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Case Study to Analyse Problems and Issues in IBS Building Maintenance

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Abstract
The practices of conventional methods for maintenance management in Malaysian Industrialised Building System (IBS) building faced many issues due to IBS component aesthetic and structural defects which occurred repeatedly compared to building maintenance on conventional building, no integration between maintenance systems, lack of co-ordination between design and construction, less defect diagnosis in decision making process as well as lack the intelligent capabilities of linking defect diagnosis operations in maintenance affecting various building elements with IBS component defects knowledge. The purpose of this study is to develop a mechanism to improve IBS component defects knowledge transfer on IBS building maintenance projects through the integration of defect diagnosis and Building Information Modelling (BIM). The case studies were conducted with eight maintenance organisations from client/contractor. The selected maintenance organisation is based on conventional method practices and its major problems, attempt to implement computerised technology and the willingness of staff to share their experiences. The responses from semi-structured interview with engineer was recorded using video camera and transcribed verbatim. The overall findings of this research indicated; design defect, poor quality work by contractor and defect repetition. There is also need to overcome lack of knowledge between engineer and technician regarding with materials, method and design of structure repair which existed with all eight maintenance organisations. In addition, the study also found that several computerised system such as Building Automation System (BAS) and Supervisory Control and Data Acquisition System (SCADA) are used by client/maintenance contractor. BIM technology awareness was found to be limited, with no implementation in IBS building maintenance organisation yet. The proposed solutions are intended to be used for maintenance management practices at Malaysian IBS buildings in order to provide IBS component diagnosis integration with the BIM technology.

Keywords: Maintenance Management, Conventional Method, Maintenance Management System, Malaysian IBS Building, Building Information Modelling, Diagnosis, Defect Knowledge Transfer.

Introduction
Method could be a pillar of fundamental importance for the implementation of an effective and efficient maintenance management component on construction site. Method of practice in managing 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 [1]. Maintenance management method is defined as the combination of all technical, administrative and management activities of the post-construction life cycle of a facility. These activities overview are concerned with the technical specifications, administrative processes and management such as contract conditions, policy and maintenance strategy related issue. In addition, it considered the maintenance factors of labour skill, interpersonal relationship, maintenance performance, material quality control and investment control in order to support the sustainable maintenance of building facility [2]. Besides, it is the recursive process of coordination and collaboration (e.g. designer and site engineer) to provide the effective service delivery of building maintenance to perform building facilities long-lived and reduction of life cycle cost [3,4]. The method of processes start from identification, defect diagnosis, maintenance planning and execution of the facilities [5]. In general, maintenance management method is the larger service of post-construction activity and process.

Introduction of ICTs in maintenance management method has prompted to yield a wide range of new computer-based tools to support the effective management of maintenance activities [6]. This trend has challenged the industry to become more efficient, integrated and more attractive as well, with maintenance organisations investing a better service and projects that meet the client's requirements more meticulously [7,8]. However, as ICTs and its positive impact in maintenance development have advanced, the use of strategies, tools and techniques to improvement in the method of practice of building maintenance is still rare and are seen as "non-core" functions that provide "supportive" services in organisations [9,10]. Majority of the current implementation of tools in maintenance management processes mainly focus on the conventional methods with little emphasis on decision making and defect diagnosis tools. The conventional methods means that all the design and construction process will be conducted in sequential manner to provide maintenance teams in assessing building degradation, choice of optimal maintenance strategies for component or materials in an IBS building with the most minimal life-cycle analysis of projects (e.g. requirements, operational, and maintenance information) [11,12]. In response to the need for improving the quality of maintenance process in complex and high-rise building components, clients and contractors should change their method from conventional practices to more enabling technology in ensuring the effective and efficient monitoring process of maintenance activities and to increase productivity and a new level of interoperability and collaboration.

There were many problems related to the conventional method (paper-based reports/unsystematic database) at the IBS building such as IBS component aesthetic and structural defects which occurred repeatedly compared to building maintenance on conventional building, no integration between maintenance systems, lack of co-ordination between design and construction, less defect diagnosis in decision making process as well as lack the intelligent capabilities of linking defect diagnosis operations in maintenance affecting various building elements with IBS component defects knowledge. The paper-based reports/unsystematic database wasted a lot of time, effort and materials. The conventional method restrict clients and contractors from being involved in the design stage of a performance project, which often results in design changes and a corresponding maintenance and operation cost increase including construction time, production and labour cost [13,14]. According to [15], the defect diagnosis in maintenance management becomes as problems for storing and processing quality maintenance data of precast concrete elements to provide the reliable inspection due to ineffective implementation strategies and best practices need to be undertaken with the implementation of systematic BIM-based diagnostic system in the organisation. Effective management of maintenance relies on the sophisticated technology in ensuring the successful of dependability building facility and to achieve the expected return on investment in maintenance (ROIIM) [16]. Another difficulty for conventional method is to provide the adequate strategic decision making to analyse diagnosis information and knowledge in improving the maintenance project outcomes (cost, time, quality, safety, functionality, maintainability, etc.) [17]. This allows the repetition of defects to happen without realising the actual main causes and will result in the unexpected losses to optimise the maintenance for most sophisticated building facilities in maintenance industry and at the IBS buildings. Therefore, the current method difficulties append the competition in the market for emerging of the managerial defect knowledge transfer technology of ICT-based system that focuses on improvement of complex maintenance management processes such as defect diagnosis knowledge and decision making process which most organisation need [18].

Case Study

The case studies was pursued to ensure the comparability on the current practices of maintenance management at IBS building with the literature studies that described the use of conventional method in managing maintenance processes for building structure. Besides, the key problems areas of maintenance processes were discovered to analyse the causal explanations and elements of good practices to overcome particular problems. The case studies were also to gather data on the requirement for integrating the certain processes in maintenance management with information database in developing the ICT-based system. Through these case studies, the conventional process of maintenance management can be established to gain in-depth understanding for clarifying the desirable system under maintenance management staff required at the IBS building.

The multiple case studies approach has been used to yield many insights about the maintenance management at the IBS building and to illuminate different aspects of the research problem and purpose. This strategy involved the comparison of phenomenon within eight clients/maintenance contractors to identify the key problems, approaches to addressing problems, ICT implementation, use of emerging technologies and maintenance management system at the IBS building. They were also used to perceive the appropriateness of criteria on the particular maintenance management processes to be integrated with the information database in order to expand the competency of maintenance management for building structure.

For the purpose of this case study, a component of qualitative research can be described. The component has been separated into the unit of analysis to vary across specific research situations.

i. Unit of analysis: The unit of analysis is the entity on which there are data and which will be subjected to statistical analysis [19]. 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 as follows:
   a. *Maintenance Management Problems*: To investigate the major problems on the maintenance management practices at the IBS building;
   b. *Approaches to address problems*: To reduce the problems that involved in maintenance operation;
   c. *ICT implementation*: To identify the current technology of ICT practices to improve the particular maintenance processes at IBS building;
   d. *Use of emerging technologies*: To investigate the potential of the emerging technologies to facilitate maintenance management practices; and
   e. *Maintenance Management Systems:* To identify the maintenance procedures at IBS building.

Case Study Projects

The case studies on the eight IBS 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. 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 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 Table 1, 2, 3 and 4 [20,21,22].

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		

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		

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

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

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, C, D, F, G and 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 computerised technology and the willingness of staff to share their experiences in improving the maintenance management 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 Centre. The summary on the eight case studies is presented in Table 5.

Table 5: List of case studies

Interviewee	**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
Interviewee	**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
Interviewee	**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
Interviewee	**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
Interviewee	**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
Interviewee	**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
Interviewee	**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
Interviewee	**H**
Type of IBS Building Project	Integration News Centre
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

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 five hours 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.

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 summarised 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 (4) Maintenance Management System.

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 buildability (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
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	Building Automation System (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
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)

Synthesis of Good Practices

Table 7 below represents the suggested solutions from the case studies to improve the current practices on the maintenance management by implementing three approaches at the IBS building. Case A, B, C, D, F, G and H suggested improving the transfer of knowledge in the defect diagnosis by combining with the related software technology such as CMMS and CAD. In fact, the problem of knowledge transfer 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 maintenance contractors will use the inadequate knowledge to handle the defect problem and less detail of the defect source explanation to gather accuracy information record for inspection and planning works. The other suggestion from the client/contractor was to provide the transfer of knowledge 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 quality knowledge management, which are associated to the defect repetition for handling the defect of structures and facilities with IBS score usage about 70% on its structure development of IBS building.

Case C, D, E, F and G suggested on efficient controlling of building performance based design and monitoring the defect diagnostic operation in maintenance through implementation of emerging technology (BIM) on the IBS building maintenance. These are also recommended by Case A, B and H to integrate the design/construction and maintenance's database in order to facilitate better decision support and coordination within and across multiple field (e.g. civil, mechanical and electrical) for effective management of the IBS building 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. As the overall results indicated in Table 7, it was deemed necessary to analyse the use of emerging technology further. Therefore, the systematic system with the emerging technology, defect diagnosis and decision making process should be developed to improve the building structure and facility performance by conducting effective knowledge transfer on the structure component maintenance defects.

Table 7: Suggested Solutions from Case Studies

Case	Suggested Solutions
A,B,C,D,F,G,H	Provide more transfer of knowledge in defect diagnosis
A,B,D,F,G,H	Provide more transfer of knowledge to improve the maintenance quality in maintenance execution
A,B,C,D,E,F,G,H	Implementation of emerging technology (BIM) (efficient control of building performance based design/ monitor the defect diagnostic operation in maintenance)

Conclusion

There is a total of eight case studies have been used to analyse the key problems, approach to address problems, ICT implementation, use of emerging technologies and maintenance management system at IBS building. The factor of design defect, less competent contractor, defect repetition and poor quality work by contractor were the main problems identified at the IBS building that utilised the conventional method in the maintenance management processes. These factors were due to the inadequate and inaccurate information in the contractor's knowledge of IBS building maintenance. 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. In order to improve the complete information in the defect knowledge transfer, the new system would be developed provided with the building attributes, for instance, the design operating procedure in detail. Other than that, the new system can manage maintenance technique such as leaking on the execution effectively and facilitate the engineer and technician to assess the condition of component for the maintenance process. Regarding the above findings, this research will concentrate on the development of a new system to integrate the knowledge transfer approach to improve the defect diagnosis and decision making process at IBS building.

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