have been successfully completed by implementing these technologies (Cheng and Ma, 2013; Mahdjoubi et al., 2013; Irizarry et al., 2013; Marzouk and Abdelaty, 2014; Love et al., 2014). As a term and method that is rapidly gaining popularity, BIM and its related interoperable software components are under the scrutiny of many building professionals questioning its potential benefits on their maintenance practices (Motawa and Almarshad, 2013). By implementing the integration of BIM and CMMS technology, there is predicted that in the future project construction teams will adopt digital information to facilitate maintenance management where all the components condition will be evaluated in advance. For example, BIM software can store all the information of a building and visualise the maintenance process of a project over its entire lifecycle, to generate the building simulations (e.g. component utilisation, component failure, scheduling, resource allocation, etc.). Hu et al. (2012) has been suggested the use of BIM and information accumulated during the design, construction, operation and maintenance period to provide building simulation services and decision support for the choice of maintenance measures, the scheduling of maintenance and the control of maintenance cost.

3. Case Study

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 generalisation approach on improvement of maintenance management practices between case studies. The multiple case studies involved eight IBS maintenance projects as the unit of the analysis with embedded unit of the analysis for each of the eight IBS maintenance projects. 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 organisations. The "embedded units of analysis" adopted were maintenance management problems, ICT implementation and approaches to addressing problems.

Those IBS buildings are selected based on major problems of using conventional method (manual practices) in the comparison to investigate the maintenance management practices in each IBS building. There are total 73.5% IBS building constructions in Malaysia using conventional method (manual practices) and inadequately use of modern ICT tools compared to other type of IBS construction (e.g. infrastructure) and is presented in Table 1 (CIDB, 2009; Nawi et al., 2014a).

Table 1
List of IBS Construction

No.	Type of IBS Construction	IBS Work Practice Level	Total Construction (100%)	Maintenance Management System	Case Study
1	Residential	New	18.5	Conventional Method	/
2	Non-Residential	New	55	Conventional Method	/
3	Infrastructure	Old	26.5	Conventional Method	-

The case studies on the eight PC buildings were undertaken in order to identify the maintenance management problems, the current approaches to addressing the problems, the ICT implementation, use of emerging technologies and the maintenance management system (MMS) to obtain information relating to the maintenance identification, assessment, planning and execution processes. The summary of the eight case studies is presented in Table 2. Eight maintenance clients/contractors are selected based on major problems of using conventional method (paper-based reports/unsystematic database) in the comparison to investigate the maintenance management practices in each PC building. There are around 51 contractors of Industrialised Building System (IBS) building maintenance from a classification of PC system have the highest of IBS building maintenance projects in Malaysia according to 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 PC system classification in IBS building maintenance management in Malaysia. The adopted synthesis of good practices of maintenance operations is based on the findings of the interviews and case studies conducted with professional engineers working in PC building maintenance departments (Ismail et al., 2016). This paper is part of a larger research and will only introduce and discuss the synthesis of good practices of the interviews and case studies. This synthesis is illustrated in the following sections.

Table 2
List of Case Studies

Case	Type of Building Project	Type of IBS Building	Age of IBS Building	Cost of IBS Building
A	Quarters	Old	8 years	1.1 billion
B	Malaysian Institute of Pharmaceuticals and Nutraceuticals (IPHARM)	Old	5 years	124 million
C	National Youth Skills Institute (IKBN)	Old	5 years	90 million
D	Anti-Corruption Agency Office Complex and Housing	Old	5 years	23.4 million
E	Double Storey Super link House	New	2 years	13.6 million
F	Inland Revenue Board Of Malaysia Complex	New	3 years	45.4 million
G	National Audit Department Office	New	3 years	12.3 million
H	Integration News Centre	New	3 years	100 million

4. Key Findings

The eight case studies involved in this research were to identify the maintenance management problems, the approaches to address problems, ICT implementation, use of emerging technologies including the maintenance management system at the selected PC building. The problems identified from the eight case studies revealed that each case study experienced similar problems with defect repetition at the specific component part of PC building and are summarised and presented as below. The discussion involves a cross-case analysis and has been grouped into five main 'embedded units of analysis' identified which are (1) Maintenance Management Problems, (2) Approaches to Address Problems, (3) ICT Implementation, (4) Use of Emerging Technologies and (5) Maintenance Management System.

3.1. Maintenance Management Problems

Generally, the findings from the case studies reveal that the major problems in term of maintenance management activities relate to defects repetition (leaking, jointing, surface cracking and less competent contractor) (see Table 3). It is evident that defects repetition (leaking) were the highest occurring problems, with seven cases (Case A, C, D, E, F, G, H). Defects repetition (jointing) and less competent contractor problems were the second highest occurring problem with six case studies (Case A, C, D, E, F, G) and (Case A, B, C, D, F, H) respectively. Defects repetition (surface cracking) problems were the third highest occurring problem with four case studies (Case A, B, C, E). Previous research highlighted similar

maintenance management issues such as less competent contractor lead to the defect repetition problems (cracking, leaking and jointing) (Ismail, 2014). Poor quality work by contractor was the minor problems for three cases. The cases were Case A, B and D for poor quality work by contractor. Poor waterproofing and limited budgets were also problems for two cases. The cases were Case A and D for poor waterproofing and Case B and C for limited budgets. Other issues such as: defects repetition (scaling), poor buildability (Mechanical and Electrical (M&E) coordination), poor maintainability and lack of commitment for handling defect affected Case A; defects repetition (aircond belting) (Case B); surface cracks due to improper jointing and deep cracks due to settlement (Case C); poor plumbing fitting (Case E); overload current trip (Case G); and deep cracking on structure (Case H).

Previous research indicated that the sophisticated system and database were needed for managing the maintenance information with high emphasis on assessment and defect diagnosis (Ismail et al., 2015). Poor quality work by contractor was not highlighted directly, but remain problems in the case studies. The limited budgets (included Case B) was one of the problems in Case C. The senior technicians can be categorised into three major fields, namely, civil engineering, mechanical engineering and electrical engineering. The task involved in the maintenance management consisted of several stages particularly on the maintenance inspection. However, the engineer had found it difficult to manage the maintenance action based on the less competent senior technician to identify the cause of the building component defect. Sometimes, the defect was occurred due to the budget constraint by top management to execute building maintenance.

Table 3
Maintenance Management Problems from Case Studies

	Maintenance Management Problems	A	B	C	D	E	F	G	H
MAJOR	Defects repetition (leaking)	/		/	/	/	/	/	/
	Defects repetition (jointing)	/		/	/	/	/	/	
	Less competent contractor	/	/	/	/		/		/
	Defects repetition (surface cracking)	/	/	/		/			
MINOR	Poor quality work by contractor	/	/		/				
	Poor waterproofing	/			/				
	Limited budgets		/	/					
	Lack of staff		/						
	Defects repetition (air-conditioning belting)		/						
NIL	Defects repetition (scaling)	/							
	Poor buildability (M&E coordination)	/							
	Poor maintainability	/							
	Lack of commitment for handling defect	/							
	Surface cracks due to improper jointing			/					
	Deep cracks due to settlement			/					
	Poor plumbing fitting					/			
	Defects repetition (overload current trip)							/	
	Deep cracking on structure								/

3.2. Approaches to Address Problems

Table 4 below described the findings conclusion of the approaches to address problems from the case studies at the PC building. The initial feedback identified that the issue of defects repetition (leaking, jointing and less competent contractor) has been experienced by many maintenance companies. There were many approaches to addressing the defects repetition (leaking and jointing) including other related defect problems such as cracking, scaling, aircond belting and overload current trip which differed from one case to another. In dealing with these problems, Case A, D, E, G and H had been planning to improve the maintenance assessment and building control from being damaged due to false works by the contractors and to ensure the sustainability of the PC building structure and facility provided at that area. While, the engineer gradually replaced the conventional defect detection method (e.g. visual inspection) with the sophisticated ICT application (e.g. CMMS) to improve the maintenance identification on maintaining the building structure and facility (Case B). In addition, Case C had decided to provide more frequent inspection at the site location to manage the defect in the particular duration. There was new approach to measure the contractor's performance at the PC building. The maintenance management staff had conducted the critical maintenance plan for building structures and facilities at the site location (Case F). The defect repairs by the contractor had been supervised in strict condition for reliability improvement and quality maintenance toward the maintenance execution.

Poor quality work, poor waterproofing, poor buildability (M&E coordination) poor plumbing fitting, poor maintainability, lack of commitment for handling defect and deep cracking on structure were experienced by three maintenance companies interviewed and affected both complex and high-rise PC building (Case A, B, D). However, this problem needs more consideration for high-rise PC building due to the size of the buildings and the risk of failure of maintenance execution. Some approaches that have been undertaken to overcome these problems include: to carry out everyday inspections (Case A), to undertake regular consultations and coordinate inspections (Case B) and monitor and provide clear

methods (Case D). Limited budgets and lack of staff are affected by the management of human resource to the PC building due to productivity of staff for complex tasks. In overcoming these problems there are a few approaches implemented such as: to improve more standard repair inspection on site (Case A, C) and to increase quality staff (Case B).

Table 4
Approaches to Address Problems from Case Studies

	Approaches to Address Maintenance Management Problems		
1.	Defects repetition (leaking, jointing, surface cracking)	Case A	to improve the maintenance assessment and building control
2.	Defects repetition (scaling)	Case B	to improve the maintenance identification
3.	Defects repetition (air conditioning belting)	Case C	to provide more frequent inspection at the site location
4.	Defects repetition (Overload current trip)	Case D	to improve the maintenance assessment and building control
5.	Surface cracks due to improper jointing	Case E	to improve the maintenance assessment and building control
6.	Deep cracks due to settlement	Case F	to conduct the critical maintenance plan
		Case G	to improve the maintenance assessment and building control
		Case H	to improve the maintenance assessment and building control
7.	Poor quality work by contractor	Case A	to carry out everyday inspections
8.	Poor waterproofing	Case B	to undertake regular consultations and coordinate inspections
9.	Poor buildability (M&E coordination)	Case D	to monitor and provide clear methods
10.	Poor plumbing fitting		
11.	Poor material quality		
12.	Poor maintainability		
13.	Lack of commitment for handling defect		
14.	Deep cracking on structure		
15.	Less competent staff	Case A	to improve more standard inspection requirements on site
16.	Limited budgets	Case B	to increase quality staff
17.	Lack of staff	Case C	to improve more standard inspection requirements on site

3.3. ICT Implementation

Case B, D, E, F and G had used the basic ICT tools (e.g. MS Word and MS Excel spreadsheet) to improve the complaint management, assessment, maintenance planning and execution for the structure and facility defect at the PC building (see Table 5). The senior technician would submit the information from the report received through the paper based form to the relevant technician for further inspection and assessment. The maintenance status was then recorded into the database in Word and Excel after the planning and executing processes had been completed. Presently, a few of maintenance organisation had been using advance technology system being developed by the Public Works Department (PWD) and Malaysian Administrative Modernisation and Management Planning Unit (MAMPU) to improve the inventory management for the mobile and immobile building structures and facilities. These systems namely ‘mySPATA’ and ‘mySPA’ assisted the maintenance management staff to inspect and repair the facilities where the defect information such as location and facility type were described in detail in the database application (Case A and C). Moreover, time taken due to inadequate explanation such as the location of defect was reduced with the use of the systems. Case A also had implemented ‘mySMS’ system as a tool to reduce the utilised time in managing the report without having to send the paper based form personally at the maintenance management office. Normally, the entire building is accommodated with internet network where the staffs are able to access the system using laptop, netbook or other portable devices where they can submit their defect complaint.

In Case H, ‘E-Aduan’, Building Automation System (BAS) and Supervisory Control and Data Acquisition (SCADA) and systems were used to facilitate complaint report, risks monitoring and control of the electrical and mechanical system based on microprocessor and computer. The main function of BAS and SCADA was to achieve more efficient operation and to implement energy management strategies. ‘E-Aduan’ system became a dedicated structure to manage the complaint in the entire day compared to the conventional method and the maintenance management staff had found it was easy to compile the data and to record the complaints from 1000 customers per year.

Table 5
ICT Implementation from Case Studies

ICT Implementation	A	B	C	D	E	F	G	H
MS Word		/		/	/	/	/	
MS Excel		/		/	/	/	/	
mySPATA	/		/					
mySPA	/		/					
mySMS	/							
E-Aduan								/
BAS								/

SCADA	/

3.4. Use of Emerging Technologies

Most case study companies revealed that Case A, B, C, D, E, F, G and H were inadequate used of emerging technologies (such as BIM) into their PC structures maintenance management practices. The implementation of ICT or emerging technologies was not suggested by the top management in Case B due to budget constraint for the specific task (e.g. human resource planning). However, Case H used BAS and SCADA to build a series and maintenance tasks of mechanical and electrical control systems.

In the adoption of BAS and SCADA there are few additional requirements which affected the maintenance staff. This is involved the training requirements to improve ICT knowledge and technical capability, and increasing discipline and willingness to learn and accept emerging technologies. The maintenance industry needs to support the retraining and education of maintenance staff, and provide adequate ICT technical expertise. The significant advantages by the adoption of such technologies can create overall changes throughout the mechanical and electrical control systems maintenance management process. These can give a better solution to the current issues in handling maintenance such as: poor quality work, poor material quality, and poor buildability (M&E coordination). The respondents (Case F and G) realised the importance of using emerging technologies such as BIM technologies in their maintenance management practices. The implementation of emerging technologies can help speed up assessing, maintenance planning, reduce paper work, and facilitate the more efficient control and inspecting of structure component defects more efficiently. Respondent from Case F also realised the importance of using BIM technologies in improving their maintenance management practices for defect diagnosis and decision making process.

3.5. Maintenance Management System

Assessing, planning and executing activities on PC building such as defect diagnosis is still facilitated by manual operations in all of the case studies (Case A, B, C, D, E, F, G and H) and it is challenge many human errors and excessive paperwork. Many respondents from the case studies mentioned the used to develop a systematic database on the defect category and condition, including the justifications of structures and facilities defect involved at the PC building. The paperless office was recommended by respondent from Case A where the maintenance management staff would be able directly update and assess the defect information into the online system frequently. Respondent from Case B was in the process of using the CMMS for maintenance management depending on the organisation budgets and requirements. Respondent from Case C and D suggested that the paper based reports be replaced with a computerised system that has the potential to control and reduce the cost on the maintenance repairs at the PC building.

In Case H, BAS is utilised in the PC building to facilitate effective maintenance management. The process involves the identification and validation of mechanical and electrical control systems maintenance operation in order to know the specific function, location, time and date. Moreover, SCADA was used to aid tracking and controlling of the mechanical and electrical systems during maintenance delivery. Throughout Case H, the implementation of BAS was implemented for assisting monitoring system daily processes and SCADA was used to track mechanical and electrical control systems operations.

5. Results

Table 6 below represents the suggested solutions from the case studies to improve the current practices on the maintenance management by implementing six approaches at the IBS building. Case A, B, C, D, E, F, G and H suggested improving the particular defect of knowledge in the defect diagnosis by combining with the related software technology compared to other cases. In fact, the problem of unspecific knowledge in the defect diagnosis delivery also does affect the other IBS buildings to some extent and the significance of this factor is quite obvious. The less competent manpower will use the inadequate knowledge to handle the defect problem and less detail of the defect source explanation to gather accuracy of the inspection and planning works. The other suggestion from the engineer was to provide the information on the particular defect to improve the maintenance quality of structure and facility at the IBS building (Case A, B, D, F, G and H). All the related cases are facing the impact of problems for the maintenance quality information management, which are associated to the less competent man power for handling the defect of structures and facilities with the total cost of above 10 million and IBS score usage of about 70% on its development of IBS building.

The engineer also suggested in improving the maintenance assessment for the material specification used and construction practiced in the building structure and facility in regard to the repetition of defect at the IBS building (Case A, C, D, E, F and G). The case studies (Case A, E, F and G) recommended monitoring the contractor's performances in maintenance management practices in order to provide the sustainable buildings for the entire structure components at the IBS buildings. Meanwhile, Case A-H suggested on efficient controlling of building performance based design and monitoring the failure diagnostic operation in maintenance through implementation of emerging technology (BIM) on the ad-hoc and preventive maintenance. This suggested solution is ranked as the most important solution due to suggest from almost case studies in order to manage the large maintenance services for the building structure and

facility. The using of emerging technology is also the lowest in terms of existing practice for better managing IBS building components including mechanical and electrical control systems.

Case E, F and G suggested avoiding poor waterproofing and doing the same mistakes for efficient maintenance waterproofing and Case A and D suggested providing more quality inspection at the IBS building for waterproofing installation and construction method. Issues regarding systematic database among design/construction management and building maintenance staffs were also suggested to improve the overall maintenance management process. These are recommended by Case A, B and H to integrate the design/construction and maintenance's database in order to facilitate better decision support in defect diagnosis and coordination within and across multiple field (e.g. civil, mechanical and electrical) for effective management of the IBS building maintenance. As the overall results indicated in Table 6, it was deemed necessary to analyse the use of emerging technology further. Therefore, the systematic database with the ICT, defect diagnosis and decision making process should be developed to improve the building structure and facility performance by conducting effective monitoring on the maintenance repairs.

Table 6
Suggested Solutions from Case Studies

No.	Solutions/Case	A	B	C	D	E	F	G	H
1	Provide specific knowledge on defect diagnosis	/	/	/	/		/	/	/
2	Improve the maintenance quality in maintenance execution	/	/	/	/		/	/	/
3	Decrease the defect repetition through assessment for material specification used and construction practiced	/		/	/	/	/	/	
4	Implementation of emerging technology (BIM) (efficient control of building performance-based design/ monitor the failure diagnostic operation in maintenance)	/	/	/	/	/	/	/	/
5	Avoid poor waterproofing and similar mistakes	/			/	/	/	/	
6	Coordination (integration of design/ construction and maintenance's database for decision support in diagnosis)	/	/						/

6. Discussion

A few clients at the PC building were not have specific knowledge for the structure defect that to be diagnosed. The deficiency of information was also due to the lack of the PC knowledge among the technician and staff about the technicality when addressing the defect problems at the PC site location. The maintenance management staff found that it was difficult to identify their building condition in order to manage the component defects and this affected the decision taken for maintenance defect diagnosis. Meanwhile, the 'mySMS' and 'E-Aduan' system were the technology used in managing the complaint at the PC building. However, both of these technologies were inadequate compared to the modern ICT tools to record the information related to the maintenance diagnosis management into the database system. The paper-based reports mostly used at the PC building provided not enough data and explanations such as structure and facility type, defect description, location and visual inspection such as condition categories in details that could help the maintenance management staff to conduct effective execution on the defect.

There was no dedicated system to improve the maintenance diagnosis for reducing the repetition of defect problems where the defect took more time to be investigated to identify the causal explanation. 'mySPATA' and 'mySPA' only supported the inventory management for the facilities while BAS and SCADA monitored the electrical and mechanical control systems as well as its conditions. The implementation of emerging technologies could solve defect problems for maintenance management processes. There was an inadequate use of modern ICT tools such as BIM and CMMS integration to assist with a maintenance management, which could provide real-time information of PC building maintenance. The maintenance management processes at the PC building was also lack with ICT tools that can associate the design, construction and maintenance operation in one system with high level programming, defect diagnosis and decision making process.

7. Lesson and Enlightenments

1) The PC building maintenance and the application of diagnosis techniques should be paid highly attention. Because of the defect repetition of structure components and limitation of understanding about the PC knowledge, the maintenance approach is very important. The application of modern ICT tools such as BIM and CMMS integration can avoid or alleviate the defect of critical structure.

2) The appropriate modern ICT tools should be selected in assessment areas (diagnosis and decision making process on the design specification used and construction practiced) especially for PC buildings. The high-rise or complex structure should be given the priority for these types of PC buildings.

3) The maintenance quality of PC buildings should be strictly guaranteed.

4) The deficiency of PC buildings knowledge affected the quality of competent maintenance staff in Malaysia. The

future work should be strengthened to guarantee the quality and knowledge in case of defect repetition.

8. Conclusions

Maintenance management is one of the aspects neglected most by the top management of complex and high-rise IBS buildings. New solution development is a method whereby organisations can improve their maintenance management systems and making use of a new solution approach can assist maintenance managers to deliver maintenance work effectively. 'Less competent manpower' 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 staff of buildings are also made aware of the importance of ICT-based maintenance, they can assist the organisations greatly by analysing any defective items using emerging technology. Meanwhile, a 'defects repetition (leaking) due to spalling/ erosion' and a 'defects repetition (jointing) due to spalling/ erosion' were perceived to be the 2nd and 3rd maintenance management problems respectively.

It is crucial that top management should take a serious look at how the maintenance of IBS buildings and is managed and realise the importance of maintaining their structure and facility to good standards, make sufficient provision for competent manpower and realise 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.

The data obtained in the case studies revealed that the PC buildings are using the conventional method such as paper-based reports in managing the maintenance processes for building structure and facility. This arise a problematic situation such as defects repetition (leaking, jointing and cracking) and poor quality work by contractor that need sophisticated tools towards a solution. Presently, the implementation of ICT tools in the new system is the better improvement to lead the tremendous saving in budget, time planning and to receive the precise data in handling the defect diagnosis and control. The suggestion for good practices was through the implementation of ICT to reduce the repetition of defect on the design specification used and construction practiced for the building structure and facility.

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