

# INTERNET OF THINGS (IOT) APPLIED IN CONSTRUCTION INDUSTRY: A SYSTEMATIC REVIEW

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## ABSTRACT

The Internet of things (IoT) involves several internet-connected devices that interact with each other to learn and share information between humans and machines and between machines and machines, making the related processes more comprehensive, innovative, simple, and efficient. There are several applications of IoT in construction, such as using computational tools in structural design, georeferencing, construction management, and using technological tools in construction sites. Therefore, this article presents a systematic review of the most relevant studies from Industry 4.0 and the application of IoT in the construction industry to present the impacts these technologies can promote in construction. On this, the 4.0 technology implementation and their construction innovations can improve work conditions through innovative tools, machines, and devices, increasing productivity and reducing production costs. Therefore, drone operation is one of the most used construction technologies, mainly because the costs are low for construction companies and their owners. However, technologies such as BIM and robotics are widely used.

**Keywords:** Internet of Things, Internet-Connected Devices, Construction Technology, Industry 4.0, Civil Engineering, Drones

## 1. INTRODUCTION

During construction development, delays in construction materials deliveries, misallocated funds, or even lost equipment are usual. Several of these occurrences could result from inefficient communication, coordination, and the absence of punctuality and accessibility of information [Silva et al. \(2021\)](#).

The construction industry has a stereotype defined as a "traditional industry", which is notoriously slow to innovations and technological advances and reluctant

to accept changes. However, technological development has become a driving force and differential for advances in civil construction. [Dos Santos Júnior et al. \(2019\)](#).

The Internet of Things is responsible for involving different internet-connected devices, which interact with each other in order to acquire information, monitor, create automatic reports and share information between humans and machines and between machines and machines, aiming to make the processes more comprehensive, innovative, simple, and efficient, so that it can be used in the most distinct sectors, such as economy, politics, leisure, among others.

In the contemporaneity of the 21st century, we are experiencing Industry 4.0 or Fourth Industrial Revolution, where human and market needs have to correspond to each other, requiring more than efficiency and effectiveness.

The IoT in construction allows surveillance of the location of machines or tractors used in works through monitoring sensors and network infrastructure.

The use of computational tools in structural design, georeferencing, project management, and even the management of construction sites with technological tools are increasingly used by engineers and designers, for example, measuring tapes with infrared technology, laser levels, and computational topographic stations [Simão et al. \(2019\)](#).

There are several applications of information technology in construction. Technological innovations are being widely used, studied, and more visible, especially in the academic field, such as the use of tablets and drones for construction site inspection, use of robots on construction sites, among others [Simão et al. \(2019\)](#).

Given the assumption, this article presents a Systematic Review of the most relevant studies concerning Industry 4.0 and the application of IoT in construction in general in order to present the deepest impacts that these technologies can create in this area.

The importance of this study is to show the existing impacts of the use of these contemporary technologies in Brazil's construction, giving more insight into the results of its use. Implementing technology 4.0 and its innovations may improve working conditions through new tools, machines, and innovative devices, improving productivity and reducing production costs [Simão et al. \(2019\)](#).

## 2. THE INTERNET OF THINGS

The Internet of Things (IoT) can be defined as "an environment of Internet-connected devices, through small sensors, creating a global computing system that aims to facilitate and simplify people's daily lives, introducing functional solutions in the daily processes [Da Silva \(2020\)](#).

In Brazil, the Federal Government, in partnership with the Ministry of Science, Technology, and Innovation and the National Development Bank, created the National Plan for the Internet of Things through Decree No. 9,854 on June 25, 2019. This plan aims to implement and develop the IoT in the country based on the free flow of data, observing the information security and personal data protection guidelines [Brasil \(2021\)](#).

Among the objectives of the plan, the most relevant would be the proposal to improve citizens' quality of life, promote professional training in the area of IoT, increase productivity and seek partnerships with the public and private sectors to implement IoT [Silva \(2020\)](#).

In the world economy, the estimated contribution of IoT to the world's GDP is between US\$3.3 trillion and US\$11.1 trillion, representing up to 11% of the world's GDP by 2025. At the national level, IoT-based innovations can contribute R\$ 122 billion to the Brazilian GDP [TERRA. \(2022\)](#).

In Brazil, the information of technology department has a growth forecast of 10.6% in 2022. [IDC. \(2022\)](#). This growth expectation in the Brazilian Information and Communication Technology (ICT) market was the highest in the last eight years, even in the face of a moderate economic scenario and during an election period in Brazil.

IoT is mainly applied in civil engineering construction, smart buildings, safety, and lifecycle system management.

### **3. BRAZILIAN CONSTRUCTION INDUSTRY**

The Civil Construction Industry, from the economic perspective, is one of the crucial sectors in Brazil since the national production capacity is directly related to the growth of this sector [Da Silva \(2018\)](#).

In this bias, construction is essential because it involves a set of activities necessary to the economy, contributing substantially to the economic and social evolution of the entire country. In addition, the sector contributes to the development of other areas by promoting the consumption of goods and services.

The performance of the construction industry is directly related to GDP growth. This affirmation will occur through the consolidated growth of 7.6% in the sector, the highest in the last ten years. The increase in real estate financing and labor hiring was one of the positive points for all this growth [SEBRAE. \(2021\)](#).

In order for engineering and construction professionals to succeed in their projects, reduce materials waste, reduce the production cost and make them faster, it is necessary to use technology as an ally through devices or even applications that can assist in construction budgets, planning, and monitoring of the work and material management [SEBRAE. \(2021\)](#).

Industry 4.0 has been established in the construction industry by creating new technologies specific to the construction area. Therefore, one of the leading technologies developed in this sector was Building Information Modeling (BIM) which can be defined as a device capable of designing projects in an integrated manner, including all information relevant to the project work cycle, encompassing subjects from geometry, construction materials, thermal efficiency, structure, and energy performance, production cost, safety, life cycle, among others [Cavalcanti et al. \(2018\)](#).

In traditional building projects, the engineer takes care of his project separately, having only the project as a reference. Thus, there may be conflicts between complementary projects, such as hydraulic, sanitary, and electrical, as they hardly exchange information. [Figure 1](#) below illustrates the relationship of the members of a work without BIM modeling, working traditionally.

All this technological integration in the production chain is provided by the Internet of Things and industry 4.0, which allow communication between man and machines/electronic devices.

#### 4. APPLICATION OF THE INTERNET OF THINGS IN CONSTRUCTION

The Internet of Things (IoT) is defined as "a connection network where things are connected wirelessly through sensors and smart devices" (Li, Xu, & Zhao, 2015). In this way, the IoT can interact without human intervention. Some of its main applications are in the healthcare, transportation, and automotive industries.

Over the last few decades, IoT technologies are still in their early stages. However, many improvements have occurred with the addition of sensors in the cloud-based Internet. Thus, the development of IoT involves many issues, such as infrastructure, communications, interfaces, protocols, and standards [Li et al. \(2015\)](#).

Construction waste management has been one of the most challenging problems due to the large volume of waste generated. These possible problems are often caused by the inadequate management of these wastes, which have the tremendous harmful potential for public health and the environment [Júnior and Júnior \(2021\)](#).

The final Municipal Solid Waste (MSW) disposal is an environmental problem in urban centers, especially in Brazil, where there is the presence of disposal in open dumps. This bias in order to solve this reality, municipalities need to seek intelligent and sustainable adaptations for better solid waste management.

MSW management consists of 5 stages: Collection, transport, recycling, energy use, and final disposal. These stages are undergoing constant technological evolution with the advent of the Fourth Industrial Revolution or Industry 4.0.

Internet of Things technology has been commonly applied to data management and transforming that data into a connected and intelligent system for MSW management. Among the numerous possibilities are smart bins for waste collection, vehicles with a tracking system, automated recycling robotics, and monitoring gas emissions in landfills. However, the application of these technologies is still at an early stage in solid waste management [Júnior and Júnior \(2021\)](#).

Given the assumption, it is essential to analyze the correlation of the Internet of Things with solid waste management, aiming to help municipal managers adopt efficient strategies that benefit public health and the environment.

Drones are the most widespread IoT application in the construction industry because they have simple configurations and relatively low cost, being accessible even to non-professionals. Drones can assist with construction work progress, usually used to photograph, or film all construction stages [Dos Santos Júnior et al. \(2019\)](#).

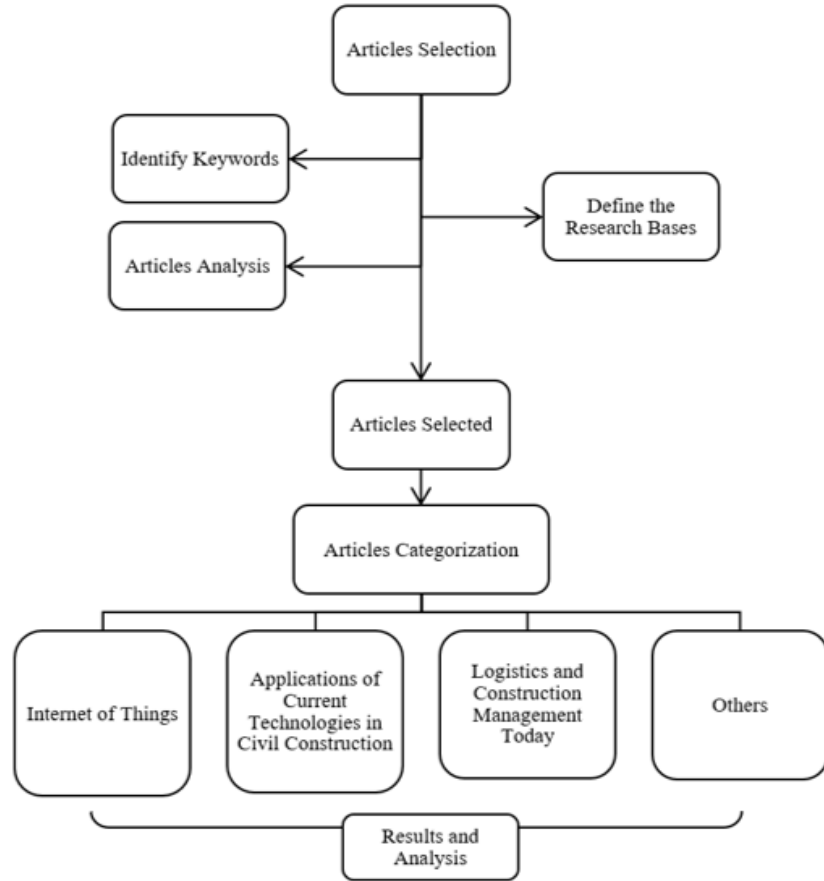
#### 5. MATERIALS AND METHODS

The Systematic Literature Review (SLR) is one of the most used methodologies in scientific and academic research to know and analyze resources needed to build a study with specific characteristics and identify possible inconsistencies in the research [Galvão and Ricarte \(2019\)](#).

SLR is a research modality that follows specific protocols and seeks to understand and give longevity to a documentary corpus to verify what works or does not work in a given context [Galvão and Ricarte \(2019\)](#).

In this bias, to carry out a systematic review, it was necessary to adopt a two-stage process, as illustrated in [Figure 1](#).

**Figure 1**



**Figure 1** Systematic Literature Review Flowchart

The scientific articles picked were those published in national and international journals from 2019 to 2022, available on the scientific platforms CAPES, Scientific Electronic Library Online SCIELO, and Google Scholar. [Table 1](#) illustrates how the selection process of scientific articles that composed this work was carried out.

**Table 1**

**Table 1 Scientific Articles Selection**

Subject	Conclusion	Qualis Capes Rating
Construction Technologies	The construction sector must explore more technologies and apply more IT in its projects.	B2
Industry 4.0 for the construction industry	Despite the many benefits of applying IoT in construction, there still needs more studies and the participation of specialists in this area.	B2

Scientific articles published in journals of national excellence were prioritized. Thus, the vast majority of authors who composed the theoretical framework of this work stated that the application of the Internet of Things in construction would innovate the projects. However, this technology still needs to be applied, and there are few scientific studies on the subject.

Also, the majority of the authors who researched the application of IoT in Brazilian construction reported that this area is still in a growth phase, despite the significant contribution that the technology will make to the development of civil engineering and Brazil.

## 6. RESULTS AND DISCUSSIONS

Most Brazilian construction companies do not use information technology (IT) in management and process control, emphasizing information, management, and storage inefficiency.

Little study has addressed the subject of the Internet of Things (IoT) in construction. In the literature, there are very few materials with this approach. However, in the last five years, there has been a considerable increase in publications. As of 2018, it is possible to observe the notorious growth trend in the number of publications, mainly on the scientific platforms Scientific Electronic Library Online (SCIELO) and Google Scholar. Thus, it can be concluded that the study area is on the rise.

During the analysis of the published articles, the main advances in the application of IoT in Civil Engineering were identified:

- Building Information Modeling – BIM: a device capable of developing projects in an integrated manner, covering all information relevant to the work cycle [Cavalcanti, et al. \(2018\)](#);
- Robotics: The application of robotics in civil construction is indicated, mainly in construction processes or in maintenance that involves excellent risks of accidents or deaths. being demolition as an example [Dos Santos Júnior et al. \(2019\)](#);
- Waste management: IoT in managing solids from civil construction can be applied in numerous situations. As example, intelligent dumpsters for waste collection, vehicles with a tracking system and, automated robotics for recycling, monitoring of gas emissions in landfills [Júnior and Júnior \(2021\)](#);
- Construction 3D Printing: Printing of concrete structures for buildings in full size. Also, the 3D printer can be located on a construction site [Dos Santos Júnior et al. \(2019\)](#);
- Drones: Compared to other technologies, this is the most accessible nationwide because it is easier to program and because it has a relatively low cost [Dos Santos Júnior et al. \(2019\)](#).

## 7. CONCLUSIONS AND RECOMMENDATIONS

It is a fact that the civil construction sector needs to explore more of the available technologies and invest in the use of IT devices in its projects. Through the systematic analysis, it can be concluded that this topic is still growing at the national level and that there are still few studies on it.

Currently, one of the most used technologies in construction is the use of drones, as it is more accessible, both for the technical manager and for the company. Other technologies were also highlighted, such as BIM and robotics. BIM is the one that grew the most in applications, although it was evidenced only in 2011.

Aiming to propose future studies, the application of IoT is essential for the sector because it promotes a better adaptation of the people who are part of the construction process. Also, it enables better monitoring of structural pathological

problems, in addition to optimizing the maintenance of structures through the use of integrated urban building systems.

Thus, the applications of Information Technologies were presented, more specifically, the Internet of Things (IoT) in civil construction, along with the impacts that this application can cause and the numerous benefits. In this way, the main objective of this article was achieved.

### **CONFLICT OF INTERESTS**

None.

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