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Internet of Things (IoT) Impact on Facility Management of Office Buildings: A Qualitative Study

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Abstract: Most office buildings are not optimal due to the slow adoption of the Internet of Things (IoT) in facility management (FM) processes. As a result, the collected data, information, and system processing are not completely exploited. In consequence, the impacts of IoT on FM are expected to intensify soon. However, the integration of IoT and FM in implementing new technologies, capabilities for high-quality service delivery, and changes in management approaches in office buildings are still low. This study intends to explore IoT's positive and negative impacts on the FM of office buildings. The data was collected from open-ended interviews with 20 FM professionals and analyzed using the thematic analysis method to identify the impacts of IoT on FM office buildings. The findings show that IoT positively and negatively impacts the FM of office buildings in terms of people, system, safety, time, and cost. The study findings can assist key FM players in developing and creating a better convergence of people, place, environment, and process for business and services in office buildings by considering impacts.

Keywords: Internet of Things, Facility Management, Office Buildings.

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1. Introduction

Industry after industry, all around the world, has been revolutionised by the internet of things (IoT) as it has developed and been more widely used (Verma et al., 2021; Brozzi et al., 2020; Agrifoglio et al., 2017). The IoT equips physical things with sensors, computing power, software, and other technologies that enable data interchange with other systems and devices through the internet or other communications networks (Schilit and Theimer, 1994; Welbourne et al., 2009; Manino et al., 2021).

IoT is being adopted in office buildings as it can develop quick and cost-efficient facility management (FM) systems, including processes related to sensing, processing, and computing information (Ahmed et al., 2017). When the IoT is adopted in FM, they collect, deliver and manage the: i) real-time results and condition of every feature and component of a facility and its operation; ii) the placement of people and things; iii) the processing and analysis system for facilities, which includes determining the risk status of assets or facilities; and iv) the performance of preventative and condition-based maintenance.

Despite the fact that there have been several past studies on integrating BIM and IoT for FM (Wong et al., 2018; Edirisinghe and Woo, 2020; Atta and Talamo, 2020; Valinejadshoubi et al., 2021), IoT opportunities, challenges, barriers and solutions in FM and IoT on maintenance based in FM are still lacking (Zikria et al., 2021; Durdyey et al., 2022; Tedeschi et al., 2017; Chen et al., 2019; Villa et al., 2021). It may be due to cybersecurity threats and privacy challenges. It has been mentioned in National Strategic IoT Roadmap (2012-2020) that the lack of a complete IoT ecosystem, the absence of standardisation in the technologies of present-day IoT components, and national security and privacy concerns are the major obstacles to the establishment of the national IoT business. Prior works mostly focus on the significance, importance, benefits, challenges, application, implementation, and adoption of IoT in various fields. However, they lack a thorough evaluation and analysis of IoT's effects on FM.

In Malaysia, the initiatives are still in emerging stages, and the implementation or adoption of IoT is still low due to the impacts of various aspects. The forecasts on impacts of IoT in FM of existing office buildings still do not exist. Therefore, this study intents to fill this gap by identifying and analyzing IoT's positive and negative impacts on FM of office buildings.

2. Literature Review

2.1. IoT's Impact on Facilities Management

Most FM lacks space to develop IoT. According to Valinejadshoubi et al. (2021) the problem in sensor-based FM and the reason facilities moves towards inefficient management is due to the lack of details on visual information about the built facility. The deployment of the IoT while continuously monitoring and maintaining is critical. It has a significant impact on building operations and end-user work performance. Hoxha et al. (2021) argue that the building industry and FM professional has not yet realized the importance of adopting IoT technologies in their building as they create the complex configuration of the connection between physical asset of IoT and dynamic maintenance networks. Johannes et al. (2021) found fifteen barriers and seventeen smart-maintenance drivers and created the maturity dimensions. Based on eight maturity dimensions of smart maintenance (IoT system) that have been scientifically identified and validated, it has given a better understanding of maintenance engineering and linked data platform as its requirements for engineering and managerial decision-making (National Institute of Standards and Technology (NIST), 2020). The capital facilities in the United States (US) suffer the most from a lack of well-integrated information management systems and storage documentation methodologies when it comes to efficiency-related interoperability between FM communication, engineering, and computer-aided design systems.

2.2. Facility Management's Adoption and Implementation of IoT

Many researchers have studied and still conduct breadth and depth works on topics that direct the integration of IoT in smart buildings. Jia et al. (2019), emphasized two key areas that are important for assessing the challenges related to IoT: i) the communication-enabling technology and its challenges and ii) difficulties with widely utilized sensing technology in the building and construction industry. The problems will have an unpredictable influence on the entire building operation and end-user. Researchers face the following obstacles and problems in a varied domain: i) security and privacy issues, ii) data gathering, processing, and storage issues, and iii) feasibility, adaptability, and practicality issues.

Thakur and Thakur (2019), investigated how IoT adoption impacts organizational and corporate business culture by cross-referencing company organization asset management activities to skills required and improvements with IoT adoption, by identifying organizational structures, policies, and decision-making business processes, and by analyzing how IoT adoption brings decision-making changes regarding the on-technology choices of an asset management organization.

Besides, many researchers have studied relevant topics on IoT and FM in different types of buildings, such as hotels, restaurants, campuses, and manufacturing industries. However, there is no work on office buildings. (Hidayat et al., 2021; Kalsoom et al., 2021; Turner et al., 2022; Mercan et al., 2020).

2.3. Study's Positioning

The existing literature on IoT-FM has not considered the impacts, especially for office buildings. Most of the works focused on the issues, challenges, implementation, adoption, and importance of integration of IoT and FM, and the evolution of IoT in different industries and sectors such as manufacturing, production, automotive, hospital, construction, and agriculture (Talavera et al., 2017; Lopez and Posada, 2019; Ibrahim et al., 2019; Bajaj et al., 2018). Although many works have been conducted, work on the topic of IoT impacts on FM of office buildings is lacking. Many countries have studied the advent, enhancement, and implementation of IoT technologies in their sectors, including China (Gao and Bai, 2014), The Netherlands (Kahlert, 2016), Korea (Shin, 2017), India (Chatterjee et al., 2018), The United States (Aldossari and Sidorova, 2020), Jordan (Al-Momani et al., 2018), Taiwan (Hsu and Lin, 2016) and Malaysia (Termizi et al., 2016). However, the development of IoT in FM and the involvement of FM towards adoption are still low. The reasons highlighted by IFMA (2018), Suriyarachchi et al. (2019), and Marocco and Garofolo (2021) are:

- Lack of understanding of FM and IoT prevents the organizations and building functionality in implementing comprehensive FM strategies.
- A lack of suitable and particular recovery processes in the event of difficulties with Internet of Things (IoT) technologies and a lack of technical understanding and experience on the part of FM when dealing with such technologies.
- Lack of guidelines on FM that measure the performance achievements due to the absence of a uniform KPIS system that focuses on adopting IoT to the desired level.
- Slow-moving plans towards appropriate building maintenance and operation techniques are due to i) cost and budget consideration, ii) inappropriate FM planning to adopt IoT, and iii) low sensitivity of sustainability.

To conclude, the current literature on IoT is more specific to challenges and strategies. Malaysian researchers also focus less on IoT in FM areas, including the impacts, importance and strategies that are align with Malaysian policies. In addition, there is no work on the IoT impacts on FM, specifically in office buildings.

Consequently, this study aims to fill the gap by identifying the IoT's impact on FM office buildings in Malaysia and highlighting the positive and negative impacts on private and government office buildings.

3. Methodology

3.1. Research Methods

This study employs a qualitative research approach for gathering and analyzing non-numerical data. The qualitative technique, according to Bhat (2019) comprises performing either i) structured interviews, ii) semi-structured interviews, or iii) unstructured interviews that h to narrow down a broad field of research into an unproblematic researchable topic. Generally, a semi-structured or open-ended interview is used widely as a primary research method by many disciplines in which the topics of research have been identified as the question to be asked by individual participants (Roulston and Choi, 2018). Therefore, this study used the open-ended interview method to gather data and information. Fig. 1 shows the research methodology for exploring and identifying IoT's positive and negative impacts on the FM of office buildings.

3.2. Data Collection

An open-ended interview was conducted with twenty respective FM professionals of office buildings in Malaysia, as shown in Table 1. This approach has been used to identify strategies for improving organizational capabilities in digital construction (Munianday et al., 2022) and addressing pandemic impacts on construction projects (Zamani et al., 2022). The selection of respondents is based on their involvement in managing the operations of building facilities and systems since they have acquired knowledge and experience on the impacts of IoT on FM in office buildings. The main two questions asked are i) What are the positive impacts of IoT on FM for their office building? and ii) What are the negative impacts of IoT on FM for of their office building? Following the interview, a summary of the respondent's responses was sent to the respondent for validation. As the data collected was saturated, 20 interviews were used in the data gathering (i.e., data saturation). Data saturation is commonly used in qualitative research methods in assessing needed data sample sizes when there are no additional points and the data findings are in a redundant state (Hennink and Kaiser, 2022). Several works have found data saturation in sample sizes below 20 (O'Brien et al., 2019; Saunders et al., 2017). The minimal number of respondents required for data analysis was therefore reached, and the data obtained was saturated.

3.3. Data Analysis

Thematic analysis was used to analyze the interview data. Thematic analysis is a technique for detecting, evaluating, and reporting patterns and recurring themes within collected data (Majumdar, 2022). The approach was also adopted by Radzi et al. (2019) and Zamani et al. (2022) to analyze their interview data. It is not a linear process but a recursive process that moves back (Ddovskiy, 2019). The analysis consists of six phases (Masudi et al., 2022) and according to Neuendorf (2018) the steps to conduct the thematic analysis to produce output are;

i) Phase 1: Familiarize with the data
   Identifying and understanding the meaning, patterns, and themes.

ii) Phase 2: Generating initial codes
   Listing out the related ideas for transcribing and producing the possible codes involved in the data

iii) Phase 3: Theme exploration
   Sorting the different codes into prospective themes and gathering pertinent code data to extract depending on the themes.

iv) Phase 4: Reviewing themes
   Reviewing the code by extracting and analyzing the themes that suit the research content analysis.

v) Phase 5: Theme definition and naming
   Determining the part of the data that captures the themes by defining and refining themes utilized for analysis.

vi) Phase 6: Produce the report
   Interpretations focus on themes and demonstrate the themes to develop the overall output in matrix table and cognitive map format.

4. Results and Discussion

The findings identified five key themes of IoT's positive and negative impacts on FM of office buildings. The themes are People, Systems, Safety, Cost and Time. The key themes and sub-themes are summarized in Fig. 2.

4.1. Positive Impacts of IoT

Table 2 shows five elements that have positively impacted IoT's work and building performance. The elements are People, System, Safety, Cost, and Time.

4.1.1. People

According to interviewee responses, one of the positive impacts of IoT is People. It is described as end-users or employees. This element is related to and positively impacts employee workflow, comforts of the workplace, performance, environment, and productivity, as shown in the three subthemes in Table 2.

- **Workplace productivity increased**

Productivity can be achieved when workplace space, environment, and safety are maintained and enable employees to feel comfortable and safe to work. Workplace productivity depends on how the employers maintain the buildings and their functions for employees to be productive at the workplace. IoT provides better insight into operations, equipment, or component and access to real-time data. Hence, the Integrated Building Management System (iBMS) with the advent of IoT positively impacted employees to create productivity, work in convenience and improve sustainability.

- **Employees' performance increased**

In the *People* element, the most positive impact of IoT has increased employee performance. It makes their work accomplished in a frictionless way and with minimum mistakes or faults. Furthermore, it can reduce staff turnover.

- **Employees' physical comfort increased**

With the convergence of IoT and Building Management Systems (BMS), the sensor system is developed to collect and analyze rich data sources and provide a realistic overview of building operations. Most of the equipment and components in buildings are fixed with sensors to monitor, control, and stop or switch off the assets when not in use. Every employee will look into comfortable space, good air quality, lighting intensity, soundlessness, ambient temperature, and humidity level during office hours. Hence, the smart sensor of the IoT system helps reduce environmental disruptions and improve space utilization by reading real-time data and continuous tracking to protect employees and assets.

4.1.2. Systems

IoT has positively impacted *Systems* where IoT devices in the existing system work wireless that are connected to an internet network to send, receive, analyze and transmit data. The system element describes internet network coverage, mobile remoting system, and integrated data storage system, as shown in Table 2.

- **Coverage network is widely used**

IoT works on a network for communication, transferring information seamlessly via devices and equipment. It acts as a bridge to transfer points and convert data as it passes between systems. Selection of the network shall be according to the size of employees, devices, and areas and receive data and information without interruption.

- **Mobile remote access system for employees**

It is good to have a mobile remote access system to monitor, control, and adjustment on assets. The facility team or management could receive regular update regarding maintenance for assets and alert on any emergency that requires action immediately. This helps to reduce the impact of system downtime and operational costs. Managing a thousand devices with a remote access system should be seamless and trouble-free.

Table 1. Profile of respondents

No. of Respondents (R)	Position	Company size (approximate number of employees)
R1	Facility Developer	11,500
R2	Assistant Facilities Manager	220
R3	System Analyst Engineer (BMS)	500
R4	Process Engineer (O&M system component)	10,000
R5	Maintenance Engineer	280
R6	Senior Engineer Facility Management	10,500
R7	Project Facility Engineer (BMS)	10,500
R8	Senior Assistant Engineer, O&M department	250
R9	Building Operation Executive	5,000
R10	Maintenance Engineer	1,000
R11	Engineer Quality Assurance	20,000
R12	Operation Assistant Engineer	20,000
R13	Maintenance Operation Manager	180
R14	Facility Engineer, Building Department	250
R15	Facilities Maintenance Manager	200
R16	Facilities Maintenance Engineer	10,000
R17	Reliability Engineer (O&M)	1,000
R18	Senior Technician (M&E)	350
R19	Assistant Facilities Manager	2,000
R20	Senior Facilities Engineer	10,000

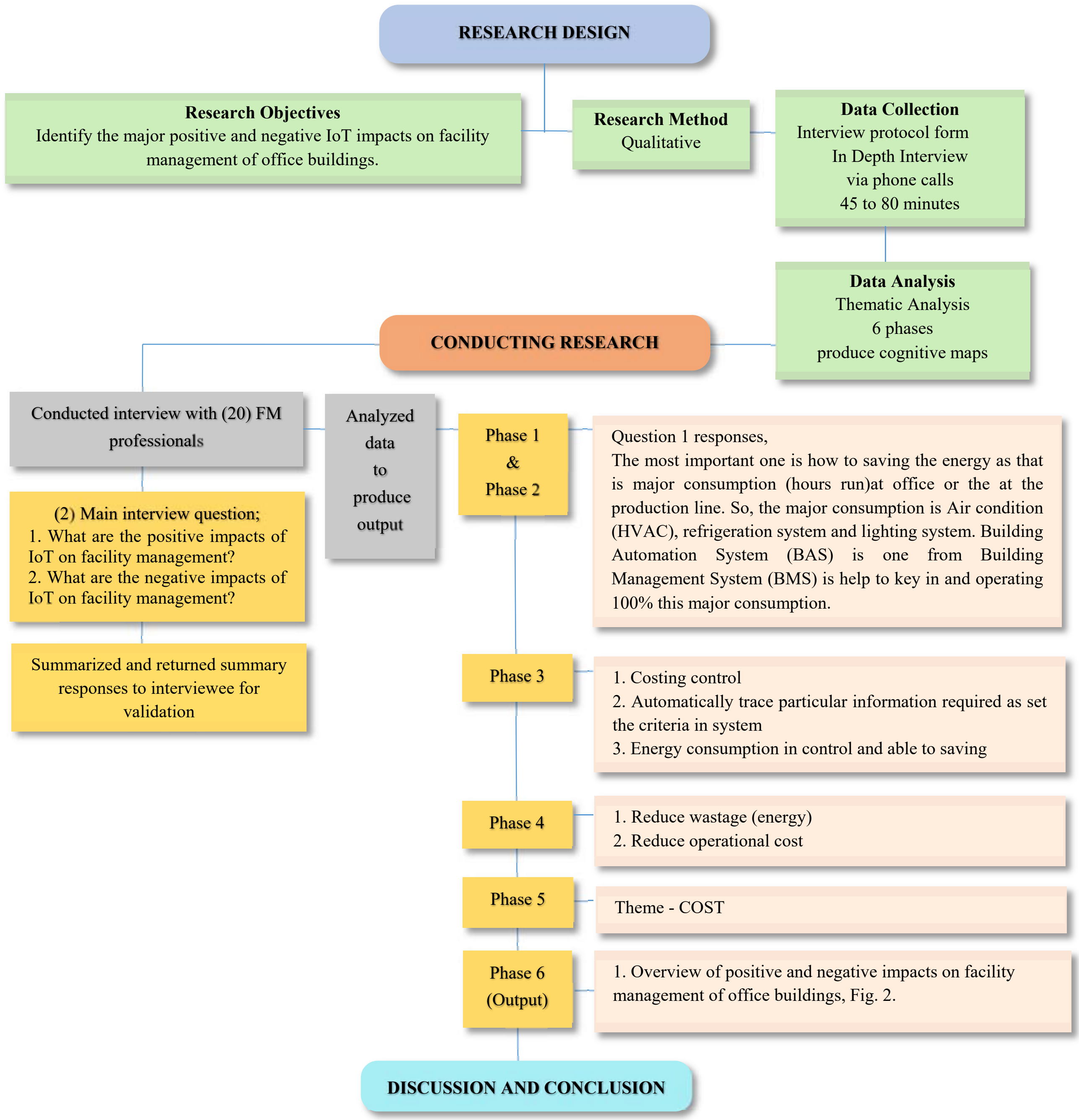

Fig. 1. Research methodology

- **Reliability of data storage system**

Every data requires physical storage space, but most of the devices and equipment remote servers now require digital consent. It depends on how big data can store, the number of devices, and the prediction of the amount of cloud and edge computing solutions needed. This cloud platform will provide data collecting with real-time intelligence monitoring and control.

4.1.3. Safety

IoT is a convenient device to strengthen system security and physical safety. The invention of IoT helps in terms of real-time security alerts and proactiveness when dealing with cybersecurity threats. The invention of IoT has brought about the system, workplace, and physical safety through improved monitoring of possible risks, environmental monitoring equipment, health monitoring technology, rescue operation system, and fire safety sensor system. The elements are shown in the three subthemes in Table 2.

- **Security technology for building and system improved**

IoT security technology includes safety that protects the system from breaches and threats, helps to fix vulnerabilities, and identifies risks to assets and employees while monitoring. Security systems are needed to monitor possible IoT devices or equipment risks before ill-fated accidents occur. It allows FM to do proactive action according to predictive maintenance data patterns.

Table 2. Positive impacts of IoT on FM of office buildings

Themes	Subthemes	Respondent																				Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
People	Workplace productivity increased	√	√			√	√	√		√	√		√	√	√		√				√	12
	Employees performance increased	√	√	√	√		√	√			√	√			√	√	√	√	√	√	√	15
	Employees physical comfort improved	√			√	√				√								√				5
System	Coverage of the network is widely used	√								√												2
	Mobile remote access system for employees			√																		1
	Reliability of data storage system			√	√							√	√								√	5
Safety	Security technology for building and system improved			√		√	√															3
	Safety automate responses system for emergency					√																1
	Workplace and employees' hygiene improved					√																1
Cost	Numbers of workforce reduced	√				√	√							√	√	√	√	√	√	√	√	11
	Wastage reduced																					
	i Energy	√					√		√					√		√						5
	ii Water	√																				1
	iii Paper	√																				1
	Low maintenance work	√									√											2
	Operational cost reduced									√						√						2
Time	Manual works reduced		√																			1

- **Safety automates response system for emergencies**

This system with IoT helps the FM team access information that will monitor and prevent any risks such as unexpected accidents, injuries, losses, damages, or other safety issues in the workplace. Fire accidents have become a serious issue and may occur due to the high heat temperature of the asset or working area. IoT devices allow for the collection of real-time temperature rise and exact locations, which may cause critical situations by identifying as early as possible before occurring.

- **Workplace and employees' hygiene improved**

IoT inventions mainly focus on reducing human intervention that helps control the spread of germs and infections. IoT sensor devices help to detect human movement to the system assets to work as set according to functionality.

4.1.4. Costs

Implementing IoT can reduce costs and minimize unexpected downtime. Most companies that use IoT devices are experiencing an increase in growth by saving and making money simultaneously. More costs can be saved up with IoT on maintenance systems, energy monitoring systems, and labor costs (revenue systems).

- **Numbers of manpower reduced**

IoT can save labor costs and boost profit by automatically revolutionizing the monitoring and checking operation process. The workforce is less required, especially on technical parts in which the main tasks are inspection, monitoring, adjustment controlling, and daily maintenance. IoT can replace these workmen with sensor devices to maintain the performance of assets perfectly, even in complex simulations. It saves labor costs and time, allowing the employee to focus on other strategic tasks.

- **Wastage reduced**

Cost can be reduced by minimizing the wastage of energy, water, and paper through integration with IoT devices and integrated building systems. The building depends on the energy system with proper design and effective operations and maintenance. For paper wastage, IoT cloud system and edge computing system helps to cut cost and reduce the space of rack to keep thousands of files and document papers, even a few past years' records. Water can be minimized by implementing a smart sensor system on equipment to control water use.

- **Low maintenance works**

IoT can save facility teams from daily or scheduled maintenance on assets because IoT supports predictive maintenance. With internet connectivity and sensor embedded in assets, maintaining the assets from failure, performing maintenance only when required, and giving early trigger notifications when a safe operating limit is breached helps save up costs from replacing assets.

- **Operational cost reduced**

Automatic operational processes and work associated with IoT devices will deliver an accurate and vast status on the network. The manual processes become less feasible by centralizing and automating operation that works on system assets. The cost of operation is reduced by cutting the time and the human error activities inherent in the setup or adjusting work.

4.1.5. Time

Less work on monitoring, controlling, managing, and low time consumption can increase company profit. The employees can focus on other important tasks, either planning, improvising, or developing the design system to work more functionally.

- **Manual work reduced**

IoT can reduce human activities directly to the system or asset control. It can deliver data and information rapidly and manage overall system activities via a dashboard from a desk table.

4.2. Negative Impacts of IoT

Table 3 shows five elements that negatively impacted IoT's work and building performance. The elements are People, System, Safety, Cost, and Time.

4.2.1. People

According to themes shown in Table 3, the negative impact of implementing IoT under People is divided into six subthemes: work performance, process and system functionality, accessibility to the system, career opportunities, employee capabilities level, and organization profit.

- **Affect employees' performance**

IoT devices run on an internet connection. When many employees use one system simultaneously, the system is buffering. It distracts the workflow of gathering or collecting data. It may also affect other functions of a system when IoT devices are fixed as interconnected. Other than that, live interaction communication among employees or top management is getting less since IoT updates the overall process of machines via the system. Discussion or reviewing process will be conducted virtually among employees. Hence, the productivity and performance of employees are affected due to slow processes on machines, less opportunity to grow the network, and low environmental quality.

- **Slow down the process and efficiency of the system**

Competency to handle and manage IoT is still lacking due to the intricate navigation of the system. It can cause failure on assets due to improper maintenance. Suppose a breakdown or failure occurs on IoT devices. In that case, an external supplier is required to rectify the issue due to a lack of competent and knowledgeable people in dealing with IoT technologies. Hence, the efficiency of the system and process decreased.

- **Unemployment rate increased**

Work opportunities will become less when IoT technologies can replace employees for manual processes work to monitor and maintain the company assets. IoT automatically can run assets and set up the devices everything according to the requirement of the system. IoT cuts the workforce for daily maintenance or predictive maintenance in tracking the status of devices, forecasting the consumption and demand patterns, and detecting what and where the failure or breakdown occurs.

- **Reduction of employee's self-reliance on responsibility**

Another negative impact on employees is the possibility of losing an independent attitude toward responsibility as IoT can run a system of machines without human intervention. Therefore, employees' high dependency on the IoT will cause production and routine work to be disrupted when losing an internet connection or when IoT devices break down. Employees who depend on IoT technologies may have less initiative to deal with IoT when it is not working.

- **Loss revenue for building operation**

When building assets and operations run smoothly and function well, company profit will increase as building performance and employee productivity improve from adopting IoT technologies. However, companies that do not trust IoT technologies will face revenue loss due to unexpected failure or defects, slow functionality, and requiring longer operation times to collect and gather the data manually.

4.2.2. Systems

The system is related to functionality, communication distraction, interrupted maintenance, and inaccurate equipment data readings.

- **System functionality process delayed**

When a building operates with IoT devices, it requires high energy, especially when computational facilities use a big system to gather, collect, and analyze data. The integrated system with devices required frequent updating of the software system on time or in advance to avoid any delay or distraction.

- **Unreliable internet connection**

IoT works through the Internet and other network connections to various and multiple sensors, devices, and things. Without an internet network connection, IoT technologies cannot function, and the ability to process, gather or collect data get distracted.

- **Discontinuation system on maintenance time**

During breakdown or maintenance activities or any unexpected incident, IoT devices and sensors are not functioning, and there is no backup system to support them. As a result, running the system to collect data may require a manual process.

- **Inaccurate system data readings**

Data processes could be inaccurate due to the devices, and the sensor runs irregularly due to faulty. It takes time to replace or redesign it. It can turn into emissions, uncertain output, and performance issues.

4.2.3. Safety

The safety of IoT technologies is usually related to cybersecurity for data and files in cloud and edge computing systems and private and confidential matters of company details.

- **System vulnerable to cyberattacks**

Cyberattacks can happen from time to time in managing and overcoming malware or data leaks. The attacks may start from network connections used to run IoT devices and sensors.

Table 3. Negative impacts of IoT on FM of office buildings

Themes	Subthemes	Respondent																				Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
People	Affect employee's performance	√					√		√	√								√	√			6
	Slow down the process and efficiency of the system		√	√	√	√	√		√					√	√		√					9
	Unemployment rate increased						√															1
	Reduction of employees' self-reliance on responsibility																			√		1
	Loss of revenue for building operations											√									√	2
System	System functionality process delayed			√	√			√							√							4
	Unreliable internet connection						√									√						2
	Discontinuation system on maintenance time				√		√	√		√								√				5
	Inaccurate system data readings									√			√						√		√	4
Safety	System vulnerable to cyberattacks	√									√	√	√		√	√		√		√	√	9
Cost	Return of Investment decreased		√		√	√			√				√	√							√	7
	Operational building system in risky		√							√												2
Time	Building ecosystem disrupted	√	√			√			√												√	5

4.2.4. Costs

IoT implementation may affect company financial performance related to managing building assets and generating revenues.

- **Return of investment decreased**

IoT technologies are developed with microelements and materials thus, the cost will be high according to the quality and capabilities of IoT devices and sensors. Some companies are still not confident in adopting IoT because of the high budget required to implement and handle its embedded-on assets. Even maintenance requires an adequate budget to maintain the IoT devices to function well.

- **Operational building is risky**

Without a proper automated building system to control and handle overall building operation, the building will be perceived as risky because the things embedded into our assets shall be of high quality and perform well, reducing the maintenance work. However, it requires a high budget.

4.2.5. Time

Time is related to and impacted by all areas; employee performance, building operations, adoption of IoT, and planning and development stages for company revenues. However, maintaining the utilization of Time depends on how fast management takes action in planning to execute the smart system for a better building ecosystem.

- **Building ecosystem disrupted**

Management delays to execute IoT systems in their company due to concern about costs and security matters rather than optimizing employee experience and physical environment with the IoT platform.

5. Conclusion

This study aims to overview the positive and negative IoT impacts on FM of office buildings and identify how IoT technologies, platforms, and applications have positively and negatively impacted employee performance and building operations. According to Fig. 2, IoT has significantly impacted the employees to perform better in their daily work schedule. It also makes the FM teams maintain and handle the IoT of the building operation of company assets and systems more effectively. It positively impacted employee performance and building operations by reducing employee movement, centralizing an integrated system, creating a healthy environment, and saving the environment by reducing wastage and low maintenance inspection or onsite work. However, the FM team respondents also mentioned the negative impacts of implementing IoT in their office buildings. The negative impacts are due to insufficient budget allocation, cyberattacks, poor quality of elements, unreliable mindset to adopt IoT, lack of job opportunities requiring a long duration to execute IoT, and incompetency of persons to handle IoT.

Therefore, the overall findings show conversely between positive and negative output based on the respondent company experiences and scopes. The finding has several managerial, theoretical, and practical implications. First, the study provides a list of IoT impacts on FM of office buildings. These findings identify and justify the need for continual growth revenue, consistent training and professional development about IoT technology, planning, and development of the effectiveness of digital transformation to be a strategic corporate function. Second, these findings are essential to the FM team to improve the understanding and emphasize IoT's positive and negative impacts to produce new strategies and expand the range of quality services for employee performance and building operations. It helps to overcome the complexity of technology in the office building working environment by considering the impacts with a predictive approach. Third, this will help industry practitioners and research domain to develop strategic plans to improve the positive impacts towards productivity and effectiveness of building asset function and develop a strategic plan to reduce the negative impacts to foster and spur IoT adoption and reliability on it for office building by FM.

Despite the implications of the findings and the main aim being achieved, some limitations were identified. First, the respondents are only 20. However, the applied data saturation and redundancy of the theme have been reached, and. Second, this study is limited to statistical analysis as it employed a qualitative method and conducted interviews as data collection. However, researchers of high intention and aim can empirically address future research in identifying and obtaining more comprehensive data to determine an appropriate strategic plan for the impacts with statistical methodological direction.

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Author Contributions

Jaya Devi Anathan contributed to conception, methodology, data collecting, data analysis, and writing-first manuscript preparation. Liyana Mohamed Yusof contributed to supervision, project management, editing of the manuscript and validation. Rahimi A. Rahman contributed to project management, funding procurement, and editing of the manuscript. All of the authors read the manuscript and agreed with it before it was sent in and published.

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Institutional Review Board Statement

No applicable.

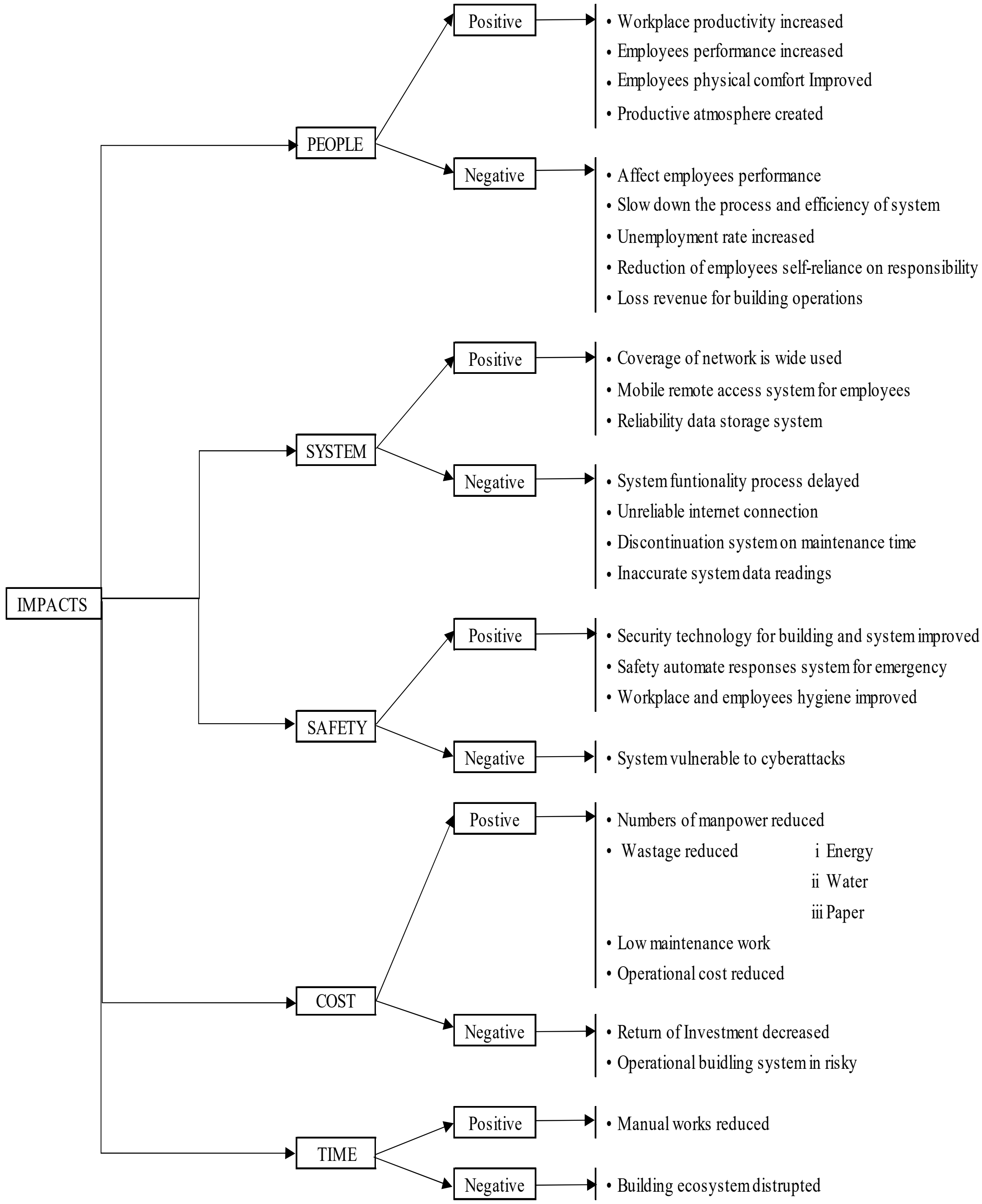

Fig. 2. Positive and negative impacts of IoT on facility management of office building

References

Agrifoglio, R., Cannavale, C., Laurenza, E., and Metallo, C. (2017). How emerging digital technologies affect operations management through co-creation. Empirical evidence from the maritime industry. *Production Planning and Control*, 28, 1298 - 1306.

Ahmed, V., Tezel, A., Aziz, Z., and Sibley, M. (2017). The future of Big Data in facilities management: opportunities and challenges. *Facilities*, 35(13/14), 725-745.

Aldossari, M. Q. and Sidorova, A. (2020). Consumer acceptance of Internet of Things (IoT): Smart home context. *Journal of Computer Information Systems*, 60(6), 507-517.

Al-Momani, A. M., Mahmoud, M. A., and Ahmad, M. S. (2018). Factors that influence the acceptance of Internet of things services by customers of telecommunication companies in Jordan. *Journal of Organizational and End User Computing (JOEUC)*, 30(4), 51-63.

Atta, N. and Talamo, C. (2020). Digital transformation in facility management (FM). IoT and big data for service innovation. In *Digital Transformation of the Design, Construction and Management Processes of the Built Environment* (pp. 267-278). Springer, Cham.

Bajaj, R. K., Rao, M., and Agrawal, H. (2018). Internet of things (IoT) in the smart automotive sector: a review. In *IOSR Journal of Computer Engineering (IOSR-JCE), conference on recent trends in computer engineering (CRTCE)* (pp. 36-44).

Bhat, A. (2019). QuestionPro. Retrieved April 27, 2019, from Types and Methods of Interviews in Research: https://www.questionpro.com/blog/types-of-interviews/

Brozzi, R., Forti, D., Rauch, E., and Matt, D. T. (2020). The advantages of industry 4.0 applications for sustainability: results from a sample of manufacturing companies. *Sustainability*, 12(9), 3647.

Chatterjee, S., Kar, A. K., and Gupta, M. P. (2018). Success of IoT in smart cities of India: An empirical analysis. *Government Information Quarterly*, 35(3), 349-361.

Chen, W., Cheng, J. C., and Tan, Y. (2019). BIM-and IoT-Based Data-Driven Decision Support System for Predictive Maintenance of Building Facilities. In *Innovative Production and Construction: Transforming Construction Through Emerging Technologies* (pp. 429-447).

Dias, J., Restivo, A., and Ferreira, H. (2022). Designing and constructing internet-of-things systems: An overview of the ecosystem. *Internet of Things*, 19, 100529.

Dudovskiy, J. (2019). Inductive Approach (Inductive Reasoning) - Research-Methodology.

Durdyev, S., Ashour, M., Connelly, S., and Mahdiyar, A. (2022). Barriers to the implementation of Building Information Modelling (BIM) for facility management. *Journal of Building Engineering*, 46, 103736.

Edirisinghe, R. and Woo, J. (2020). BIM-based performance monitoring for smart building management. *Facilities*, 39(1/2), 19-35.

Gao, L. and Bai, X. (2014). A unified perspective on the factors influencing consumer acceptance of Internet of things technology. *Asia Pacific Journal of Marketing and Logistics*.

Gubbi, J., Buyya, R., Marusic, S., and Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645-1660.

Hennink, M. and Kaiser, B. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science and Medicine*, 292, 114523.

Hidayat, W., Hendayun, M., Sastrosubroto, A., Hidayat, R., and Haris, S. (2021). Developing smart campus readiness instrument based on Pagliaro's smart campus model and smart city council's readiness framework. *Journal of Physics: Conference Series*, 1783(1), 012051.

Hoxha, V., Hoxha, D., and Hoxha, J. (2021). Current situation, challenges and future development directions of facilities management in Kosovo. *Property Management*, 40(3), 343-369.

Hsu, C. L. and Lin, J. C. C. (2016). An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives. *Computers in Human Behavior*, 62, 516-527.

Ibrahim, F., Esa, M., and A. Rahman, R. (2021). The Adoption of IoT in the Malaysian Construction Industry: Towards Construction 4.0. *International Journal of Sustainable Construction Engineering and Technology*, 12(1).

Jia, M., Komeily, A., Wang, Y., and Srinivasan, R. (2019). Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications. *Automation in Construction*, 101, 111-126.

Johannes, K., Theodorus Voordijk, J., Marias Adriaanse, A., and Aranda-Mena, G. (2021). Identifying Maturity Dimensions for Smart Maintenance Management of Constructed Assets: A Multiple Case Study. *Journal of Construction Engineering and Management*, 147(9).

Kahlert, M. (2016). *Understanding customer acceptance of Internet of Things services in retailing: an empirical study about the moderating effect of degree of technological autonomy and shopping motivations* (Master's thesis, University of Twente).

Kalsoom, T., Ahmed, S., Rafi-ul-Shan, P., Azmat, M., Akhtar, P., and Pervez, Z. et al. (2021). Impact of IoT on manufacturing industry 4.0: A new triangular systematic review. *Sustainability*, 13(22), 12506.

López de Lacalle and Posada. (2019). Special Issue on New Industry 4.0 Advances in Industrial IoT and Visual Computing for Manufacturing Processes. *Applied Sciences*, 9(20), 4323.

Majumdar, A. (2022). *Thematic Analysis in Qualitative Research*. Research Anthology on Innovative Research Methodologies and Utilization Across Multiple Disciplines.

Mannino, A., Dejaco, M., and Re Cecconi, F. (2021). Building information modelling and internet of things integration for facility management—literature review and future needs. *Applied Sciences*, 11(7), 3062.

Marocco, M. and Garofolo, I. (2021). Integrating disruptive technologies with facilities management: A literature review and future research directions. *Automation in Construction*, 131, 103917.

Masudi Far, P., Mossalanejad, A., and Azizi, M. (2022). A Framework for project portfolio strategic planning by utilizing thematic analysis method. *Industrial Management Journal*, 13(4), 634-663.

Mercan, S., Cain, L., Akkaya, K., Cebe, M., Uluagac, S., Alonso, M., and Cobanoglu, C. (2020). Improving the service industry with hyper-connectivity: IoT in hospitality. *International Journal of Contemporary Hospitality Management*, 33(1), 243-262.

Munianday, P., Radzi, A.R., Esa, M., and Rahman, R A. (2022). Optimal strategies for improving organizational BIM capabilities: PLS-SEM approach. *Journal of Management in Engineering*, 38, 04022015.

Neuendorf, K. A. (2018). *18 Content analysis and thematic analysis*. Advanced research methods for applied psychology: Design, analysis and reporting, 211. Retrieved 2 June 2019, from https://research-methodology.net/researchmethodology/research-approach/inductive-approach-2/

O'Brien, B., Tuohy, D., Fahy, A., and Markey, K. (2019). Home students' experiences of intercultural learning: A qualitative descriptive design. Nurse Education Today, 74, 25-30.

Radzi, A. R., Bokhari, H. R., Rahman, R. A., and Ayer, S. K. (2019). Key attributes of change agents for successful technology adoptions in construction companies: a thematic analysis. *Computing in Civil Engineering 2019: Data, Sensing, and Analytics*, 430, 437.

Roulston, K. and Choi, M. (2018). Qualitative interviews. The SAGE handbook of qualitative data collection, 233-249.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., and Bartlam, B., Bartlam, B., and Burroughs, H. (2017). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality and; Quantity*, 52(4), 1893-1907.

Schilit, B. and Theimer, M. (1994). Disseminating active map information to mobile hosts. *IEEE Network*, 8(5), 22-32.

Shin, D. H. (2017). Conceptualizing and measuring quality of experience of the Internet of things: Exploring how quality is perceived by users. *Information and Management*, 54(8), 998-1011.

Suriyarachchi, C., Waidyasekara, K. G. A. S., and Madhusanka, N. (2019, June). Integrating Internet of Things (IoT) and facilities manager in smart buildings: A conceptual framework. In *The 7th World Construction Symposium 2018: Built Asset Sustainability: Rethinking Design Construction and Operation* (Vol. 29, pp. 325-334).

Talavera, J., Tobón, L., Gómez, J., Culman, M., Aranda, J., and Parra, D. et al. (2017). Review of IoT applications in agro-industrial and environmental fields. *Computers and Electronics in Agriculture*, 142, 283-297.

Tedeschi, S., Mehnen, J., Tapoglou, N., and Roy, R. (2017). Secure IoT devices for the maintenance of machine tools. *Procedia Cirp*, 59, 150-155.

Termizi, A. A. A., Ahmad, N., Omar, M. F., Wahap, N. A., Zainal, D., and Ismail, N. M. (2016, June). Smart facility application: exploiting space technology for smart city solution. In *IOP Conference Series: Earth and Environmental Science* (Vol. 37, No. 1, p. 012049). IOP Publishing.

Thakur, R. and Thakur, A. (2019). Enabling technologies and applications of the internet of things. *SSRN Electronic Journal*.

The National Institute of Standards and Technology's (NIST) (2020), available at: www.nist.gov/

Turner, C., Okorie, O., Emmanouilidis, C., and Oyekan, J. (2022). Circular production and maintenance of automotive parts: An Internet of Things (IoT) data framework and practice review. *Computers in Industry*, 136, 103593.

Valinejadshoubi, M., Moselhi, O., and Bagchi, A., (2021). Integrating BIM into sensor-based facilities management operations. *Journal of Facilities Management*, 20(3), 385-400.

Verma, S., Kawamoto, Y., and Kato, N. (2021). A Smart Internet-wide Port Scan Approach for Improving IoT Security under Dynamic WLAN Environments. *IEEE Internet of Things Journal*, 1-1.

Villa, V., Naticchia, B., Bruno, G., Aliev, K., Piantanida, P., and Antonelli, D. (2021). IoT open-source architecture for the maintenance of building facilities. *Applied Sciences*, 11(12), 5374.

Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., and Raymer, S. et al. (2009). Building the internet of things using RFID: The RFID ecosystem experience. *IEEE Internet Computing*, 13(3), 48-55.

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

Zamani, S. H., Rahman, R. A., Fauzi, M. A., and Yusof, L. M. (2022). Government pandemic response strategies for AEC enterprises: Lessons from COVID-19. *Journal of Engineering, Design and Technology.*

Zamani, S. H., Rahman, R. A., Fauzi, M. A., and Yusof, L. M. (2021, February). Effect of COVID-19 on building construction projects: Impact and response mechanisms. In *IOP Conference Series: Earth and Environmental Science* (Vol. 682, No. 1, p. 012049). IOP Publishing.

Zikria, Y. B., Ali, R., Afzal, M. K., and Kim, S. W. (2021). Next-generation internet of things (IoT): Opportunities, challenges, and solutions. *Sensors*, 21(4), 1174.

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