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Industry 4.0 implementation: The relevance of sustainability and the potential social impact in a developing country

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ABSTRACT

This study expands the technical approach that dominates the academic literature on Industry 4.0, identifying relevant benefits and challenges for its implementation process, assessing the relevance of sustainability in Industry 4.0 and analyzing its potential social impact in a developing country. Using a survey-based methodology, specialists on Industry 4.0 from multinationals and national companies in the manufacturing sector in Brazil were consulted. The results showed that the increase in the global competitiveness of the companies and the improvement in the quality of the production lines were the most expected benefits; and the difficulty in changing the organizational culture, the high investments and the difficulty in hiring/training people in digital technology were the most cited challenges. Sustainability was considered strategically secondary, with its social dimension little considered. The implication of this study is to draw attention to the problem of unemployment generated by the implementation of Industry 4.0 and the potential social impacts on local society. The originality and theoretical contribution are to encourage researchers and civil society to contribute with theory and practice to the social dimension of sustainability in Industry 4.0, seeking to prevent the aggravation of social inequalities.

1. Introduction

In an increasingly globalized world, manufacturing needs to outperform the competition to meet the growing demands of consumers, while preserving the natural resources needed for production. There is also a general hope that digital technologies can improve manufacturing performance (Bokrantz et al., 2020; Jabbour et al., 2020a; Dubey et al., 2019), but other authors consider that sustainability is considered secondary in Industry 4.0 (Ghobakhloo et al., 2021).

In 2011 **Industry 4.0** was launched, made possible by digital technologies (Ardito et al., 2019), in order to improve manufacturing performance. The use of Information Technology (IT) and automation, based on the Internet, has opened the possibility that humans and machines can exchange information and data, so supply chain, consumers and relevant stakeholders can be integrated, interact, and if necessary, actuate in the production system (Cao and Yang, 2017; De Carolis et al., 2017; Jain and Ajmera, 2020), It is expected that Industry 4.0 implementation can bring many benefits, such as the possibility of mass customization by the flexibility introduced in the production process, so companies can produce individualized products with reduced lead-time to market (Asif, 2020; Zhong et al., 2017; Hermann et al., 2015), it also promises to increase productivity, reduce resources consumption, improve quality and efficiency (Asif, 2020; Tseng et al., 2019; Romero-Gázquez and Bueno-Delgado, 2018), benefiting circular economy (Jabbour et al., 2020b; Dev et al., 2020; Yadav et al., 2020).

Despite these benefits, there are also challenges to implement Industry 4.0 (Lu, 2017; Yunus, 2020), such as: difficulty in changing the organizational culture (Birkel et al., 2019; De Sousa Jabbour et al., 2018; Jabbour and Jabbour, 2016), necessity of new managements skills (Raj et al., 2020) and difficulty in hiring/training people in digital technology (Birkel et al., 2019; De Sousa Jabbour et al., 2018; Jabbour and Jabbour, 2016).

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Authors diverge on the impact of Industry 4.0 on sustainability. There are authors who consider that the technologies and concepts of Industry 4.0 improve not only production, but also the environment and society (Frederico et al., 2021; Granrath, 2020; Islam et al., 2020; Koenig et al., 2019), benefiting: (1) the environment (Dev et al., 2020; Luthra et al., 2020; Tabuenca et al., 2020), optimizing energy and water consumption (Jena et al., 2020; Lin, 2018; Luthra et al., 2020); (2) the economy (Dev et al., 2020), through the right use of resources and process optimization (Ding et al., 2017; Liao et al., 2017; Luthra et al., 2020); and (3) bringing social benefits, through training, developing human capabilities and better social integration (Hermann et al., 2015; Ding et al., 2017). However, there are also authors who report that the technologies involved with Industry 4.0 increase energy consumption of the manufacturing process (Indri et al., 2018; Ghobakhloo and Fathi, 2020), having a negative impact on the environmental dimension of sustainability.

Authors also differ on the role of sustainability in Industry 4.0. Some state that the intent of Industry 4.0 is to transcend from the traditional economical focus, incorporating the ecological and social aspects, reaching all three dimensions of sustainability (Hermann et al., 2015), bringing social benefits and opportunities (Ghobakhloo, 2020; Müller et al., 2018). Other authors emphasize that Industry 4.0 can also promote imbalance of business relationships, impacting the economic and social dimension (Ghobakhloo and Fathi, 2020; Waibel et al., 2017), with concerns about the unskilled workforce that does not adapt to new technologies (Bonilla et al., 2018), and some state that the environmental preservation is not considered a strategic priority in Industry 4.0 (Ghobakhloo et al., 2021).

The academic literature has been influenced by technical studies, focusing on performance, productivity, competitiveness, and possible economic gains.

Like other production paradigms, Industry 4.0 is expected to have an impact on social life (Oztemel and Gursev, 2020). There is still no consensus on the theoretical concepts of Industry 4.0 (Pereira and Romero, 2017), nor on the social impact it brings with its adoption (Sartal et al., 2020), and which construct should be used more appropriately to evaluate social sustainability (Hutchins, 2010; Sartal et al., 2020).

As it is the object of recent studies, there is a need to develop theories and definitions about Industry 4.0 to support the practice and accelerate this digital transformation (Lin et al., 2018), especially in the social aspect, that has been scarcely analyzed.

The aim of this study is to collaborate to the studies of Industry 4.0 in production management theory (Schiavone and Sprenger, 2017), expanding the discussion beyond the technical approach that has dominated the academic literature, identifying some relevant benefits and challenges for the implementation of Industry 4.0, assessing its relevance for sustainability, and analyzing its potential social impact in a developing country. In this sense, the following research questions were formulated:

RQ 1. What are the main benefits expected with the Industry 4.0 adoption?

RQ 2. What are the relevant challenges expected in the process of implementing Industry 4.0?

RQ 3. Are the environmental and social dimensions of sustainability considered priority strategies in Industry 4.0?

Following this Introduction, section 2 presents the theoretical background, showing the constructs of benefits and challenges collected in the scientific literature. Section 3 contains the research method, sampling and research strategy. Section 4 presents the results and discussion, section 5 discusses the general implications of Industry 4.0, and section 6 exposes the results and limitations of this study.

The relevance of this study to is to discuss theoretically and practically the importance of cleaner production and sustainability in Industry 4.0. To this end, a survey-based methodology was used to consult specialists in the manufacturing sector in Brazil, responsible for implementing Industry 4.0 on the expected benefits and challenges of adopting Industry 4.0, and to assess its relevance for sustainability. The increase in the global competitiveness of companies and the improvement in the quality of the production lines were the most expected benefits. The difficulty in changing the organizational culture, the high investments and the difficulty in hiring/training people in digital technology were considered the most cited challenges. Sustainability was considered weakly strategic, with its social dimension little considered.

2. Theoretical background

The mechanization of manufacturing and the use of water and steam power, in the 1760s, brought important changes in the production processes being conventionally called the first industrial revolution (Industry 1.0), enabling the replacement of human physical effort by machines, increasing productivity and the quantity of products (Lezoche et al., 2020; Lo Bello et al., 2017). Around 1800, electricity and the steel industry brought the second industrial revolution (Industry 2.0), enabling mass production (Singh et al., 2019; Türkeş et al., 2019). By 1969, computers, software, Information Technology (IT), the first Programmable Logic Controllers (PLC), robots, and electronics were introduced, automating production processes in the so-called third industrial revolution or Industry 3.0 (Duarte et al., 2017; Hsu et al., 2020).

The fourth industrial revolution was launched in 2011 at the Hanover Fair, as a program of the German Government (Kagermann et al., 2013; Sanders et al., 2016) to create value through the connection between the internal and external environments of the factories, supported by the communications network (Kang et al., 2016; Hermann et al., 2015).

Industry 4.0, also called digital manufacturing or Industrial Internet of Things, appears to be an umbrella term that encompasses all digital technologies that are transforming the production processes worldwide (Laird, 2017; Moeuf et al., 2018; Wagner and Walton, 2016), based on the Internet, networks, and Cyber-Physical Systems (Lu, 2017). There are many different definitions of Industry 4.0 as the concept is new (Su et al., 2017).

2.1. *Sustainability and industry 4.0*

Recently, Industry 4.0 is being promoted as a key instrument to increase productivity, provide economic growth and sustainability for companies (Rosin et al., 2020). It is expected that the data generated by the Industry 4.0 technology can be converted into intelligence and bring benefits for these companies to remain competitive and sustainable (Ahmad et al., 2020), using, for example, the Internet of Things (IoT) to control information, energy consumption, pollution and waste more precisely (Cui et al., 2020). However, technologies that support Industry 4.0 consume resources and energy, impacting negatively the environment (Waibel et al., 2017). A study with 200 companies in Italy showed that the respondents felt that Industry 4.0 support technologies contributed weakly to any relevant advance in environmental conditions (Chiarini et al., 2020).

Industry 4.0 may bring benefits to manufacturing, but job creation will require skilled workers with higher qualifications (Dirgová et al., 2018; Waibel et al., 2017), creating unemployment of the low-skilled workforce, and also generating an immediate negative impact on the society in which the manufacturers are located (Ghobakhloo and Fathi, 2020; Kerin and Pham, 2020; Waibel et al., 2017). Industry 4.0 can also bring the imbalance in commercial relationships, as large manufacturers will be able to implement it faster than small and medium-sized ones, due to the high costs and risks involved (Ghobakhloo and Fathi, 2020; Waibel et al., 2017). Suppliers that do not adapt to supply Industry 4.0 companies tend to perish, aggravating social inequalities (Bag et al., 2018).

In the strategy implementation process, manufacturing should keep in balance social, economic and environmental sustainability (Fritzsche et al., 2018; Jabarzadeh et al., 2020; Kerin and Pham, 2020). Although there is evidence that Industry 4.0 contributes to the improvement of sustainability, new studies should consider the analysis of the impact of the social dimension on the future of society, especially for employees (Varela et al., 2019).

2.2. Research model

The research model (Table 1) addresses the expected benefits and challenges from Industry 4.0 in companies and sustainability collected in the scientific literature.

3. Research method

3.1. The questionnaire and sampling criteria

Survey-based methodology was selected for assessing the relevance of sustainability in Industry 4.0 (Forza, 2002), as it allows responses to be classified in order of importance, making it possible to measure the relevance of sustainability and other parameters.

The sample survey was applied to companies from the Brazilian National Automotive Vehicle Components Industry Association (SINDIPECAS) and from the Brazilian Machinery Builders Association (ABIMAQ). To keep the validity and relevance of this study, only companies that had specialists or people involved with Industry 4.0 concepts/technologies were considered and contacted by telephone, email, videoconference, and some in person, despite the restrictions required by the social distance of the COVID-19 pandemic.

Table 1
Variables of the expected benefits and challenges from Industry 4.0 in companies and sustainability.

Constructs			
Benefits	Challenges	Statement	References
Competition		Increase the company's global competitiveness	Bokrantz et al. (2020); *Dubey* et al. *(2019)*; Sung (2018)
Quality		Improve the quality of production lines	Belli et al. (2018); Tayier and Janasekaran (2020)
Sales		Market share rise	Illa and Padhi (2018); Tekin et al. (2020).
Delivery		Faster than competitors	Bocewicz et al. (2019); D'Addona (2019)
Reliability		Be seen or become a reliable company	Contador (2008)
Sustainability		Achieve cleaner production within the manufacturing process	Shivajee et al. (2019); Jena et al. (2020); Lin (2018); Luthra et al. (2020)
		Be seen as a company concerned with the environmental and social responsibility	Ghobakhloo and Fathi (2020); Kerin and Pham (2020); Waibel et al. (2017)
	Costs	High investments for implementation	Ghobakhloo and Fathi (2020); Waibel et al. (2017)
	Culture	Difficulty in changing the organizational culture	Birkel et al. (2019); de Sousa Jabbour et al. (2018); Jabbour and de Souza Jabbour (2016); Raj et al. (2020)
	Technology	Difficulty in hiring/training people in digital technology	Birkel et al. (2019); Raj et al. (2020)
	Sustainability	Sustainability is considered secondary	Ghobakhloo and Fathi (2020); Kerin and Pham (2020); Waibel et al. (2017)
		Possibility of unemployment	Ghobakhloo and Fathi (2020); Kerin and Pham (2020); Waibel et al. (2017)

3.1.1. Questionnaire distribution and potential biases

After contacting nearly 160 of the companies indicated by these two associations, 63 companies agreed to participate, but one was excluded because the respondent made it clear that he/she did not consider Industry 4.0 relevant, which could influence the results, and three others who answered to the questionnaire marking responses with numbers in sequences were also excluded, to rule out possible biases that could compromise the reliability of the survey, leaving 59 companies in total.

3.1.2. Research ethics

In order to meet the international requirements of research ethics, it was informed at the beginning of the questionnaire that, by answering the questionnaire, respondents had consented to participate in the research, as well as authorized the use of their data only for scientific purpose, anonymously. They were also informed that they could choose not to complete the questionnaire at any time.

3.2. Characterization of respondents

The sample comprised respondents from Metal-mechanics: 34% (20 respondents); Electro-mechanics: 34% (20 respondents), Auto parts: 22% (13 respondents), Chemical: 7% (4 respondents) and Consulting: 3% (2 respondents).

The companies' size was measured by the number of employees, accordingly to the Organization for Economic Co-operation and Development (OECD – Organization for Economic Co-operation and Development, 2021) criteria, that is: small enterprises employ from 10 to 49 employees; medium-sized enterprises from 50 to 249 and large enterprises for more than 250. The hierarchical position of respondents within companies has the majority formed by managers that represented 59% (35 respondents), followed by engineers with 24% (14), CEO/-Directors with 15% (9) and one specialist. Finally, the origin of capital refers to Brazilian capital: 54% (32 companies), multinational companies: 20% Germany (12), 7% Japan (4); 5% American (3), 5% French (3), 3% Swiss (2), 2% Sweden (1); 2% Austrian (1), and one company with American and Brazilian capital.

3.3. Research strategy

The research strategy was to indirectly assess the relevance of sustainability in Industry 4.0. Instead of asking the respondents directly, they were asked to rate some of the most expected benefits and challenges with the Industry 4.0 implementation process, in which sustainability was included.

3.4. Questionnaire validation and data collection

Three pre-tests were conducted with scientific researchers, with more than 10 years of experience in research and teaching, to guarantee the validity of the instrument (Hair Jr. et al., 2009). They gave minor suggestions to simplify and make the questionnaire more understandable, which were incorporated into it.

All the companies were established in Brazil, and most of the respondents located in Greater São Paulo. The questionnaire was prepared in Portuguese, taking from 30 to 45 min to be answered. The questionnaire based on the literature review constituted of a structured questionnaire using a five-point Likert scale to classify the benefits (RQ 1) and challenges (RQ 2) in a degree of importance, and to assess the relevance of the environmental and social dimensions of sustainability (RQ 3).

3.5. Data analysis

A two-step cluster analysis was performed to identify distinct groups with similar characteristics (Marodin et al., 2016).

The first step was to perform a hierarchical cluster analysis (HCA) to identify the adequate number of groups to divide the sample (Milligan and Cooper, 1985). HCA was employed with Ward's method in the cluster method, and the measure interval of similarity among respondents used was the squared Euclidean distance. The division in three groups was adopted as it did not present any non-significant variable.

The second step was accomplished with the non-hierarchical K-means cluster analysis to refine the cluster solution (Hair Jr. et al., 2009). After identifying the clusters members, a demographic analysis of each cluster member was performed to identify possible patterns in each cluster, but it was not possible. In each of the three clusters, there were respondents from different sectors, company size, capital of origin and hierarchical positions.

3.6. Data reliability

To assess the consistency of the entire scale, Cronbach's alpha was used as the reliability coefficient (Cronbach, 1951; Landis and Koch, 1977; Hair Jr. et al., 2009). The generally accepted lower limit of Cronbach's alpha is 0.70, but for exploratory research, as in this case, it can decrease to 0.60 (Landis and Koch, 1977; Hair Jr. et al., 2009). The Cronbach's alpha of the questionnaire was 0.623, considered substantially reliable (Landis and Koch, 1977).

4. Results and discussion

4.1. Benefits with industry 4.0

The dendrogram displayed in Fig. 1, represents the groups of similarities identified with the hierarchical cluster analysis to study the benefits with Industry 4.0, based on the variables selected in Table 1.

4.1.1. Results of the benefits clusters

Table 2 lists the K-means results for the Benefits cluster, showing the contribution of each variable to the formation of three groups, as well as the size of the companies, and sector of activity. The mean of the benefits expected with Industry 4.0 is statistically different among the three groups for all variables (see ANOVA F-values).

Cluster 1, with 9 respondents, was mostly composed from large (56%), medium (22%) and small (22%) companies, and a predominance of the metal-mechanical sector (56%). The group called the Quality to Compete Group ranked *improving the quality of production lines* as the main benefit of Industry 4.0 (mean: 4.2); followed by the *possibility to increase the company's global competitiveness* (mean: 4.1). Respondents from this group saw quality products as strategic to raising global

Table 2
K-means results for Benefits clusters variables.

Variables	Cluster Mean + Std. Dev.						ANOVA F-value
	Custer 1 - *Quality to compete*		Cluster 2 *-Compete to sell*		Cluster 3 - *Sustainability*		
Quality	4.2	±1.0	4.6	±0.6	3.5	±1.0	5.07*
Competition	4.1	±0.6	4.8	±0.4	4.0	±0.8	12.46*
Sales	3.6	±0.5	4.6	±0.6	3.5	±0.6	14.59*
Delivery	3.4	±1.0	4.5	±0.7	3.3	±1.0	10.16*
Sustainability. Cleaner production	2.4	±0.5	4.2	±0.8	4.8	±0.5	24.04*
Sustainability Social responsibility	2.6	±0.5	3.8	±1.0	4.5	±0.6	8.02*
Reliability	3.0	±1.1	4.6	±0.5	4.3	±1.0	19.83*
Nr. of companies	9		46		4		
Company size							
Small companies	22%		20%		25%		
Medium companies	22%		30%		25%		
Large companies	56%		50%		50%		
Sector of activity							
Metal-mechanics	56%		30%		25%		
Electromechanics	11%		40%		25%		
Auto-parts	0%		26%		25%		
Chemical	11%		4%		25%		
Consulting	22%		0%		0%		

*p < 0.01.

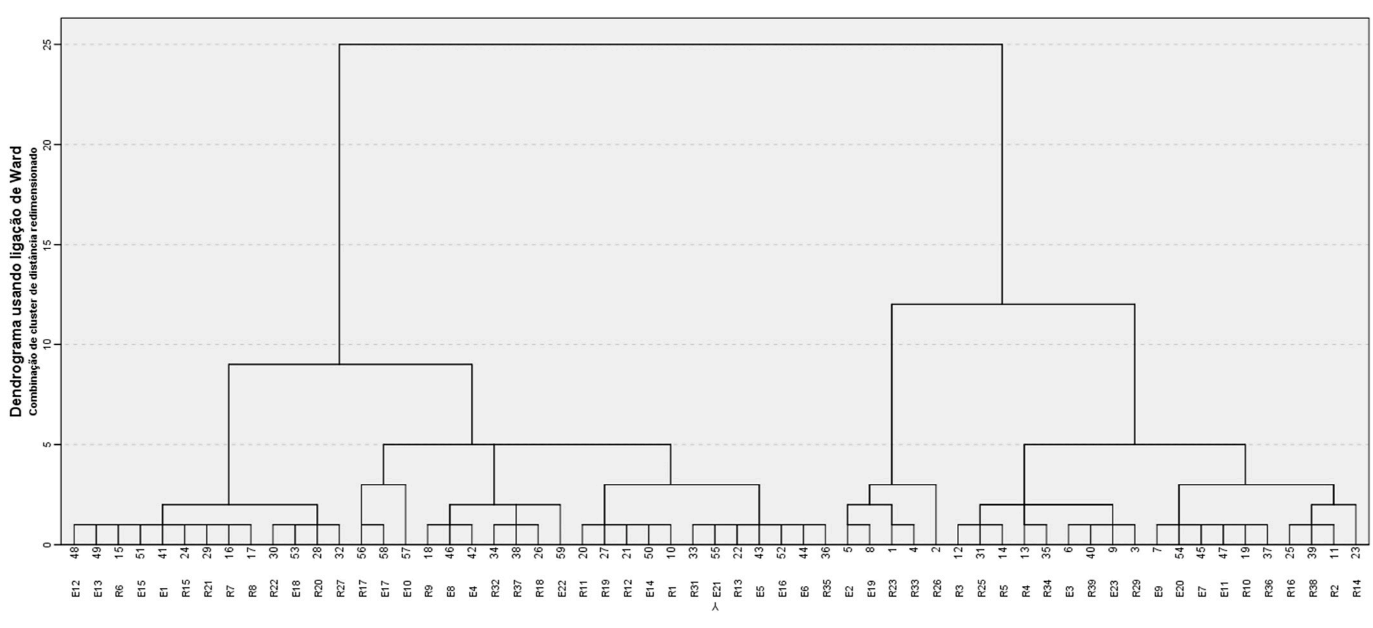

Fig. 1. Dendrogram for selecting the Benefits clusters.

competitiveness and hoped that Industry 4.0 could help in this regard. *Market share rise* (mean: 3.6); and *deliver products faster than competitors* (mean: 3.4), were classified soon after, but with less certainty. For this group, sustainability was not considered strategic, and *be seen or become a reliable company* (mean: 3.0) could be achieved by other factors of Industry 4.0 not directly related to sustainability as the last classified were: *be seen as a company concerned with the environment and social responsibility* (mean: 2.6), and *achieve cleaner production and a more sustainable manufacturing process* (mean: 2.4).

Cluster 2 was formed by respondents with a predominance of large companies (50%), but also included small (20%) and medium (30%) companies. The electromechanical sector (40%) was predominant, followed by metal-mechanics (30%) and auto-parts (26%) and chemical (4%). This cluster was composed by the largest number of respondents (46 elements). Cluster 2, called the Compete to Sell group, attributed maximum importance to the *possibility of increasing the company's global competitiveness* (mean: 4.8), with a standard deviation of 0.4, which means that most respondents agreed that this is the main benefit of Industry 4.0. This competitiveness could be achieved by *be seen or become reliable companies* (mean: 4.6) and, at the same time, *increasing market share* (mean: 4.6), which could be reached by *improving the quality of products* (mean: 4.6), benefits that could also help these companies to *deliver products faster than competitors* (mean: 4.5); *achieve cleaner production and a more sustainable manufacturing process* (mean: 4.2); and *be seen as a company concerned with the environment and social responsibility* (mean: 3.8) were also considered benefits. This cluster considered sustainability strategic in Industry 4.0, and despite being ranked last, sustainability scored high.

Cluster 3, was composed by the smallest number of respondents (4 elements). It was made up of respondents from predominantly large companies (50%) and an equal number of small (25%) and medium (25%) companies. The metal-mechanics (25%), electromechanics (25%), auto-parts (25%) and chemical (25%) activity sector were represented. The called Sustainability group saw in Industry 4.0 the possibility of achieving *cleaner production and a more sustainable manufacturing process* (4.8), in addition to *being seen as a company concerned with the environment and social responsibility* (4.5) as a basis *of being seen or becoming a reliable company* (4.3) to *increase global competitiveness* (4.0), and so *increase market share* (3.5), supplying *quality products* (3.5) using the strategy of *delivering faster than competitors* (3.3).

4.1.2. Discussion about the benefits

Cluster 1 was the only one among all the clusters that considered *improving the quality of products* as the main benefit of Industry 4.0, but it ranked *reliability* in one of the last places, probably because large companies are already considered reliable, and not of great concern. However, Cluster 2, the largest in terms of number of respondents, and also formed mainly by large companies, puts *competitiveness* above all other surveyed benefits. Cluster 3 attributed low importance to the possibility of *delivering faster than competitors*, but rated *sustainability* as more important than the other clusters.

The general expectation was the possibility of *increasing global competitiveness* with Industry 4.0, confirming Bokrantz et al. (2020), Dubey et al. (2019) and Sung (2018), but although each cluster has drawn different strategy, they were all concerned with providing *quality* products (Belli et al., 2018; Tayier and Janasekaran, 2020) to rise competitiveness. *Quality* was among the most expected benefits.

The *increase in market share* (Illa and Padhi, 2018; Tekin et al., 2020) and the increase in corporate revenues were ranked third by the general respondents. Companies need capital to pay for Industry 4.0 investments and continue to operate. The concern with *reliability* as a competitive strategy (Contador, 2008) and *fast deliver*, confirming Bocewicz et al. (2019), and D'Addona (2019), came next, as these benefits are important to create empathy with customers, and be able to rise sales.

Lastly appeared the interest in *sustainability: cleaner production and a more sustainable manufacturing process* (Jena et al., 2020; Lin, 2018; Luthra et al., 2020; Shivajee et al., 2019) and *the concern with the environment and social responsibility* (Ghobakhloo and Fathi, 2020; Kerin and Pham, 2020; Waibel et al., 2017). The respondents of Cluster 3 were more involved with sustainability than the others, Cluster 1 and Cluster 2 were the group with the least concern about sustainability, concentrating 93% of the total respondents.

4.2. Challenges with industry 4.0

The dendrogram represents the groups of similarities identified with the hierarchical cluster analysis of the challenges with Industry 4.0 (Fig. 2), established with the selected variables in Table 1.

4.2.1. Results of the challenges clusters

Table 3 displays the K-means results for the Challenges clusters, indicating the contribution of each variable to the formation of three groups, in addition to the size of the companies, and sector of activity. The mean of the challenges expected with Industry 4.0 is statistically different among the three groups for all variables (see ANOVA F-values).

Cluster 1 was formed by 13 respondents of medium (23%), small (31%) and large (46%) companies. The electromechanics (39%) predominated, followed by auto parts sector (30%), metal-mechanics (16%), and chemical (15%). Called the Investment group, it ascribed great relevance to the *investments* (3.9) to implement Industry 4.0 and considered that *sustainability was not considered strategic* (3.1). The *difficulty in changing the organizational culture* (3.0) and in *hiring/training people in digital technology* (2.8) were equally considered challenges that may hinder or impede implementation projects. These respondents considered the *possibility of unemployment* (2.2) as the challenge with the least impact.

Cluster 2 was predominantly formed by large (53%), medium (29%) and a reduced number of small companies (18%). Seventeen respondents represented sectors of electromechanics (35%), metal-mechanics (30%), auto parts (24%) and chemical sectors (11%). The Culture and Technology group showed great concern with the *difficulty in changing the organizational culture* (4.6), and with the *difficulty in hiring/training people in digital technology*, challenges that demand time, expose companies to risks, and that need *investment* (4.4). For this group, sustainability was considered strategic in Industry 4.0 (1.4), contradicting their little interest in the social dimension of sustainability and expressing little concern about the *possibility of unemployment* (2.1).

Cluster 3 was made up of 29 respondents from large (52%), medium (31%) and small (17%) companies, from Metal-mechanics (45%), electromechanical (31%), auto parts (17%) and consulting companies (7%). The Investment and culture group considered the main challenge to be the *investment* (4.4) required to implement Industry 4.0, followed by the *difficulty in changing the organizational culture* (4.3) and in *hiring/training people in digital technology* (4.2) which were considered equally important for the implementation of Industry 4.0. *Sustainability was neither considered strategic in Industry 4.0* (4.1), nor the *possibility of unemployment (3.9)*.

4.2.2. Discussion about the challenges

Although Cluster 1 highlighted that *sustainability should be considered more strategic in Industry 4.0*, it ranked last for the *possibility of unemployment*. Cluster 2 did not consider of great importance the necessity of *high investments* as the other two clusters, possibly because it was mainly formed by large companies, and ranked with the worst mean among the other clusters: *sustainability strategic in Industry 4.0* and the *possibility of unemployment*, pointing out that sustainability was not the main concern of this group with Industry 4.0. Cluster 3 considered all challenges presented relevant, showing a classification similar to the total clusters, with *sustainability strategic in Industry 4.0* and the *possibility of unemployment* at last, but with high mean.

Industry 4.0 brings new technology and new concepts. The *difficulty in changing the organizational culture* appeared in first place in the

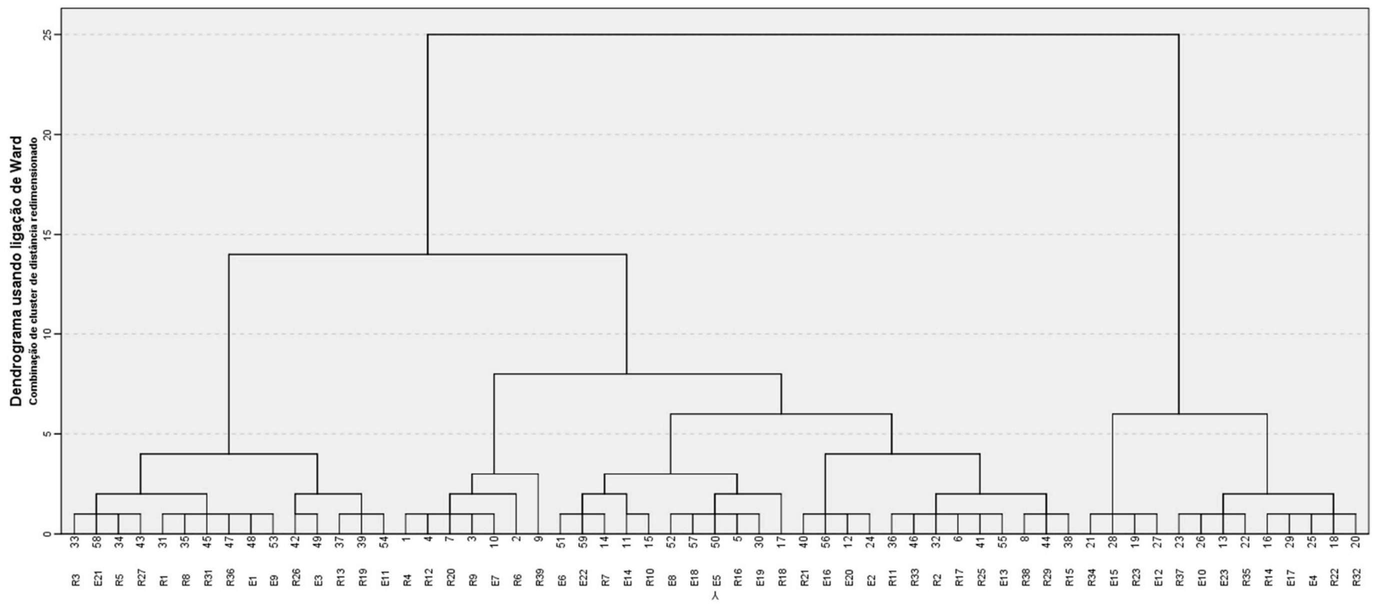

Fig. 2. Dendrogram for selecting the Challenges clusters.

Table 3
K-means results for Challenges clusters variables.

Variables	Cluster Mean + Std. Dev.						ANOVA F-value
	Custer 1 *Investment*		Cluster 2 *Culture and technology*		Cluster 3 *Investment and culture*		
Investments	3.9	±0.6	3.2	±1.3	4.4	±0.7	9.49*
Technology	2.8	±1.0	4.4	±0.8	4.2	±0.9	12.96*
Culture	3.0	±0.8	4.6	±0.6	4.3	±0.6	22.33*
Unemployment	2.2	±0.9	2.1	±0.9	3.9	±0.9	25.39*
Sustainability not strategic	3.1	±1.0	1.4	±0.7	4.1	±0.9	52.51*
Nr. of companies	13		17		29		
Company size							
Small companies	31%		18%		17%		
Medium companies	23%		29%		31%		
Large companies	46%		53%		52%		
Sector of activity							
Metal-mechanics	16%		30%		45%		
Electromechanics	39%		35%		31%		
Auto-parts	30%		24%		17%		
Chemical	15%		11%				
Consulting					7%		

*p < 0.001.

analysis of the total number of respondents, as stated by Birkel et al. (2019), De Sousa Jabbour et al. (2018), Jabbour and de Souza Jabbour (2016), and Raj et al. (2020), showing that these respondents considered that Industry 4.0 requires a change in the companies' structure, based on their organizational culture.

The total number of respondents ranked second: (1) The general apprehension with the *high investments,* confirming Ghobakhloo and Fathi (2020), and Waibel et al. (2017), required for implementation. This economic challenge can intensify inequalities between companies, and even nations, causing social imbalances, and (2) The challenge of *hiring/training people in digital technology* (Birkel et al., 2019; Raj et al., 2020), which, as well as the need to *change the organizational culture,* above, demand time, investments and can hinder, delay or even impede the implementation process.

The challenge of *changing the organizational culture* and of *hiring/training people in digital technology* were grouped in sequence in all clusters, and the *possibility of unemployment* generated by automation and informatization processes was ranked last in cluster 1 and 3, and second to last in cluster 2. This reinforces the fact that sustainability should be incorporated more explicitly and strategically in Industry 4.0 (Ghobakhloo and Fathi, 2020; Kerin and Pham, 2020; Waibel et al., 2017).

Unemployment of less qualified labor and of those who do not adapt to new technologies/concepts is expected, and this can bring social problems affecting local societies. The number of people dismissed must be greater than the number of qualified laborers to be hired, deepening social inequalities (Dirgová et al., 2018; Waibel et al., 2017). These results suggest that Industry 4.0 was only partially associated with sustainability in the minds of these experts, pointing out improving sustainability is not associated with an important point for these respondents.

5. Implications of industry 4.0

The term Industry 4.0 represents an assembly of different advanced and digital technologies (Calabrese et al., 2021; Wagner and Walton, 2016), aiming to improve operational processes to increase productivity and performance with higher level of customization and flexibility (Hermann et al., 2015), and the potential to bring new business models (Berger et al., 2020; Culot et al., 2020) that can impact traditional business.

Although some authors affirm that Industry 4.0 could incorporate social and environmental dimensions (Ding et al., 2017; Hermann et al., 2015; Luthra et al., 2020) to promote social benefits (Ghobakhloo, 2020; Müller et al., 2018) and sustainability (Elkington, 1998, 2004), the results of this study indicate that companies are more motivated to implement Industry 4.0 for performance and productivity gains to increase competitiveness and not sustainability, especially with regard to its social dimension. Renowned consulting firms project high investments in Industry 4.0, but the consequent unemployment is treated as a "forbidden area". The concern with the environmental dimension refers mainly to the reduction in the consumption of raw material and generated waste.

Industry 1.0 and 2.0 brought the workforce from the fields to industrialized areas; during Industry 3.0 unemployed people in industry found employment in services, now the Industry 4.0 is spreading to all other sectors of economy. If the unemployed people try to return to the countryside, they will face Agribusiness 4.0 and, if they try to go to services, they will face Service 4.0, both reducing the workforce.

It is essential to focus on the human being in studies of Industry 4.0, so that the gains can be reflected in both environmental and social dimensions, generating gains for all and balanced growth in all territories. A possible solution could be the implementation of Society 5.0, term coined in the 5th Science and Technology Basic Plan by the Government of Japan in 2015, which proposes a human-centered society to provide harmony between economic development and related social issues, through a system that integrates physical and cyberspace (Casazza and Gioppo, 2020; Oztemel and Gursev, 2020).

6. Conclusions

The focus of this study is to expand the discussion on Industry 4.0 beyond the technical approach that has dominated the academic literature, identifying some relevant benefits and challenges for its implementation, assessing the relevance of sustainability, and analyzing the potential social impact in a developing country, where Industry 4.0 is being adopted.

As implications for the research, this study identified four trends, contributing to the studies of Industry 4.0 in production management.

First, the most expected benefits of Industry 4.0 were: increasing the company's global competitiveness and improving the quality of the production lines with high consensus among the respondents. Achieving cleaner production and a more sustainable manufacturing process, as well as being seen as a company concerned with the environment and social responsibility, and unemployment were last classified.

Second, difficulty in changing the organizational culture, the high investments for implementation, and the difficulty in hiring/training people in digital technology were cited as important challenges. Few groups considered strategic sustainability in Industry 4.0 (not one of its main focuses).

Third, in general the respondents were more concerned with performance, productivity, technology, products and sales, reinforcing the trend to consider sustainability secondary in Industry 4.0.

Fourth, the concern with unemployment was ranked in the last positions. Several studies emphasize the large number of new specialized jobs that Industry 4.0 will generate, but few address the unemployment resulting from the low-skilled workforce (Ghobakhloo and Fathi, 2020; Kerin and Pham, 2020; Waibel et al., 2017), and even less on how to help this workforce to get back to work, recover purchasing power, and then buy Industry 4.0 products. To improve the social responsibility was also underemphasized by the respondents.

As a contribution to practice, this study alerts to the need for everyone involved in the implementation of Industry 4.0 to consider sustainability equally strategically important to achieve a higher degree of competitiveness, or the world will be regressing focusing only on technology in Industry 4.0 studies.

Unemployment affects territories, generating social pressures and inequalities and, although Society 5.0 intends to overcome it, it is a perspective somewhat distant from the reality of developing countries like Brazil, with strong economic and social inequalities, with an unemployment rate reaching 14.1%, affecting 14.4 million people, in addition to 5.6 million people identified as discouraged (IBGE, 2021), because after so long looking for a job and not finding it, they stopped the search, which in total represents more than the population of the Netherlands (World Population Review, 2021).

This study contributes by identifying the lack of research in the social dimension when Industry 4.0 is intended to be applied to a country. The results of this study provide an overview of the real perceptions of specialists in Brazil related to the selected indicators to assess the benefits and challenges of Industry 4.0, and that can be used in practice to provide information to public policy makers: displaying sustainability indicators that should be considered when formulating future policies, and warning about the possibility of aggravation of unemployment and differences between nations.

In the eagerness for productivity, performance and competitiveness, the human being was forgotten, sustainability left as a secondary aspect and its social dimension underestimated and understudied. Industry 4.0 came to stay. The world is turning digital, and it is natural that production follows the same path, but sustainability should be considered more strategic, in a way that people can clearly associate Industry 4.0 with sustainability, contributing to the balanced growth of all territories, and preventing the deepening of social inequalities.

6.1. Limitations and future research

There are some limitations of this study. The benefits and challenges used from the scientific literature are not extensive, as well as the reduced number of respondents, who belonged to few sectors of the economy of one country. Although the study made it possible to point out trends, it does not allow generalizations, but the results can induce similar research in several other countries. Future studies may use the same method, involving more people from other countries and other sectors, to confront with the findings of this study.

CRediT authorship contribution statement

Walter Cardoso Satyro: Conceptualization, Writing – original draft, Writing – review & editing. **Cecília Maria Villas Bôas de Almeida:** Conceptualization, Methodology, Supervision. **Marcos José A. Pinto:** Formal analysis, Visualization, Investigation. **José Celso Contador:** Formal analysis, Validation. **Biagio F. Giannetti:** Conceptualization, Resources, Supervision. **Anderson Ferreira de Lima:** Software, Validation. **Marco Aurelio Fragomeni:** Software, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Here follows the questionnaire of the 5-point Likert scale.

A) What benefits do you expect with the implementation of Industry 4.0 in your company?
   1) Increase the company's global competitiveness
   2) Improve the quality of production lines
   3) Increase the market share
   4) Deliver products/services faster than competitors
   5) Be seen or become a reliable company
   6) Achieve cleaner production within the manufacturing process
   7) Be seen as a company concerned with the environmental and social responsibility

B) What challenges do you expect with the implementation of Industry 4.0 in your company?
   1) Industry 4.0 requires high investments for its implementation
   2) There are difficulties in changing the organizational culture
   3) There are difficulties in hiring/training people in digital technology

4) Sustainability should be considered more strategic in Industry 4.0
5) Industry 4.0 can bring unemployment

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