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Original Article

Industry 4.0 technologies in a brazilian furniture industry

Tecnologias da indústria 4.0 em uma indústria de móveis brasileira

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ABSTRACT

Purpose: The objective of this study is to analyze the technical feasibility of adopting I4.0 technologies in a large furniture industry located in the southern region of Brazil.
Design/methodology/approach: Strategy research is a single case study, qualitative approach, collecting empirical data through in-depth interviews, participant observation, and a documental survey submitted to content analysis.
Findings: Results evidenced that technologies I4.0 were considered technically viable for adoption in the company, and some of these technologies have already been adopted in some of its operations, such as IoT, big data, Cyber-physical Systems (CPS), Additive Manufacturing (AM)/3D printing, cloud computing, and vertical integration. On the other hand, RFID, collaborative robots, digital twins, augmented reality, and AI present technical feasibility but have not yet been adopted.
Research limitations/implication: The limitation of the research stems from the strategy option for the case study, which restricts the possibility of generalizing the results obtained.
Practical implications: The results of the study provide a review of the operational processes of the furniture industry, with the aim of identifying industry 4.0 technologies that can be adopted from the perspective of cost-benefit ratio.
Originality/value: The increasing integration of the Internet of Things (IoT) in the industrial segment enables a new industrial era. However, furniture manufacturing is in the initial stages of adopting these technologies. The study addresses a topic that still represents a taboo in the corporate environment of the industrial sector in question and therefore offers elements for debate.

Keywords: Technical feasibility; Technologies I4.0; Furniture industry; Brazil

RESUMO

Proposta: O objetivo deste estudo é analisar a viabilidade técnica da adoção de tecnologias I4.0 em uma indústria moveleira de grande porte, localizada na região sul do Brasil.

Design/metodologia/abordagem: A estratégia de pesquisa foi um estudo de caso único, abordagem qualitativa, coletando dados empíricos por meio de entrevistas em profundidade, observação participante e levantamento documental submetido à análise de conteúdo.
Resultados: Os resultados evidenciaram que as tecnologias I4.0 foram consideradas tecnicamente viáveis para adoção na empresa, sendo que algumas dessas tecnologias já foram adotadas em algumas de suas operações, como IoT, big data, Cyber-physical Systems (CPS), Additive Manufacturing (AM)/ impressão 3D, computação em nuvem e integração vertical. Por outro lado, RFID, robôs colaborativos, gêmeos digitais, realidade aumentada e IA apresentam viabilidade técnica, mas ainda não foram adotados.
Limitações da pesquisa: A limitação da pesquisa decorre da opção de estratégia pelo estudo de caso, que restringe a possibilidade de generalização dos resultados obtidos.
Implicações práticas: Os resultados do estudo facultam a revisão do processo operacional das indústrias de móveis, com o intuito de identificar as tecnologias da indústria 4.0 que podem ser adotadas, sob a perspectiva da relação custo x benefício.
Originalidade/valor: A crescente integração da Internet das Coisas (IoT) no segmento industrial possibilita uma nova era industrial. No entanto, a indústria moveleira, encontra-se em fase inicial de adoção dessas tecnologias. O estudo aborda um tema que representa ainda um tabu em meio corporativo do setor industrial em questão e, portanto, oferece elementos para o debate.

Palavras-chave: Viabilidade técnica; Tecnologias I4.0; Indústria de móveis; Brasil

1 INTRODUCTION

Different perspectives and trends about markets are influencing manufacturing world scenario, posing challenges and modifying perception about future perspectives and trends. Globalization of the markets may represent threat or opportunity. It will depend on how company will interpret scenarios and adapt internally to cope with it. New technologies may offer alternatives to maintain competitiveness or lose it. The increasing integration of the Internet of Things (IoT) in society and in the industrial segment drives an acceleration and enables a new industrial era (Hermann et al., 2016; Schwab, 2017).

Roblek et al. (2016) and Schwab (2017) point out that in 2011, in Germany, a group of researchers identified a set of technologies, dependent on connectivity, giving rise to the basic concept for I4.0, called the fourth industrial revolution. These technologies began to be adopted both in the industrial environment and in people's daily lives (Rifkin, 2016).

The set of I4.0 technologies aim precisely this, to provide greater operational efficiency, cost reduction, autonomy of operational processes, thus contributing to increase of industrial competitiveness and productivity, in addition to the precision and quality of the operation. In this way, I4.0 technologies can be considered relevant for economic growth, oriented towards the creation of new products and the constitution of new market niches through the transition from the industry based on centralized manufacturing, to the decentralized production model and autonomous (Souza & Nunes, 2020). Based on the perception of potential benefits of I4.0, with emphasis on the integration, autonomy and connectivity of machines, it is possible to say that the introduction of I4.0 technologies is increasingly encouraged.

Oztemel and Gursev (2020) highlight that I4.0 is incipient and has a scarcity of evaluation methodologies, so its implementation and applications are not mature enough. The reason may be the fact that many companies still have difficulties with simple adaptations, noting that the implementation of these technologies starts slowly, justified by the lack of empirical evidence of the benefits, resulting from the adoption of these technologies.

These new technologies can contribute to increasing industrial competitiveness, enabling increased productivity, greater precision in execution, cost reduction, increased quality of manufactured products, among others (Firjan Senai, 2019). In this perspective, it is highlighted that digital manufacturing enables the design of smart factories, with the generation of a significant volume of data that allow machines to make decisions, robots acting with humans, product impressions, replicas with identical behavior to physical products, among others. Therefore, industries must understand the resources and content of I4.0 to achieve the desired benefits, what require to analyse, first, if the operational structure and the practices already adopted in the organization, will facilitate organizational integration with I4.0 technologies.

Some industrial sectors are in a more advanced stage of adoption of I4.0 technologies, such as automotive, electronics and electronics and industrial machinery manufacturing. Some others, such as furniture manufacturing, are in the initial stage of adopting these technologies. The furniture industry is considered one of the most relevant in Brazil (Sindmoveis, 2022) and the state of Rio Grande do Sul is the second largest national producer, with about 2,800 industries employing 36,066 direct jobs. In addition, it is also the second largest exporter of furniture, with revenue, in 2020, estimated at R$ 8.22 billion (Movergs, 2022).

Previous academic research in Brazil on the subject of I4.0 technologies in the furniture sector is scarce and recent. Galera (2020) carried out a diagnosis regarding the organization's capacity in relation to I4.0 practices, Marko (2021) identified the skills of workers needed in I4.0 and Brambatti (2022) analyzed the adequacy of projects and production to enable automation of the processes, in that economic sector. These studies represented an important advance in the discussion of a topic that has not yet been explored, highlighting some of the structuring elements to enable the adoption of industry 4.0 technologies in furniture manufacturing. Firstly, the concern of the authors of the aforementioned studies with the human element stands out, both from the perspective of organizational culture and appropriate technical knowledge. Secondly, there is a need to review processes to introduce new technologies. The gap identified from previous work is the absence of a systemic approach, with analysis of all industry 4.0 technologies, their characteristics, from the perspective of the furniture manufacturing process, highlighting the set of elements that could support the management analysis of whether or not to invest in certain industry 4.0 technologies.

In this context and to provide more information, to the discussion on the topic of adopting I4.0 technologies in the furniture manufacturing process, the objective of this study was to analyze the technical feasibility of adopting I4.0 technologies in a large furniture industry, located in the southern region of the country. It is understood that the study can contribute to industrial praxis, especially in the furniture sector, which has a production process that can be adapted or transformed into a more technological environment through the adoption of I4.0 technologies.

The main contributions of the study include evidence of the technical feasibility of adopting all I4.0 technologies, especially IoT, big data, CPS, AM/3D printing, cloud computing and vertical integration, which have already been operationalized in the company analyzed. The study also showed that RFID technologies, collaborative robots, digital twins, augmented reality and AI have characteristics that guarantee their technical feasibility, but have not yet been operationalized. The preparation stage for migration to the smart factory model was highlighted, considering as most important investment in employee training and changes in organizational culture.

The work begins with a theoretical review of I4.0 technologies. The set of methodological procedures used in the development of the study is detailed below. In the following topic, the results of the study are presented. The work ends with final considerations and references.

2 TECHNOLOGIES OF I4.0

I4.0 differs from previous revolutions, as "it is not just about intelligent and connected systems and machines [...] what makes the fourth industrial revolution different [...] is the fusion of these technologies and the interaction between domains physical, digital and biological" (Schwab, 2017, p. 16). The scenarios about each industrial revolution made the way to perform the production more efficient, that is, production with speed, agility and less manual effort (Cuogo, 2012). Sakurai and Zuchi (2018) emphasize that industrial revolutions aimed to leverage production processes by adapting them to the most efficient technologies of the time, bringing productivity gains at high level.

The convergence of the industrial environment for the adoption of I4.0 technologies must occur, according to Galera (2020) in the organizational, managerial and technological sphere. The organizational sphere refers to organizational culture, work environment, leadership, human resources, professional and personal development, professional skills, hierarchical levels, continuous learning, technological unemployment, awareness of technological trends, among others. The managerial sphere corresponds to processes and infrastructure, which is, for example, organizational structure, new business models, new sales channels, customers, lean production, production processes, material flow, information and knowledge flow, systems integration, between others. The technological sphere, on the other hand, concerns the use of technologies related to I4.0, such as Cyber-physical Systems (CPS), Iot, internet of services, big data, robotics, simulation, cyber security, cloud computing, Additive Manufacturing (AM), augmented reality, among others.

IoT refers to software, sensors and devices connected in computer networks to allow the exchange of data with other devices, systems, applications and users, whose objective is to create a network infrastructure to facilitate the transit of goods, services and information. "Aims to connect anything and anyone at anytime and anywhere, giving rise to new innovative applications and services", as highlighted Lu et al. (2018, p.01) and Oppitz and Tomsu (2018).

AM is a manufacturing process in which thin layers are built on top of each other to form a solid part (Coelho et al., 2018). Scientists are already working on 4D prints that have the characteristic that the products themselves can shape and adapt to the environment they are inserted in, such as shoes and clothes adapt and shape to climatic variations (Schwab, 2017).

Radio Frequency Identification (RFID) technology is based on the use of radio frequency electromagnetic waves, wirelessly, to identify, track, locate and manage products, documents or people, without the need for contact and a visual field through data communication. of identification. The RFID system is composed of a reader, tags/tags/transponder, which can be classified as active (with attached battery) and passive (without battery), antenna and the software that allows the management of information. The working principle is through the emission of the signal to the chip, activating it and sending the signal back if the chip is passive, or transmits its own signal if the chip or tag is active (Ávila, 2012).

According to Oztemel and Gursev (2020) CPS is the integration of computing and physical processes and this integration is essential for the implementation of I4.0. CPS's must interact with big data and make decisions without generating production delays. An important feature of these systems is its ability to respond to any feedback, allowing instantaneous control and verification of process returns in order to generate the expected results.

Vido et al. (2019, p. 04), define collaborative robot as "a robot designed to physically interact with humans in a shared workspace and fill the gap between a manual and an automatic workstation". Vido et al. (2019, p. 13) state: "in the environment of I4.0, collaboration between humans and robots on the factory floor is one of the trends to increase the development of this type of manufacturing". It will become natural and increasingly present in the operating environment, man and machine working together.

For Oztemel and Gursev (2020, p. 144), "cloud computing is a storage system for all applications, programs and data on a virtual server". Cloud computing has options as (i) Hybrid, which can be a combination of community, public or private clouds to share specific data between organizations, (ii) private clouds that are provided for a specific organization, and (iii) public clouds that anyone can access. Big data's main characteristics are the large volume of data. The variety that this large volume generates, in addition to the speed at which it is entered, represent a challenge to organizations, to be interpret and use it to support decision process (Mcafee & Brynjolfsson, 2012, Davenport et al., 2012, Schwab, 2017).

According to Warshaw and Parrott (2017) and Mussomeli et al. (2018), digital twin is a profile or digital image that can be produced in real-time with physical object or process. It is a replica created that combines the use of modeling and simulation with sensors and big data. Digital twins help in business optimization and make it possible, in addition to correcting problems as mentioned above, to experiment with the future, through the creation of scenarios predicting or simulating the future and how the digital twin will behave in this environment, and that from safe and more affordable way (Mussomeli et al., 2018).

Smart factories are autonomous systems that unite the means of production, such as machines, production units, suppliers, warehouses, human resources and the flow of information. Among main characteristics of smart factories it´s worth to mention that they are not centrally controlled, what means that little human intervention isn´t necessary. Each unit has its own control system, with autonomous communication between systems and people through IoT, in real time, where human needs only to solve specific problems and production becomes more efficient. based on customer requirements, which include prices, quality and deadlines, fewer production defects, autonomous communication and a significant increase in productivity (Oztemel & Gursev, 2020; Sevic & Keller, 2021).

The concept of horizontal integration is defined as the integration of a production chain from the supplier to the customer, connecting all of them, supported by autonomous and intelligent systems. The concept of vertical integration consists of the transition of information between all hierarchical levels of a company. In operation, it requires placing sensors on machines, to generate information that is sent to systems such as Programmable Logistics Controllers (PLC), supervisory systems and integrated management system (ERP's) (Pederneiras, 2019).

For Oztemel and Gursev (2020, p. 151), "Augmented reality (AR) is an enhanced version of reality in which direct or indirect views of real-world physical environments are augmented with computer-generated images". For Lamas et al. (2018 p. 13359) augmented reality (AR) "involves a set of technologies that make use of an electronic device to visualize, directly or indirectly, a real-world physical environment that is combined with virtual elements".

3 METHODOLOGICAL PROCEDURES

In order to achieve the proposed objective, the authors opted for the strategy of a single case study, carried out in a large industry, in the furniture manufacturing sector, located in the southern region of the country and the qualitative approach. In 2021, Brazil reached the position of the 28th largest furniture exporter in the world, with exports of USD 1.03 billion in 2021. Rio Grande do Sul, one of brazilian states, was the second largest furniture producer (Movergs, 2022). with more than 6,500 employees in several units in other states of Brazil.

In addition to these criteria, was considered that the company is also perceived as of great relevance on the national scene due to its participation in national and international fairs that dictate trends for the furniture market worldwide and, in addition, it has more than fifty years of history with operations in the furniture sector and with great potential for growth in its business, a relevant item for supplying large retailers in the international market.

The two choices mentioned, both in terms of strategy and approach, reflect the interest of researchers in investigating the phenomenon in greater depth, because the adoption of I4.0 technologies depends on multiple variables, with emphasis on the economic sector, the technology, the profile of employees, with regard to knowledge related to I4.0 technologies, existing organizational culture and the type of previous experiences in the process of adopting new technologies. The two choices of the methodological path find support and support in the scientific literature, especially Gil (2002) and Prodanov and Freitas (2013).

This research was performed at a large furniture industry located in southern Brazil, that in this research will be called as Hardwood (fictitious name).

Empirical data were collected through in-depth interviews, participant observation, since one of the authors is a permanent collaborator of that organization, and documental research. Were interviewed six professionals who occupy strategic positions in the organization, which have a direct relationship with the operational area and work for more than 5 years in that organization: a) engineering and product development manager, b) coordinator of the upholstery unit, c) programming coordinator, d) logistics manager, e) coordinator of the furniture sector and f) industrial director of the subsidiary manufacturing unit, named as E1, E2, E3, E4, E5 and E6, respectively.

In documental research, electronic records were consulted in the organization's ERP, such as notes of meetings, quotations and budgets, operational activity reports, prepared by internal and external audit, and by managers of engineering, production and operations planning and control. Documents available on the internet, in the link of information for society and investors, were also consulted. The empirical data collection procedures are supported by scientific literature specially Gil (2002) and Prodanov and Freitas (2013).

It is also worth mentioning that the script of questions for the interviews was composed of 14 questions, which reflect the state of the art of the literature reviewed on the topic addressed, namely, I4.0 technologies and the context of the furniture industry. These questions also guided the preparation of the checklist for participant observation and document survey. Both the script of questions and the checklist were prepared with the purpose of capturing the perception of the interviewees, as well as finding evidence that could evidence the organizational knowledge about the technologies of I4.0 and their perceptions about operational processes, which would be more susceptible to their integration with technologies I4.0, as well as financial assessments, for their feasibility. Before its application, the questions script and the checklist were previously submitted for validation to three experts with knowledge in the furniture production and technological innovation, as recommended by Gil (2002) and Prodanov and Freitas (2013). Empirical data collection happened in February, March and April 2022. The interviews lasted an average of 40 minutes, were audio recorded and transcribed within 72 hours.

The empirical data obtained, both from the interviews and from the documentary survey and participant observation, were submitted to content analysis, following the procedures indicated by Bardin (2011). Figure 1 shows the categories of analysis that guided the execution of that step, as well as the authors that theoretically support each of them.

Table 1 – Theoretical categories

Categories	Main authors
Diagnosis of the current situation of Alfa's furniture industry manufacturing system.	Schwab (2017), Oztemel and Gursev (2020), Hermann et al. (2016), Firjan (2016), Firjan SENAI (2019), Pederneiras (2019), Saltiel et al. (2017).
Feasibility of I4.0 Technologies in the "Alpha" Industry	Souza and Nunes (2020), Rifkin (2016), Hermann et al. (2016), Firjan (2016), Schwab (2017), Oztemel and Gursev (2020), Roblek et al. (2016), Gjeldum et al. (2018), Soares (2019), Koehler et al. (2019), Vido et al. (2019), Bahrin et al. (2016), Davenport et al. 2012), Mcafee and Brynjolfsson (2012), Warshaw and Parrott (2017), Mussomeli et al. (2018), Sevic and Keller (2021), Pederneiras (2019), Oian (2019), Lamas et al. (2018), Masood and Eggera (2019), Qião et al. (2018).
Positioning of the Alfa company in the market scenario	FIEP (2017), Brainer (2019), IBGE (2021), IEMI (2021), Abimóvel (2019), Movergs (2022), Souza and Nunes (2020), Oztemel and Gursev (2020), Schwab (2017), Ratnasingam et al. (2020), Pagano et al. (2021), Firjan (2016), Firjan SENAI (2019), Sebrae (2019).

Source: Elaborated by the authors from research data

4 RESULTS AND DISCUSSION

Through first question researchers intended to verify comprehension level of the interviewed about technologies I4.0, as recommend scientific literature (Oztemel & Gursev, 2020, Souza & Nunes, 2020, Schwab, 2017). The E1 stated that it is *"a revolution that focuses very heavily on interconnectivity, automation, machine learning and real-time data. One of the strengths is the exchange of data between manufacturing technologies such as cybernetic systems and the internet of things"*. E2 conceptualizes it as *"an industrial revolution, being a broad system of advanced technology at the internet level, advanced computing that can be inserted into the processes and controls of the industry"*. E3 understands that *"it is an automation system, where operations previously performed by humans are now performed by machines. I4.0 will provide companies with a reduction in labor and those that do not adopt it, will be without labor availability"*. E4 and E5 have the same understanding and stated that it is related to the *"industries with* *high technology, robotics, fully automated processes and little use of human labor in the processes"*. The E6 said: *"companies that invest in new technologies that aim to reduce costs, in addition, guarantee the consumer quality in the product and safety for the employees"*. All interviewed perceive that the technologies of I4.0 are more discussed than effectively operationalized. The same was observed through a documental research and participant observation and is supported by scientific literature (Hermann et al., 2016; Rifkin, 2016; Saltiel et al., 2017; Schwab, 2017; Firjan SENAI, 2019; Pederneiras, 2019; Souza & Nunes, 2020).

All interviewees recognize the relevance of I4.0 technologies, as well as potential benefits that could come from their adoption, but its implementation is a challenge due to the complexity of replacing current technologies, traditions, layout and lack of knowledge. The concern about precarious knowledge about industry 4.0 technologies was highlighted by the interviewees, despite the fact that they themselves demonstrated that they had adequate knowledge of most of the aforementioned technologies and the possible benefits they can offer to industries, when adopted. This apparent paradox is justified by the profile of the interviewees, all professionals, occupying management positions, with complete higher education and experience of more than 5 years in the operation. It is also worth highlighting that the relevance of qualified, trained and knowledgeable people in industry 4.0 technologies is not exclusive to the Brazilian industrial context.

This perception is supported by conclusions of Ratnasingam et al. (2020) and Pagano et al. (2021) from studies carried out in Malaysia and Italy, respectively, about the implementation of I4.0 technologies. It was evidenced that the knowledge on the subject in the companies surveyed in these countries is small and the workforce is not qualified, which makes implementation difficult. Still, in Italy, Pagano et al. (2021) concluded in their studies that knowledge about technologies I4.0 is fragmented, but potential benefits from its adoption are recognized. According to SEBRAE (2019) furniture production in Brazil is carried out by small and medium companies, with a low technological investment, but due to the increasing competition companies are planning technological transformations to increase productivity and product diversity, as to invest in integration of I4.0 technologies.

At Alfa company, the furniture and upholstery sector has increased the portfolio of products, but there are many difficulties to increase productivity based on the adoption of the technologies of I4.0 due to the lack of the knowledge to enable the implementation. It may be explained based on data from Firjan (2016) and Firjan SENAI (2019) that reveal that in the furniture production sector in Brazil, both the processes and the set of machines and equipment adopted in the production are related to the industry 3.0. Figure 2 present interviewees knowledge level about technologies I4.0. The most well-known technologies are 3D printing, because the company has a printer, and artificial intelligence, that is becoming very well known by large public, what is supported by Ratnasingam et al. (2020) and Pagano et al. (2021) who recognize the lack of knowledge as a limiting factor for the implementation.

Table 2 – Knowledge of technologies I4.0

	AI	IoT	Big Data	AM/3D	Rfid	Robot	CPS	Cloud Comp.	Dig. Twins	Intelig. Firm	Vert.+Horiz Integr.	AR
1	■	■	■	■	■	■			■	■	■	■
2	■	■				■	■	■				
3	■	■	■	■	■	■	■	■		■	■	
4	■	■		■		■	■	■				■
5	■		■	■								
6	■			■	■							

Source: Elaborated by the authors from research data

The speed and quality of the information was also mentioned as relevant. For Oian (2019) and Pederneiras (2019), the understanding is that vertical and horizontal integration is also the basis for the implementation of I4.0, with agility in decision-making and information sharing, because information more precise and less susceptible to errors turns processes more efficient and organizations more competitive. However, only two of the interviewees demonstrated knowledge of this industry 4.0 technology, which may represent the risk of operationalizing other technologies in the company, due to possible obstacles to sharing data and information, generating delays, rework or even mistakes in the process. management, which was emphasized also by Oian (2019).

Regarding IoT, E1 highlights the application to supply the OEE (Global Equipment Efficiency) indicator in the optimizing machines in the woodworking sector, while E3 and E4 mentioned the use of production order control in PPCP. The three interviewees reported that IoT adoption in the aforementioned processes is happening, with tests, data analysis, with the purpose of validation and supporting the decision to invest in the operationalization of the technologies I4.0. Big data was considered relevant by E3 to enable all processes to be interconnected via ERP, Power BI and other tools that support operations. E1 and E5 confirmed the information from E3 and emphasized the benefits generated, with real-time reports, what allow action to prevent causes and solve specific problems. The processed data can be modeled and directed to processes and activities with greater recurrence of failures, as Lu et al., (2018) have already demonstrated in its study. AM/3D printing is used according to E1, E2 and E3, in the development sector to manufacture some product parts and miniature prototypes. Its use allows greater flexibility, speed and cost reduction. With the market increasingly divided into specific niches, requiring customized service, industries need to invest in new technologies focusing on need of specific groups of consumers, who demand collections of furniture with different characteristics, what isn´t possible to perform during traditional product development processes (Lu et al., 2018; Oppitz & Tomsu, 2018; Davenport et al., 2012).

RFID, smart factories, augmented reality, cloud computing, collaborative robots and digital twins are not implemented. Among the mentioned reasons, there is little support from national suppliers for the adoption of these technologies, due to the high investment value required and the lack of clarity regarding the benefits arising from its adoption, as is shown also in a study conducted by Oztemel & Gursev (2020). Despite the reasons indicated as obstacles to its adoption, according to E3 and E4, vertical and horizontal integration is used throughout the organization since the ERP integrates all spheres, that is, information is supplied and used by everyone. CPS was mentioned by E4 in the processes of controlling indicators in the woodworking and wooden furniture sector (Ávila, 2012; Oztemel & Gursev, 2020). As for cloud computing, all communication via email, chat, office documents and real-time indicator controls are stored in the cloud. The other information is on their own servers.

In relation to the CPS, through participant observation was evidenced that it is being used in the process of production of foam blocks. Foaming machines, cutting saw, conveyor belts and curing drawers communicate with each other and automatically store the blocks (Oztemel & Gursev, 2020). Similarly, in relation to horizontal and vertical integration, through participant observation and documental research, it was identified that the integration is vertical, but not horizontal due to the limitation of access, by employees, to information related to the operation, regulations, guidelines and general information.

Despite having been informed that Big Data technology is already adopted in several processes in the company, generating relevant benefits for improving management, the majority of interviewees understand that it is possible to advance in its use. E1 and E3 stated that Big Data could be used for decision making at all levels of the production and administrative process. They also perceive ERP SAP as a relevant source of big data, because, nowadays, the company has a large database of products and processes of furniture and upholstery units, in the management system. With the collection of information in real time and its treatment, the process tends to provide more agile and accurate answers (Mcafee & Brynjolfsson, 2012, Davenport et al., 2012, Schwab, 2017).

The same was also observed in relation to cloud computing technology, which despite already being operationalized in several operational processes, is still considered underutilized. From this perspective, cloud computing was mentioned by E3 and E4. E3 stated that it would be possible to use it in almost all processes and E4 considers that would be fine its adoption for information sharing, as of technical sheets. Regarding AM/3D printing, E1, E2, E3, E4 understand that its adoption would be technically feasible in the process of making moulds for modelling and in the development of new furniture and upholstery collections and, also, in various industrial maintenance activities. The technical feasibility of adopting radio frequency identification technology (RFID) for E1, E3, E4 and E6 would be in the manufacturing and logistic process, in production controls with the notes of production processes and inventory management (Ávila, 2012). RFID technology has already been widely adopted in organizations from different economic sectors, enabling better supply management and logistics systems. The value of the investment required for its adoption is decreasing, providing access to this technology even for smaller companies.

Collaborative robots are seen as potentially advantageous by E1, E2, E3 E4, E5 as they provide a more efficient process with a lower incidence of errors. They mentioned that the applications would be in the supply process for machines such as 5 axes, CNC band saws, packaging process, welding, painting, assembly of upholstery skeletons, foam bonding and transport of components and finished products. Participant observation also pointed out the possibility of transporting components and finished products by collaborative robot. The reviewed scientific literature about collaborative robots also indicates several benefits from the adoption of this technology, mainly by enabling protection of human beings in activities that pose some type of risk, as well as those that present characteristics of monotony and fatigue (Vido et al., 2019).

Another technology mentioned by E3, E4 and E5 was digital twins. They stated that it could be applied in production engineering to simulate processes, to monitor equipment, in development process and to test and validate products, as for inspection and providing product assembly instructions. The study conducted by Sevic & Keller (2021) highlighted relevant contributions to various industrial activities that digital twins offer, with emphasis on the prior simulation of operational processes, enabling review, testing and evaluation and CPS were mentioned by E2, E3 and E4 as a possible source of strategic advantage when applying process controls to have real-time information in addition to reducing the manual controls that exist and generate late effects. The reviewed literature also highlights these benefits, in industries that have implemented the aforementioned technology (Oztemel & Gursev, 2020).

E1, E3 and E4 perceive that smart factories would be viable in the production of furniture because controls and information would be more accurate and E4 also stated that he sees the possibility of 3D printed sofas, dismantled and packed by robots and the customer doing assembly. Smart factories, as one of the technologies of industry 4.0, comprises investment in the integration of other technologies, which, as interviewees E1, E3 and E4 correctly interpreted, could allow more precise and consumer-focused operational management, sharing data, with specific analysis for needs evidenced in each situation and context. Artificial intelligence would help solve complex problems in the production process, improving decision-making, according to E1, E3 and E4 and can offer support to minimize the incidence of errors in all organizational areas (Sevic & Keller, 2021).

The perception of the interviewees, data from participant observation and documentary research, corroborate the reviewed literature, notably the authors Oztemel and Gursev, (2020), Souza and Nunes (2020), Senai (2019) and Schwab (2017). Was evidenced that some I4.0 technologies have already been adopted in the Alfa company, such as IoT, big data, MA/3D, cloud computing, vertical integration and CPS, as found Sevic and Keller (2021) and Qião et al. (2021) who identified difficulties in implementation in their studies. Figure 3 presents the scenario related to the technologies of I4.0 found in the company Alfa.

Table 3 – Technologies I4.0 x technical feasible x benefits

(Continued)

Technologies	Available and used	Technically feasible	Benefits generated by these technologies - interviews	Benefits generated by these technologies – observation and documental research
AI		■	Assistance and resolution of complex problems, making more assertive decisions.	Greater efficiency and effectiveness of production and administrative processes, reduction of inconsistent information, monitoring and information in real time.
IoT	■	■	Real-time information, more agile decisions, greater vertical and horizontal integration.	Monitoring of multiple machines, flexibility in management and decision making.
Big Data	■	■	More accurate information and updates, more assertive decisions.	Greater volume of data in all spheres, generating more information, integration, precision, efficiency and effectiveness throughout the chain.
AM/3D	■	■	Making molds, prototypes, production of components for products and maintenance.	Same perception of the interviewees.
RFID		■	Automatic production controls and inventory management.	Reduction of errors, operational costs, information in real time, agility in decision making, tracking throughout the chain.
Collaborative robots		■	Reduction of errors and increase of efficiency in processes such as supply and shortage of machines, etc.	Assembly of products in the final processes of furniture and upholstery, reduction of occupational health problems, reduction of operational costs.

Table 3 – Technologies I4.0 x technical feasible x benefits

(Conclusion)

Technologies	Available and used	Technically feasible	Benefits generated by these technologies - interviews	Benefits generated by these technologies – observation and documental research
CPS			Process controls, real-time information, reduction of manual controls.	Greater efficiency, quality, reduction of operating costs, integration of production and management processes, more assertive and agile decision making.
Cloud computing			Sharing of information/ instructions according to the degree of responsibility.	Reduction of internal storage costs such as servers and labor.
Digital twins			Simulate processes, monitor equipment, test and validate products, inspection, product assembly instructions.	Increase production efficiency, lead time reduction, identify bottlenecks, early management.
Inteligent firm			Precise controls and automatic process for sofa production.	Operational cost reduction, efficiency increase, quality increase, lead time reduction, accurate and real-time information, integration.
AR			Sales by the commercial, training in production and maintenance areas.	Cost reduction in the printing of work instructions, production instructions for prototypes and pilot batches, increased efficiency in maintenance work.
horizontal and vertical integration			Greater vertical integration between purchases, ppcp and warehouse, reduce sending emails, calls and consultations in spreadsheets.	Agility in obtaining information and decision-making, reduction of operation management costs, suppliers, customers, administrative and productive process updated in real time or close to it.

Source: Elaborated by the authors from research data

From the perspective of operational processes, production costs and quality, empirical data didn´t identify any possible disadvantages in adopting I4.0 technologies.

E1, E2, E4 and E5 stated that the great challenge in the implementation is related to the lack of qualified employees, of incentive policies and dissemination of technologies of I4.0 from government agencies, of partnerships between companies, public authorities and universities (SEBRAE, 2019, Ratnasingam et al., 2020; Oztemel & Gursev, 2020, Pagano et al., 2021).

5 CONCLUSIONS

This research evaluated technical feasibility of adopting I4.0 technologies in a large furniture industry, located in the southern region of the country, collecting empirical data through participant observation, documental research and in-depth interviews with six professionals. Research results pointed out that all the technologies of I4.0 were judged susceptible of adoption from a technical point of view, and some of them organization has already adopted, as the IoT, big data, CPS, AM/3D printing, cloud computing and vertical integration. On the other hand, RFID, collaborative robots, digital twins, augmented reality and AI have characteristics that ensure their technical feasibility, but they have not yet been operationalized. Was evidenced preparation stage of migration to the smart factory model, that refers, mainly, to the investment in employee training and change of the organizational culture.

As limitations of the study it´s worth to mention the scarcity of publications, both national and international, about the adoption of I4.0 technologies in furniture manufacturing. This finding is supported by Ciano et al. (2020) who claim that there is a small number of studies and the publications found cannot contribute to the advancement of knowledge on the subject in question. In this way, the theoretical contribution of this study arises from the deepening and expansion of the knowledge about the adoption of industry 4.0 technologies, in the Brazilian industrial environment, in a traditional sector, such as furniture manufacturing. As a practical contribution of the study, it is worth to mention operational practices, in a large industry, in the furniture manufacturing sector, what may indicate possibilities and alternative analyzes that should precede the decision to invest in the adoption of industry 4.0 technologies.

As a suggestion for future research, it is recommended to analyze more cases of effective implementation of I4.0 technologies in the furniture area, both through a qualitative approach, as well as a quantitative approach. Furthermore, it is also suggested to carry out research to verify the contribution that the adoption of industry 4.0 technologies, both in furniture manufacturing and in other industrial sectors, to sustainability, i.e. reducing environmental impact and, consequently, green manufacturing.

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