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Industry 4.0: features and potential impacts on the internal environment of companies

Reinaldo Guerreiro[1] ID **, Juliana Ventura Amaral[2]** ID **, Paschoal Tadeu Russo[2]** ID **, Daniel Magalhães Mucci[1]** ID

[1]Universidade de São Paulo, São Paulo, São Paulo, Brazil.
[2]Fundação Instituto de Pesquisas Contábeis, Atuariais e Financeiras, São Paulo, São Paulo, Brazil.

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[1]reiguerr@usp.br

[2]juliana.amaral@fipecafi.org

[3]paschoal.russo@fipecafi.org

[4]danielmmucci@usp.br

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Abstract

Objective: To analyze the structuring elements of Industry 4.0 and reflect on its potential impacts on the business environment and the internal environment of manufacturing companies, using the approach of organizational subsystems proposed by Guerreiro (1989).

Methodology: This study is characterized as bibliographic and descriptive, focusing on the characteristics of Industry 4.0 and its implications for the internal environment of organizations based on evidence from previous studies.

Results: The fourth industrial revolution is underway, which began at the beginning of the third millennium with the advent of the Internet and has brought changes in the ways of production and in the business models of companies. The study discusses different types of technologies that affect each of the subsystems such as: Institutional Subsystem (beliefs and values of Industry 4.0), Social Subsystem (digital and automation skills, leadership mediated by virtual and augmented reality), Organizational Subsystem (integration of value chain, complex and autonomous structures), Management Subsystem (machine decision-making process, artificial intelligence), Information Subsystem (big data, autonomous systems, cloud computing), Physical-Operational Subsystem (new physical, biological and digital inputs, new productive technologies like autonomous robots, Process Automation, Machine-to-Machine Integrated System and 3D printing).

Contributions: The main contribution of this work is the analysis of the elements of Industry 4.0, as well as the assessment of the impact of this technological and business revolution, in various business subsystems. Complementarily, from an academic perspective, this work can constitute a conceptual platform on the subject to guide future empirical studies.

Keywords: Industry 4.0, organizational subsystems, industrial revolution, fourth revolution.

Introduction

Society, and more specifically, the industrial environment, has been evolving technologically for nearly three centuries, through cycles known as industrial revolutions. Schwab (2016) mentions that the word 'revolution' implies abrupt and radical change, and that, throughout history, revolutions have arisen from new technologies and new ways of perceiving the world, consequently leading to changes in social structures and economic systems.

The first industrial revolution, which occurred from the late 18th century (1760) to the early 19th century (1850), was marked by manual processes that began to be performed with the assistance of mechanical machines, using steam as a source of energy. The second industrial revolution, which started in the late 19th century (1850) and ended around 1945, was characterized by the electrification of factories, the application of the mass production concept, and significant inventions such as the automobile and the airplane. The third industrial revolution, dated between 1945 and 1970, was a result of developments in electronic technology, semiconductors, and automated equipment in telecommunications and manufacturing processes. It was characterized by industrial automation and the integration of mechanical and electronic systems. The fourth industrial revolution began in the early third millennium with the advent of the Internet and is still ongoing, so it is not yet fully characterized (Schwab, 2016). It refers to the digital revolution in manufacturing (Nosalska et al., 2020).

From a technological perspective, so far, the fourth industrial revolution comprehensively encompasses the integrated application of an extensive range of advanced technologies, such as robotics, big data, cloud computing, artificial intelligence, and the Internet of Things. These technologies are causing transformations in the business models of organizations. By enabling smart factories, the fourth industrial revolution creates a world in which manufacturing systems work cooperatively in both virtual and physical dimensions, allowing for complete product customization and the development of new operational models (Kagermann, 2015).

The buzz surrounding this new revolution has once again brought industrial production and industrial employment into the spotlight after both had almost been relegated to "historical texts." Industrial activity in various countries was already seen as discarded, considered only as a remnant in a post-industrial society. The idea of the fourth industrial revolution was initiated by the German government and first appeared at the Hannover industrial fair in 2011 under the German expression "Industrie 4.0," created and promoted by three engineers: Henning Kagermann, a physicist and one of the founders of SAP, Wolfgang Wahlster, a professor of artificial intelligence, and Wolf-Dieter Lukas, a physicist and high-ranking official in the German Federal Ministry of Education and Research. In Germany, the term "Industrie 4.0" has become a well-known element of communication and marketing regarding the concept of the industry of the future (Pfeiffer, 2017).

Nosalska et al. (2020) mention that in addition to the term Industry 4.0, other expressions are used to refer to the fourth industrial revolution, highlighting "smart factories," "intelligent industry," "digital manufacturing," and "smart production." Regardless of the definitions employed, Industry 4.0 can be considered as a combination of intelligent technology that transcends the physical, digital, and biological fields, providing the foundation for the digitization of manufacturing. It involves collecting data from manufacturing processes, supply logistics, and supply chain logistics, using data sensors from operations such as sensors, smartphones, and other devices.

In summary, Industry 4.0 involves complete transparency of the operational environment, where robotic operations generate data captured by sensors, and this data is stored using the concept of big data, facilitated by cloud computing. It is used for decision-making through the use of algorithms. In the end, this data mass is employed by artificial intelligence technology, where machines process decision-making.

Studies on this topic generally focus heavily on the technological aspects of Industry 4.0, with few studies addressing its interaction in business management and control. Pereira and Romero (2017) specifically mention that the influence of Industry 4.0 has been widely researched by academics and professionals in recent years, but its potential consequences in the industry and manufacturing are not yet clearly defined. In this sense, this bibliographical and descriptive work was guided by the following research question: What are the potential impacts of the so-called Industry 4.0 on the subsystems of industrial companies? The study aims to analyze the structural elements of Industry 4.0 and reflect on its potential impacts on the business environment and the internal environment of manufacturing companies, using Guerreiro's (1989) organizational subsystems approach as a basis.

In Brazil, and similarly in other countries around the world, it can be said that the development of Industry 4.0 involves several challenges, such as investments in equipment that encompass new technologies, the adaptation of factory layouts and production processes, as well as the development of new competencies, among others (CNI, 2016).

Du Chenne (2019) emphasizes that the long-proclaimed

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

106

changes are finally at the doorstep, and in the next 10 years, production and distribution environments will be unrecognizable. Management decisions will be made through artificial intelligence, which will make the role of management professionals even more challenging. Therefore, understanding in a structured way how Industry 4.0 can impact business management through the business subsystems can contribute to the work of professionals by analytically pointing out the consequences of the new Revolution. Ortt et al. (2020) stress that the growing global competition, revolving around production costs and quality, is increasingly observed in industrial companies. The competition between the USA and China in the manufacturing sector is becoming fiercer, with the risk of escalating into a trade war. As a result of this competition, many countries around the world are investing in Industry 4.0, such as China, the USA, Germany, and many other countries.

From a theoretical perspective, this work addresses a gap in the literature regarding the systems involved in Industry 4.0 (Cimini et al., 2017). The approach to business systems and the impacts of Industry 4.0 can expand knowledge on the subject by revealing specific dimensions of the managerial process. Furthermore, Industry 4.0 is an evolving concept, and it can be observed that, outside of German-speaking countries, the terminology "Industry 4.0" is not widely known (Lasi et al., 2014). In this sense, it's important to note Pfeiffer's (2017) assertion that there is no single Industry 4.0. Which innovations will be adapted in each region of the world and by which companies depend on specific configurations induced by various factors, such as the degree of automation, product complexity, value chains, and production technology. Pfeiffer (2017) emphasizes that there is little knowledge about these factors in today's economy, including in German industrial production. The author points out that there are no official statistics, for example, on how many people work in hybrid assembly stations (semi-automated) or which companies plan preventive maintenance with data support. Therefore, she highlights that, "given the lack of robust data, we must be very cautious with predictions" (Pfeiffer, 2017, p. 111).

Following this introduction, the theoretical framework underpinning this work is presented and discussed, focusing on the concept of a system and the systemic view of a company, as well as the concept of Industry 4.0 and its structural elements. Section 3 describes the impacts of Industry 4.0 on business subsystems, and the final section presents the concluding remarks.

2. Theoretical Framework

2.1. Concept of System and Systemic View of the Company

One of the most important theoretical contributions, with applications in various fields of knowledge, is the so-called General Systems Theory (GST). This theory was developed by the Austrian biologist Ludwig von Bertalanffy (Von Bertalanffy, 1968). Mele et al. (2010) mention that Von Bertalanffy promoted the idea of systems thinking across all disciplines to find general principles that are valid for all systems. This seminal author introduced the "system" as a new scientific paradigm that contrasts or competes with the analytical, mechanical paradigm traditionally observed in classical science.

Systems theory is a theoretical perspective that allows for the analysis of a phenomenon as a whole and not just as the sum of elementary parts. This theory focuses on the interactions and relationships between the parts of an organization, promoting a dialogue between holism and reductionism (Mele et al., 2010). A system can be defined as "an entity that is a coherent whole, with a boundary perceived around it to distinguish internal and external elements and to identify inputs and outputs related to and emerging from the entity" (Mele et al., 2010, p. 127).

Von Bertalanffy (1968) defines a system as a complex of interacting elements, which are referred to as subsystems. In the business context, Emery and Trist (1960) approach organizations as socio-technical systems, emphasizing the two components of a company within the perspective of a system: a social component (people) and a technical component (technology and machinery).

In Guerreiro's work (1989), the concept of the systemic view of the company is presented, which can be broken down into an analytical set of subsystems. In this approach, the company system is comprised of six subsystems, and their analysis allows for a comprehensive and complete view of the internal environment of organizations. The subsystems include the institutional subsystem, social subsystem, organizational subsystem, management subsystem, information subsystem, and operational subsystem (Catelli, 2001; Guerreiro, 1989). These subsystems will be discussed in more detail in Section 3.

2.2. Industry 4.0

2.2.1. Concept of Industry 4.0

An objective definition for Industry 4.0 can be found in the work of Nosalska et al. (2020, p. 849): "Industry 4.0 is a concept of organizational and technological changes, along with the integration of the value chain and the development of new business models that are driven by customer needs and requirements for mass customization, enabled by innovative technologies, connectivity, and information technology integration."

From this definition, it can be inferred that Industry 4.0 encompasses everything from smart factories to rapid changes in mass consumption in various markets, with technological integration throughout the value chain (Müller & Birkel, 2020), contributing to performance

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

107

(Dalenogare et al., 2018). These transformations trigger substantial technological changes in multiple productive sectors, increasing industry heterogeneity while deepening the structural gap that existed before the Fourth Industrial Revolution (Mon & Giorgio, 2022). As stated by Oesterreich and Teuteberg (2016), the visionary idea of Industry 4.0 nowadays describes the trend towards digitization, automation, and the increasing use of information and communication technology in the manufacturing sector.

Rüttimann and Stöckli (2016) critically analyzed Industry 4.0 and concluded that the new technologies, although not yet implemented in all factories, are already causing a great stir. Gažová et al. (2022) note that the revolution in Industry 4.0 is strongly associated with automation, where companies implement automated production lines and have individual tasks performed by robots. Automation is defined as "a set of technologies that allow the execution of machine and system operations without significant human intervention" (Gažová et al., 2022, p. 1500).

Pfeiffer (2017) mentions that all devices in the production process should be equipped with transponders that communicate the position and production status to the equipment performing the processing. In smart factories built on these principles, the constraints present in mass production systems can be overcome. The idea is to manufacture customized products in response to individual needs and only on-demand. The industrial automation process relies on the automatic collection of information, allowing for the collection of large volumes of data with minimal errors due to the absence of human intervention. It is expected that each product can be unique to meet customer needs.

Mujiono (2021) goes further and mentions that not only automation characterizes Industry 4.0, but also a series of nine elements that are currently present to varying degrees in almost all businesses and professions, highlighting: (i) Internet of Things; (ii) Big Data/Data Analytics; (iii) Augmented Reality/Virtual Reality; (iv) Cybersecurity; (v) Artificial Intelligence; (vi) Autonomous Robots/Robotic Process Automation; (vii) Integrated Systems (Machine-to-Machine); (viii) Additive Manufacturing/3D Printing; and (ix) Cloud Computing. Once these nine elements are known, it's worth mentioning that Roblek et al. (2016) emphasize that Machine-to-Machine (M2M) communication and smart products are not considered as independent elements of Industry 4.0. M2M serves as a facilitator for the Internet of Things (IoT), and smart products are a subcomponent of the cyber-physical system, which promotes connections between the real world and the virtual world. Below, we will provide details on each of the nine elements.

2.2.2. Elements of Industry 4.0

The Internet of Things (IoT) is a concept associated with the digital connection of everyday objects to the internet. IoT consists of a network of physical objects that have the ability to receive, gather, and transmit data. More and more things, such as household appliances, surveillance cameras, transportation means, clothing, and other objects, are being connected to the internet and other devices like computers and smartphones. IoT establishes networks, smart devices, and web-connected services that can detect, connect, infer, and take action. IoT allows sensors and actuators connected to computers to facilitate new products and services, reducing costs, increasing efficiency, and improving the usability of existing systems (Patel et al., 2016; Shendge, 2021). An IoT architecture is sensitive to three aspects: privacy, security, and the efficiency of resource utilization (Mujiono, 2021).

Big Data consists of large, rapidly growing datasets with great diversity. These datasets are so massive that traditional data processing software often lacks the capacity to receive and manage them adequately. Data is essential for preparing information that guides the decision-making process. There are various types of data, such as structured data, which corresponds to a company's organized database and can be processed effectively with data analysis, and unstructured data, which is heterogeneous data like a combination of text files, images, videos, among others. The key steps to optimize big data work include establishing a big data strategy, identifying data sources, accessing, managing, and storing data, analyzing data, and making decisions based on data (Mujiono, 2021). Addo-Tenkorang and Helo (2016) discuss that the concept of big data has evolved to include five attributes (the 5 Vs), which are translated as Variety, Velocity, Volume, Veracity, and Value.

Augmented Reality is the real-time visualization of virtual visual and/or auditory elements overlaid onto the real world environment. Generally, Augmented Reality and Virtual Reality technologies aim to stimulate the user's perception and senses so that they can feel like they are in another world and interact with it (Bun et al., 2021). The difference is that Virtual Reality places users in a virtual world, whereas Augmented Reality brings virtual effects into the real world. Along the same lines, Virtual Reality is a computer-generated three-dimensional environment that creates a sensation of immersion for the user. This environment is viewed through Virtual Reality goggles, which can be accompanied by other devices like gloves or special suits that allow greater interaction with the environment and the perception of different stimuli that enhance the sense of reality.

Cybersecurity is based on the implementation of tools and applications that ensure the integrity, privacy, confidentiality, and availability of an organization's information system assets against both internal and external threats (Mon & Giorgio, 2022). The proper implementation of cybersecurity aims to prevent or

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

108

reduce potential intrusions and threats to information systems, especially in an environment with an increasing volume of digital traffic, which leads to a rise in digital risks and threats. Cybersecurity deals with various types of cyber threats, including (i) cybercrimes, which involve individuals or isolated groups attempting to infiltrate systems for financial gain or disruption, (ii) cyber-attacks that involve politically motivated data collection, and (iii) cyberterrorism, which aims to damage electronic systems, causing panic or fear. Innovation in digital technology is progressing not only in terms of software, hardware, and applications but also in terms of threats.

Artificial Intelligence is defined as a simulation of human intelligence processes performed by machines, encompassing the study of continuously changing data, reasoning to understand the data, and self-correction mechanisms to make decisions (Mujiono, 2021). Thus, Artificial Intelligence includes (i) simulation of human senses - vision, hearing, smell, taste, and touch, (ii) simulations of learning and processing, referred to as deep learning and machine learning, (iii) simulation of human responses, characterized as robotics (Bader & Kaiser, 2019). Applications of Artificial Intelligence include problem-solving, gaming, natural language processing, speech recognition, image processing, automatic programming, and robotics (Malik et al., 2021).

Autonomous Robots or Process Automation refer to equipment that performs some physical movement function through artificial mechanics, which are called robots. This equipment is made up of computers that contain an electromechanical system made up of microprocessors and software that allows it to carry out automatic repetitive tasks independent of human control. Robotic Process Automation is a software technology that facilitates the creation, deployment and management of software robots that mimic human actions to interact with digital systems and software. Just like humans, robotic software has the ability to complete the correct execution of buttons, navigate the system, identify and extract data and carry out pre-programmed actions. Robot software performs repetitive, low-value jobs such as logging into applications and systems, moving files, folders, extracting, copying, entering data, filling in forms and completing analyses of reports. Advanced robots are also capable of performing cognitive processes, such as interpreting texts, participating in conversations, understanding unstructured data and also applying advanced machine learning models. When robots perform these types of repetitive, high-volume tasks, humans can concentrate on what needs to be done most - innovating, collaborating, creating and interacting with customers (Mujiono, 2021).

Machine-to-Machine (M2M) communication, also known as Machine-to-Machine Integration, refers to any technology that enables networked devices to exchange information and perform actions without any manual human intervention.

Artificial Intelligence and Machine Learning facilitate communication between systems so that they can make their own choices (Mujiono, 2021). M2M is the foundation of the Internet of Things, allowing technology to control data from remote equipment, and M2M applications translate data that can trigger pre-programmed automatic actions applicable in an industrial environment (Manavalan & Jayakrishna, 2019). The M2M application system has been widely used in digital businesses and can be found in our daily lives in the form of devices and applications such as vending machines, smart home systems, remote control software, and many other applications.

Additive Manufacturing, also known as 3D printing, is the process of creating items by layering material from a Computer-Aided Design (CAD) file (Mujiono, 2021), and this technology has dramatically transformed the industrial environment. 3D printers consist of a set of additive manufacturing technologies where a three-dimensional object is created by overlapping successive layers of material. They improve communication by providing a realistic, full-color 3D model that conveys much more information than a computer image. The object is built layer by layer using different materials, such as polymers, composites, ceramic pastes, and metals. Additive Manufacturing is more inclusively associated with industrial applications, such as mass production of physical components as inputs or end products (Mujiono, 2021). One of the main benefits is associated with flexibility since it replaces specific machines whose function is limited to a particular product.

Cloud Computing can be defined as computing services over the internet (cloud), which include servers, storage, databases, networking, software, analytics, and data intelligence. Cloud computing offers a range of benefits such as speed, flexibility, and economies of scale (Mujiono, 2021). In particular, cloud computing leads to reduced operational costs, efficiency in managing infrastructure, and flexibility for business transformation. The main reasons organizations opt for cloud computing are cost, speed, global scale, productivity, performance, reliability, and security. Various types of cloud computing have emerged with different services, such as public cloud, private cloud, and hybrid cloud (Mujiono, 2021). Public clouds are operated by third-party cloud service providers. Private cloud refers to exclusive cloud computing resources (service and infrastructure) of an organization, managed on a private network. Hybrid clouds combine public and private clouds so that data and applications are shared between them, providing greater flexibility, more deployment options, and optimization of infrastructure, security, and compliance (Mujiono, 2021).

2.2.3. Drivers of Change in Industry 4.0

Pfeiffer (2017) observes that Industry 4.0 enables the creation of a digital network with the largest number

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

109

of elements involved in production processes, support services, and logistics, where the material merges with the digital. A local production line integrated into global value chains must be part of a global virtual network controlled locally. To make this happen, Industry 4.0 implies changes in the productive aspects of companies, and these changes can be of four types: (i) changes in customer expectations, both as individuals (B2C) and as businesses (B2B); (ii) changes in products, which are being enhanced by data, improving asset productivity; (iii) changes in how new partnerships are being formed, as companies recognize the importance of new forms of collaboration; and (iv) changes in operational models, which are being transformed into new digital models (Schwab, 2016).

All of these changes have significant impacts on society, and "the scale and breadth of the current technological revolution will unfold into economic, social, and cultural changes of such phenomenal proportions that they are almost impossible to predict" (Schwab, 2016, p. 35). Businesses will be established through global networks that incorporate equipment, storage systems, and industrial facilities in the form of Cyber-Physical Systems. To enable them, the elements of Industry 4.0 can be grouped into three types of drivers: (i) physical category, (ii) digital category, and (iii) biological category.

As drivers within the physical category include autonomous vehicles, 3D printing, advanced robotics, and new materials. The main drivers in the digital category are the Internet of Things (IoT) and sensors and other means of connecting things from the physical world to virtual networks, blockchain, and especially the integration between these elements. Finally, in the biological category, innovations in biology, particularly in genetic sequencing and potential advances in synthetic biology, stand out.

In these three categories, technology is merely a facilitator of Industry 4.0 and evolves in an incremental manner, with the truly revolutionary aspects stemming from new business models, which determine the depth of the revolution and the pace of change (Schneider, 2018). Industry 4.0 business models are expected to be designed around new value propositions, characterized primarily by highly individualized products, integrated product-service offerings, well-synchronized combinations, and innovative digital service solutions. These value propositions are driven by the use of data, the integration of customers into product and service engineering processes, and the increasing importance of the software component of products (Arnold et al., 2016; Iansiti & Lakhani, 2014; Porter & Heppelmann 2014; Schneider, 2018).

These drivers enable structural changes in the manufacturing technological foundation, allowing flexibility in product specifications, quality, design, production volume, and production time. Industry 4.0 also enables more efficient use of resources and cost optimization (Ortt et al., 2020). It helps ensure that customers are better served and optimization occurs not only within the value chain within companies but also across the entire supply chain of companies in an industry (Oesterreich & Teuteberg, 2016; Ortt et al., 2020).

Current consumers tend to value not only the physical and tangible aspects of a product but also its functionality, accessibility, and associated services. For this reason, merely reflecting on new value propositions is not sufficient when seeking to develop new and coherent business models for Industry 4.0. Deciding whether and to what extent a business model needs to be adapted, however, remains a challenge in itself (Schneider, 2018). An approach that can assist in understanding this adaptation of the business model is the one presented in Guerreiro's study (1999) of the business subsystems that characterize the internal environment of organizations.

3. The impacts of industry 4.0 on business subsystems

Sanchez et al. (2020) point out that in the context of systems, it's important to understand interoperability, which is the ability of systems to understand and utilize each other's functionalities in a way that they can produce joint results. Interoperability enables the exchange of information between devices, business processes, interfaces, people, among others, in order to resolve conflicts and achieve the execution of their tasks.

In studies related to the economic management model (Catelli, 2001), it is argued that economic performance is the best measure for assessing the fulfillment of a company's mission. In the process of fulfilling their specific missions, companies increasingly seek to offer customers products and services with the best quality, lower costs, and greater speed. Observations about the new environment of Industry 4.0 suggest that companies can continue to do what they did before and do new things in a revolutionary way, with greater speed and a much higher level of information.

Nobre's work (2011) addresses this fundamental point by questioning what the essential competencies of the new industrial organization in the 21st century are. This article presents the concept and characteristics of what the author calls customer-centric systems (CCS). These are new industrial organizations that establish high degrees of organization, cognition, intelligence, and autonomy, and consequently, high levels of agility and flexibility, managing high levels of environmental complexity and uncertainty to operate through intense mass customization with deep customer immersion.

Pereira and Romero (2017) note that Industry 4.0 will significantly change products and manufacturing systems in terms of design, processes, operations, and services.

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

110

Furthermore, it is expected that Industry 4.0 may influence the creation of new business models and product lifecycle, which will have a major impact on industry and markets, ultimately leading to process improvements and increased competitiveness for organizations. According to these authors, Industry 4.0 will bring about potential profound changes in several domains beyond the industrial sector. Its impact and influence can be categorized into six main areas: (1) industry, (2) products and services, (3) business models and markets, (4) the economy, (5) the workplace, and (6) skill development (Pereira & Romero, 2017).

In this section, the approach of the systemic view of the company, initially proposed by Guerreiro (1989), is used. In the systemic approach, the company is characterized as a classical system with inputs, processing, and outputs, structured from various integrated subsystems whose interaction results in a series of processes and activities that contribute to fulfilling the company's ultimate goal, which is fulfilling its mission (Guerreiro, 1999). From this perspective, the company system can be broken down into six subsystems, the analysis of which provides a comprehensive and complete view of the internal environment of organizations. These subsystems are: the institutional subsystem, the social subsystem, the organizational subsystem, the management subsystem, the information subsystem, and the operational subsystem. Subsequently, we discuss how the elements of Industry 4.0 tend to bring about changes that impact each of these six subsystems and identify potential barriers to their incorporation.

3.1. Institutional Subsystem

Guerreiro (1989) argues that a company arises from the need or desire of someone who has expectations to be met and is willing to invest their assets in a venture. Therefore, the beliefs, values, and expectations of the entrepreneurs end up being converted into guidelines that will guide the other components of the company system. In other words, the institutional subsystem corresponds to the set of beliefs and values that permeate the organization, structured based on the beliefs and values of the owners and key agents of the company. The well-established beliefs and values in the organizational culture are converted into guidelines and definitions that guide all other business subsystems. Within the broad set of beliefs and values of a company, a specific group stands out, namely, beliefs and values related to business management, which are referred to as the management model (Reginato & Guerreiro, 2011).

The definitions of the management model are of fundamental importance because, ultimately, they determine the characteristics of the other business subsystems. The main beliefs and values underlying the culture of Industry 4.0 that should impact the other company subsystems are the focus on serving customers

with the best quality, lowest cost, and in the most agile way. The continuous incorporation of new technologies from Industry 4.0 should be highly valued, and companies should ensure that their employees are proficient in these new digital technologies. A culture of security for business systems against cyberattacks should be increasingly encouraged.

As barriers related to the institutional system that may be encountered, Müller et al. (2018) argue that entrepreneurs perceive that the benefits of Industry 4.0 take a long time to be realized. The authors concluded that a significant portion of entrepreneurs understands that Industry 4.0 significantly increases costs without a proportional increase in customer willingness to pay. In other words, the successful implementation of Industry 4.0 will only be achieved if entrepreneurs believe that the initial costs will be rewarded.

The study by Brettel et al. (2014) follows this line and shows that the German manufacturing industry is facing increasing global competition in terms of product quality and production costs. Customers, in turn, are not willing to pay higher prices, and as a consequence, many German manufacturing companies are shifting their focus to customized products with a quick time to market, which means reducing the time between product conception and its market launch.

3.2. Social Subsystem

This subsystem relates to the set of human elements within the organization, involving characteristics and variables related to individuals, including objectives, skills, motivation, needs, leadership, and other equally relevant aspects (Guerreiro, 1989). The social subsystem of companies in the fourth industrial revolution will be profoundly impacted.

While some authors (Schwab, 2016) seek to downplay the impact of the fourth industrial revolution on employment levels, others provide forecasts of a massive replacement of people by machines in the industrial environment (Mujiono, 2021). This new 4.0 environment will bring a significant change in the characteristics of human resources demanded by organizations, given the level of digitization and automation required. The researched studies forecast new forms of work, dedication, and remuneration.

Pereira and Romero (2017) emphasize that a fundamental factor for the successful implementation of Industry 4.0 is the development of skills in line with demographic and social changes. The future vision of work requires new competencies as automation of tasks necessitates employees to be prepared for other activities. Therefore, employees who do not embrace this new work configuration can also constitute barriers to the

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

111

implementation of Industry 4.0.

3.3. Organizational Subsystem

This subsystem refers to the organizational structure of the company, that is, how it divides and groups activities into departments, and also includes the degree of desirable decentralization (the trade-off between authority and responsibility), among other various related issues. One of the aspects observed in this research is the degree of decentralization that should prevail in the Industry 4.0 environment. However, the integration of internal processes and the integration of the supply chain, concepts already strongly established in companies, become even more important in this new business environment.

Over time, along with technological advances, the structure of industrial production organization has undergone various adjustments to cope with changes in markets. In a seller's market, where production is the main bottleneck, the organizational structure is focused on optimizing results through increased productivity, with less emphasis on changes in customer needs. As market saturation increases, companies are forced to adopt product differentiation strategies (Brettel et al., 2014). The dilemma between economies of scale and economies of scope has been addressed through the concept of mass customization, which can be defined as the mass production of goods and services that meet the specific needs of each individual customer, with costs at the same levels as non-customized products.

Pereira and Romero (2017) point out that the elements of Industry 4.0 change the way products and services are sold and offered. Value chains have become more responsive, and an integration between producers and customers has become necessary, allowing greater interaction and adaptation to market requirements. However, this integration is often complex and can pose a barrier to Industry 4.0.

3.4. Management Subsystem

The management subsystem is characterized as the administrative process that unfolds in the stages of planning, execution, and control of business activities. This subsystem encompasses the decision-making process of the company in order to support the achievement of its objectives. The volume of information available for decision-making addresses significant changes in decision-making processes with the support of simulators and artificial intelligence.

Guerreiro (1989) states that it is through this system that the company performs its functions in order to achieve its ultimate goal, which is the fulfillment of its mission. The basic condition for the proper development of the planning, execution, and control process of activities

is knowledge of reality. Therefore, a likely aspect is the transfer of decision-making from managers to machines. The process of strategic and operational planning is likely to occur more frequently, and the process of executing activities will be strongly impacted by the new characteristics of the operational subsystem.

Every company seeks to be effective, that is, to fulfill its mission, and for that, it needs to ensure its continuity, with the fundamental premise being the optimization of its economic results (Catelli, 2001). The generation of economic results depends on a wide range of variables, which are ultimately, directly or indirectly, related to meeting the needs of its customers. In recent decades, company managers have been increasing their level of awareness about delivering excellent customer service. Classic authors in the field of integrated logistics and supply chain management (Lambert & Burduroglu, 2000) argue that companies should strive to achieve three objectives in serving their customers: the highest quality, the lowest cost, and the shortest lead time. It should be noted that these objectives were already well-established for many decades in the context of the so-called Toyota Production System (Rüttimann & Stöckli, 2016). What is new in recent times is related to the new means available to companies to achieve these objectives. The revolutionary technological change in today's world has provided new resources to achieve the age-old and ever-relevant goal of maximizing customer satisfaction. The new technological possibilities of Industry 4.0 contribute to meeting each of these objectives - high quality, lower costs, and speed.

Nobre (2011) states that in the future, humans will be less present, not only on the factory floor but also in managerial activities, as cognitive machines will tend to occupy technical and managerial positions in organizations. In this sense, there is a need for proper parameterization of managerial tasks to make it possible to automate them as well. However, this task is not straightforward and can potentially become another barrier to Industry 4.0.

3.5. Information Subsystem

The information subsystem of the company is characterized as the set of elements that primarily aims to generate information to support the execution of operational activities, as well as the planning and control phases of the management subsystem (Guerreiro, 1989). The development of business functions at a more analytical level is formalized through the execution of a series of activities. Among these activities are those that aim to manipulate information and involve receiving data, processing data, and generating information (Catelli, 2001; Guerreiro, 1989).

One can imagine that the development of new management information systems in the Industry 4.0

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

112

environment will be based on the current conceptual framework. The conceptual models currently available in the theory and practice of management accounting will be enhanced by the new technological possibilities. The level of technological advancement that has already occurred and its future potential indicate that the storage and processing of large volumes of information can be done at competitive costs (with a positive cost-benefit ratio). The integration of operational systems as modules of ERP (Enterprise Resource Planning) and the integration of operational systems with management systems and BI (Business Intelligence) will be increasingly facilitated. The incorporation of simulation systems that generate information for choosing alternatives in the process of operational and economic decision-making should become more common.

The generation of operational and managerial information about various management objects will be greatly facilitated. The integration among modules of management support information systems – budgeting, simulations, actual results reporting, variance analysis – should generate information automatically. Given the degree of technological advancement, it can be stated that the major constraint in the design and implementation of effective information systems (operational and managerial) is the mental model of the managers and the professionals responsible for the conceptual modeling of new solutions.

Lu (2017) argues that the integration of information and communication technologies into production components can generate a massive amount of data. However, the author assures that the development of algorithms to handle this data is expected to be one of the main challenges of Industry 4.0. The lack of expertise in developing these algorithms may, therefore, pose barriers to Industry 4.0.

3.6. Operational Subsystem

The operational subsystem can be characterized as the company's hardware, consisting of all the tangible elements of the company, excluding people, and also incorporating various intangible elements. The operational subsystem serves as a platform where business processes and activities take place. These processes and activities originate from the dynamism and interaction between all subsystems. In the current stage of Industry 4.0 development, it is observed that this subsystem is being significantly impacted by the volume and innovative nature of the new technological resources available to companies, as discussed in the previous section of this work.

The new physical/operational/informational platform of Industry 4.0 provides a wide range of new conceptual and technological resources for the execution of the company's operational processes, from the conception of new products to the supply, production, marketing processes, and the generation of support services. Due to the new technological features available, the innovation of manufacturing processes is expected to occur at a rapid pace within companies.

Lasi et al. (2014) mencionam que essa nova indústria pode ser definida por dois movimentos. Por um lado, existe o potencial de grande volume de novas aplicações (application-pull) que puxam ou atraem a necessidade de grandes mudanças tecnológicas na indústria, e que são derivadas das atuais condições sociais, políticas e econômicas. Por outro lado, existe um excepcional desenvolvimento tecnológico (technology-push) na prática industrial que empurra ou impulsiona a prática de novos negócios. Numa perspectiva do futuro da produção, pode-se observar sistemas de fabricação modulares e eficientes, sendo possível visualizar cenários onde o produto controla seu próprio processo de fabricação. Visualiza-se a fabricação de produtos individuais em lotes de uma única unidade, enquanto as condições econômicas da produção em massa continuam a ser mantidas (Lasi et al., 2014). A crescente demanda por produtos personalizados em combinação com a diminuição dos ciclos de vida dos produtos endereça transformações nas estruturas organizacionais para que as empresas possam lidar com o aumento da complexidade do ambiente.

In Industry 4.0, products, various stakeholders such as customers, employees, and suppliers, and production equipment are in constant interaction within a virtual network that exchanges data in different phases of the product's lifecycle. This lifecycle includes product development, production system engineering, and actual product production (Stock & Seliger, 2016), and it requires skills and investments to be realized, which, in their absence, can pose barriers to Industry 4.0.

3.7. Impacts Summary

Figure 1 illustrates the main points of interaction between the concepts and technologies associated with Industry 4.0 and the organizational subsystems, summarizing the key elements of each subsystem that will be affected by the ongoing changes.

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.
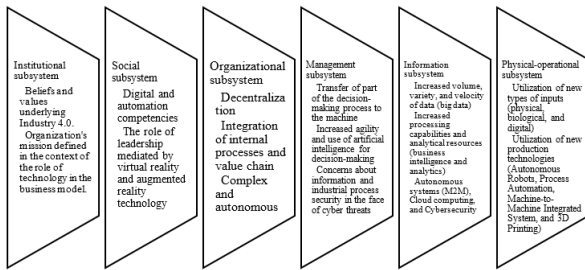
113

Figure 1. Points of Interaction between Industry 4.0 and Organizational Subsystems
Source: Developed by the authors

As for the institutional subsystem, beliefs and values are expected to be strongly influenced by the ongoing revolution. Firstly, it is essential to highlight the importance of awareness that this revolution is impactful and here to stay. This awareness among business owners and leaders is not trivial, especially in small and medium-sized enterprises. New values regarding the strategic importance of the new technology base and new management concepts should be embraced by leaders. Old habits, such as "don't change a winning team," will need to be rethought. In this context, many organizations will need to adjust their missions and visions and also modify their business models. It's likely that companies that do not adopt new beliefs and values will fall by the wayside.

The people within the social subsystem of companies will be significantly affected. The new industrial environment will require new skills for individuals to cope with contemporary digital technologies and the automation processes being implemented. It's likely that traditional personal skills and creativity will lose their relative value in an environment where machines control processes. Therefore, the development of digital and automation skills is essential, and the role of leadership needs to be reconsidered in the context of remote and hybrid work, as well as the use of virtual and augmented reality technologies.

In terms of the organizational subsystem, several elements will be impacted. The number of people to be managed will be much smaller, and the production environment will be permeated to a greater extent by complex and autonomous structures forming integrated processes and value chains. In this context, the span of control and decentralization will be completely transformed. The guidelines for policies and procedures to be observed will be contained in the intelligence of autonomous equipment, and complex, horizontal, and autonomous organizational structures will become increasingly common.

A highly relevant aspect in terms of the management subsystem is the transfer of many decisions to machines.

The integration of the Internet of Things with big data, artificial intelligence, and other concepts is expected to generate a large volume of information. Equipment will process data and generate information. A large number of decisions, especially at the more operational levels, will be made by machines. The speed of decision-making will be much faster than it is currently, and the decisions will be more accurate. A new aspect in terms of management relates to information security against cyber threats. Recent research demonstrates the impact of these technologies on the finance function (Oesterreich et al., 2019; Oesterreich & Teuteberg, 2019).

The information subsystems are expected to have new configurations due to the new technological possibilities that provide faster processing and greater storage capacity (Oesterreich & Teuteberg, 2018). Current ERP systems will need to adopt new levels of integration in both the managerial and operational dimensions. In the managerial dimension, ERP systems will feed and integrate with new BI-type system structures. In the operational dimension, ERP systems will need to connect with autonomous operating systems, automatically collecting information at the most analytical level as operations occur. Autonomous systems, structured in the M2M concept, are expected to prevail.

Finally, the physical-operational subsystem is expected to be completely redesigned in the Industry 4.0 environment of industrial companies, permeated by the set of new technologies. New physical, biological, and digital inputs, new ways of obtaining and receiving inputs, and new autonomous and integrated production processes, supported by more efficient quality control methods, will support innovative customer service processes, providing higher quality, lower costs, and greater flexibility and speed, within the mass customization strategy.

4. Conclusions

Industry 4.0 is an evolving concept, and it can be observed that outside of German-speaking countries, the term Industry 4.0 is relatively unknown. In this sense, it's important to note Pfeiffer's (2017) observation that there is no single Industry 4.0. The specific innovations that will be adopted in each region of the world and by which companies depend on unique configurations induced by various factors, such as the degree of automation, product complexity, value chains, and production technology, as well as various stakeholders, including governments, research institutes, consultancies, and other entities.

It is possible to observe in various studies that the characterization of Industry 4.0 is based on the description of elements of the current technological foundation available in companies, while also considering potential future technological developments. What already exists is significant, but it represents only a small sample of the

Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

114

vast potential for technological and business development anticipated in the future.

This work, based on a literature review of current technological developments, is descriptive on the one hand, as it reports on the state of the art of Industry 4.0, and at the same time, it has a predictive aspect as it seeks to draw up reflections on the potential business impacts of Industry 4.0, and specifically, the impacts on the subsystems of industrial companies.

Therefore, this research divided the company system into its six subsystems: the institutional subsystem, the social subsystem, the organizational subsystem, the management subsystem, the information subsystem, and the operational subsystem. The impacts of Industry 4.0 on these systems and potential barriers in each of them have been presented and discussed, with the analysis parameters being based on the review and discussion of prior literature.

It is expected, therefore, that this work provides theoretical contributions by adding elements to the ongoing discussion of Industry 4.0. From an academic perspective, the main contribution of this research is to provide an informative conceptual framework for Industry 4.0 and an insight into its potential impacts on the internal environment of companies, thus aiding the development of future empirical research on the subject.

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115

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116

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■ Guerreiro, R., Ventura Amaral, J., Tadeu Russo, P., & Magalhães Mucci, D.

117