

# 4th Industrial Revolution in Brazil: Architecture, Engineering and Civil Construction<sup>1</sup>

*A Quarta Revolução Industrial no Brasil: Arquitetura, Engenharia e a Construção Civil*

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## Abstract

This paper aims to conduct exploratory research into dissemination of the purpose of the Industry 4.0 concept in Brazil, especially in the Architecture, Engineering and Civil Construction (AEC) sector. For this aim, a survey was conducted in on line magazines. In Brazilian territory the theme arises since 2016 in traditional manufacturing sector. In AEC the papers on these organizational mechanisms are incipient, especially when talking about possible networks of connections between clients, production, machines with data feedback and specialized programming.

**Keywords:** Industry 4.0 (I4.0); Technologies; Architecture, Engineering and Construction in Brazil.

## Resumo

O objetivo do artigo é verificar as discussões sobre a temática Indústria 4.0 no território brasileiro e, em especial no setor da construção civil brasileira. Realiza-se a pesquisa do tipo exploratória em meio eletrônico sobre o conceito I4.0. No território brasileiro o tema surge a partir de 2016, nos setores industriais tradicionais. Na AEC, os artigos sobre esses mecanismos de organização são incipientes, principalmente quando se fala nas possíveis redes de conexões entre clientes, produção, máquinas com retroalimentação de dados e programação especializada.

**Palavras-Chave:** Indústria 4.0 (I4.0); Tecnologia, Arquitetura, Engenharia e Construção Civil no Brasil.

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## Introduction

**T**he process of digitalization or digitization of analogue systems for encoding in matrices organized by 0 (zero) and 1 (one) is still the basis for the logic that has transformed the whole rationality of the digital system and that has led to the leap in technology, shifting paradigms in various sectors of society (BRETON; PROUX, 2006; MATTELART, 2002). The computer is the “universal machine” used in all areas and disciplines; it performs mental tasks, makes changes in processes and organizations. These changes feedback, further expanding the possibilities offered (BRYNJOLFSSON, McAFEE, 2011).

In the current context, it is possible to use the technology of sensors applied in strategic locations which check the humidity of the environment and decide how much and how to irrigate plantations in various regions; urban systems that can be organized based on devices

that inform when and where to collect garbage, energy and water supplies, sewage, traffic monitoring, etc. Microprocessors built into objects and machines enable them to be programmed to become self-sustaining and intelligent, machines receive orders and can make the product, such as medicines or clothing, and send them directly for delivery to the customer; the internet makes it possible to share work from any geographical point in real time.

“Automating” is understood as becoming independent of some process. The word was shortened to automation, which comes from the Greek *automotos*, motion, and ion, from Latin, which means state; it is the replacement of man’s physical and mental work with that of machines (KATSUNDO, 1994). Automation, according to the Britannica dictionary, means the application of machines in tasks performed by human beings. Currently, it is applied to a set of techniques with

the purpose of making the accomplishment of tasks automatic, replacing human, physical and mental strength with electromechanical computational devices (SILVEIRA; LIMA, 2003).

The aim of replacing human work with that of machines has always existed, particularly when associated with increased productivity and decreased costs. The oldest machine-tools were the cannula borers of the 16th, 17th and 18th centuries. They are flexible machines that enable the adaptation of different tools, used for machining, drilling, milling, reaming and turning, without the need to remove the object. This equipment was driven by an axis connected to an external water wheel, which moved the rails, pulleys and ropes (MORAES; ABREU, 2006).

As history shows, the processes of mechanization and automation went through several stages, characterized sometimes by their energy supply, sometimes by organization in the method of production. **In the current context**, it is a process that is configured for a new proposal of serving the consumer market. This conformation is also known as Industry 4.0, as it proposes to reorganize production and 4.0 because it is in the 4th Industrial Revolution.

The first version of Industry 4.0 (I4.0) was created at the Hannover fair (2011) to announce a German government strategy for high-tech development promoting the digitization of industry “High-tech

2020 Strategy” (ANTONIO, 2016). The authors consider the movement to be a modification of the means of production.

Industry 4.0 describes a project of intelligent and autonomous systems of robotic factories and machines, using nanotechnology and additive production, connected to networks and with the consumer. Production processes are decentralized in the places of consumption, with devices to evaluate performance problems, disseminating knowledge, and not only the product (LEE; KAO; YANG, 2014) (LASI et al., 2014) (LARIZZA, 2016) (TRENTESAUX, BORANGIU; THOMAS, 2016) (SOMMER, 2015) (SHAFIQA et al., 2015) (WANG et al., 2015).

The main targets of Industry 4.0 are: 1. Produce in a customized way, increasingly meeting the needs for personalization of objects according to demand; 2. Adapt manufacturing flexibly to serve the production chain; 3. Intelligently recognize information about networked objects and machines; 4. Appropriation of interaction with contemporary machines such as robots and autonomous machines, and 5. Adaptation of services offered that contribute to the value chain (SHAFIQA et al., 2015).

The Germany Industry 4.0 initiative (I4.0) - Industry 4.0 - in 2011, drove European territories toward technological opportunities, scientific challenges related to the entry of new generations

of technology, communication and services into industrial production systems. In the United States, Industrial Internet was introduced in 2012 by General Electric and was considered the third wave of innovation after the industrial revolution (SILVEIRA, LIMA, 2003; POSADA et al., 2015).

As mentioned by the authors, in order to obtain mass customization or Advanced Customization (NABONI; PAOLETTI, 2015), there is a need to reduce hierarchies and decentralize commands. An intelligent logistics system to manufacture the product in different parts and powerful algorithms to manage internal and external information flows (ANTONIO, 2016).

This configuration gives industries a high degree of autonomy, in which components acquire independent behavior, process information, learn from it, and react in real time for self-control and organization. The network is open to establish new partners and create new models according to costs and risks (ABRAMOVICI; GÖBEL; NEGES, 2015).

Among the main instruments for this constellation of relationships between consumers, companies, equipment and state-of-the-art technologies are digitized devices, Internet-enabled communication, data clouds, intelligent machines from factories with high technological capacity and, of course, workers responsible for data development, capture, analysis, storage and response.

## **Architecture, Engineering And Civil Construction (Aec)**

The Civil Construction is made several disciplines as Architecture, focused on design buildings, structure, hydraulic, electric, air conditioning engineering, service providers and developers, management constructors, etc. called as AEC – Architecture, Engineering and Civil construction.

Technology used in the Architecture, Engineering and Civil Construction (AEC) industry has gradually accompanied the process of automation and auto-control of machinery maintenance mechanisms, customer metadata management and final product manufacturing aiming to gather efforts to better detect user needs and add skills between industries in the sense of forming a complex production network. Therefore, the aim of this article is to verify discussions on the theme Industry 4.0 in the Brazilian territory and, especially in the Brazilian civil construction and architecture sector.

In order to consolidate automation in civil construction, different efforts are needed (BALAGUER; ABDERRAHIM, 2008, p.17):

1. Integration between the various processes of building development, with feedback of data that feed into other stages, diversification of projects, using similar unified elements, and standardization of the programs for a rapid change between the different disciplines;

2. Pre-fabrication of new materials other than concrete. Mass customization with the use of the CIM (Computer Integrated Manufacturing) concept, which means interweaving between the flexibility of a product and manufacturing productivity;
3. Robots and automated machines: a key point in increasing productivity, developing robotic equipment with lower cost and increasing the level of automation of existing machines;
4. Investments in international programs, with a change in the culture of the operators directly involved in the construction process.

The Industry 4.0 theme has not yet gained importance in AEC factories, especially when it comes to the possible networks of connections between customers, production, data feedback machines and specialized programming (OESTERREICH, TEUTEBERG, 2016). In general, the construction industry is more conservative. In many cases, when the new automatic products are not complementary to the old ones, they are difficult to implement and their use is minimal (BALAGUER; ABDERRAHIM, 2008).

The I4.0 concept for AEC covers a multiplicity of interdisciplinary technologies to enable the digitization, automation and integration of the construction process at all stages of the construction value chain. A range of communication and information technologies are at different levels of maturity, such as BIM (Building Information Modeling) platforms, which consist of a system of information handling used from modeling, simulations, to cost management,

solutions for pre-fabrication, energy consumption analysis, certification, post-occupation analysis, information management to data clouds, which enable the development of the project in its various disciplines, with possibilities for sharing processes and also incorporating mobile devices such as GPS verifiers used in earthmoving, drones, etc.

Architects are using software to simulate energy efficiency, associating digital fabrication and prototyping to understand the behavior of the building in its life cycle. Emergent shapes are possible to manufacture with these computer numeric control (CNC) machines. At the same way Engineers apply their knowledge using computer programs that speed up the process of work.

Even so in AEC, communication technologies and advanced devices such as tablets are already employed on a small scale, and gradually are occupying spaces in assembly services, the automation of the manufacturing and construction process, but are still far from forming an intelligent network aimed at customer needs, which is mainly the case found in industrialized countries.

## **Method**

For this paper, exploratory online research was conducted. We used the Capes Periodicals database, SIBIUSP, and Google Scholar. The key words used were Industry 4.0 (in English and Portuguese), Civil Construction and Brazil.

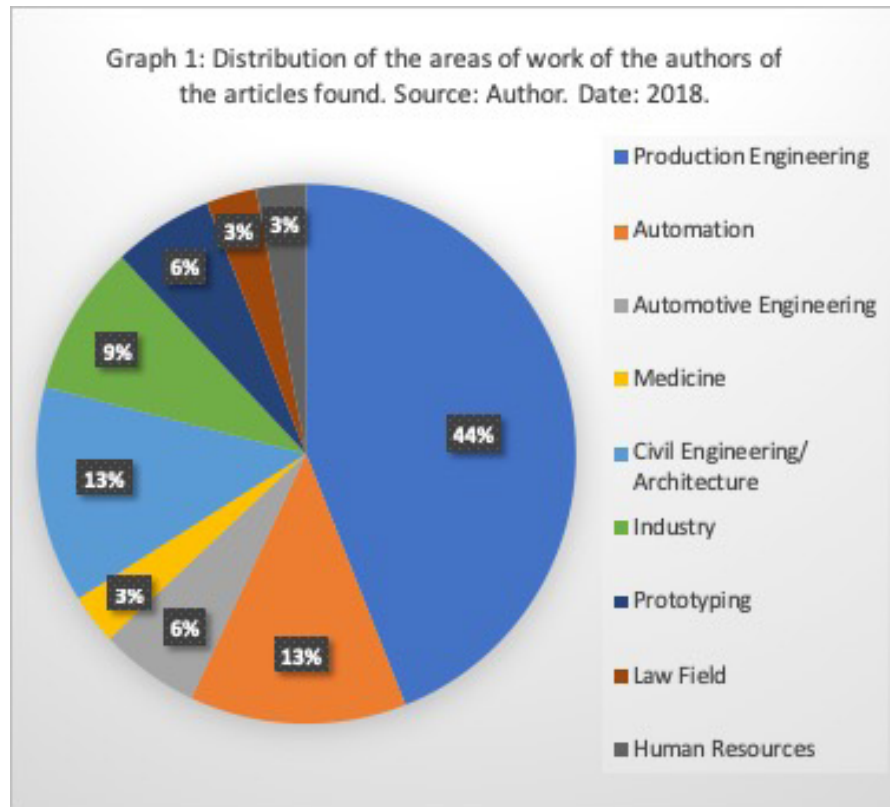
Through this filter, we obtained 580 articles, which were verified by the title, had been published within the last ten years and which discussed new organization through Industry 4.0. Among the results, 32 articles were selected, which were read, analyzed and evaluated regarding their content and interests.

## Results

According to the data surveyed, this research tried to understand the theme I4.0 distributed in several sectors and verify where is AEC in this context. As shown in the graph 1 below, it was found that the main area was concerned with the new form of market organization is Production Engineering, followed by sectors associated with automated control. In the field of civil engineering and architecture, two articles were found, one of which deals with the use of automation for monitoring urban trains (VLT) and the second analyzes a case study in the context of Industry 4.0.

Professionals are mainly working in the branches of organization and management of industry, others with the development of devices for cardiac monitoring, regulation of rights and duties, and training human resources to perform in this new organizational model.

In relation to the topics researched, there are issues related to modularization, which in a



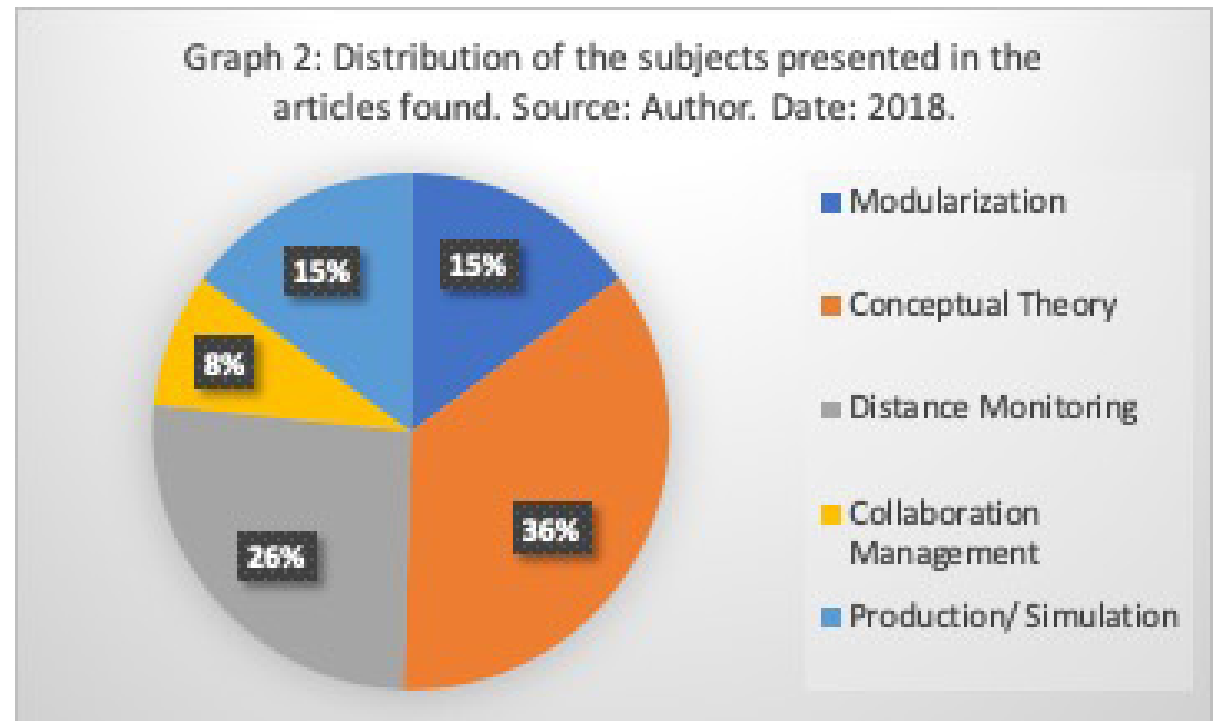
Graph 1: Distribution of the areas of work of the authors of the articles found. Source: Author. Date: 2018.

nutshell means segmentation of smaller systems, products and processes, which provides flexibilization of production for the production of a larger number of objects with available resources and low costs (CLAUDIA, 2017).

Moreover, the theme of remote monitoring is present in almost 30% of the articles as shown in graph 2, since this is one of the challenges posed by Industry 4.0, which intends to create a network of intelligent Industries, clients' mobile devices and other databases linked to a cloud that are

the basis for in-depth analysis with increased operational capability and product design to meet the specific needs of customers.

As reported in the literature regarding operation in the Brazilian territory, the research is mainly focused on the appropriation of knowledge regarding the new proposal and its adaptation to factory production. It is evident that the main sectors concerned with strategic innovations are directed at the automotive sector and branches that have investments in the area of



Graph 2: Distribution of the subjects presented in the articles found. Source: Author. Date: 2018.

automated monitoring, such as footwear and glass production, urban transport and technology companies.

Regarding the concepts of I4.0 associated with Brazilian territory, specially in AEC, it was found that literature on the subject is still scarce, the proposal essentially affecting manufacture, for the customization of the final product, with investment in equipment, management and data security, and training of new skills of workers (FREITAS, 2016).

Cardoso (2017) argues that there is a distance to go for Brazil to reach similar levels to developed countries, since university and technical education is far from the business reality, investment in state-of-the-art technologies and that must be supported by targeted government policies for development.

In the article by Rita et al. (2015), it states that investment in the industrial sector include research, universities, vocational training and education, political coordination in different ministerial agencies and at different levels, and financing made responsible by the federal and state levels. The author also considers that the Brazilian innovation system is essentially composed of public institutions, such as Embraer, Petrobrás and Embrapa, that don't include Architecture, Engineering and Construction.

[...] Brazilian policies to stimulate industrial competitiveness have always been weak and ineffective, mainly because intellectual capital was not developed, but only importation of equipment that distanced itself from a way of thinking oriented toward quality, innovation and competitiveness [...] (RITA, et al, 2015, p.15)

In the AEC sector it is no different, as established in the texts, the Industry 4.0 theme remains far from the construction processes and managing enterprise. There are some discussions regarding light vehicle monitoring systems on rails and monitoring water supply systems.

The AEC industry sector has to be analyzed with due specificity, given that its product is part of a specific chain, and that the concepts of I4.0 fall within the scope of marketing, production, management or preparation of its project. As Miyasaka, Paoletti & Fabricio (2016) point out, the process is aided by data storage, project and project management technologies through BIM programs and digitized equipment that contributes to production of the building.

As such, the AEC sectors are also far from achieving the organizational forms of Industry 4.0, since it is an environment in which the political guidelines are not focused on investment in the sector but rather the sectors of the industry itself. At the same time, research shows that researchers are appropriating the concepts and



theories that deal with the proposal, and gradually experimenting and reflecting on the theme by adapting the proposals to the context in Brazil.

### **Discussion**

In order for our country to reach Industry 4.0 production levels, a range of efforts that thus far are not of interest to emerging countries are necessary. Conducting exploratory research and identifying levels of discussion on the subject contribute to Brazilian industrialization being adapted to the local reality in future perspectives.

To fully achieve the context of I4.0 in the AEC industry, there is a need to meet the challenges with independent manufacturing platforms, increased levels of automation, improvements in production equipment to benefit shop floor environments, components with better energy efficiency and implantation of fiber optics to improve manufacturing internal and external communication capacity (LEONARD, 2015).

Companies have to deal with organizational and process changes, with high implementation costs and unclear forecast of reduced investment or increasing need for data security and protection. From a technical point of view, there are a number of problems to be faced, such as the lack of standards for technologies, the requirements for equipment or the growing need for advanced communications networks, legal and contractual

uncertainties (BRYNJOLFSSON, McAFEE, 2014). Automation affecting the project considers the various stages, such as integration, organization, informal aspects and machine technology, which improve the efficiency, quality and complexity of the product. Logistics, assembly, degree of automation structuring in the factory and on site are also verified, development based on modular coordination, monitoring of variations and the relation of manufacturing with the customer needs.

Automation processes and their applications in AEC, as described by Balaguer; Abderrahim (2008) can be divided into two main groups: the first is characterized by the use of robots in external environments for the infrastructure area, such as paving and compacting roads, tunnels and bridge construction, excavation, dredging, maintenance of urban sectors etc. The second group is in the area of housing construction, in the construction and assembly of structures, assembly of sealing panels, compaction of concrete, final internal finishes or assembly of the complete building.

The greatest difficulty of Robotics and Automation in Construction (RAC) and Architecture, Engineering and Civil Construction is related to the work environment, which, in general, is poorly structured. Working in these locations involves heavy objects, highly tolerant elements, low levels of standardization, insufficient levels of industrialization and pre-fabrication, as well as

the number of actors. It is necessary to make an effort to increase the level of automation involving processes in this important economic sector with the purpose of increasing their productivity (BALAGUER; ABDERRAHIM, 2008).

Moreover, Oesterreich; Teuteberg (2016, p. 137) state that the important aspects for the implementation of automation in the AEC sector are:

1. Change of attitude in companies, in industry machinery, in research centers and in government directions, in order to develop new commercial products with state-of-the-art technologies;
- 2 . Implementation of new information technologies, changing work processes in all segments,
3. The globalization market and, consequently, the adaptation of the commercial structure in the civil construction sector introduce a high level of competitiveness, which forces companies to adopt automated, more efficient techniques.

Advanced research technologies have used various means for preparing computerized operations in AEC. Such robotic equipment can be highly flexible, as it can change the function by changing the tip that defines different actions, such as additive processes with mortar, subtractives like milling machines, transformation, with modification of materials and assembly, with positioning of components.

In recent cases, the authors point out that planning policies using the concept of smart cities are focused on the use of technology in integration for education, in communication between communities, in infrastructure systems, in extensive internet access, in management of a network of cities, controlled and informed mobility, climate monitoring, among other projects, integrating a diversity of information for greater predictability and searching for solutions to problems in advance, resulting in a higher quality of life for residents and that supports maintenance of the environment (MONZON, 2015).

Another important aspect is the increasing use of BIM software and computerized equipment for digital manufacturing. On the one hand, BIM contributes to the information modeling with possibilities of better management and programming to design organic architectures. On the other hand, advanced digital equipment such as milling machines, laser cutters, 3D scanner, 3D printers among others; enables the construction and elaboration complex architectures that are a new contribution to contemporary design.

As can be seen, Industry 4.0 associates factories, customer participation, decentralized network, problem assessment devices, democratization of knowledge and use of information technology with sensors, actuators, mobile devices, the

Internet, etc. however it happens scarcely in the AEC. The sector in Brazil is gradually adapting with companies that work each other and contribute themselves to the value chain, but it is still far from having an autonomous sector, with objects and robotic machines and a flexibilization of manufacturing.

The situation is optimistic, with a growing application of innovative technologies in our country specially to Architects, Engineers and Construction Managers. Of course, there is no anxiety to apply the molds of industrialized processes in industrialized countries, but rather finding the means and best uses for the new form of organization of I4.0 that certainly has benefits for all involved in the process.

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