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Implementation of Internet of Things (IoT) in the Iraqi Construction Industry

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Abstract

The Internet of Things (IoT) is the connectivity of a device with a sensor or software to transfer data between them in real-time. The construction industry may get many advantages by using IoT. These advantages are represented in safety, productivity, cost, time, and so on. However, adopting IoT within the construction industry is limited and requires management attention. The objective of this study is to investigate IoT implementation in the construction industry and find a structural framework for it, considering the needed processes and factors. The theoretical research aims to determine aspects of IoT implementation. The practical research involves observing the implementation of projects and conducting interviews with stakeholders. This study found that the stakeholders used an intelligent camera to observe project activities. However, the stakeholders' awareness regarding IoT is minimal. In addition, to implement IoT, there is a real need for a compatible system to connect the construction activities and with a programming system to track progress in the construction project. However, IoT implementation requires a significant investment and smooth execution. Based on the research findings, this study revealed the factors and methods for IoT implementation and represented them in a framework.

Keywords: Construction, Construction Industry, Construction Project, Internet of Things (IoT), Implementation.

1. Introduction

The Internet of Things (IoT) is one of the most important new technologies of the last several decades. IoT is a broad term that describes how many devices or equipment may link to each other and send and receive data over the internet without the user having to do anything [1]. IoT makes it possible to monitor, record, and make decisions in real time thanks to improvements in sensors, communication technologies, and computer control systems [2]. Its impact may be seen in many fields, and the building industry is one of the most promising areas for widespread use.

IoT has a lot of potential to make the construction sector safer, more efficient, and more productive [3], [4]. For example, wearable gadgets with sensors can keep workers safe by monitoring their health and alerting them to hazardous situations [5],[6]. Also, sensors and drones placed around construction sites can collect operational data, monitor site activities, and track the performance of sound equipment in real time [7],[8]. These apps not only help people get more done, but they also help with project management by sending collected data to central systems for analysis and making decisions based on that data [2].

IoT is essential for more than just making operations more efficient. It also helps reduce material waste and total project costs by making better use of resources [8]. Real-time monitoring helps identify errors and discrepancies early, which reduces delays and prevents unnecessary spending. Also, new uses for technology, such as combining IoT with blockchain for secure data management [2], [9], or adding sensors to monitor the drying of concrete [9], demonstrate its growing importance in building projects. These changes show how the Internet of Things (IoT) may change traditional methods into more sustainable, automated, and data-driven ones.

Even with these benefits, there are still several problems that hinder the widespread adoption of IoT in construction. Research has identified concerns regarding data security, recurrent internet outages, and insufficient awareness of IoT advantages among stakeholders [2], [5], [10]. Interoperability, sustainability, cost, system complexity, and connectivity restrictions are other problems [6], [11]. These concerns highlight a significant deficiency in research concerning both the practical obstacles and strategic remedies for the use of IoT in the construction industry [12].

Previous studies argued the challenges of using IoT devices in construction, such as [5] and [10]. Other studies discussed the barriers of IoT, such as [11]. This study clarified issues related to the security of the data and the problem of repeated internet disruption. In addition, Elghaish et al [2] and other studies refer to the issue of awareness regarding the IoT application and benefits in the construction environment. There are several challenges, barriers, and disadvantages that IoT faces, such as: Harmony, Sustainability, Connectivity, Simplicity, and Uncostly [6].

This study aims to enhance the expanding knowledge base on IoT in construction by creating a theoretical and practical framework for its implementation. The theoretical contribution offers a comprehensive grasp of IoT applications, problems, and implications. In contrast, the practical contribution serves to assist construction enterprises in planning the integration of IoT into their projects and operations.

According to research objectives, the following questions have been generated:

1. What are the IoT devices and tools being used in the Iraqi construction industry and projects?
2. Is there awareness about the benefits and applications of IoT in the Iraqi construction industry and projects?
3. What are the most critical factors, reasons, obstacles, or barriers that prevent the use of IoT in the Iraqi construction industry and projects?
4. What are the factors or steps that lead to implementing IoT in the Iraqi construction industry and projects?
5. When is IoT implementation feasible from a financial and technical viewpoint?

2. Research Methodology

This study adopted both theoretical and practical approaches to investigate the use, implementation, applications, benefits, and barriers of the Internet of Things (IoT) in the Iraqi construction industry. The research methodology is illustrated in Figure 1.

In the theoretical approach, a literature review was conducted to examine previous studies on IoT applications in construction. The findings from this review guided the design of the practical investigation. The helpful research involved direct observations of construction institutes and active project sites, including selected bridge, road, and infrastructure projects. Since IoT adoption in Iraq is still in its early stages, the study relied on field observations and structured interviews to collect relevant insights.

Structured interviews were conducted with stakeholders, managers, and expert engineers working in construction and technology. The study population was drawn from the Iraqi Ministry of Housing and project management teams. Purposive sampling was employed to ensure that participants possessed relevant expertise. The final sample included 10 participants, with demographic information summarized in Table 1.

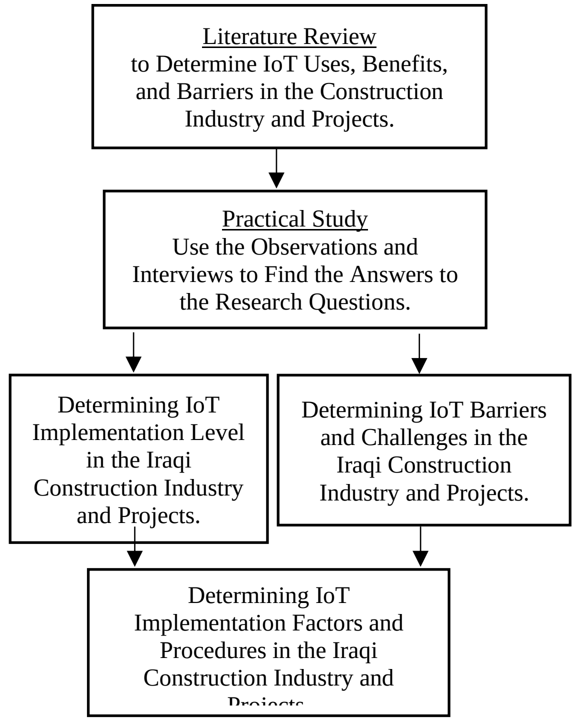

Figure 1. Flow Chart of Research Methodology

Table 1. The demographic information of the interview sample.

Participant ID	position	Education level	Years of experience
P1	Project Manager	Master's in Civil Eng.	20
P2	Civil Engineer	Bachelor's in Civil Eng.	25
P3	Site supervisor	Diploma in Construction Management	15
P4	Architect	Bachelors in Architecture	20
P5	Civil Engineer	Bachelor's in Civil Eng.	18
P6	consultant	PhD in Structure	23
P7	Structural Engineer	Masters in Structure	17

The interview process was carried out in two stages. The first stage investigated strategies for addressing construction challenges and current practices in project implementation. The second stage involved open-ended questions to explore participants' knowledge, awareness, and perspectives regarding IoT. The key questions covered IoT knowledge, devices in use, perceived benefits, implementation barriers, enabling factors, and the feasibility of adoption. Interview responses were analyzed statistically to assess homogeneity, reliability, and sample adequacy [13], [14]. The detailed answers are available from the authors.

By integrating the results of the literature review and the practical study, the research identified the current status of IoT in Iraqi construction projects and proposed processes for broader implementation. To evaluate and validate the developed framework, a qualitative study was conducted, involving structured, closed-ended interviews with ten different experts. Table 2 shows the demographic information for the participants.

The interviews consist of seven questions as follows:

1. Is the framework comprehensive and applicable?
2. Does the framework address all the critical processes?
3. Are the processes of the framework well structured?
4. Does the framework provide a precise and correct sequence for the processes?
5. Does the framework address all the critical factors?
6. Are the factors related in the right way to the processes?
7. In your opinion, is there any redundant factor included in the framework?

The entire set of interviews is available with the authors.

3. Results

3.1. Theoretical approach

Through the literature review, the author found several previous related studies, such as [2], [15]-[17], which explained the devices being used within the construction industry. Table 3 lists some of the devices and tools being used within the construction projects. Here are also some other references [8], [11] that argue the significant challenges and barriers faced in the use and implementation of IoT. Table 4 lists some of these challenges. Authors of references [9], [18]-[20] described some of the required techniques to implement IoT as explained in Table 5.

3.2. Findings of Research Observations and Interviews

By observing the ridges and road projects currently being implemented in Iraq, the author recognized that they adopted some techniques of IoT represented in satellite observation and intelligence cameras. They used these techniques to determine the capacity of the roads and the expansion requirements.

Table 2. The demographic information of the evaluation interview sample.

Participant ID	Position	Education level	Years of experience
P1	Project Manager	Master's in Project Management	15
P2	Construction Manager	Bachelor's in Civil Engineering	20
P3	Resident Engineer	Bachelor's in Civil Engineering	10
P4	Consultant Engineer	PhD in Civil Engineering	15
P5	Architect	Master's in Architecture Eng.	18
P6	Project Manager	Bachelor's in Civil Engineering	20
P7	Project Manager	Bachelor's in Civil Engineering	18
P8	Designer	Master's in Structural Eng.	13
P9	Construction Management	Master's in Construction Management	15
P10	Project Management	Bachelor's in Civil Engineering	20

Table 3. Some of the IoT Devices and Tools being used in a construction project

IoT Device or Tool	Use
Wearable tool	The worker wears a helmet, boots, or a vest to monitor their health and work and alert them to any dangerous conditions [21].
Sensor	It is equipped with sensors, materials, or a part of a building structure to detect technical errors and transmit them to the main store to take action. As well as the takeal sensors attached to the workers' wearables may not be able to follow up movements [22] efficiently,[23]
Drone	It flies over the construction project site to get pictures and record videos for survey, inspection, and security requirements [24].

Table 4. IoT Challenges within the Construction Industry

Challenge	Description
Harmony	IoT may require using more than one device or tool, which may be manufactured from different sources, and may lack compatibility between them. Also, there may be no compatibility between the new IoT technique and the existing infrastructure or system. This can cause different issues regarding integration and efficiency [5].
Sustainability	Construction projects involve continuous movement of loads, dust, high temperatures, wet conditions, high humidity, and other weather conditions. All these conditions may cause inaccuracy and errors in the data of Ioan T devices, which require repeated maintenance and replacement [9].
Connect ability	When there is a large amount of data being transferred or received, there may be some issues with the connection and bandwidth of the IoT device. These issues may cause data loss or corruption [14].
Simplicity	Using IoT devices and applications may introduce complexity to the construction process in terms of project management, data security, and analysis.
Uncostly	There are many financial requirements related to installation, implementation, training, operation, and other related activities. These costs may require significant investment and a feasibility study to determine their feasibility.

Table 5. The techniques are being used to implement IoT.

Technique	Description
Radio Frequency Identification (RFID)	This technique depends on a serial number to transfer information related to an object using a wireless radio wave—the advantages of this technique are represented in low cost, accuracy, reliability, and efficiency.
Electronic Product Code (EPC)	There is a code (which could be 64-bit or 128-bit) registered electronically on an RFID tag to enhance the design of the EPC barcode and store information about the type, serial number, specifications, and manufacturing.
Bar Code	It is a label placed on an object that a machine can read. This label records the item's information.
Internet Protocol (IP)	It is a prime network protocol for data transitions through its branches.

All the respondents explained that the use of IoT within the Iraqi construction projects is severely restricted. Eighty percent (80%) of managers and stakeholders adopted traditional approaches to manage the projects and faced the expected problems. Six interviewees (60%) believed that there is no real need to use IoT devices and techniques when the implementation of it is considered costly. Five respondents (50%) are not aware of the potential cost savings that IoT could achieve. However, the analysis of interview answers comes up with the following points: -

1- All interviewees (100%) know about IoT. However, the sample has been chosen based on their knowledge.

2- Six interviewees (60%) explained that the IoT device used in the construction site is an intelligent camera to monitor activity and address any potential issues that may arise.

3- Ten interviewees (100%) stated that the awareness of most project managers and stakeholders is minimal and restricted to using cameras without supported tools or devices such as censors.

4- Six interviewees (60%) agreed that IoT was not implemented because most of the engineers preferred a traditional system over new or modified systems. Some of them stated that the financial support is an obstacle to implementing it.

5- Seven interviewees (70%) explained that to implement IoT, there is a real need for a compatible system to connect construction and production activities directly. These activities should be associated with a programming system to follow up and support the progress in the construction process. However, these systems and procedures will require significant financial support to ensure that this procedure proceeds smoothly and without issues.

6- Seven interviewees (70%) believed that production construction factories are the best institutions to implement IoT techniques and systems, and will be feasible from both technical and financial perspectives. However, they revealed that implementing IoT should be subjected to an economic feasibility study to determine its feasibility.

3.3. Homogeneity, Reliability, and Sample Sufficiency

1- Homogeneity Analysis

Based on a Statistical Calculation of Mean, Variance, and Standard Deviation, the coefficient of variance (CV) is 20.5%. This result indicates moderate variability in responses. This suggests the reactions are consistent. Table 6 shows the Homogeneity Analysis results.

Table 6. The Homogeneity Analysis test results.

Answer	Percentage Agreement	Score Representation (1-5)
1	100%	5 (Strong Agreement)
2	60%	3 (Moderate Agreement)
3	100%	5 (Strong Agreement)
4	60%	3 (Moderate Agreement)
5	70%	4 (High Agreement)
6	70%	4 (High Agreement)

2- Reliability Analysis

Based on a statistical calculation, Cronbach's Alpha (α) = 0.84. This result indicates high reliability. Responses are consistent across the questions.

3- Sample Sufficiency Analysis

The Kaiser-Meyer-Olkin (KMO) test is used to determine the adequacy of sampling through the evaluation of the ratio between partial correlations and total correlations by computing the squared correlations (which is 12.5) and partial correlations (3.5); the KMO value is 0.78. This result shows average sample adequacy, which is sufficient for statistical analysis.

3.4. Determining Success Factors and Procedure

Based on the theoretical and practical studies, the authors suggested the following processes to implement IoT.

- Process number one is investigating the possibility of reducing the duration and cost of the construction project or improving safety for workers around the project.
- Process number two is conducting a financial feasibility study to consider whether to implement IoT after determining all the technical and economic requirements of it.
- Process number three is providing and preparing all the logistical requirements.
- Process number four is launching the implementation process.
- Process number five is observing and following up on the implementation process to detect any errors and mistakes, and trying to repair them.
- Finally, process number six is to evaluate the implemented IoT process and try to determine the visible and invisible benefits, as well as strategic values.

The factors that could affect the implementation process are: the need, the feasibility, the availability of IoT requirements, the availability of financial support, the awareness, and determining the IoT's visible, invisible, and strategic benefits.

By drawing inspiration from the previous series of studies on Information Technology implementation frameworks, such as [25]-[27], and considering the above-mentioned processes and factors of the IoT implementation process, Fig. 2 shows the suggested framework diagram of the IoT implementation process.

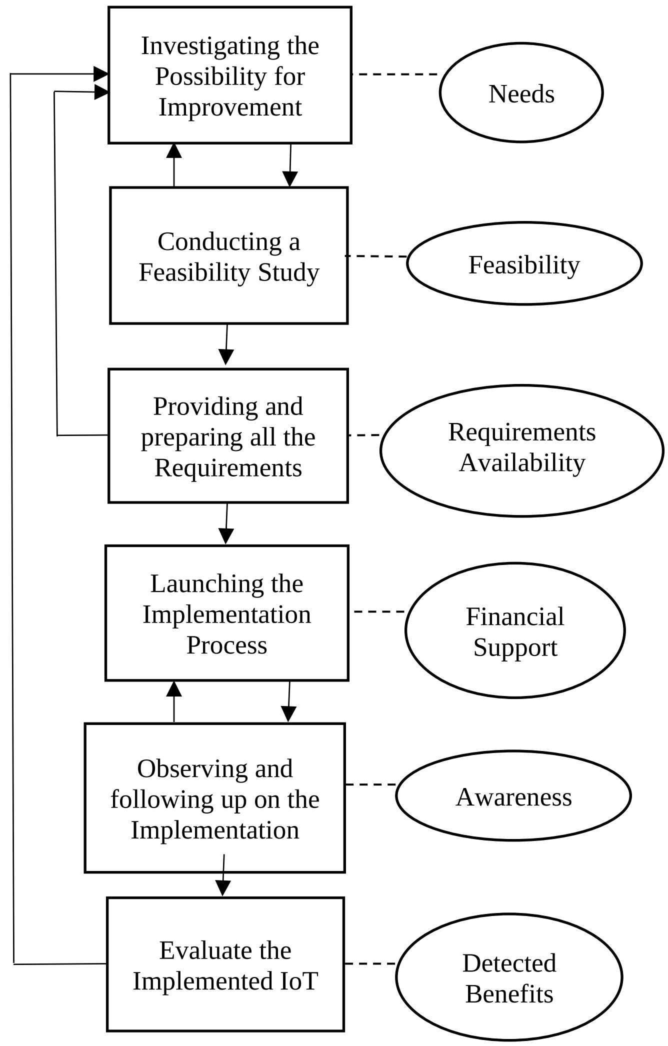

Figure 2. Framework diagram of the IoT implementation process

3.5 Framework validation

The statistical analyses for all the responding answers are as follows:

1- Nine respondents (90%) stated that the framework is comprehensive and applicable.

2- Seven respondents (70%) stated that the framework addresses all the critical processes.

3- Six respondents (60%) stated that the framework's processes are well-structured.

4- Ten respondents (100%) stated that the framework provides a precise and correct sequence for the processes.

5- Eight respondents (80%) stated that the framework addresses all the critical factors.

6- Seven respondents (70%) stated that the factors are related in the right way to the processes.

7- Ten respondents (100%) stated that no redundant factors were included in the framework.

The results provide practical insights and evidence that the framework is well-structured, useful, and applicable in implementing IoT within the construction industry.

4. Conclusions

The study showed that the Internet of Things (IoT) has several uses and benefits in the construction business. These include better worker safety, more productive equipment, better work performance, and lower costs and project times. Even with these benefits, the use of IoT in Iraqi construction projects is still limited and mainly only used for simple tasks.

The statistical analysis of the replies from the respondents showed that only a few IoT technologies, such as sensors and drones, are currently in use. In real life, the main technology used to monitor activities and fix critical problems on-site was cameras with IoT. However, project managers and stakeholders were unaware of the broader benefits of IoT; they only knew about how it could be used for camera-based monitoring. This shows how important it is to have technologies that can connect construction operations directly to project management platforms. Some of the main problems that are stopping people from using IoT are that devices don't work well together, IoT equipment doesn't last long in tough construction sites, and the initial costs are exorbitant. For successful implementation, there needs to be enough money and well-organized steps to ensure a smooth process.

The study also indicated that the best place to use IoT is in building factories. Experts and stakeholders confirmed a suggested strategy for implementing the Internet of Things (IoT) that includes six basic steps: (1) Looking into ways to make things better, (2) doing a feasibility study, (3) making and giving the requirements, (4) starting the implementation process, (5) watching and following up on implementation, and (6) judging the results of IoT adoption. Several essential elements affect these procedures, such as showing a need, determining feasibility, having enough resources, securing financial support, informing stakeholders, and identifying both short-term and long-term benefits.

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Conflict of interest

The publication of this article causes no conflict of interest. The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

The first author proposed the research problem, developed the theory, and performed the computations. The second author verified the analytical methods and conducted the investigation. The third author supervised the findings of this work.

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