Implementation of Information and Communication Technology (ICT) for Building Maintenance

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***Abstract*—The current maintenance management method has affected the efficiency of the building facility management due to the usage of conventional method application (paper-based form and unsystematic database). Initially, the application of ICT in building maintenance contributes the new impression to the management processes in the organisation. The demands on ICT for maintenance management, hereafter denoted as Maintenance Management IT (MMIT), has shifted from being tool to automate corrective and preventive maintenance management, such as task scheduling and inventory management. The objective of this paper is to review existing literature of the technologies in maintenance management, and subsequently identify the challenge in improving the current maintenance management technologies. As a precursor to this work, the paper reviews the challenges of ICT implementation for defect diagnosis and strategic decision making in building maintenance activities. The findings reveal the need for more sophisticated maintenance management system with implementation of ICT. In conclusion, the implementation challenges of ICT for building maintenance can improve the maintenance management technologies effectiveness to provide high-quality building facility for safe and healthy environment.**

Keywords—Information and Communication Technology; Maintenance Management System; Maintenance Management Function; Building Maintenance

I. Introduction

The development of ICT offers possibilities of efficiently processing and communicating a large amount of information during the building maintenance. The ICT-area facilitates new and innovative solutions in many disciplines, certainly in the area of sustainable construction. The recently developed CMMS concept is an example of an ICT-dependent innovative solution that includes methods, systems and tools for corrective and preventive maintenance management [1]. Essentially, maintenance management in the organisation consists of identification, assessment, planning and execution in the building facility development. The source of information is based on report defect from customer, annual planning, preventive maintenance, ad- hoc maintenance and others implemented by maintenance management staff.

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The application of paper-based form, email, verbal communication are practiced for the maintenance management processes till recently, where the emerging techniques and technologies using ICT such as CMMS and Non-Destructive Testing (NDT) are utilised to improve the maintenance operation which considered to have higher impact as a result of the previous approaches of maintenance process. The advancement of CMMS adds to the understanding of today's computer applications for building maintenance management, which is crucial for every maintenance manager using or purchasing CMMS [2]. The ICT application is also expected to assist in generating sustainable building facility and infrastructure besides reducing maintenance cost and erratic accident [3].

The conventional method in managing maintenance becomes as a backup mode for ICT-based system during breakdown such as electricity blackout that interrupt the work process of maintenance operation. Nevertheless, the various functions in the ICT for maintenance management improve the current conventional processes practices. The maintenance management staff are contented to use for the building inspection, to gain the precise information of the maintenance status on the building facility without delaying time and problems of inaccurate delivery on information [4]. In addition, the smoothness of maintenance management processes directly prevents budget badly-behaved and maintenance backlogs in the organisation to reach higher levels of maintenance quality and overall building effectiveness [5].

This paper provides a brief summary of the practical implementation technologies and challenges of the maintenance management system in an effort to suggest a more effectively viable approach to future maintenance management system development.

II. ICT Implementation for Building Maintenance

Literature further reveals that ICT usage in maintenance management are mainly in three areas of Information

Technology (IT) based systems, general software and databases. Reference [6] and [7] further categorise IT based systems used for maintenance management such as Building Management Systems (BMS). Meanwhile, general software used for maintenance management includes word processor, spreadsheet, project management and AutoCAD. The database management system used for maintenance management includes electric meter reading database, water meter reading database, maintenance request details database and Heating, Ventilation and Air Conditioning (HVAC) system log sheet database [3].

Presently, there are many maintenance management systems that employed IT based systems are available in the market to replace the early systems using conventional method such as paper-based form, email and verbal communication in managing planning, execution and follow up of maintenance activities [8, 9]. The latest maintenance management system is using ICT whether integrating by IT based systems or by instrument assisting such as, Radio Frequency Identification (RFID) and NDT. The development of IT based systems consists of various names such as, CMMS, Computer-Aided Facility Management (CAFM), Facility Management Information System (FMIS) and Integrated Workplace Management System (IWMS).

These current technologies of maintenance management either developed by public or private companies are to add-value to the good maintenance management practices in minimising the amount of maintenance works as well as posses a significant reduction in the maintenance backlogs and improving user satisfaction [10, 11, 12]. The functional disciplines from the different latest technologies are described in Table I and six (6) current systems are selected based on major functions in the comparison over maintenance management practices:

TABLE I. VARIOUS TECHNOLOGIES IMPLEMENTATION FOR MAINTENANCE MANAGEMENT

No.	Type of System	Function
1	Building Management System (BMS)	To monitor the condition of the building components for preventive maintenance [13].
2	Information and Communication Technology for Sustainable and Optimised Building Operation (ITOBO)	To monitor, analyse and evaluate the performance of the building systems [7].
3	BIM-based Facility Management (BIMFM)	To support the 3D CAD-based models for identifying, tracking, coordinating and accessing particular facility maintenance into a database system [14].
4	Context-Sensitive Maintenance Management using Mobile Tools (Integration with BIM, BMS and PDA)	To control and monitor the building facility in the real-time mapping and facilitating data transformation into the mobile devices [15].
5	Mobile RFID-Based Instruments Maintenance Management (M-RFIDMM)	To support asset identification and inventory management [16, 17, 18, 19].
6	Preventive Maintenance Period Optimum Model	To provide the decision-making for corrective and preventive maintenance planning [20].
7	Condition Monitoring of Low Speed Machinery (COMOLOS)	To provide remote monitoring and real time diagnosis for conditioning based maintenance [19].
8	Web-Based RFID Building Maintenance System	To provide automatically identifying equipment and facility including adopting the decision support for maintenance assessment [21].
9	E-Maintenance System	To reduce maintenance cost, maintenance system design period using multi-agents system (MAS) and case-based reasoning (CBR) [22].
10	Roofing Maintenance Management System	To determine the priority for maintenance, to account the time-dependence and uncertainty of the roof defect [23].
11	MAINTA	To plan the corrective and preventive maintenance and monitoring the maintenance operation [24].
12	Petroliam Nasional Berhad (PETRONAS) Maintenance Management System (PMMS)	To manage the inventory, maintenance operation and performance of facilities [25].
13	Mobile Maintenance Decision Support System (CMMS)	To identify, assess the defect problems based on the condition based maintenance for building facility [26].
14	CMMS based on Reliability Centred Maintenance (RCM)	To record failure and maintenance history of facilities as well as to provide reliability risk assessment [27, 28].
15	CMMS based on Failure-Based Maintenance (FBM)	To asses and monitor the overall defect problems including contractors performance for facilities [29, 30, 31].
16	Decision Support System to Urban Infrastructure Maintenance Management	To use priority in the maintenance planning and strategy for maintenance execution using Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) and Analytic Hierarchy Process (AHP) multi criteria methods [32, 33].
17	CAFM	To support operational and strategic management of facilities for building maintenance with a combination of Computer Assisted Design (CAD) [7].
18	FMIS	To improve the decision and to generate the effective and efficient collection, storage, retrieval, communication and use of information [34].
19	Internet Based Maintenance Decision Support	To assess and monitor the performance of facilities for maintenance planning using decision support [35].
20	IWMS	To monitor the optimisation of the building facility in maintenance management

		performance [36].
21	Destructive and Non-Destructive Testing in Maintenance Application	To detect the fault and analyse the severity of the concerned facility using sound judgments [37].
22	CWorks (CMMS)	To monitor asset, location, manpower, maintenance cost beside to produce the statistical report [38].
23	TMA System (CMMS)	To assist for account management and planning of asset with incorporating of CAD [39].
24	AMPRO (CMMS)	To reduce maintenance cost and improve productivity for structuring asset operation [40].
25	ARCHIBUS (CMMS)	To plan the project manpower and to optimise the maintenance cost and duration for building facility [41].
26	OMMS (CMMS)	Device the schedule time for optimising repair on preventive maintenance operation [42].
27	MANTRA (CMMS)	To plan the maintenance execution with flexible time schedule [43].
28	AMMS (CMMS)/ MAINTelligence (CMMS)	To manage the asset inventory, procurement process and work order management [44, 45].
29	APIPRO (CMMS)	To support notification process for the work order, statistic and project management [46].
30	EMaint (CMMS)	To support the reporting defect using mobile solution and to manage the inventory for maintenance planning [47].
31	E-Maintenance (CMMS)	To carry out the maintenance activities using ERP concepts [48].

Table II shows the comparison of current technologies where there is the same gap among those systems which is the decision making support function.

TABLE II. COMPARISON OF MAINTENANCE MANAGEMENT TECHNOLOGIES

System / Functions	RFID	CMMS	CAFM	FMIS	IWMS	NDT
Asset Inventory & Registration	Yes	Yes	Yes	Yes	Yes	Yes
Labour Management	-	Yes	-	Yes	-	-
Work Order	-	Yes	-	-	-	-
Asset Management	-	Yes	Yes	Yes	Yes	-
Corrective Maintenance (CM)	Yes	Yes	-	-	-	-
Preventive Maintenance (PM)	-	Yes	-	-	-	-
Procurement Management	-	Yes	-	-	-	-
Account Management	-	Yes	-	-	-	-
Mobile Solution/GPS/ GIS	Yes	Yes	-	-	-	-
Defect Inspection	Yes	Yes	-	-	-	Yes
Complaint Management		Yes	-	-	-	-
Maintenance Planning	Yes	Yes	-	-	-	-
Decision Support in Identification	Yes	Yes	-	-	-	-
Decision Support in Assessment	Yes	Yes	-	-	-	-
Decision Support in Diagnosis	-	-	-	-	-	-
Report & Statistic	Yes	Yes	Yes	Yes	Yes	Yes

This function is a necessity to facilitate maintenance management staff in maintenance planning including coordination of budget allocation in the organisation [27]. The common attributes used for decision support are the facility inventory, location of defect and the management of complaint. For example, facility inventory that consists of corrective and preventive planning is recorded based on the location, equipment and defect problems brought by customer [49, 33]. The high-quality database with decision support provides the specific data that enable maintenance management staff to identify the facility deficiency and find the solution immediately [28].

Furthermore, CMMS can be derived as the most wanted system in the maintenance management practices due to a lot of functional disciplines compared to other systems [50, 51]. The CAFM, FMIS and IWMS do not provide the whole functions in the maintenance processes whereas emphasis is given on the data registration and inventory that dismiss on maintenance planning functional for prioritising the building defects and execute the maintenance effectively. Nevertheless, the integration of PROMETHEE or AHP

application in the CMMS is assisted to improve the technologies on those functional disciplines [32].

Meanwhile, M-RFIDMM and NDT application in the system are lodging on inventory, tracking of asset including defect in maintenance inspection. However, the maintenance management system using CMMS is completed with work process started from asset identification to maintenance execution. The functional improvement of the CMMS needs to be complemented through more decision support input to ensure the effectiveness and efficiencies of maintenance management processes in the organisation [52, 53, 24].

III. ICT Implementation Challenges for Building Maintenance

The expansion of current technologies is to assist the maintenance management processes using ICT-based system. The processes start from identification, defect diagnosis, maintenance planning and execution of the facilities [54]. The defect diagnosis in maintenance management becomes as challenges for defining the objective of the latent and patent defects to provide the service in time due to ineffective implementation strategies and best practices need to be undertaken with the implementation of ICT-based diagnostics system in the organisation [55]. Effective management of maintenance diagnosis relies on the sophisticated technology in ensuring the successful of dependability building facility and to achieve the expected return on investment in maintenance (ROIIM) [56].

Another challenge for current technology is to provide the strategic decision making in the maintenance operation [57]. The decision making process consists of database management and also automation decision support in the system [58]. In the database management, the systematic mechanisms references of using graphical tools or diagrammatic tools like graphs, flow charts and Analytic Hierarchy Process (AHP) are used to analyse the defect report without any negligent information [59]. For example, the particular information complaint is assessed with the highest of intervention for the funding prioritised and time consideration about the considered plans of the related facility maintenance [60, 61].

Meanwhile, the automation decision support system is to improve the quality of decision with the precise and comprehensive information based on technology application used [62]. The developed model of automation decision making support quantifies the overall condition properly and evaluates the possible alternatives regarding selecting a solution for facility improvements [63]. Therefore, the current technology challenges append the competition in the market for emerging of the managerial decisions technology of ICT-based system that focuses on improvement of complex maintenance management processes such as defect diagnosis which most organisation need [28].

IV. Proposed Theoretical Framework

Reference [64] state that constructability concept is an effective approach to enhance the performance of facility by integrating construction expertise (e.g. ICT) into the planning and strategy of project. This definition of constructability concept will be the basis in developing a theoretical framework for this research but stress is given on the maintenance management for building facility.

The theoretical framework consists of a few stages in order to establish the requirement for integrating maintenance management processes and elements of good practice in pre-development of maintenance management systems (MMS). This is also concerned with suitable software programming application with respect to system effectiveness. There are two theories in the development of Maintenance Management Systems (MMS), namely Computer Maintenance Management Systems (CMMS) model and constructability concept, as shown in Figure I. The purpose of these theories is to design the Maintenance Management Systems (MMS). The following are in-depth explanations of constructability concept and CMMS as they are related to this research.

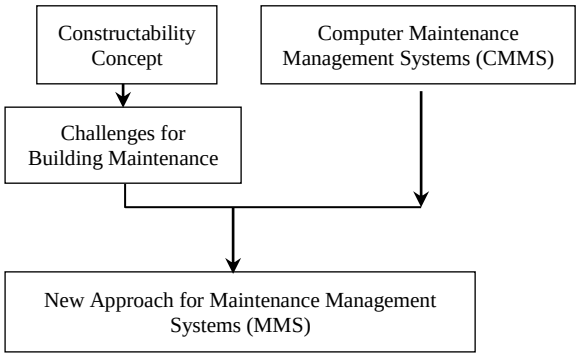

FIGURE I. THEORETICAL FRAMEWORK

Constructability Concepts

A constructability concept is about knowledge and experience analysis resulted from identifying potential problems, causes and reasons to meet the objectives. This approach provides the efficient solution and decision that improve management in the organisation. The constructability concept also is the extended research toward the development of post-construction management [65]. The challenges are defect management due to cumbersome services. Defect management is depending on technique application in maintenance management processes. The deficiency of building defect diagnosis leads to the

weakness skill in maintenance management. In the data analysis using constructability concept, the reasons for defect management are divided into two categories which are technical defects and managerial defects. These can be further breakdown into such as low exposed of the modern technology and less knowledge skills with respect to ICT. Based on amendments and probable solution, an initial extended system is developed and expected to meet the solutions needs [12].

Computerised Maintenance Management Systems (CMMS)

There are many excessive downtimes that remain a problem for many organisations, particularly in complex capital intensive of building and infrastructure. However, the CMMS offers fall short of delivering useful information and the preferred system such as to solve the facilities demands over the priority maintenance management action [66]. According to [2], maintenance management has set the goal to transform into sophisticated application using ICT. The new technology needs to be improved with decision making processes to support reactive maintenance and operative maintenance. In addition, it should lead the equipment histories in order to achieve root cause failure analysis. The basic information such as symptom, problem, corrective action and unusual conditions provides important historical data for future troubleshooting efforts. The new system can perform the best decision and subsequent action accurately [67].

CMMS application is widely used in maintenance management processes that present the typical selection of ICT tools and techniques used for strategic maintenance [68]. This application instantly improves the management of organisation toward quality and efficiency work practices. The CMMS also become the world class management in maintenance for the multi-faceted of building and infrastructure due to its complete attributes and entities data [69]. Though CMMS can reduce the negligent management and enable students to lodge defect complaint easily by using internet application, it is not provided with decision making process [53].

Summary

The idea of studying ICT application and development in the building maintenance is a necessity to reflect the technology efficiency besides to replace the use of conventional method for supporting the maintenance revolution. Therefore, the challenge of ICT in building maintenance has significant benefits as a benchmark that improves the facility assessment and decision making to the overall maintenance management practices.

The factor of building defect diagnosis and decision making process are the main challenges identified in the maintenance management processes. The suggestion for good practices is through the implementation of ICT with the improvement for the existing system. The new system will be developed to manage the maintenance on the ad-hoc and preventive maintenance effectively.

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