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Relationship between Skill Requirements and Challenges of Internet of Things (IoT) Implementation in Construction Project

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Abstract

The research investigates the crucial relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects. Recognizing the transformative potential of IoT in enhancing project management and efficiency, the study aims to address obstacles that impede its successful integration. It delves into the relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects, shedding light on various aspects of its adoption. The objective is to identify specific skill requirements, examine challenges faced during IoT implementation, and analyze the correlation between skill requirements and challenges in construction projects. Utilizing a quantitative approach, the study gathered primary data through surveys distributed to G7 contractors in Johor, Malaysia. Moreover, secondary data from existing literature was reviewed to provide comprehensive insights. The SPSS software was employed for meticulous data analysis, facilitating the extraction of meaningful statistics such as frequency distributions. This analysis aids in understanding the relationship between IoT skills and challenges in construction projects. This research significantly contributes to the construction industry by providing clarity on the skill requirements necessary for successful IoT adoption. This enables businesses to effectively train their staff and enhance project outcomes. The study adds to the body of knowledge by evaluating precise skills required and offering insights into challenges hindering IoT integration. In conclusion, the study underscores the essential nature of IoT skills for successful implementation in construction projects, emphasizing the need for skill development to overcome challenges and contribute to the overall advancement of the industry.

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1. Introduction

1.1 Research Background

The research delves into the crucial relationship between skills requirements and challenges of the Internet of Things (IoT) in construction projects. It underscores the potential of IoT technology to revolutionize project management and enhance efficiency in construction by facilitating real-time monitoring, data collection, and analysis, leading to improved decision-making. However, the successful implementation of IoT is not without its challenges. The study emphasizes the involvement of experts from various fields, including civil engineering, electrical engineering, computer science, and data analytics. It highlights their pivotal roles in designing, deploying, and maintaining IoT devices, as well as processing collected data for practical insights (Chen & Li, 2020). Recognizing the advantages of IoT technology is vital for its seamless integration into construction projects. Real-time monitoring provides insights into project status and potential issues, enabling the timely resolution of structural irregularities. Furthermore, IoT enhances safety on construction sites by identifying risks and facilitating prompt responses. It is also acknowledged for increasing productivity, achieving cost savings, and improving decision-making in construction projects (El-Saadani *et al.*, 2019).

Despite these benefits, the study acknowledges technological challenges associated with utilizing IoT in construction, such as connectivity issues, interoperability problems, and concerns about data security and privacy (Brown & Williams, 2019). Addressing these challenges necessitates the establishment of reliable network infrastructure, ensuring smooth communication between IoT systems and devices, and implementing necessary data security measures (Laghari *et al.*, 2021). The research recognizes potential resistance to change, a lack of awareness about IoT benefits, and challenges in organizing and coordinating multiple project stakeholders as additional obstacles to IoT adoption in construction (Gonzalez & Thomas, 2021). Overcoming these challenges requires effective communication and engagement among project stakeholders, and the study underscores the importance of comprehensive training programs to equip construction professionals with the necessary skills to work with IoT devices and analyze collected data (Ajeel *et al.*, 2020).

In conclusion, the study suggests that implementing IoT technology in construction projects holds the potential to significantly improve project management and productivity. Success in integration involves addressing skill requirements, overcoming technical barriers, and effectively managing organizational challenges. By harnessing the benefits of IoT, including preventative maintenance, optimized resource allocation, and informed decision-making, construction project outcomes and costs can be enhanced. Recognizing specific skills required and implementing strategies to address challenges are deemed essential for the successful integration of IoT technology in construction projects.

1.2 Problem Statements

The utilization of Internet of Things (IoT) technology in construction projects has significantly enhanced project management and productivity (Akcamete *et al.*, 2020). However, the introduction of IoT into the construction industry has posed challenges related to talent requirements and implementation hurdles. This study aimed to investigate the relationship between skills requirements and challenges of the Internet of Things (IoT) in construction projects. To successfully leverage IoT technology in construction projects, a multidisciplinary approach is essential, involving experts in civil engineering, electrical engineering, computer science, and data analytics (Chen & Li, 2020). These professionals play a crucial role in designing, implementing, and operating IoT devices, as well as analyzing the collected data to enhance project outcomes and decision-making (Brown & Williams, 2019).

The challenges associated with IoT implementation in construction projects are diverse. Technical barriers encompass connectivity, interoperability, data security concerns, and integration with existing processes (Brown & Williams, 2019). Overcoming connectivity challenges requires a robust network architecture and seamless communication between IoT systems and devices. Addressing interoperability issues and implementing adequate data security measures are crucial for effective integration. Furthermore, integrating IoT with current construction processes demands careful planning to avoid disruptions and compatibility problems. In addition, organizational issues can hinder the adoption of IoT in construction projects. Resistance to change, lack of awareness of IoT benefits, and stakeholder coordination problems are significant obstacles (Gonzalez & Thomas, 2021). Overcoming these hurdles requires effective communication and collaboration among project stakeholders to establish a shared understanding of IoT advantages and goals. Comprehensive training programs are essential to equip construction personnel with the necessary skills to work with IoT devices and analyze collected data (Wang & Lee, 2022). Cultivating a culture of openness to technological innovation and advancement is vital for successful IoT adoption in the construction industry.

In conclusion, this addresses the relationship between skills requirements and challenges of the Internet of Things (IoT) in construction projects. A multidisciplinary approach involving professionals from various fields is necessary for successful integration. Resolving technical challenges related to connectivity, interoperability, data

security, and process integration is essential. Moreover, effective training programs and communication strategies are needed to address organizational hurdles. By overcoming these challenges, construction companies can harness the full potential of IoT technology, improving project management, operational efficiency, and decision-making skills. Therefore, the objectives of the study are to identify the skill requirements, the challenges, and the relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects.

The study focuses on the relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects. It offers clarity on the specific skills necessary for the successful adoption of IoT, enabling companies to train and prepare their staff for the effective integration of IoT technology. This knowledge empowers the sector to handle projects efficiently, enhance productivity, and make well-informed decisions, ultimately contributing to better project outcomes. The research delves into the specific skill requirements for successful IoT adoption and explores the relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects. It highlights the difficulties faced in incorporating IoT technology, providing valuable insights into the obstacles that hinder successful integration. The findings of this research have practical applications in the construction sector, offering businesses the opportunity to enhance their staff capabilities and develop solutions to overcome challenges. Thus, advances the understanding of IoT adoption in construction and its potential impact on the industry.

2. Literature Review

2.1 Skill Requirements of IoT Implementation in Construction Project

Professionals must possess a range of technical and non-technical skills to effectively embrace and utilize IoT technology in projects. Technical skills include a solid understanding of sensor technology, data communication protocols, network architecture, and proficiency in data analytics tools (Fan *et al.*, 2022). In addition, construction professionals need the capability to analyze data gathered by IoT devices to derive valuable insights (Wang *et al.*, 2021). Moreover, cybersecurity expertise is crucial to protect project data and ensure the secure operation of IoT networks (Zhan *et al.*, 2022). Successfully incorporating IoT technology into project designs and managing its deployment necessitates strong project management abilities (Hammad *et al.*, 2021). Effective teamwork and stakeholder involvement rely on excellent collaboration and communication skills (Cheng *et al.*, 2018). By acquiring and enhancing these skill requirements, construction professionals can adeptly address the challenges associated with IoT adoption and capitalize on its potential to improve project outcomes. Table 1 shows the summary of skill requirements of IoT implementation.

Table 1 *Skill requirements of IoT implementation*

No	Skill Requirements of IoT Implementation	Author
1	Technical Skills	• Abbas *et al.* (2021) • Alam *et al.* (2020)
2	Data Analysis Skills	• Mourtzis *et al.* (2015) • Akintoye *et al.* (2015)
3	Cybersecurity Skills	• Alaba *et al.* (2020) • Kumar *et al.* (2020)
4	Project Management Skills	• Martic *et al.* (2018) • Mendoza *et al.* (2017)
5	Collaboration and Communication Skills	• Chua *et al.* (2018) • Zhang *et al.* (2021)

2.2 Challenges of IoT Implementation in Construction Project

Implementing IoT in construction projects has brought about challenges due to the necessity for intricate infrastructure, involving the establishment of connectivity and integration of devices in constantly changing site conditions. Construction professionals faced difficulties in addressing issues such as remote locations, harsh weather conditions, and limited connectivity. Efficient management of data and ensuring its security were critical aspects, involving the handling of diverse data types and implementing measures such as encryption and access restrictions. Overcoming compatibility and interoperability challenges required careful selection of devices and verification of their seamless integration into the existing system. Closing the skill and knowledge gap became a continuous process that demanded ongoing training programs, collaborative efforts, and

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investment in the development of staff expertise. In addition, considering costs and return on investment played a vital role in the successful adoption of IoT. This required a thorough analysis of potential benefits in comparison to investment expenses. Successful implementation in construction projects demanded a thoughtful and strategic approach to navigate the complexities of infrastructure, data management, security, and workforce development. Table 2 shows the summary of the challenges of IoT implementation.

Table 2 *Challenges of IoT Implementation*

No	Challenges of IoT Implementation	Author
1	Complex Infrastructure	• Abdullah *et al.* (2020) • Lee *et al.* (2020)
2	Data Management and Security	• Smith *et al.* (2018) • Davis *et al.* (2021)
3	Compatibility and Interoperability	• Johnson *et al.* (2018) • Anderson *et al.* (2019)
4	Skill and Knowledge Gap	• Miller *et al.* (2019) • Harris *et al.* (2021)
5	Cost and Return on Investment	• Clark *et al.* (2022) • Jones *et al.* (2023)

2.3 Relationship between Skill Requirements and Challenges of Internet of Things (IoT)

Integrating IoT skills into construction projects encounters notable challenges, particularly in the areas of Security and Privacy, Organization, Cost, Connectivity, and Service. Security and Privacy concerns arise due to the interconnected nature of devices, requiring measures to ensure data confidentiality and integrity against cyber threats. Organizational coordination is crucial, demanding aligned efforts among stakeholders for successful IoT deployment. The challenge lies in harmonizing the goals of project managers, contractors, and technology experts. Cost, Connectivity, and Service represent another critical relationship, with the need to strike a balance between substantial initial investments in IoT infrastructure and the anticipated long-term benefits. Reliable connectivity and robust support mechanisms are essential for the seamless operation of IoT in construction projects. Additional challenges include Knowledge and Skills, where a shortage of expertise can impede progress, and staying abreast of technological advancements. Quality considerations involve not only the technology itself but also its impact on construction processes and outcomes. Effectively addressing these challenges requires a strategic and collaborative approach, emphasizing cybersecurity, organizational alignment, and cost-effectiveness. This approach is essential to unlock the full potential of IoT in construction and navigate the complexities of security, organization, and connectivity.

3. Research Methodology

3.1 Research Design

This section describes the approach that was employed in this study. Furthermore, this will present the research design, research process, research population and sampling, data collection methods, and data analysis methods for accomplishing research objectives. Fig.1 below shows the research process flow chart.

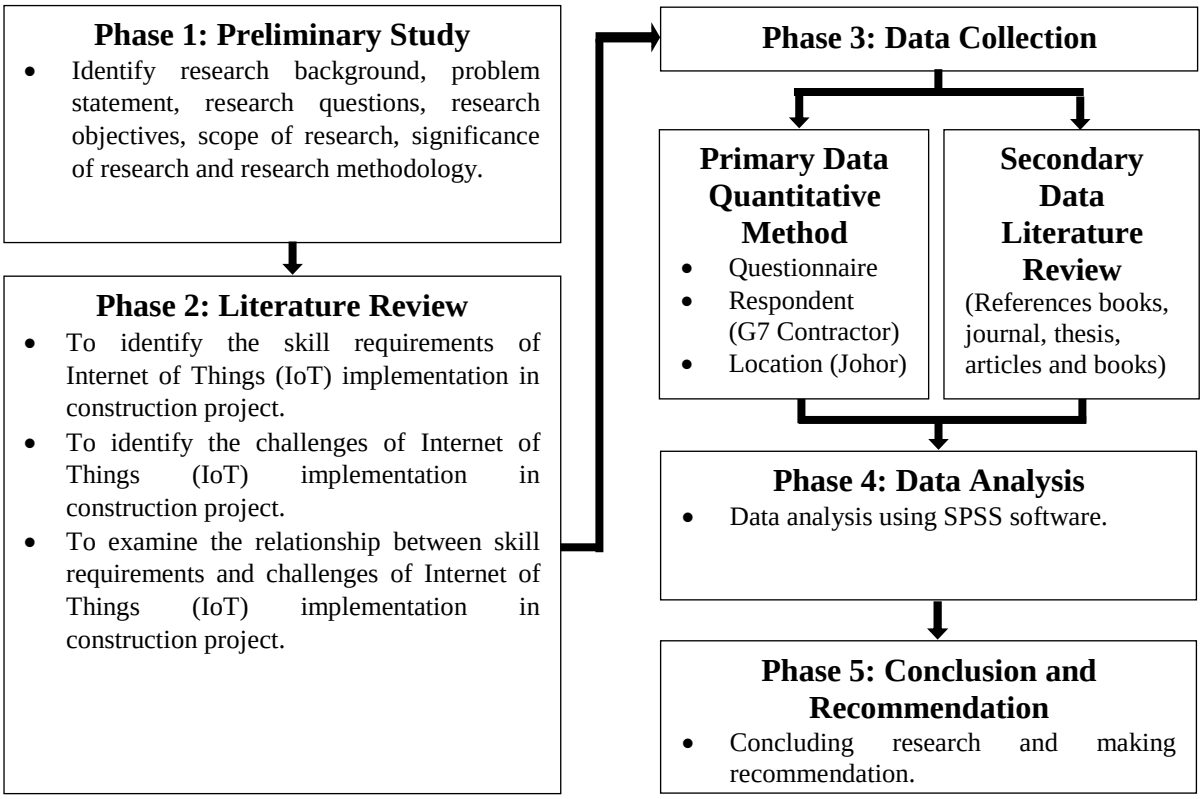

Fig. 1 *Research process flow chart*

The research was conducted in five phases, covering every step from the beginning to the end of the process. In Phase 1, the focus was on researching and discussing the problem statement's title. This involved delving into the research background, defining the problem statement, formulating research questions and objectives, outlining the research scope, emphasizing the research's importance, and detailing the chosen research methodology. Fig. 1 visually represented this comprehensive research process. Moving on to Phase 2, a thorough review of existing research on the relationship between skill requirements and challenges in implementing the Internet of Things (IoT) among project managers in construction projects was conducted. This phase involved extracting information relevant to the study's objectives from various sources, such as references, journals, newspapers, articles, and publications. Phase 3 was dedicated to data collection, which was divided into two categories: primary data and secondary data. Primary data was gathered through questionnaires distributed to respondents, while secondary data involved extracting information from books, journals, newspapers, and research articles related to the study. This literature research aimed to enhance understanding of the challenges, influencing factors, and potential solutions for improving IoT implementation among project managers in construction projects. Moving to Phase 4, the focus shifted to data analysis and results presentation. The collected data underwent analysis using the SPSS program, and the study's findings were displayed using the questionnaires given to the respondents. Descriptive statistics, including frequency, average, percentage, and standard deviation, were utilized to present the information in charts, tables, and graphs. Finally, Phase 5 marked the conclusion of the study, incorporating the summarized outcomes of the data analysis. This phase also included recommendations for future research improvements, collaborative opinions, and proposals.

3.2 Data Collection

The process of data collection involves gathering information to gain a better understanding of the research issue, and different types of data correspond to various collection techniques (Taherdoost, 2022). For researchers, gathering data is a significant challenge that requires a considerable amount of time and effort. Before collecting any data, nurse researchers must decide the type of information to be gathered and its source. Both new and existing data can serve as sources. In certain research investigations, pre-existing data, such as that derived from records and documents already in existence, can be exceptionally valuable. However, if no existing data is available to address the study issue, new data must be gathered. The types of data can also be categorized into primary and secondary data (Sadan, 2020). In this study, both primary and secondary data were used. The data collection process was carefully examined, highlighting the importance of making informed

decisions about the type of data to be collected and selecting appropriate sources to address the research issue effectively.

3.3 Data Analysis

Data analysis is the process of collecting, modeling, and scrutinizing data using various statistical and logical methodologies. Businesses heavily rely on analytics procedures and tools to gather information crucial for both operational and strategic decision-making (Calzon, 2023). Effective data analysis plays a vital role in aiding organizations in making informed decisions. Businesses nowadays collect data continuously through various channels such as surveys, online tracking, online marketing analytics, and the collection of membership and registration data, including newsletters and social media monitoring (Stevens, 2023). In this study, the SPSS software was employed to analyze the data obtained from fully-filled questionnaires. Prior to presenting the research findings, the collected data underwent analysis to generate precise and valid responses. This analysis aimed to extract frequency and mean score values, which are later depicted in diagrams, tables, and graphs in the subsequent chapter. This systematic categorization, summarization, and interpretation of observations facilitated by data analysis contribute to the researcher's ability to draw meaningful conclusions (Rahman, 2021).

4. Results and Discussion

4.1 Response Rate & Reliability Test

As per Krejcie and Morgan's (1970) sampling size table, the determined sample size for this study was 254. Accordingly, 254 sets of questionnaires were distributed to respondents. However, only 128 sets of questionnaires were returned with answers out of the 254 distributed, and all the returned questionnaires were utilized for data analysis. This means that 50.39% of the questionnaires were collected, while 50.00% were not returned. To assess the internal consistency of all variables in this study, a reliability test was conducted. The Cronbach's alpha values were 0.826 for IoT Skills, 0.832 for IoT Challenges, and the total Cronbach's Alpha was 0.866. All Cronbach's alpha values exceeded the conventional minimum of 0.70 for reliability. This indicates that all variables in this study were considered reliable, ensuring the robustness of the data collected and analyzed.

4.2 Demographic Profiles

In this study, the participants mainly consisted of individuals currently employed in the quantity surveying industry, and a total of 103 participants provided survey responses. According to Table 4.4's demographic profiles, there was a nearly equal distribution in terms of gender, with 54.7% being male (n = 76) and 45.3% being female (n = 58). Regarding age, the majority of participants were 46 years old or older, making up 94.5% (n = 121). The second-largest age group was between 31 and 35 years old, comprising 3.1% (n = 4), while those aged 30 or younger constituted only 0.8% (n = 1) of the respondents. In addition, individuals aged 36 to 40 years and 41 to 45 years each represented 0.8% (n = 1). Concerning academic qualifications, the majority held a Bachelor's degree (90.6%; n = 116), followed by those with a Master's degree (4.7%; n = 6), Diploma holders (3.1%; n = 4), and respondents with a Ph.D. (1.6%; n = 2). Regarding working positions, participants were spread across various roles, with Project Managers (26.6%; n = 34) and Site Supervisors (21.9%; n = 28) being prominent. Architects accounted for 20.3% (n = 26), Engineers 14.1% (n = 18), Site Managers 11.1% (n = 15), and other roles such as Quantity Surveyors, Lecturers, Sales Support, Admin Managers, and Research Assistants collectively represented 5.4% (n = 7). The majority of respondents had extensive experience in the construction industry, with 95.3% (n = 122) having 16 years of experience and above. In addition, 3.9% (n = 5) had 6 to 10 years of experience, while a few had 5 years or less (0.8%; n = 1). Table 3 shows the summary of respondents' demographic profiles.

Table 3 *Respondents' demographic profiles*

Item		Frequency	Percentage (%)
Gender	Male	70	54.7
	Female	58	45.3
Age	30 years old or below	1	0.8
	31 - 35 years old	4	3.1
	36 - 40 years old	1	0.8
	41 - 45 years old	1	0.8
	46 years old and above	121	94.5
Highest academic qualification	Diploma	4	3.1
	Bachelor degree	116	90.6

Position	Master	6	4.7
	PhD	2	1.6
	Site Supervisor	28	21.9
	Architect	26	20.3
	Engineer	18	14.1
	Project Manager	34	26.6
	Site Manager	15	11.7
	Others	7	5.4
Working Experience	5 years and below	1	0.8
	6 - 10 years	5	3.9
	11 - 15 years	0	0
	16 years and above	122	95.3

4.3 Knowledge about Internet of Things (IoT)

The survey included questions aimed at assessing the respondents' existing knowledge of the Internet of Things (IoT). An overwhelming majority, accounting for 99.2% (n = 127), confirmed their general awareness of IoT, while only 0.8% (n = 1) expressed uncertainty. Further exploration into the respondents' understanding of IoT implementation within their respective organizations revealed that 99.2% (n = 127) acknowledged their company's utilization of IoT in their management systems, with only 0.8% (n = 1) indicating otherwise. Moreover, all respondents affirming IoT application (100%) emphasized its role in assisting and managing the company's data, reflecting unanimous agreement (100%) that their companies prioritize the importance of IoT skills for effective construction project management. Beyond their current practices, respondents were probed about their perspectives on the potential future use of IoT in their organizations. The results indicated unanimous consensus (100%) that possessing proficient IoT skills is crucial for utilizing IoT in their work. Similarly, there was unanimous agreement (100%) that their companies should adopt IoT for data management, reflecting their collective interest in utilizing IoT in the future. Table 4 shows the summary of knowledge about the Internet of Things (IoT).

Table 4 *Knowledge about the internet of things (IoT)*

No. Item	Questions	Responses Yes	No	Not sure
1	Do you know about the Internet of Things (IoT)?	127 (99.2%)	0 (0%)	1 (0.8%)
2	Did the company apply the use of IoT management system?	127 (99.2%)	1 (0.8%)	-
3	If your answer YES for Q2, is the use of IoT helpful in assisting and managing the company?	128 (100%)	0 (0%)	-
4	Does the company emphasize on the important of IoT skills for handling construction project?	128 (100%)	0 (0%)	-
5	Do you think it is important to have good IoT skills to use in assisting your work?	128 (100%)	0 (0%)	-
6	Do you think that your company should apply the Internet of Things (IoT)?	128 (100%)	0 (0%)	-
7	Would you like to use the Internet of Things (IoT) in the future?	128 (100%)	0 (0%)	-

4.4 The Skill Requirements of Internet of Things (IoT) Implementation in Construction Project

Addressing the first research question, "What are the skill requirements of Internet of Things (IoT) implementation in construction project?" the overall mean of 4.673 indicates a high level of consensus among respondents regarding the importance of IoT skills. Moreover, the mean values for each of the five specified IoT skills—technical skills, data analysis skills, cybersecurity skills, project management skills, and collaboration and communication skills—are all above 4.00. This underscores the significant importance attributed to these skills for effective implementation in construction projects. The specific skill related to "Collecting real-time data from the building" achieved the highest mean value at 4.92, with unanimous agreement (100%). Following closely, "Real-time data analysis and decision making" garnered a mean value of 4.88, also with unanimous agreement

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(100%). These findings highlight the paramount importance of technical skills in IoT implementation within construction projects. Conversely, the skill item with the lowest mean value (4.52), related to "Control policies with project data," while still receiving 97.6% agreement, indicated a more moderate perception of its significance in construction projects, with 0.8% disagreement and 1.6% uncertainty. This suggests that, while the majority sees this skill as important, there is a small portion that views it with less significance or uncertainty. Table 5 shows the summary of descriptive statistics on IoT skills.

Table 5 *Descriptive statistics on IoT skills*

No	Item (Overall mean = 4.673, SD = 0.256)	% Disagree	% Neutral	% Agree	Mean	SD	Rank
	Technical Skills	0	0	100	4.83	0.351	1
1	Collecting real-time data from the building	0	0	100	4.92	0.269	
2	Communication between project stakeholders	0	0	100	4.70	0.462	
3	Real-time data analysis and decision making	0	0	100	4.88	0.323	
	Data Analysis Skills	0	0	100	4.65	0.469	4
4	To find the performance and state of the building	0	0	100	4.54	0.500	
5	Statistical analytical in the construction industry	0	0	100	4.64	0.482	
6	Data visualization makes information clearly	0	0	100	4.77	0.425	
	Cybersecurity Skills	0.3	2.6	97.1	4.56	0.559	5
7	Protect the sensitive project data gathered	0	0.8	99.2	4.63	0.500	
8	Control policies with project data	0.8	1.6	97.6	4.52	0.575	
9	Keep up with the most recent cybersecurity dangers and best practices	0	5.6	94.4	4.54	0.601	
	Project Management Skills	0	0	100	4.67	0.470	2
10	To manage and monitor project plans	0	0	100	4.71	0.455	
11	To gather needs, handle issues, and guarantee that project objectives	0	0	100	4.61	0.490	
12	Managing risks throughout the project lifecycle	0	0	100	4.69	0.465	
	Collaboration and Communication Skills	0	0.8	33.1	4.65	0.491	3
13	Skill integrating IoT into teamwork	0	0.8	99.2	4.65	0.495	
14	Skill in integrating IoT to disseminate project goals and objectives	0	0.8	99.2	4.60	0.507	
15	Skills integrating IoT in knowledge sharing and problem-solving	0	0.8	99.2	4.71	0.472	

4.5 The Challenges of Internet of Things (IoT) Implementation in Construction Project

Addressing the second research question, "What are the challenges of Internet of Things (IoT) implementation in construction project?" the overall mean of 4.693 indicates a high level of consensus among respondents regarding the challenges associated with IoT implementation. Furthermore, the mean values for each of the five specified IoT challenges which is complex infrastructure, data management and security, compatibility and interoperability, skill and knowledge gap, and cost and return on investment are all above 4.00. This suggests a general acknowledgment among respondents of the substantial challenges involved in implementing IoT in construction projects, covering various dimensions such as infrastructure complexity, data management, compatibility issues, skill gaps, and cost considerations. The specific challenge related to the "Long duration for IoT setup in construction sites" recorded the highest mean value at 4.78, with a 99.2% agreement. This was closely followed by challenges associated with "Complicated IoT infrastructure with unique conditions in the construction environment" and "Technical problems of IoT in building projects," both with a mean of 4.78 and unanimous agreement (100%). These findings emphasize the significance of complex infrastructure as a primary challenge in IoT implementation within construction projects. Conversely, the challenge item with the

lowest mean value (4.57), related to "Must have strong security systems in construction," still garnered a 99.2% agreement, with 0.8% expressing uncertainty. This suggests that while security concerns were acknowledged, they were moderately perceived as a major challenge in construction projects. Table 6 shows the summary of descriptive statistics on IoT challenges.

Table 6 *Descriptive statistics on IoT challenges*

No	Item (Overall mean = 4.693, SD = 0.256)	% Disagree	% Neutral	% Agree	Mean	SD	Rank
	Complex Infrastructure	0	0.3	99.7	4.74	0.442	1
1	Long duration for IoT setup in construction sites	0	0.8	99.2	4.78	0.434	
2	Complex IoT infrastructure design is driven by flexible design building	0	0	100	4.66	0.477	
3	Complicate IoT infrastructure with unique conditions in the construction environment	0	0	100	4.78	0.415	
	Data Management and Security	0	1.1	98.9	4.65	0.496	5
4	Must have strong security systems in construction	0	0.8	99.2	4.57	0.513	
5	Project data protection and unauthorized access	0	0.8	99.2	4.62	0.504	
6	Lack of data protection laws and regulations compliance	0	1.6	98.4	4.75	0.470	
	Compatibility and Interoperability	0	1.1	98.9	4.68	0.487	3
7	The lack of different IoT data types requires unity for meaningful analysis in the construction	0	1.6	98.4	4.68	0.501	
8	Lack of understanding of communication protocols	0	0.8	99.2	4.62	0.504	
9	Lack of construction professionals	0	0.8	99.2	4.74	0.457	
	Skill and Knowledge Gap	0	0	100	4.71	0.447	2
10	IoT in building projects knowledge shortages	0	0	100	4.73	0.443	
11	Lack of training and knowledge-sharing platforms	0	0	100	4.63	0.484	
12	Technical problems of IoT in building projects	0	0	100	4.78	0.415	
	Cost and Return on Investment	0	0	100	4.68	0.466	4
13	Poor financial feasibility analysis in building projects	0	0	100	4.66	0.474	
14	Ignoring the cost-benefit analysis	0	0	100	4.68	0.468	
15	Poorly informed IoT adoption decisions	0	0	100	4.71	0.455	

4.6 Relationship between the Skill Requirements and Challenges of Internet of Things (IoT) Implementation in Construction Project

In addressing the third research question, "What are the relationships between the skill requirements and challenges of Internet of Things (IoT) in construction projects?" the study utilized Pearson correlation analysis to explore the relationship between skill requirements and challenges of Internet of Things (IoT) implementation. The results, as presented in Table 4.8, confirm the presence of significant moderate positive relationships, with a correlation coefficient (r) of 0.383, at a 0.01 confidence level. This implies that as IoT skills increase, there is a corresponding increase in the acknowledgment and understanding of IoT challenges in the context of construction projects. The findings underscore the interdependence between skills and challenges, emphasizing the necessity of well-rounded skill requirements to effectively navigate and address the challenges associated with IoT implementation in construction projects. Table 7 shows the summary of correlation analyses between all variables.

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Table 7 *Correlation analyses between all variables*

Components	IoT Skills	IoT Challenges
IoT Skills	1	
IoT Challenges	0.383*	1

4.7 Result Analysis Discussion

4.7.1 The Skill Requirements of Internet of Things (IoT) in Construction Project

The study successfully achieved its primary goal of identifying skill requirements of Internet of Things (IoT) implementation in construction project. Questionnaires distributed to G7 contractors in Johor facilitated a comprehensive analysis, revealing five key skills. Technical skills emerged as the most crucial, securing the highest mean value of 4.83. Following closely were project management skills with a mean value of 4.67, and collaboration and communication skills with a mean value of 4.65. These findings underscore a consensus among respondents on the critical importance of these skills for successful IoT integration in construction projects. Moreover, professionals in the construction field must possess the ability to analyze data collected by IoT devices to extract valuable insights (Wang *et al.*, 2021). In addition, expertise in cybersecurity is essential for safeguarding project data and ensuring the secure functioning of IoT networks (Zhan *et al.*, 2022). The successful integration of IoT technology into project designs and its efficient deployment requires robust project management skills (Hammad *et al.*, 2021). Effective teamwork and engagement with stakeholder's hinge on excellent collaboration and communication abilities (Cheng *et al.*, 2018). In essence, the combination of these insights highlights the multifaceted nature of skills necessary for the effective implementation of IoT in construction projects, encompassing technical proficiency, cybersecurity, project management, and strong collaboration and communication capabilities.

4.7.2 The Challenges of Internet of Things (IoT) in Construction Project

The accomplishment of the second objective, aimed at unraveling the challenges of Internet of Things (IoT) implementation in construction project, was effectively realized through the scrutiny of data derived from the distributed questionnaires among G7 contractors in Johor. The meticulous analysis of questionnaire results has seamlessly met the intended goal of pinpointing five prominent challenges. The top three challenges, as determined by respondents' votes and mean values, were identified as follows: complex infrastructure, securing the highest overall mean of 4.74; skill and knowledge gap, securing a mean of 4.71; and compatibility and interoperability, with an overall mean of 4.68. This outcome successfully addresses the second objective, emphasizing the identification and comprehension of challenges intrinsic to IoT implementation in the construction project context. Furthermore, the construction environment might have involved the use of temporary structures or unfinished infrastructure during various project phases, requiring agility and flexibility in the design of the IoT infrastructure (Lee *et al.*, 2020). Addressing these challenges and ensuring seamless connectivity and data transmission throughout the project's lifespan demanded careful planning and design by construction professionals. Additionally, as the project progressed, the infrastructure needed to be scalable to support the expanding network of IoT devices (Zhou *et al.*, 2019).

4.7.3 The relationship between skill requirements and challenges of Internet of Things (IoT) in construction project

The third objective of this research, aimed at exploring the intricate relationship between skill requirements (objective 1) and challenges (objective 2) of Internet of Things (IoT) implementation in construction projects, was successfully accomplished through a comprehensive analysis of questionnaire data. The results, examined using crosstabs analysis to generate correlation numbers, emphasize a clear relationship between the skill requirements and challenges of IoT implementation in construction project. The challenges, encompassing aspects like data security requiring cybersecurity skills and the necessity for technical skills to ensure the harmonious functioning of diverse IoT devices, highlight the critical nature of specific skills in addressing these issues. Crucially, data analysis skills bridge knowledge gaps, while project management skills play a pivotal role in cost management and achieving a favorable return on investment. In essence, the successful adoption of IoT in construction projects depends on adeptly addressing these challenges with the appropriate skill requirements. The application of Statistical Packages for Social Science (SPSS) software validated these findings, confirming a significant moderate positive relationship (at a 0.01 confidence level, where r is less than 0.5) between IoT Skills and IoT Challenges (r = 0.383). Furthermore, a significant moderate positive relationship (at a 0.05 confidence level) was observed between IoT skills and IoT challenges, as indicated by a Pearson

correlation coefficient of r = 0.383. These compelling findings underscore the relationship between skill requirements and challenges of IoT implementation in construction projects. This relationship between skill requirements and challenges of IoT implementation in construction projects is highlighted by the significance of a multidisciplinary approach (Chen *et al.*, 2020). The fields of civil engineering, electrical engineering, computer science, and data analytics are recognized as essential, emphasizing the necessity for professionals with diverse expertise (Brown & Williams, 2019). This multidisciplinary collaboration is crucial for effectively addressing challenges related to connectivity, interoperability, data security, and organizational hurdles, ultimately ensuring the successful integration of IoT in construction projects.

5. Conclusion

In conclusion, this research sheds light on the relationship between skill requirements and challenges of Internet of Things (IoT) implementation in construction projects. The identified challenges, including security and privacy, organization, cost, connectivity, and service, pose significant hurdles that necessitate strategic solutions for successful IoT deployment. The interconnected nature of devices raises concerns about data confidentiality and integrity, emphasizing the need for robust cybersecurity measures. Organizational alignment emerges as a pivotal factor, requiring coordinated efforts among project managers, contractors, and technology experts. The delicate balance between initial investments and long-term benefits in terms of cost, connectivity, and service further underscores the complexity of IoT implementation. Moreover, addressing knowledge and skills shortages, staying abreast of technological advancements, and ensuring the quality impact on construction processes are crucial for overcoming obstacles.

Furthermore, the construction industry, being a significant sector, should prioritize the strengthening of IoT utilization for information data storage management. Embracing universal technology, including IoT, is essential for staying competitive globally. The industry should explore the latest applications and software to streamline tasks and contribute to becoming a developed nation. In addition, researchers planning future studies in this field are encouraged to adopt a mixed methods approach, combining quantitative and qualitative methods for a more comprehensive understanding. Expanding the research scope to include diverse perspectives within the construction industry, considering different roles and responsibilities, will enrich insights. Exploring locations with a higher population of respondents can contribute to a more diverse and nuanced understanding of IoT implementation skill requirements and challenges. Lastly, the study emphasizes the critical role of IoT skills and knowledge in successful implementation. Strengthening these skills is imperative for addressing challenges, facilitating effective IoT deployment in construction projects, and contributing to the overall development of the construction industry in Malaysia.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Lee Chin Ying, Narimah Kasim;* ***data collection:*** *Lee Chin Ying;* ***analysis and interpretation of results:*** *Lee Chin Ying;* ***draft manuscript preparation:*** *Lee Chin Ying, Narimah Kasim, Rozlin Zainal, Mohd Hilmi Izwan Abd Rahim. All authors reviewed the results and approved the final version of the manuscript.*

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