Review

Impact of Industry 4.0 Platform on the Formation of Construction 4.0 Concept: A Literature Review

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Abstract: In recent years, due to the rapid development of the fourth industrial revolution and new platforms of information technologies, intelligent systems have received widespread attention in many industries and have brought the potential to improve the efficiency of the construction industry. These facts led to the appearance of a new concept in construction industry called Construction 4.0. Therefore, this article seeks to explore the state of implementation of Industry 4.0 technologies in the construction industry and analyze their impact on the formation of the Construction 4.0 concept. In order to achieve the aim of this article, a literature review was conducted using the most relevant publication in this field. Moreover, authors carried out a bibliometric analysis among 195 selected research articles related to the Industry 4.0 and Construction 4.0 to identify interconnections between these concepts. The results show that Industry 4.0 has the greatest impact on productivity growth in construction and that interest in digital technologies is growing every year, but their penetration into the construction industry is currently slow and limited. The authors suggest that further research needs to be focused on future ethical issues that may arise and on synergies between Construction 4.0 technologies.

Keywords: Industry 4.0; Construction 4.0; digital technologies; interrelation; BIM

1. Introduction

We live in an era of change, which is measured not in years, but in days or even hours, when the digital revolution is pushing forward all aspects of life at an ever-faster pace [1]. New technologies develop with great speed. For instance, the development time of the Industry 1.0 lasted for centuries; development from the 1.0 to 2.0 phase was approximately 100 years. The transition to Industry 3.0 took 70 years, and after 30–40 years from the third revolution, the German federal government introduced the term Industry 4.0 in 2011 [2–4]. It should be noted that version 5.0 is expected in the near future [3]. For instance, Japan is already committed to developing "Society 5.0" by fully leveraging technological innovations, including the Internet of Things, artificial intelligence and big data from the fourth industrial revolution [5].

The construction industry has also benefited from this development, which gave rise to the term Construction 4.0 [6]. However, the complexity of construction has led to its slow industrial evolution, so in some developing countries the construction industry continues to follow traditional labor-intensive industry practices [7]. Thus, some businesses still exist in the warp of time, stuck between the old order and craft-based processes and the modern computer-driven existence [1]. In that case, construction could transform into a technology-driven industry through the adoption of ideas and technologies of Industry 4.0 [8].

Industry 4.0 is a stage of the industrial revolution associated with the development of digital technologies. Moreover, Industry 4.0 can be described as the current trend towards digitalization, automation and widespread use of information and communication

technologies (ICT) in the industry [9]. Hamelink [10] as cited from [11] termed digital technologies as advanced information and communication technology that allow capturing, storing, processing, displaying, communicating, integrating and collaborating information. There are some examples of modern digital technologies: cloud-based storage, augmented reality, virtual reality, digital twin, artificial intelligence, cyber–physical systems, big data, blockchain, laser scanner, robotics and automation, sensors, Internet of Things, actuators, sensors and so on [6]. Study conducted by Perrier et al. shows that existing 4.0 tools are mainly used to optimize, locate and simulate actions. At the same time, technologies can have several different applications and could be associated with different project management processes at different phases of a project's life cycle. This approves the universality of the 4.0 technologies [12].

The number of publications related to Industry 4.0 has grown steadily since the first publication in 2013, but still this field of research requires further development [3]. According to the literature review carried out by [4], publications are mainly focused on Industry 4.0 applications in the computer science, engineering sector, business management, decision science, material science, mathematics, social science [13,14], electrical, electronic, industrial, manufacturing and mechanical [15]. A very limited number of studies was found on the applications of Industry 4.0 principles in the construction sector, which is consistent with other studies [4,8]. That led us to the conclusion that the Construction 4.0 is still in the process of formation and there is a need for further investigation [4].

Construction 4.0 is a fairly new concept, but it is getting a lot of attention, therefore many researchers have attempted to define it. The literature review revealed that the definitions are vague and mostly adopt broader concepts from Industry 4.0, which is considered as a predecessor of Construction 4.0 [6]. Before even the term Construction 4.0 appeared, researchers tried to define the Industry 4.0 concept from a construction perspective. Oesterreich and Teuteberg describe it as a variety of interdisciplinary technologies that digitize, automate and integrate the construction process at all stages of the value chain [8]. One of the proposed classifications, developed to characterize the Construction 4.0 concept, is based on two pillars: the digitalization of the construction industry and the industrialization of construction processes [6,16].

There is no doubt that emerging information technology is the core driving force endorsing the smart construction system [17]. A number of articles have described the use of technology as a tool to change construction processes, but research on Building Information Modeling (BIM) as a potential catalyst for industry change has not received an adequate attention [1]. However, BIM has the potential to be the key to transforming the entire industry. Through the use of integrated tools such as collision detection, 4D planning and 5D cost estimation, business processes can be managed directly in the digital realm [1,18].

Furthermore, in the reviewed literature, authors mainly examined methods associated with Construction 4.0 separately and did not consider the potential synergistic effects of the technologies [19]. On the one hand, the integration of multiple technologies will bring more potential benefits than fragmented applications. On the other hand, the high heterogeneity of these technologies and various special characteristics of the construction industry create a difficult environment for implementation and require deep research [7]. In addition, the main results indicate that the current research streams pay little attention to ethical, economical, socio-cultural or environmental questions and mainly focus on studying technical aspects of technologies associated with Industry 4.0 [8].

The aim of this article is to contribute to the body of knowledge about Industry 4.0 and Construction 4.0, to determine the relationship between these two concepts and to understand how emerging digital technologies affect the information revolution in construction. An analysis of a large number of articles can provide a reliable overview of existing research gaps [19], therefore a literature review was conducted to achieve the aim of this article. A record of the most relevant publications was obtained through the Web of Science and Scopus platforms. A three-step literature search was conducted to analyze the

relevant articles. It became obvious that described 4.0 concepts are all about evolution of emerging digital technologies, therefore authors investigated these digital technologies and analyzed their application in the construction industry. We hope this review will provide researchers with comprehensive information, shed light on research gaps, and open up opportunities for future research.

The structure of this review is organized as follows. The general understanding of Industry 4.0 and Construction 4.0 concepts are presented in Section 1. In Section 2, we design the three-step study selection process in order to provide a comprehensive literature review and content analysis. Section 3 contains results from the study selection process, followed by the bibliometric analysis of selected publications in Section 3.1 and the comparison of Industry 4.0 and Construction 4.0 technologies in Section 3.2. The discussion organized in Section 4 presents the current state of Construction 4.0, summarizes the evidence for a conclusion, and points out possible future issues. Finally, conclusions and further research directions are provided in Section 5.

2. Methodology

The research methodology for this study was chosen as a literature review. The choice of this approach has demonstrated the advantage of combining evidence from a multitude of studies on the subject [11]. Web of Science and Scopus databases were chosen as the main source of the literature; however, this article also contains data from Google and Google scholar as a source of practical literature.

The process for selecting studies for this review was conducted in three steps: Step 1—search by topic field and publication year; Step 2—refining the results; Step 3—selection by visual screening and citation. Figure 1 summarizes the designed framework for selecting studies. The study selection process was conducted subject to the following restrictions:

(i) The topic search field included the title, abstract, and keywords of the articles;
(ii) The search period is limited to 2014–2020;
(iii) Research articles, journals, conference papers, and conference proceedings were included;
(iv) The subject area was delimited to Engineering, Computer Science, Materials Science areas;
(v) Selected articles must be in English only or written in two languages, one of which is English;
(vi) Articles should all have open access.

Step 1-Search by topic field and year
- Search keywords:
- Industry 4.0;
- Construction 4.0;
- Industry 4.0 AND construction industry;
- BIM AND Construction 4.0;
- Building information modeling AND Construction 4.0.
- Year: 2014-2020

Step 2-Refining the results
- Search characteristics:
- subject area;
- language;
- access conditions;
- publication stage;
- source type;
- keywords.

Step 3- selection by visual screening
- Reading through the titles, abstracts, findings, conclusions and citation percentile;
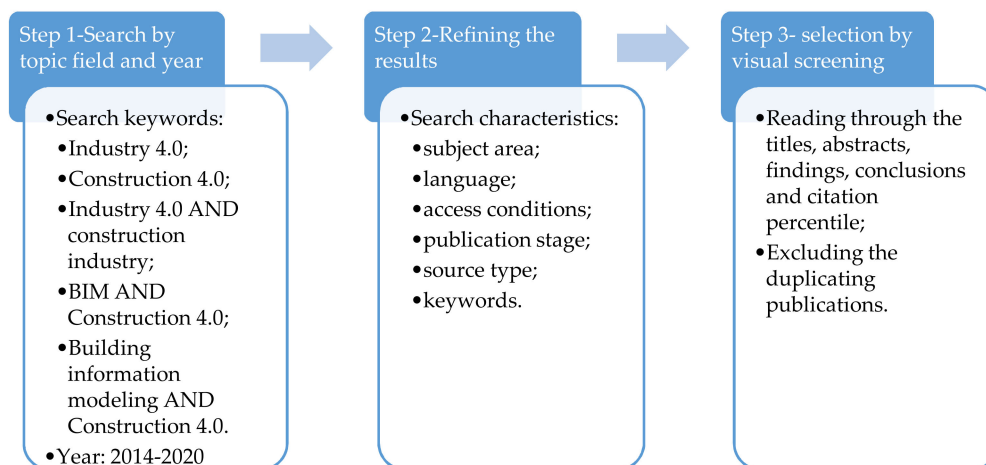- Excluding the duplicating publications.

Figure 1. Designed framework for selecting studies.

The authors of the present study visualized the distribution of selected publications related to interconnection of the Industry 4.0 and Construction 4.0 by year, in order to

analyze the evolution of publications over the years. Then, a bibliometric analysis was performed using the VOSviewer[TM] application in order to analyze the co-occurrence of keywords in selected publications. Moreover, we provided an overview of the countries which are interested in this problem according to the origin of these literary sources.

3. Results

According to [6], the first article that mentions "Industry 4.0" and "construction" together analyzed how automated 3D-printed prototypes could satisfy customer's demand was published in the 2014 [20]. Additionally, Roland Berger [21] first mentioned and characterized Construction 4.0 as a concept in 2016. Therefore, for literature review, the authors selected articles published between 2014 and 2020 using Web of Science and Scopus databases. The search keywords used included (but were not limited to) the following phrases: "Industry 4.0", "Construction 4.0", "Industry 4.0 AND construction industry", "BIM AND Construction 4.0", "Building information modeling AND Construction 4.0". Initially, 19,386 articles were identified during the search.

In order to find relevant publications, the research results from Stage 1 were selected by subject area (Engineering, Computer Science, Materials Science), keywords (similar to selected search keywords), language (English), access conditions (All open access), publication stage (Final), source type (article, journal, conference paper, conference proceedings). In sum, 1065 documents were selected for further iteration.

Visual screening included reading through the titles, abstracts, findings, conclusions and citation percentile. At the third stage of the search, 223 articles were identified; after excluding the duplicated publications, the final set of publications consisted of 195 units. Table 1 summarizes the study selection outcomes.

Table 1. Publications related to the interconnection of Industry 4.0 and Construction 4.0.

Keywords	Number of Publications		
	Step 1 [a]	Step 2 [b]	Step 3 [c]
"Industry 4.0";	16,013	862	155
"Construction 4.0";	2399	59	19
"Industry 4.0 AND construction industry";	761	105	34
"BIM AND Construction 4.0;	109	14	6
Building information modeling AND Construction 4.0"	104	25	9
Sum	19,386	1065	223
		Total	195

[a] Search by topic field including title, abstract and keywords and publication year; [b] refining the results with predefined search characteristics; [c] selection by visual screening and citation percentile.

The majority of selected publications were published in the years 2019 and 2020 (23% and 49%, respectively), which proves the growing interest in this area of research and is in line with the general trend of Industry 4.0 publications. Figure 2 describes the distribution of selected publications by year.
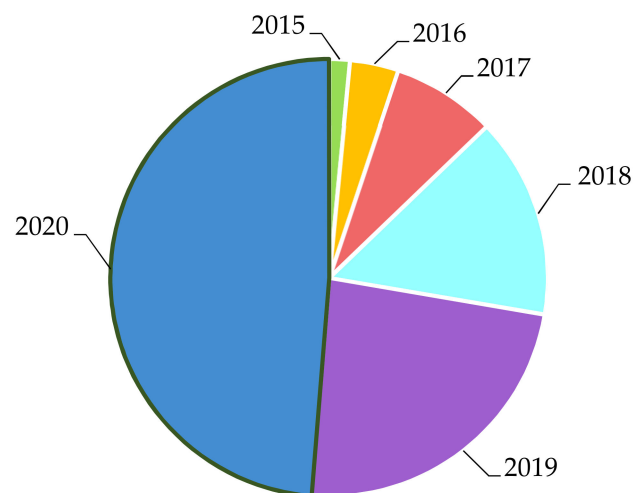
Figure 2. Distribution of selected publications related to interconnection of the Industry 4.0 and Construction 4.0 by year.

Of the 195 publications studied, 151 are articles, 25 are reviews, 15 are conference articles, and the rest are editorials and letters.

3.1. Bibliometric Analysis

Selected publications were exported in the form of a CSV report for further analyses. The authors processed these data in VOSviewer, a software for constructing and visualizing bibliometric networks [22]. Through VOSviewer, the authors created an analysis of the occurrence of keywords, to clarify what keywords are the most shared by the selected publications. The authors suggested that this would help to understand the relations between Industry 4.0 and Construction 4.0 concepts.

Two was established as the minimum number of co-occurring keywords in selected publications; therefore, of the 1432 keywords, 275 met the threshold. For each of the 275 keywords, the total strength of the co-occurrence links with other keywords was calculated. The keywords with the greatest total link strength were selected. After the manual keywords verification, 144 of the most relevant keywords remained.

Industry 4.0, embedded systems, Internet of Things, construction and smart factory appeared to be the most frequently used keywords that create the most influential clusters in respective order. Figure 3 shows the most common single- and two-word keyword combinations in titles, abstracts or keywords. Industry 4.0 was the most cited and the most interconnected keyword, with total 137 strength links. An interesting discovery was that Construction 4.0 was not even mentioned among the identified keywords. This means that there are still a limited number of research publications related to Construction 4.0. In addition, this condition was caused by the prevalence of articles related to Industry 4.0.
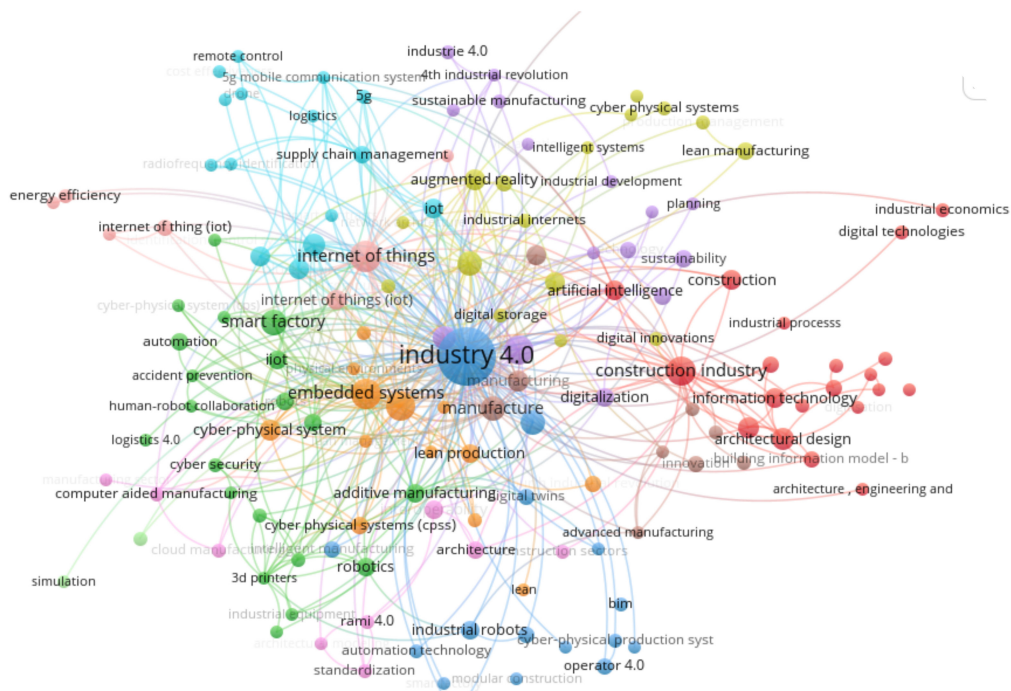
Figure 3. The most common keywords in selected publications related to the connectivity of Industry 4.0 and Construction 4.0 (outputs from VOSviewer).

In addition, the connection between construction and Industry 4.0 and some digital technologies such as the Internet of Things, augmented reality and embedded systems became apparent. This type of relationship forms the basis of the Construction 4.0 [6] concept. Figure 4 describes the interconnections between construction industry and other keywords.
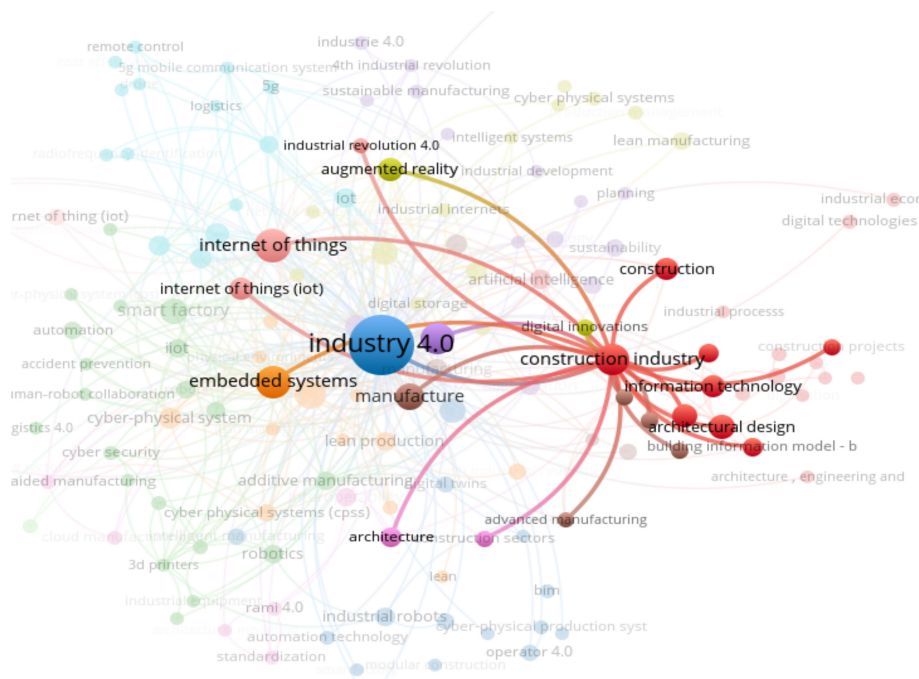

Figure 4. The interconnections between construction industry cluster and other keywords.

In the next step, the authors analyzed the origin of the publication through VOSviewer in order to determine the countries where researchers study the relationship between the concepts of Industry 4.0 and Construction 4.0. Such analysis can help to determinate what countries are at the forefront of the research and development of innovative building technologies and concepts such as Construction 4.0. A minimum number of 1 document was established. It was found that the 195 selected publications come from 55 countries. A visualization of the density of the number of publications by country of origin is shown in Figure 5.
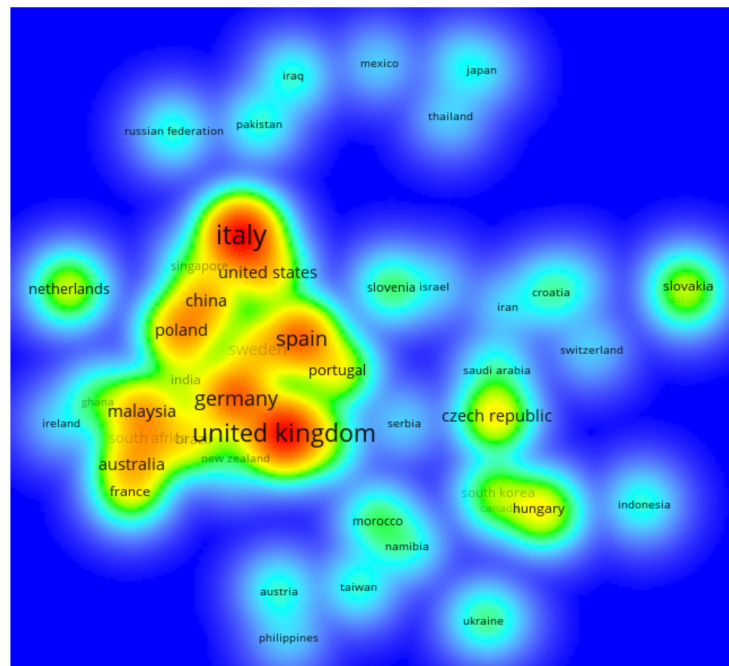

Figure 5. Visualization of the density of the number of publications by country of origin.

The majority of the studied publications are from Italy, United Kingdom and Germany in respective order. Furthermore, according to Figure 5, a significant part of the research on this topic is concerned with developed countries in Europe, Malaysia, China and Australia, which is partially consistent with the research conducted by Forcael et al. [6].

3.2. Interrelation of Industry 4.0 and Construction 4.0 Technologies

In order to understand the relationship between Industry 4.0 and Construction 4.0 technologies, it is deemed necessary to compare the applications of these technologies in terms of construction and manufacturing industries. We identified twenty digital technologies and tools and outlined their definition and key functions in Table 2.

Table 2. The comparison of Industry 4.0 and Construction 4.0 technologies.

Industry 4.0.	Digital Technology	Construction 4.0
Individual networks and devices that are connected together with security, analytics and management to help enhance manufacturing and industrial processes [23,24].	Internet of Things and Services	Combination of sensors, other communication devices, cloud applications, business intelligence technology, that enable creation of virtual networks to support a smart factory environment [8,25].
Creation of physical objects through the overlaying layers using a digital plan [6,26].	Additive manufacturing (3D printing)	Creation of 3D printing houses to decrease manpower requirements, reduce waste of materials and costs, increase housing affordability [11,27].
Correlation of large amount of data for handling, analyzing and processing [6,23,28].	Big data	Solutions for managing, collecting and processing of huge amounts of data from BIM models, embedded sensors, machines, computers or people and to make them accessible to all project participants [8].
The interactions between user and a virtual environment in real-time to enhance the real-world experience through computer-generated simulation [6,23].	Augmented Reality (AR)/Virtual Reality (VR)/Mixed Reality (MR)	A combination of real and virtual images to provide real-time user experience. Can be used for on-site inspection and defect detection, simulation for staff training and design review [11,27].
Robotics system used to replicate human actions and replace workers in manufacturing [23].	Autonomous vehicle/robotics	Vehicles that automate and simplify repetitive or complex tasks on construction site; used to reduce labor cost; enable remote operations, increase efficiency and safety [11]. For example, electric trucks, delivery vans, robot swarms, humanoid robot capable of performing basic physical tasks such as installing drywall or reinforcement on bridges [27].
A flying device with automatic piloting, commonly known as a drone [23].	Unmanned aerial vehicle (UAV)	Construction drones can monitor worksites for equipment malfunctions and security breaches, perform topographical mapping and dangerous tasks, and make hard-to-reach measurements [27].
	Building information modeling (BIM)	Software tool that allows creating an intelligent object-oriented 3D model and generates smart workflows around it. Used for visualization of real-world objects, coordination among project actors, production of construction documents, saves rework time, cost, and error throughout the entire project life cycle [6,11,27].
Computing model for providing convenient network access to a shared platform of customizable computing resources that can be easily accessed [29].	Cloud computing	Provides virtual, low-cost access to information over the Internet, which is useful for cross-company collaboration on construction site [8,11].
Satellites in Earth's orbit transmit precise signals to GPS receivers for calculating and displaying accurate location, speed, and time information to the user [23].	GPS	Tracking technology that can be used for material management, storing and recalling, provide information for logistics purposes or equipment tracking [11].

Table 2. *Cont.*

Industry 4.0.	Digital Technology	Construction 4.0
	LiDAR) / 3D Scanner	Light and range sensors that scan the surrounding jobsite and create high-resolution 3D images in real time [27].
Wireless devices used for wireless communication and technology integration [23].	Mobile devices (smart phones, tablet, handheld devices)	Devices for communication and data transmission assist with internet-based transactions through email or social media to improve productivity and safety management [11].
Creation of intelligent machines and systems that work, learn and react like humans [6,23].	Artificial Intelligence	Intelligent system that can evaluate millions of pieces of data and generate or optimize them for better scheduling and cost options [6,27].
	Modular and prefabricated construction	Production of building components off-site at the factory-like environment and transportation to the construction site for further assembly [8,27].
	New Materials	The development of new high-tech building materials, such as self-healing concrete, translucent wood, algae-infused building panels [27], to improve production productivity and protect the environment [6].
Specific type of database that maintains distributed data using new authentication technology and encryption and network-wide consensus mechanism [23].	Blockchain	
Preventative methods for protecting cyber information from being attacked, compromised or stolen [23].	Cyber security	
Automation systems with embedded sensor technologies that use wireless communication between an object (or tag) and reading device to automatically track and identify such objects [23].	RFID	Reader generates an electromagnetic field and activates the tags and then exchanges information with it. Technology can be used for tracking prefabricated components or equipment [7].
Engineered systems that are built on the synergy of computing and physical components [30].	Cyber–physical systems	A bi-directional coordination between physical construction and virtual models [8].
Design systems, where synthesized models simulate the properties of the implemented model [28,31,32].	Simulations of virtualmodels	Virtual and computerized analogue of a physical system that can be used for simulations for a variety of purposes, using real-time synchronization of incoming read data [23,33].
Automation systems with embedded sensors for capturing and monitoring data through gathering physical stimuli [23,28,31].	Sensors and actuators	Devices for the evaluation of construction workers health, body velocity, gravitational and orientation forces, to perform remote environmental monitoring and predict hazardous situations [7,34].

4. Discussion

There is a gap between Industry 4.0 and the construction industry, and it will continue to grow as long as there is a low adoption of technology and a lack of innovative processes in construction [4]. Modern construction urgently requires smarter resources, but smart construction is still in its infancy [17]. Going digital is a necessary solution to transform the construction industry for increasing its productivity [11]. For instance, the rate of productivity development in the manufacturing industry has long been higher than in all other sectors, especially compared to construction. However, in light of the developing idea of industrialization of construction, the construction industry can be considered as a sub-industry of the manufacturing industry [35]. As cited from [9], Hermann et al. [36] compared the interaction of Industry 4.0 and construction with a "smart factory", where cyber–physical systems allow all stakeholders to collaborate along the entire value chain for the communication and functioning of humans and machines via the Internet of Things, as well as to control processes and make decentralized decisions through a virtual copy of the physical integrated smart factories. A cyber–physical system is the result of the integration between BIM and IoT. Cyber–physical systems can provide bi-directional information exchange used to monitor asset performance in real time and to provide notification of any problems before they occur in the physical environment or offer and share internal and inter-organizational services across the entire value chain. Therefore, the synergy of Industry 4.0 technologies with elements of the construction sector can optimize the supply chain, control physical processes by creating virtual models and decentralize decision-making [4].

Construction 4.0 is not just traditional construction upgraded with technological innovations but is also a new way of perceiving and understanding construction through the light of innovation and increased productivity [6,37]. For example, technologies that the construction industry has adopted from Industry 4.0 are Internet of Things, simulation, autonomous system, robotics, augmented reality, additive manufacturing and big data. The technology that construction has not adopted is cyber security. On the other hand, there are special applications that are specific only to construction, namely Building Information Modeling (BIM), 3D construction printing or modularization of construction components. Thus, the construction sector has also adapted, and not only adopted, the concept of Industry 4.0 within the sector [4]. Otherwise, these technologies are on different levels of maturity. Central technologies like Building Information Modeling (BIM), mobile computing, cloud computing or modularization have reached market maturity but Additive Manufacturing, Augmented, Mixed and Virtual Reality are still at the prototyping stage [8]. According to Qi et al. [38], the most adopted and funded top three technologies in the construction industry are: BIM dimensions analysis models, sensing technology and business information models [34].

BIM is one of the most widely researched smart systems [39]. Oesterreich and Teuteberg admitted that Building Information Modeling (BIM) is considered one of the most important technologies in construction and plays a central role in digitizing the building environment [8]. BIM is a key input to a more complex system, such as creating a digital twin for construction. A digital twin provides a near-real-time connection between the physical and digital world, allowing human behavior patterns and space design to be incorporated, which is only possible through integration with other Industry 4.0 pillars like IoT, and cannot be done with BIM alone [4]. BIM combined with virtual reality technology can create a virtual construction environment that can be used for site layout, construction scheduling, safety assessment, coordination of subcontractors, and safety training of workers [7]. Contractors can benefit from digital data provided by implementing BIM at a primary project stage. BIM provides time, cost and sustainability planning, decreases waste and enhances the general project performance. In the construction phase, compatible use of BIM technology and digital processing provide advanced management, well-organized project formation and precise distribution of information [35,40,41].

Despite the availability and maturity of many technologies, they are not widely adopted by construction companies [8]. According to the survey presented in [9], among the construction professionals in Malaysia, 53% of respondents are unaware of the implementation of Industry 4.0 technology in the construction industry, while 34% have met some of the technologies during their working experience. Interestingly, the remaining 13% of respondents were unsure of the connections between listed technologies and Industry 4.0. After those respondents were provided with a list of technologies related to Industry 4.0, they changed their point of view. After the change in perspective, the share of respondents familiar with Industry 4.0 technologies became 47%.

However, there are best practices that demonstrate practical ways of introducing new technologies into the construction process [8]. You and Feng proposed a framework of the cyber–physical system that integrates these technologies into a complex organizational system and verified this framework at the pilot project of the citizen service center in Xiong'an [7]. For this case study, the following applications and tools were used:

- Visual Studio—the development tool of the application software;
- SQL Azure—the database service deployed on the cloud platform;
- Autodesk Revit—the BIM tool;
- Revit Live—software for generating a VR scene through a 3D model;
- UAV with integrated functions of camera, laser scanning and orientation for real-time construction model acquisition;
- GPS helmets to capture workers' locations in real time;
- RFID technology for tracking prefabricated components;
- Sensors for remote environmental monitoring (wind-force, wind-direction, humidity, dust, temperature and noise sensors).

The implementation of the proposed cyber–physical system in the construction project of the Xiong'an citizen service center helped complete the project according to the scheduling, contributed to the close collaboration between production, logistics and assembly processes by monitoring of the supply chain of prefabricated components, eliminated the delay of quality inspection information, and contributed to promoting sustainable construction [7].

Although Construction 4.0 is a fairly new term, it has already provoked the emergence of new concepts. For example, Calvetti et al. proposed the concept of Worker 4.0, which materializes the basic principles and behavior of workers in the Construction 4.0 scenario. Worker 4.0 is a framework for measuring craft workforce motion productivity, using embedded sensors for data collection that enable near real-time monitoring [34].

Rapid technological progress and development has also influenced technical changes in the city urban development, resulting in new models of cities, termed "smart cities". Smart city is an important concept associated with Industry 4.0 and Construction 4.0. It is a concept that involves advanced digital technologies, new government models, sustainable management of natural resources, renewable energies and information technology knowledge [42]. The digital technologies we have analyzed support the development of Smart city concept.

Yang et al. [17] proposed an emerging information technology acceptance model (EITAM) for identifying the factors that affect information technology acceptance in the construction industry. They found that the usefulness of the technology impacts perceived usefulness which indicates that the more useful the information technology is, the stronger the perceived usefulness, and the stronger the willingness to adopt this technology. Moreover, the market has an impact on perceived usefulness too, which means that a good market can stimulate technology innovation and influence perceived usefulness. Other factors that have impact on the emerging information technology acceptance are: expected benefits from use of the technology, lower input cost, demonstration projects, perceived usefulness, ease-of-use, and intention of use. According to another study, the social factor was proven to be the most important factor influencing the successful implementation of Industry 4.0 technologies in the construction industry, followed by economic as the second

and technological as the third. Security was ranked fourth, followed by legal and environmental, and the political factor was the least influential of all given factors [9]. Furthermore, the organizational change management practice has a strong influence on the technology adoption. One such practice that had the strongest positive correlation with change adoption was the usage of effective change agents, who can guide and provide support during the change. Additionally, other studies [43,44] highlighted the importance of change agents in the successful implementation of BIM in the AEC industry. Organizational change management practices including measured benchmarks, realistic timeframe, communicated benefits and training resources were listed among the five strongest practices. Otherwise, the function of the adopted technology (project-related software, business-related software, or physical technology tool) and the characteristics of the adopted technology (replacement or upgrade of technology or new technology) have no correlations with change-adoption success [39].

Alaloul et al. [35] presented a strategic plan for the transformation of the construction industry and its movement towards Industry 4.0. First, transformation must be carried out at the company level through the introduction of intelligent technologies and procedures, modern materials, automated and semi-automatic equipment, standardization, modularization, and prefabrication. Then, the wave of change will move to the industry level through the sharing of best practices and enhancing cross-industry collaboration along the value chain. After that comes the government level, which will lead to the development of consistent building standards, market openness to international firms and funding for further research and development. Oesterreich and Teuteberg [8] stated that companies should be motivated for the technological adoption through government initiatives, mandates or funding programs.

The adoption of Industry 4.0 technologies can bring economic benefits to improve efficiency, productivity, quality and collaboration, help improve sustainability, safety and recover the poor image of the construction industry. Nevertheless, to reap these benefits, companies have to deal with high implementation costs, with process and organizational changes, or the growing need for data security [8]. Meanwhile, applying emerging information technology to the development of smart construction system requires improving working efficiency of staff, enhancing construction efficiency, obtaining and updating information in a timely and easy manner, better management of smart construction sites, optimal allocation of machinery and material resources and better exchange of information from multiple sources [17]. There is a need to build an interdisciplinary team that consists of architects, civil engineers, and project managers who may have to work with artificial intelligence experts and computer scientists because no one can grasp every technical detail alone. It is predicted that the range of disciplines required will continue to expand and will create new professions such as cyber–physical system integration service providers [7]. Employees will probably have to face higher job requirements and increased levels of mental stress due to fear of losing their jobs. There are also several unresolved issues such as social, political, economic, technological (higher requirements for computer hardware), legal (lack of standards, regulatory compliance and contractual uncertainty) and environmental [8]. Some researchers have raised concerns about the unintended consequences and potential harm that could arise from the increased use of artificial intelligence as part of the Construction 4.0 revolution. The collision of artificial intelligence and construction raises ethical challenges that the industry has never seen before, like machine ethics and autonomous decision-making and legal consequences of the digitization of construction. Therefore, our job is to acknowledge and understand the moral issues that may arise in order to ensure a socially responsible industry of the future. Smart infrastructure and smart buildings can certainly bring benefits, but they can also create a smart dystopia—an unsustainable, vulnerable and unequal space, from which the poorest segments of society are excluded [45]. The results of this review indicate that there are some research gaps in exploring new technologies in the context of construction projects. There is a need to explore the synergy effects of Construction 4.0 techniques in construction projects to

optimize benefits and meet future challenges [19]. In addition, in the existing literature the research works are predominantly limited to a particular type of adopted technology or cover a limited number of cases in their data samples [39].

The main limitation of this review was a lack of prior research studies on the topic, due to the novelty of this problem. Moreover, this review described many Industry 4.0 technologies and their applications in the construction industry, but could not analyze them precisely due to the limited scope of the study. Moreover, some concepts may have gone unnoticed. Therefore, specific studies on each technology are required.

5. Conclusions

The systematic review related to the impact of the Industry 4.0 platform on the formation of the Construction 4.0 concept was conducted by using scientific papers from Web of Science and Scopus science databases. The process of selecting relevant papers was carried out in three steps. Selected publications were analyzed by VOSviewer software in order to find keywords co-occurrences and analyze correlation between Industry 4.0 and Construction 4.0. The analysis refers to research of innovative technologies from two main perspectives: find relations between Industry 4.0 and Construction 4.0 concepts and analyze the application of Industry 4.0 technologies in the construction industry.

Modern construction requires smarter resources for process transformation, increasing productivity and safety. Although the emergence of information technology offers many potential benefits for construction, there is still very little evidence for the use of these technologies in the building industry. This article demonstrates the level of digitalization in construction, which has long been considered the least productive sector. Moreover, this study identified the interconnections between Industry 4.0 and Construction 4.0 publications. According to bibliometric analysis, the most studied technologies related to Industry 4.0 in the construction industry are Internet of Things, augmented reality and embedded systems.

As we can see, studies related to Construction 4.0 technologies do not appear frequently in construction project research. Although, over the past two years there has been a significant increase in studies related to Industry 4.0 and construction. In addition, this study has provided the foundation for further research in the Construction 4.0 area and has pointed out ethical and sociological issues that may arise in connection with the extensive growth of digitalization.

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