CHALLENGES AND OPPORTUNITIES OF IMPLEMENTING ICT SYSTEMS IN OFFICE BUILDING MAINTENANCE IN KUALA LUMPUR

Cheong Peng Au-Yong[1], Chin Chuan Gan[1], Nuratiqah Aisyah Awang[1]*, Yan Peng[2]

[1]Centre for Building, Construction & Tropical Architecture (BuCTA), Department of Building Surveying, Faculty of Built Environment, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
[2]Faculty of Architecture and Engineering, Guizhou Polytechnic of Construction, 551400, Qingzhen, Guiyang City, Guizhou Province, China.

E-mail: * nuratiqahaisyahawang@um.edu.my

ABSTRACT

Maintenance is crucial for any building throughout its entire lifespan. The primary goal of building maintenance is to maintain all components and facilities in their original and functional condition to ensure continuous efficient operation. The widespread adoption of maintenance software has paved the way for more efficient communication within maintenance management, improving the effectiveness and efficiency of maintenance activities. Previous research has highlighted several challenges in the implementation of Information and Construction Technology (ICT) systems in maintenance management. This study aims to explore the key challenges associated with the use of ICT systems in maintenance management, with a specific focus on office buildings in Malaysia. A qualitative approach was adopted for this study, involving semi-structured interviews. A total of five interviewees were selected from three (3) office buildings. The findings show that two types of ICT systems—the Building Automation System (BAS) and the ARCHIBUS system—were utilised in the maintenance management of the three office buildings. This study identifies various issues and challenges that arise when implementing these ICT systems, including a lack of professional expertise in operating the systems, inaccurate information, risks of connection loss, time consumption, limitations in capability, cybersecurity threats, and financial constraints. Common issues faced across different management teams and ICT systems include a shortage of qualified personnel, time inefficiencies, and limitations in system capabilities. These challenges must be addressed promptly to enhance the efficiency and value of ICT systems in maintenance management. Effective building maintenance in office buildings is essential to ensure that all services and facilities operate smoothly and to prevent any potential downtime.

Keywords: Challenges, ICT System, Maintenance Management, Office Building, Solution.

1. INTRODUCTION

Maintenance is essential for any building throughout its entire lifespan (Mydin, 2017). The main objective of building maintenance is to preserve all elements and facilities in their original, functional state to ensure continuous efficient operation (Al-Zubaidi, 1997). Commercial office buildings, with their vast floor space and high energy consumption, require significant resources to provide services that ensure user comfort (Labeodan et al., 2015). These buildings, accommodating a variety of business activities, are equipped with diverse facilities, including structural elements like floors, walls, and ceilings, as well as building services such as air conditioning, piping, elevators, and plumbing. To meet user expectations and maintain optimal facility performance, effective maintenance practices are essential (Lai, 2015). According to Bouchlaghem and Shelbourn (2012), modern ICT systems are highly advanced and have the potential to significantly enhance maintenance management.

The use of computer systems in maintenance management dates back to the 1970s, as noted by Jones and Collis (1996), with the widespread adoption of maintenance software emerging in the 1980s. This progression paved the way for more efficient communication within maintenance management. As highlighted by Ismail and Kasim (2013), ICT systems allow staff to exchange large amounts of information effortlessly, improving coordination and response times. Furthermore, ICT systems provide maintenance managers with real-time, accurate updates on building conditions, helping to prevent delays in decision-making (Lateef, 2010). ICT system is vital in practising effective maintenance works in an office building (Ismail & Kasim, 2013). Among the popular ICT system in building maintenance management is the Computerised Maintenance Management System (CMMS), ARCHIBUS, Building Automation System (BAS), and Building Information Modelling (BIM).

2. LITERATURE REVIEW

2.1 Computerised Maintenance Management System (CMMS)

CMMS is an ICT tool used for planning, managing, and analysing maintenance activities (Falorca, 2019). Jones and Collis (1996) noted that CMMS software was introduced as early as 1985, prior to the widespread use of other maintenance software. CMMS functions as a computerised database that stores detailed records of maintenance operations, allowing managers to track the status of ongoing maintenance tasks (Olanrewaju et al., 2010). Traditionally, operator logbooks were used to document building maintenance information, but in most modern buildings, these logbooks have been replaced by CMMS (Becerik-Gerber et al., 2012). CMMS reduces downtime through better scheduling and preventive maintenance, which lowers repair costs and extends asset life (Paul et al., 2024). The system provides access to historical data, enabling informed decision-making that can minimise unnecessary expenditures (Ogbeifun et al., 2021). CMMS has become an essential ICT tool for planning, managing, and analysing maintenance activities.

2.1.1 ARCHIBUS

According to Ismail (2018a), ARCHIBUS is an ICT system that falls under the CMMS category. It is a comprehensive web-based application that stores a wealth of data and reports, accessible for review by users or clients (Kraus & Udrea, 2021). As stated by ARCHIBUS (2019), the system offers a wide range of functions, including space management, asset management, environmental management, energy management, and building maintenance. Specifically, for building maintenance, ARCHIBUS supports both preventive and on-demand maintenance tasks.

2.1.2 Building Automation System (BAS)

According to Bhatt and Verma (2015), BAS also referred to as Building Management Systems (BMS), Building Automation and Control Systems (BACS), Facility Management Systems (FMS), or Building Energy Management Systems (BEMS), are designed to control various building systems. BAS can send alerts when faults occur in these systems (Yang & Wang, 2012). In addition, BAS is capable of measuring and recording data such as temperature, humidity, pressure, and flow rate, using sensors to gather this information (Tang et al., 2020). Schein (2007) highlights that the data collected by BAS is valuable for other building applications, including energy simulation, commissioning, and maintenance. As an ICT system applicable to maintenance management, BAS controls multiple systems within a building—such as lighting, heating, ventilation, and air conditioning (HVAC), electricity, security, and fire systems—and can notify operators of any system malfunctions (Yang & Wang, 2012).

2.1.3 Building Information Modelling (BIM)

Another ICT system applied in building maintenance is Building Information Modelling BIM) (Aziz et al., 2016). Implementing BIM in building maintenance has various advantages, such as presenting all significant information in a single file, and the maintenance workers do not need to search for large amounts of data to get the information they want (Azhar et al, 2012). Vanlande et al. (2008) stated that BIM can store, manage, and exchange building information in a way that is both interoperable and reusable. As noted by Azhar (2012), one key advantage of using BIM in building maintenance is that all critical information is consolidated into a single file, eliminating the need for maintenance workers to sift through large volumes of data to find the information they need. Meanwhile, BIM can also provide 3D visual drawings (Kubba, 2012). These 3D models assist technicians in identifying the best solutions for facility issues, thereby improving the efficiency of maintenance tasks (Motamedi et al., 2014). BIM can generate 3D visual representations of all building structures and elements while sharing relevant information (Kubba, 2012). According to Lucas et al. (2013), many contracts still rely on paper documents for essential information such as preventive maintenance schedules, product data sheets, and warranties, leading to incomplete and inaccurate information. However, BIM can significantly improve this process (Lucas et al., 2013). Eastman (2011) highlights that BIM captures data in digital format, reducing the time and cost of data collection while enhancing data quality and reliability.

2.2 Challenges in Implementation ICT System in Maintenance Management of Office Building

The implementation of ICT systems offers significant potential to improve maintenance management. However, despite these advantages, the adoption and integration of ICT systems often present a range of challenges. Office buildings, which are complex environments with diverse systems and services, face unique difficulties when implementing technologies. Previous research has discovered that several challenges are encountered in the application of ICT systems in the maintenance management of office buildings. These include limitations in system capabilities, time-consuming processes, inaccurate information, a shortage of professional consultants to guide users, inefficient information sharing, cybersecurity concerns, and difficulties in transitioning from traditional ICT systems to newer ones.

2.2.1 Limitation on Capability of the ICT System

According to Wong et al., (2018), CMMS has limitations in building maintenance work. This ICT system can record and process the database of daily maintenance operations. However, CMMS cannot capture and retrieve the detailed information generated from building maintenance, including the causes of failure, chain of cause and effect to other building elements (Wong et al., 2018). Besides that, some ICT systems can only support 2D drawings instead of 3D drawings (Tang et al., 2020; Yoon & Cha, 2017). The 2D drawing in BAS may cause error-prone design in some This feature will cause the maintenance team difficulty in identifying the problems that occur on the system accurately, such as HVAC system, piping and so on (Yoon & Cha, 2017).

2.2.2 Time-Consuming

Implementing ICT systems in maintenance management can be resource-intensive, especially during the data entry phase. Tu and Chang (2017) point out that in systems like ARCHIBUS, data must be manually entered —a process that often extends over several months for maintenance teams. This initial data entry demand underscores a critical challenge in adopting digital maintenance systems. The time and workforce required may delay the effective use of the system until all data is fully captured and organised. Another significant challenge in maintenance management is the limited availability and remote locations of maintenance centres. As Chingumbe and Mahabi (2024) note, when maintenance centres are sparsely located, technicians face long travel times to reach service sites, delaying repairs and extending system downtimes. Furthermore, design flaws in infrastructure, such as inadequate trenching for fault detection, add to maintenance delays by complicating fault location and repair processes. In educational settings, the lack of an efficient maintenance support system results in delays in addressing ICT issues, leading to frustration among users (Madronio, 2023). Schools, like many institutions, may face prolonged disruptions in ICT resources due to inadequate maintenance systems that fail to support timely interventions. Similarly, implementing CMMS poses its own set of challenges, as organisations often struggle with the complexity of these systems. Makhanya et al. (2023) argue that the intricate nature of CMMS can create significant barriers to adoption, leading to inefficiencies as organisations grapple with integration.

On the other hand, a critical element often overlooked in maintenance management is data analysis from Maintenance Work Orders (MWOs). Navinchandran et al. (2019) emphasise that without a thorough analysis of

MWOs data, organisations may fail to pinpoint key factors contributing to extended maintenance times. Effective data analysis is essential for understanding patterns and reducing the duration of maintenance activities. These issues collectively point to systemic challenges in maintenance management across various sectors. The lengthy data entry demands of ICT systems reflect the need for more efficient, user-friendly platforms to reduce the initial setup burden. Additionally, the lack of easily accessible maintenance centres and the design flaws in infrastructure highlight gaps in planning and resource allocation. In educational institutions, delayed ICT support underscores the need for robust maintenance frameworks tailored to the fast-paced demands of technology. The adoption challenges of CMMS, alongside the underuse of MWOs data, reveal a pressing need for a more strategic, data-driven approach to maintenance. Addressing these issues could lead to more efficient maintenance practices, and reducing downtime.

2.2.3 Inaccurate Information

ICT systems that rely on sensor-based data collection may face significant challenges with data accuracy. Aftab et al. (2017) highlight that sensors in building systems are sometimes oversimplified, making them vulnerable to inaccuracies, which can impair the functionality and effectiveness of BAS in maintenance management. Such inaccuracies can hinder communication among technical staff, leading to delays and misunderstandings during maintenance tasks (Hussein & Oztas, 2020). Furthermore, a lack of integration across information systems can lead to data loss and higher administrative costs, both of which diminish overall productivity (Seun et al., 2023). Maintenance managers often encounter challenges due to insufficient or unreliable data, resulting in wasted resources and increased indirect costs (Hossam et al., 2019). These data issues negatively affect decision-making and strategic maintenance planning, contributing to financial inefficiencies and backlogs in maintenance tasks. Ismail (2018) argues that irregular data quality within ICT systems can impede effective defect diagnosis and result in inefficient service delivery in building maintenance operations. Inaccurate maintenance records further compromise reliability by leading to flawed maintenance policies, increased safety risks, and ineffective scheduling, ultimately affecting equipment integrity and the broader efficiency of maintenance operations (Lu et al., 2023).

Arisanti (2020) adds that poor data quality can disrupt maintenance schedules, create undocumented gaps in maintenance history, and increase operating costs, reducing system reliability and elevating the risk of structural failures. This lack of reliable data also contributes to design and technical issues that may harm occupant health and well-being by introducing delays, inflated costs, and misallocated resources (Rajus et al., 2022). A critical analysis of these issues suggests that data accuracy is a fundamental requirement for effective ICT-based maintenance management. Oversimplified sensors create gaps in data quality that ripple across maintenance systems, leading to poor resource allocation and reduced responsiveness. The lack of integrated data systems complicates information flow, while inaccurate records compromise safety and operational integrity. Such data issues also hinder strategic decision-making, making it difficult to anticipate maintenance needs, prioritise resources, or respond effectively to technical challenges. To improve ICT-based maintenance, there must be a focus on implementing high-quality, reliable sensors, ensuring system integration, and developing robust data verification processes. Addressing these challenges can enhance the accuracy and reliability of maintenance data, and contribute to the overall efficiency of maintenance management systems.

2.2.4 Lacks Professional Consultants to Guide User

ICT systems are advanced tools for maintenance management, but they require specialised expertise to operate effectively and provide proper user support. However, maintenance teams often lack the necessary skills to manage these systems proficiently. Wang et al. (2022) highlight that a shortage of professional consultants frequently limits the guidance available for clients or users operating systems like ARCHIBUS, thereby hampering maintenance management outcomes. Additionally, the retirement of skilled personnel compounds this issue, leading to a reliance on less-trained staff and slower maintenance responses (Chingumbe & Mahabi, 2024). The absence of professional consultants can significantly undermine the effectiveness of ICT systems in building maintenance by reducing access to expert insights, which are essential for accurate incident analysis and the integration of critical considerations into decision-making processes (Gościniak & Wodarski, 2019). Without this expertise, maintenance teams may struggle with diagnosing defects effectively, resulting in poor strategic planning, increased backlogs, and, ultimately, compromised service delivery (Ismail, 2018a).

These reveal that insufficient professional expertise in ICT maintenance systems creates multiple vulnerabilities. Without skilled guidance, teams may struggle to leverage the full capabilities of advanced systems, leading to inefficient problem diagnosis, missed strategic opportunities, and delayed or ineffective maintenance interventions. The reliance on under-trained personnel not only slows maintenance activities but also increases the likelihood of errors, potentially causing system reliability issues and diminished service quality. This shortage of expertise underscores the importance of structured training and succession planning within maintenance teams to ensure continuity of knowledge and skills. Addressing these skill gaps through targeted training, consultancy support, and robust knowledge transfer practices could significantly enhance system reliability and improve the overall effectiveness of ICT in maintenance management.

2.2.5 Inefficient Information Sharing

Some ICT systems used in maintenance management may face significant inefficiencies in information sharing. Tang et al. (2020) highlight that BAS often struggle to facilitate smooth information exchange among contractors, subcontractors, and designers. Without integration across various systems, the process of exchanging information becomes inefficient and fragmented. Inefficiencies in building maintenance information sharing are further compounded by insufficient coordination among design, manufacturing, and maintenance teams, as well as limited awareness and adoption of ICT tools such as BIM, this lack of integration leads to recurring defects and limited knowledge transfer about building systems and components (Ismail, 2021).

In reactive maintenance, inefficient asset information and communication management can exacerbate facilities management (FM) issues and negatively impact user experience. However, Fialho et al. (2022) argue that integrating BIM with the Internet of Things (IoT) can improve information flow, streamlining maintenance processes and increasing user satisfaction. Zhang et al. (2021) add that employing knowledge management practices and BIM technology can bridge gaps in communication between experts and non-experts, ensuring that critical maintenance knowledge is transferred effectively and remains accessible.

Despite the availability of various ICT solutions, inefficiencies persist in building maintenance. Bouabdallaoui et al. (2021) attribute this ongoing inefficiency partly to obstacles in data availability and the feedback mechanisms within maintenance processes, which restrict data-driven improvements. These challenges reveal that effective information sharing in maintenance management is essential for coordinated and proactive maintenance. The limited integration of BAS with other systems and the lack of structured information-sharing channels hinder seamless collaboration, leading to recurring maintenance issues and inefficiencies. Similarly, inadequate adoption of BIM and other ICT tools restricts the ability to share vital knowledge across teams, contributing to repetitive issues that could be avoided with better information access. Integrating BIM with IoT, along with the implementation of knowledge management practices, could be transformative for maintenance management, creating a more cohesive, efficient system. Addressing these challenges would likely reduce energy waste, streamline maintenance processes, and improve the overall user experience.

2.2.6 Cyber Security Concern

Cybersecurity poses a significant challenge in the implementation of ICT systems in maintenance management. Salamit and Wahid (2021) highlight that when maintenance data is stored in the cloud, it becomes vulnerable to various cyber threats, which can result in the corruption or destruction of essential building data. Furthermore, integrating IoT devices into BMS can introduce additional security risks, as adversaries might exploit communication channels between the BMS and IoT devices to initiate cyber-attacks on the infrastructure (Chan et al., 2022). Cybersecurity threats in smart building maintenance encompass a range of vulnerabilities, from physical attacks and network-based intrusions to malicious cyber-assaults. Sandor and Rajnai (2023) suggest that strategies such as access control, network segmentation, and regular patching are crucial for mitigating these risks and enhancing overall system security. Fakhruldeen et al. (2023) also point out that ICT systems in building maintenance face security issues due to unsupported components and vulnerabilities within multi-layered architectures, making it essential to establish reliable maintenance strategies to uphold system integrity and protect against cyber threats.

A further challenge is the lack of security maturity within BAS. Jesus et al. (2022) note that the convergence of BAS with traditional IT systems creates ambiguities in ownership and accountability, weakening the effectiveness of security measures and hindering the sector's ability to mature in cybersecurity practices. In conclusion, cybersecurity in ICT-enabled maintenance management requires a proactive, multi-layered approach. Cloud storage and IoT integration significantly broaden the attack surface, demanding that organisations implement robust security frameworks.

2.2.7 Transition from Traditional ICT to New ICT System

Key factors hindering the transition from traditional ICT systems to newer ones include organisational resistance to change, a lack of digital skills and expertise, legacy systems, cultural barriers, complexities surrounding data management, cybersecurity threats, and regulatory compliance (Syamsuddin et al., 2024). In addition, insufficient internal resources can impede progress, as organisations often struggle to allocate budgets for new technologies (Mahboub & Sadok, 2024). Organisations also face significant challenges during digital transformation, such as resistance to change, limited digital skills, inadequate infrastructure, and cultural barriers (Shahi & Sinha, 2021). Furthermore, the integration of disparate technologies, ensuring interoperability, managing the vast amounts of data generated by interconnected devices, and addressing issues related to data storage, governance, security, and privacy present additional obstacles (Sharma et al., 2024). These interconnected challenges highlight the complex nature of digital transformation and the need for strategic planning and resource allocation to overcome them.

Previous research has highlighted several challenges in the implementation of ICT systems in maintenance management. This study aims to explore the key challenges associated with the use of ICT systems in maintenance management, with a specific focus on office buildings in Kuala Lumpur, Malaysia.

3. METHODOLOGY

A qualitative approach was employed where 3 case studies located in the Kuala Lumpur area were selected. These buildings were chosen mainly due to two (2) criteria, high-rise office building and the application of ICT systems in the maintenance management practice. The buildings include Mercu Maybank, Menara Perkeso, and Menara KWSP. A semi-structured interview was conducted. A total of 5 interviewees were selected with 10 years of working experience and hold a maintenance management position as shown in Table 1. Interview protocols were followed and guidance was given to the interviewee to ensure systematic and comprehensive interview sessions. Data recorded from the interview sessions were analysed using thematic analysis. Thematic analysis allows the researcher to code and categorise the data collected throughout the research process into themes (Miles & Huberman, 1994). The main goal of thematic analysis in the research is to identify the themes or patterns of the collected data and use that theme to address the aim and objective of the research (Braun & Clarke, 2013).

Table 1. Respondents' Details

Case Studies Building	Interviewee	Position
CS 1	Interviewee A	Manager of Maintenance Management
CS 1	Interviewee B	Staff in Maintenance Management
CS 2	Interviewee C	Staff in Maintenance Management
CS 2	Interviewee D	Staff in Maintenance Management
CS 3	Interviewee E	Manager of Maintenance Management

4. RESULTS AND DISCUSSION

From the interview and thematic analysis, this study found 2 ICT systems implemented for maintenance management, including the BAS and the ARCHIBUS system. 2 case studies implemented BAS where it can provide centralised control for certain building services and components, including an alarm system, air-conditioning and mechanical ventilation (ACMV) system, electrical system, plumbing system, and fire system. Besides that, BAS facilitates the building management team to monitor the system's functionality and observe the total energy consumption. BAS can alert the building owner of potential failures in each system or any malfunctions detected in the buildings. This is the most important feature and function of BAS for building maintenance management. This alert feature can avoid severe breakdowns on building systems and require more expensive costs to fix the problem.

ARCHIBUS system was utilised in 3 case studies, where the common factor is that all the data in the ARCHIBUS system is integrated and digitalised. In other words, all information, such as the details, the location, the maintenance record and the drawing of building systems, are available in the ARCHIBUS system. The system benefits in terms of saving time because it can schedule maintenance work and can track maintenance work orders. Besides that, the helpdesk system is also available in the ARCHIBUS, allowing the maintenance management to note the current problems and defects in the building systems or components. ARCHIBUS also has other features, including space, asset, project, and energy management.

4.1 Issues and Challenges Faced in the Application of ICT Systems in Maintenance Management

Previous studies have highlighted the issues and challenges faced in applying ICT systems in maintenance management. It includes lack of professionals, limitations on capability, time-consuming, and cyber security concerns. Based on the feedback from 5 interviewees, the maintenance management team faces 7 different issues and challenges when applying the BAS and ARCHIBUS systems in respective buildings, as shown in Table 2. These issues and challenges include a lack of professionals in operating the system, inaccurate information, risk for loss of connection, time-consumption, limitation on capability, cyber security threats and financial difficulties.

For lack of professionalism in operating the system, Wang et al. (2022) mentioned that there is always a lack of professional consultants to guide the clients or users to operate and manage the ARCHIBUS system in maintenance management. The absence of professional consultants can significantly undermine the effectiveness of ICT systems in building maintenance (Gościniak & Wodarski, 2019). For the BAS system, the in-house staff is unfamiliar with the system operation and heavily relies on outsourcing staff to maintain and monitor the system. The outsourced staff are only available from time to time and causing delays when failure occurs. This study discovered that clients heavily rely on outsourced staff, which is time-consuming. On the other hand, for ARCHIBUS system, is frequently updated and staff facing difficulties using the updated version without immediate guidance from a professional consultant.

The other issue and challenge found is inaccurate information. BAS system relies on sensors to collect data. There is an issue in data transmission from the meter to the system, sometimes inaccurate and does not tally with the reading shown by the meter on site. Aftab et al. (2017) have highlighted that sensors in building systems are sometimes oversimplified, making them vulnerable to inaccuracies, which can impair the functionality and effectiveness of BAS in maintenance management. Such inaccuracies can hinder communication among technical staff, leading to delays and misunderstandings during maintenance tasks (Hussein & Oztas, 2020). Insufficient or unreliable data, results in wasted resources and increased indirect costs (Hossam et al., 2019).

Table 2: Issues and Challenges Faced in the Application of BAS and ARCHIBUS System

Issues and Challenges	**Descriptions**
Lack of expertise in operating the system	**<u>BAS</u>** • Lack of knowledge and skills to operate the system. • Rely on outsourcing staff to maintain and monitor the system. • The outsourced staff are only available from time to time. • It is time-consuming to call the outsourcing staff when problems arise. **<u>ARCHIBUS</u>** • The maintenance management staff are unfamiliar with the system at the beginning. • Misuse will happen when the staff operate the system. • The system is frequently updated, and staff face difficulties using the updated version.
Inaccurate information	**<u>BAS</u>** • BAS relies on sensors and meters to collect data. • There is an issue in data transmission from the meter to the system. • The data shown in BAS is sometimes inaccurate and does not tally with the reading shown by the meter on site.
Risk for loss of connection	**<u>BAS</u>** • Power failure can lead to communication breakdown between BAS and equipment. • The operators must manually run the building equipment or system until the system resumes. • The building operator must remember to return all equipment to automatic mode with the same pre-settings for the equipment to operate efficiently.

Issues and Challenges	Descriptions
Time-consuming	**ARCHIBUS** • All the data in the ARCHIBUS system need to be keyed in manually. • Therefore, the maintenance team need 3-6 months to insert all the required data into the system at the beginning. • Current data also need to be inserted manually into the system. • Manually upload the information from the Excel file to the system.
Limitation on capability	**ARCHIBUS** • Only support 2D drawing.
Cyber security threat	**ARCHIBUS** • Security threats alert.
Financial risk	**BAS** • The operational cost is high.

Implementing ICT systems in maintenance management can be resource-intensive, especially during the data entry phase. Tu and Chang (2017) point out that in systems like ARCHIBUS, where data must be manually entered, a process that often extends over several months for maintenance teams. Respondent also mentioned all the data in the ARCHIBUS system need to be keyed in manually where the maintenance team need 3-6 months. Current data also need to be inserted manually or uploaded from the Excel file into the system. This initial data entry demand underscores a critical challenge in adopting digital maintenance systems, the time and workforce required may delay the effective use of the system until all data is fully captured and organised.

On top of that, issues and challenges discovered are limitations on capability where the ARCHIBUS system only supported 2D drawings. Yoon and Cha (2017) have stated that the ARCHIBUS system can only support 2D drawings instead of 3D ones. The 2D drawing in BAS may cause error-prone design in some complex building systems (Tang et al., 2020). This feature will cause the maintenance team difficulty in identifying the problems that occur on the system accurately, such as HVAC system, piping and so on (Yoon & Cha, 2017). For cyber security concerns, Salamit and Wahid (2021) mentioned that there will be security threats when ICT systems are applied in maintenance management, especially when they upload maintenance data to the cloud. One of the case studies had experienced a security threats alert that required an urgent fix.

New emergency findings involve only BAS, which include risk for loss of connection, and financial risk. The risk of loss of connection due to power failure can lead to communication breakdown between BAS and equipment. The operators must manually run the building equipment or system until the system resumes. On top of that, the building operator must remember to return all equipment to automatic mode with the same pre-settings for the equipment to operate efficiently. Lastly, it is on financial risk where the operational cost for BAS is high.

4.2 Recommendation to Overcome the Challenges Faced

There are different types of recommendations being suggested by the interviewees for improving and overcoming the current challenges faced. Table 3 below shows the recommendations for each issue and challenge. For lack of expertise in operating the system, professional training should be provided to the whole management team, requiring them to rely less on the outsourced staff to monitor and control the system, which is time-consuming. Secondly, the system needs to be calibrated frequently to prevent issues in data transmission from the sensor to the system, causing inaccurate information. The system is prone to faulty due to power failure. Therefore, alternative power supply support must be provided to ensure the system runs efficiently. The fourth recommendation involves reducing the time for data updates. Additional staff is needed during the system activation. Suppliers also need to provide alternatives to ease transferring information into the system.

Apart from that, the system should support 3D drawing. Recommendations made for cyber security threats include providing an updated version that is safe from the cyber security threat, the IT team should create a robust IT security policy covering all angles (from hardware to software and data management) based on the ISO standard, and the IT team should consistently audit IT security to ensure the ICT system is always protected. Lastly, there is a financial risk, and the client is looking for an alternative system with a lower price. All of the challenges need to be addressed to increase the efficiency and value of ICT systems in maintenance management.

The way forward for implementing ICT systems in building maintenance management involves integrating advanced technologies to streamline operations, enhance efficiency, and reduce costs. Addressing issues and challenges lies in a focus on continuous research and improvement. This approach will enable the ongoing evolution and optimisation of technologies used in building maintenance, ensuring the system operates efficiently to meet the current demand and the changing needs.

Table 3: Recommendation to Overcome the Challenges Faced

Issues and Challenges	**Recommendation to Overcome the Challenges**
Lack of expertise in operating the system	• Professional training should be provided to the whole management team. • There should be less reliance on the outsourced staff to monitor and control the system.
Inaccurate information	• The service provider should consistently calibrate the system. • This action can prevent issues with data transmission from the sensor to the system.
Risk for loss of connection	• An alternative should support the system operation despite the power failure. • An uninterrupted power supply (UPS) is a good option to provide additional backup for the system.
Time-consuming	• Initially, staff should be hired for the data entry process. • Suppliers must provide alternatives to simplify the transfer of information into the system.
Limitation on capability	• The system should support 3D drawing.
Cyber security threat	• An updated version of the system should be provided to protect against cyber security threat. • Once the system is updated, the IT team should create a robust IT security policy that covers all angles (from hardware to software to data management) based on the ISO standard. • The IT team should consistently audit IT security to ensure the ICT system remains protected.
Financial risk	• The client may seek alternative systems at a lower price.

5. CONCLUSION

This study has discovered various ICT systems applied in maintenance management through the literature review, including CMMS, BAS, ARCHIBUS, and BIM. These ICT systems are essential for practising effective maintenance in office buildings. Based on the findings from the three case study buildings, the ICT systems most applied in their maintenance management are the BAS and ARCHIBUS systems. However, the implementation of these systems in the respective buildings faces several issues and challenges. These include a lack of expertise in operating the systems, inaccurate information, risks related to loss of connection, time-consuming processes, limitations in system capabilities, cybersecurity threats, and financial risks. Addressing these challenges requires continuous research and improvement to enhance system integration, improve user experience, and ensure data security. Furthermore, investing in training and resources to overcome expertise gaps and improve system reliability will help mitigate these challenges. As the building maintenance industry continues to evolve, the integration of advanced technologies like BAS and ARCHIBUS, along with a proactive approach to overcoming these issues, will lead to more efficient, cost-effective, and sustainable maintenance practices.

6. REFERENCES

Aftab, M., Chen, C., Chau, C. K., & Rahwan, T. (2017). Automatic HVAC control with real-time occupancy recognition and simulation-guided model predictive control in low-cost embedded system. *Energy and Buildings*, *154*, 141-156.

Alhojailan, M. I. (2012). Thematic analysis: A critical review of its process and evaluation. *West east journal of social sciences*, *1*(1), 39-47.

Alshehri, A., Motawa, I., & Ogunlana, S. (2015). The common problems facing the building maintenance departments. *International Journal of Innovation, Management and Technology*, *6*(3), 234.

Al-Zubaidi, H. (1997). Assessing the demand for building maintenance in a major hospital complex. *Property Management, 15*(3), 173-183.

Araszkiewicz, K. (2017). Digital technologies in Facility Management–the state of practice and research challenges. *Procedia Engineering*, *196*, 1034-1042. DOI: 10.1016/j.proeng.2017.08.059

ARCHIBUS (2019). Retrieve from https://www.archibus.net/ai/abizfiles/v24.1_help/archibus_help/user_en/archibus.htm#../Subsystems/webc/Content/bo_results/on_demand_web.htm%3FTocPath%3DBuilding%2520Operations%7COn%2520Demand%2520Work%7C_____1

Arisanti, K., Latief, Y., & Machfudiyanto, R. A. (2020). Development information system for building maintenance for structural components of government green building using Building Information Modelling (BIM). In *IOP Conference Series: Materials Science and Engineering, 830*(2), pp. 022060. IOP Publishing.

Au-Yong, C. P., Ali, A. S., & AhmAd, F. (2014). Prediction cost maintenance model of office building based on condition-based maintenance. *Eksploatacja i Niezawodnosc-Maintenance and Reliability*, *16*(2), 319-324.

Aziz, N. D., Nawawi, A. H., & Ariff, N. R. M. (2016). ICT evolution in facilities management (FM): building information modelling (BIM) as the latest technology. *Procedia-social and behavioral sciences*, *234*, 363-371. DOI: 10.1016/j.sbspro.2016.10.253

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modeling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building, The, 12*(4), 15-28.

Bainbridge, M., & Finch, E. F. (2009). Getting the attention the facilities manager deserves. *Facilities, 27*(7/8), 277–290. DOI:10.1108/02632770910956139

Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management, 138*(3), 431-442.

Bouabdallaoui, Y., Lafhaj, Z., Yim, P., Ducoulombier, L., & Bennadji, B. (2021). Predictive maintenance in building facilities: A machine learning-based approach. *Sensors, 21*(4), 1044.

Bhatt, J., & Verma, H. K. (2015). Design and development of wired building automation systems. *Energy and Buildings*, *103*, 396-413.

Bouabdallaoui, Y., Lafhaj, Z., Yim, P., Ducoulombier, L., & Bennadji, B. (2021). Predictive maintenance in building facilities: A machine learning-based approach. *Sensors*, *21*(4), 1044.

Campbell, S. (2014). What is qualitative research? *Clinical Laboratory Science*, *27*(1), 3.

Chan, R., Yan, W. K., Ma, J. M., Low, M. Y. H., Yar, K. P., Loh, K. M., ... & Phua, T. C. (2022, October). Secure IoT Deployment Checklist for Building Management System. In *2022 IEEE 8th World Forum on Internet of Things (WF-IoT)* (pp. 1-6). IEEE.

Cerić, A., Završki, I., Vukomanović, M., Ivić, I., & Nahod, M. M. (2019). BIM implementation in building maintenance management. *Građevinar*, *71*(10.), 889-900. DOI: https://doi.org/10.14256/JCE.2730.2019

Cheng, J. C., Chen, W., Chen, K., & Wang, Q. (2020). Data-driven predictive maintenance planning framework for MEP components based on BIM and IoT using machine learning algorithms. *Automation in Construction*, *112*, 103087. DOI: 10.1016/j.autcon.2020.103087

Chingumbe, A. A., & Mahabi, V. (2024). Assessment of the Factors Affecting the National ICT Broadband Backbone (NICTBB) Systems Restoration Time. *Tanzania Journal of Engineering & Technology, 43*(2).

Braun, V., & Clarke, V. (2013). Successful qualitative research: A practical guide for beginners.

Eastman, C. M. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

Elmualim, A., & Pelumi-Johnson, A. (2009). Application of computer-aided facilities management (CAFM) for intelligent buildings operation. *Facilities, 27*(11/12), 421–428. DOI:10.1108/02632770910980718

Fakhruldeen, H. F., Kadhim, K. A., Shyaa, T. A., & Al-Asady, H. A. J. (2023). Models and Methods of Information and Control System Cyber–security for Smart Buildings. *Malaysian Journal of Fundamental and Applied Sciences, 19*(3), 313-323.

Falorca, J. F. (2019). Main functions for building maintenance management: an outline application. *International Journal of Building Pathology and Adaptation, 37*(5), 490–509. DOI:10.1108/ijbpa-08-2018-0067

Fialho, B. C., Codinhoto, R., Fabricio, M. M., Estrella, J. C., Ribeiro, C. M. N., Bueno, J. M. D. S., & Torrezan, J. P. D. (2022). Development of a BIM and IoT-based smart lighting maintenance system prototype for universities' FM sector. *Buildings, 12*(2), 99.

Gościniak, T., & Wodarski, K. (2019). Effectiveness of using the method of artificial intelligence in maintenance of ICT systems. *Management Systems in Production Engineering, 27*(1), 40-45.

Gunay, H. B., Shen, W., & Yang, C. (2019). Text-mining building maintenance work orders for component fault frequency. *Building Research & Information*, *47*(5), 518-533. DOI: 10.1080/09613218.2018.1459004

Hamid, A. H. A., & Othman, M. H. (2014). Relationship between quality of building maintenance system and occupant satisfaction for office buildings. In *MATEC Web of Conferences* (Vol. 10, p. 03001). EDP Sciences.

Hauashdh, A., Jailani, J., & Rahman, I. A. (2020). Building maintenance practices in Malaysia: a systematic review of issues, effects and the way forward. *International Journal of Building Pathology and Adaptation, 38*(5), 653-672.

Horner, R. M. W., El-Haram, M. A., & Munns, A. K. (1997). Building maintenance strategy: a new management approach. *Journal of quality in maintenance engineering*, *3*(4), 273–280. DOI:10.1108/13552519710176881

Hossam, T. A. M, Eid, A. F., & Khodeir, L. (2019). Identifying The Impact of Integrating Building Information Modelingwith Maintenance Management A Literature Review. *Journal of Al-Azhar University Engineering Sector, 14*(51), 627-641.

Husaini, A. A., & Tabassi, A. A. (2014). Performance assessment of maintenance practices in government office buildings: case study of parcel e, Putrajaya. In *MATEC Web of Conferences* (Vol. 10, p. 03002). EDP Sciences.

Hussein, T. A., & Oztas, A. (2020). Effect of using building maintenance information management system in maintenance process in ministry of education. *Kurdistan Journal of Applied Research*, 24-35.

Ismail, Z. A., & Kasim, N. (2013). Maintenance management practices for building facility: a case study. *International Journal of Engineering Research and Applications (IJERA), 3*(4), 487-497.

Ismail, Z. A. (2018a). ICT-based system for Malaysian residential maintenance projects–literature review. *Journal of Facilities Management, 16*(3), 354-371.

Ismail, Z. A. (2018b). Development of a defect monitoring system (DMOSYS) for building maintenance at polytechnic. *Facilities, 36*(7/8), 403-422.

Ismail, Z. A. (2021). Implementation of BIM technology for knowledge transfer in IBS building maintenance projects. *International Journal of Building Pathology and Adaptation, 39(*1), 115-134.

Jamshed, S. (2014). Qualitative research method-interviewing and observation. *Journal of Basic and Clinical Pharmacy, 5*(4), 87. DOI:10.4103/0976-0105.141942

Jesus, V., Chang, V., & Gao, J. X. (2022, September). Externalization and Ownership of Cybersecurity for (Smart) Buildings. In 2022 International Conference on Industrial IoT, Big Data and Supply Chain (IIoTBDSC) (pp. 80-85). IEEE.

Joffe, H. (2012). Thematic analysis. *Qualitative research methods in mental health and psychotherapy*, *1*, 210-223.

Jones, K., & Collis, S. (1996). Computerized maintenance management systems. *Property management, 14*(4), 33-37.

Kassem, M., Kelly, G., Dawood, N., Serginson, M., & Lockley, S. (2015). BIM in facilities management applications: a case study of a large university complex. *Built Environment Project and Asset Management, 5*(3), 261–277. DOI:10.1108/bepam-02-2014-0011

Kraus, V. F., & Udrea, I. (2021, May). Advanced Workplace Management Platform for Monitoring and Management of Indoor Climate Parameters. In *IOP Conference Series: Earth and Environmental Science* (Vol. 664, No. 1, p. 012047). IOP Publishing.

Kubba, S. (2012). *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*. Butterworth-Heinemann.

Labeodan, T., Zeiler, W., Boxem, G., & Zhao, Y. (2015). Occupancy measurement in commercial office buildings for demand-driven control applications—A survey and detection system evaluation. *Energy and Buildings*, *93*, 303-314. DOI: 10.1016/j.enbuild.2015.02.028

Lai, J. H. K. (2015). Maintenance Performance: Examination of the Computer-Aided Maintenance Data of a Large Commercial Building. *Journal of Performance of Constructed Facilities, 29*(4), 04014118. DOI:10.1061/(asce)cf.1943-5509.0000619

Lu, Y. J., Lee, W. C., & Wang, C. H. (2023). Using data mining technology to explore causes of inaccurate reliability data and suggestions for maintenance management. *Journal of Loss Prevention in the Process Industries, 83*, 105063.

Lucas, J., Bulbul, T., & Thabet, W. (2013). An object-oriented model to support healthcare facility information management. *Automation in Construction, 31*, 281-291.

Madronio, J. T. D. (2023). Maintenance and Support System for Information and Communication Technology (ICT) Resources. *American Journal of Education and Technology, 2*(2), 76-83.

Mahboub, H., & Sadok, H. (2024). Barriers to Digital Transformation: The Case of Moroccan Companies. *Journal of Telecommunications and the Digital Economy, 12*(1), 261–277. https://doi.org/10.18080/jtde.v12n1.814

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *All Ireland Journal of Higher Education*, *9*(3).

Makhanya, B. B., Pretorius, J. H. C., & Nel, H. (2023, December). The Challenges of Implementing a Computerized Maintenance Management System in the South African Railway Sector. In *2023 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 0396-0400). IEEE.

Miles, M. B. (1994). *Qualitative data analysis: An expanded sourcebook.* Thousand Oaks.

Motamedi, A., Hammad, A., & Asen, Y. (2014). Knowledge-assisted BIM-based visual analytics for failure root cause detection in facilities management. *Automation in construction, 43*, 73-83.

Mohanta, A., & Das, S. (2016). ICT-based facilities management tools for buildings. In *Proceedings of International Conference on ICT for Sustainable Development* (pp. 125-133). Springer, Singapore.

Mydin, M. A. O. (2017). Integrated Design and Approach Of Building Maintenance Management In The Built Environment. *Robotica & Management, 22*(2).

Salamit, N. N. A., & Wahid, E. A. Z. A. (2021). Implementation of The Computerized Maintenance Management System (CMMS) In Government Hospital Facility Management Services (FMS). *Progress in Engineering Application and Technology, 2*(2), 204-213.

Navinchandran, M., Sharp, M. E., Brundage, M. P., & Sexton, T. B. (2019, September). Studies to predict maintenance time duration and important factors from maintenance workorder data. In *Annual Conference of the PHM Society* (Vol. 11, No. 1).

Ogbeifun, E., Pasipatorwa, P., & Pretorius, J. H. C. (2021). *Harnessing the Multiple Benefits of a Computerised Maintenance Management System. In Operations Management-Emerging Trend in the Digital Era.* IntechOpen.

Olanrewaju, A. L., Khamidi, M. F., & Idrus, A. (2010). Building maintenance management in a Malaysian university campus: a case study. *Australasian Journal of Construction Economics and Building, The*, *10*(1/2), 101-114.

Paul, P. O., Ogugua, J. O., & Eyo-Udo, N. L. (2024). Innovations in fixed asset management: Enhancing efficiency through advanced tracking and maintenance systems. *International Journal of Science and Technology Research Archive, 07*(01), 019–026

Rajus, V. S., Boi-Ukeme, J., Jiresal, R. S., Risopatrón, N. A., Nojedehi, P., Wainer, G., ... & Fai, S. (2022). Measured data reliability for building performance and maintenance. *IEEE Instrumentation & Measurement Magazine, 25*(1), 55-61.

Salamit, N. N. A., & Wahid, E. A. Z. A. (2021). Implementation of The Computerized Maintenance Management System (CMMS) In Government Hospital Facility Management Services (FMS). *Progress in Engineering Application and Technology*, *2*(2), 204-213.

Sampaio, A. Z., Gomes, A. R., & Santos, J. P. (2012). Management of building supported on virtual interactive models: construction planning and preventive maintenance. *Journal of Information Technology in Construction (ITcon)*, *17*(8), 121-133.

Sándor, B., & Rajnai, Z. (2023, September). Smart Building IoT Cybersecurity: A Review of Threats and Mitigation Technique. In *2023 IEEE 21st Jubilee International Symposium on Intelligent Systems and Informatics (SISY)* (pp. 000321-000326). IEEE.

Schein, J. (2007). An information model for building automation systems. *Automation in construction*, *16*(2), 125-139.

Seun, E., Babajide, G., Taye, F., Aderonke, A., Olabode, B. O. (2023). Impact of Information Systems on Operational Efficiency: A Comprehensive Analysis. *Indian journal of computer science and engineering, 14*(4), 661-673. doi: 10.21817/indjcse/2023/v14i4/231404013

Shahi, C., & Sinha, M. (2021). Digital transformation: challenges faced by organizations and their potential solutions. *International Journal of Innovation Science, 13*(1), 17-33.

Sharma, M., Paliwal, T., & Baniwal, P. (2024). *Challenges in Digital Transformation and Automation for Industry 4.0. In AI-Driven IoT Systems for Industry 4.0* (pp. 143-163). CRC Press.

Shin, J. H., & Jun, H. B. (2015). On condition-based maintenance policy. *Journal of Computational Design and Engineering*, *2*(2), 119-127. DOI: 10.1016/j.jcde.2014.12.006

Solla, M., Shaarani, A. S. M., Mustaffa, A. A., & Ismail, L. H. (2020, May). Integration of BIM and Archibus for Facility Management (FM) in FKAAS, UTHM Building. In *IOP Conference Series: Earth and Environmental Science* (Vol. 498, No. 1, p. 012088). IOP Publishing.

Stanford, H. W. (2021). *Effective building maintenance: Protection of capital assets*. River Publishers.

Syamsuddin, S., Marsudi, S., Hasanuddin, B., Umar, A., & Suprayitno, D. (2024). Adapting to Digital Transformation: Challenges and Strategies for Traditional Businesses. *Global International Journal of Innovative Research, 2*(3), 704-711.

Tang, S., Shelden, D. R., Eastman, C. M., Pishdad-Bozorgi, P., & Gao, X. (2020). BIM assisted Building Automation System information exchange using BACnet and IFC. *Automation in Construction*, *110*, 103049.

Tu, K. J., & Chang, W. C. (2017). An implementation study of transferring project data from a BIM software to a FM software via the COBie standard. *Welcome to Delegates IRC 2017*, 382.

Tulenheimo, R. (2015). Challenges of implementing new technologies in the world of BIM–Case study from construction engineering industry in Finland. *Procedia Economics and Finance*, *21*, 469-477. DOI: 10.1016/s2212-5671(15)00201-4

Vanlande, R., Nicolle, C., & Cruz, C. (2008). IFC and building lifecycle management. *Automation in construction, 18*(1), 70-78.

Wang, Y., Zhu, J., & Wei, B. (2022). Domestic and International Mainstream BIM Software Application and Comparison Study. In *Journal of Physics: Conference Series* (Vol. 2185, No. 1, p. 012088). IOP Publishing.

Wan, S., Li, D., Gao, J., Roy, R., & Tong, Y. (2017). Process and knowledge management in a collaborative maintenance planning system for high value machine tools. *Computers in Industry*, *84*, 14-24. DOI: 10.1016/j.compind.2016.11.002

Wong, J. K. W., Ge, J., & He, S. X. (2018). Digitisation in facilities management: A literature review and future research directions. *Automation in Construction*, *92*, 312-326. DOI: 10.1016/j.autcon.2018.04.006

Xiao, F., & Fan, C. (2014). Data mining in building automation system for improving building operational performance. *Energy and buildings*, *75*, 109-118.

Yahya, M. R., & Ibrahim, M. N. (2011, October). Building maintenance policy issues in high rise commercial buildings. In *2nd International Conference on Public Policy & Social Sciences (ICoPS), Kuching, Sarawak, Malaysia* (Vol. 31).

Yang, R., & Wang, L. (2012). Multi-objective optimisation for decision-making of energy and comfort management in building automation and control. *Sustainable Cities and Society*, *2*(1), 1-7.

Yoon, J. H., & Cha, H. S. (2017). Location-based facility management system framework using 3D-BIM on commercial office buildings. In *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction* (Vol. 34). IAARC Publications.

Zare, A., Feylizadeh, M., Mahmoudi, A., & Liu, S. (2018). Suitable computerised maintenance management system selection using grey group TOPSIS and fuzzy group VIKOR: a case study. *Decision Science Letters*, *7*(4), 341-358. DOI: 10.5267/j.dsl.2018.3.002

Zhang, Y. F., Yokota, H., Miao, P. Y., & Zhu, Y. L. (2021). Application of Knowledge Management and BIM Technology for Maintenance Management of Concrete Structures. In *EASEC16: Proceedings of the 16th East Asian-Pacific Conference on Structural Engineering and Construction*, 2019 (pp. 2129-2138). Springer Singapore.

Zawawi, E. M. A., Kamaruzzaman, S. N., Ali, A. S., & Sulaiman, R. (2010). Assessment of building maintenance management in Malaysia: Resolving using a solution diagram. *Journal of Retail & Leisure Property*, *9*(4), 349-356. DOI: 10.1057/rlp.2010.16