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Mapping Industry 4.0 in the Portuguese Industry

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Abstract

With Industry 4.0 and digital transformation, organisations have undergone enormous changes in business models, engineering, manufacturing, processes, and technologies. Hence, the need to investigate the status of its current knowledge and maturity. This research, supported by a survey for data collection (fifty valid responses), aims to analyse the knowledge and maturity (on a five-scale level) of Industry 4.0 in Portugal from the perspective of industrial companies. The conclusions highlight that the Portuguese organisations will have to adapt to the impact of Industry 4.0 on how their business is being developed and encompass the digitisation with new technologies. Unfortunately, adopting the concepts and methodologies inherent to Industry 4.0 is still incipient in Portugal, suggesting a possible lack of knowledge and poor leadership. Companies need to strategically change towards business models that are more flexible to the potential of technology and have a closer relationship with customers, ensuring increased operational autonomy and repositioning products and services. Having a team dedicated to digitisation increases the Industry 4.0 maturity level. Companies with a maturity Medium/High level of Products and Innovations have a higher level of perception based on their capacity for innovation, supported by new digital models and tools. Concerning Human Resources, the digitisation of knowledge management means and the promotion of new ideas for digital transformation increases its I4.0 maturity level. This study contributes to the start of the art of Industry 4.0 in Portuguese companies, mapping its present status, and providing insights for its future enhanced adoption.

Keywords: Industry 4.0; digitization; Portuguese industry; maturity level.

JEL Classification: O39, L60, C38.

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1. Introduction

Industrial revolutions contributed to significant enhancements in the output and productivity of the manufacturing industry. Industry 4.0 is transforming the manufacturing firm business models and can support production flexibility, efficiency, and productivity (GTAI, 2014; Ibarra et al., 2018; Rüßmann et al., 2015), fostering innovation, competitiveness, and improved industrial system sustainability (Müller et al., 2018; Stock, Seliger, 2016). The Industry 4.0 technologies adoption in companies and industries is a highly relevant topic (Luthra, Mangla, 2018; de Sousa Jabbour et al., 2018; Kiel et al., 2017). However, it is unclear how Industry 4.0 technologies can be integrated into existing production systems and what processes they can support (Kolberg, Knobloch, Züehlke, 2016).

Due to the lack of research encompassing the adoption of Industry 4.0 in Portugal, this research aims to analyse the knowledge and maturity of Industry 4.0 in Portugal from the perspective of industrial companies. The reaming of the paper is structured as follows: Section 2 provides an overview of the scientific literature in the industry 4.0 field. Section 3 details the Research Questions, and Section 4 the Research methods. The results and discussions are explained in Section 5, and Section 6 is devoted to conclusions, limitations, and suggestions for future research.

2. Problem Statement

Industry 4.0 leads to digital transformation where everything is interconnectted with a corresponding virtual representation, namely, business models, environments, production systems, machines, operators, products, and services (Alcácer, Cruz-Machado, 2019). Industry 4.0 is based on advanced manufacturing and engineering technologies, such as Cyber-Physical Systems (CPS). The CPSs integrate information technology with the physical system comprising the operational technologies, e.g., the production facilities and smart machines and storage systems (Kagermann et al., 2013; Qin et al., 2016). Furthermore, the Internet of Things (IoT) connects the CPS elements by monitoring the status of physical objects, capturing meaningful data, and communicating that information through networks to software applications (Blunck, Werthmann, 2017).

The enabling technologies for Industry 4.0, also called the nine Industry 4.0 pillars, have been identified as: Big Data Analytics, optimisation and simulation, cloud technology, virtual and augmented reality (VR/AR), horizontal and vertical system integration industrial IoT, additive manufacturing, autonomous robots, and cybersecurity (Rüßmann et al., 2015; Wee et al., 2015).

The main reported benefits of Industry 4.0 include: the enhanced integration of business processes across the entire value chain (Bonilla et al., 2018); innovation, flexibility, agility, productivity and efficiency improvements, in addition to cost reductions (Alcácer, Cruz-Machado, 2019; Oesterreich, Teuteberg, 2016); Support

for new business models supporting novel ways of value creation, e.g., cloud-based, service-oriented, process-oriented business models (Kiel et al., 2017); Ecological sustainability, e.g., more efficient resource utilisation, and social sustainability, e.g., workers more supported to do their job (de Sousa Jabbour et al., 2018).

Although Industry 4.0 is increasing notoriety, many organisations face obstacles to adopting the Industry 4.0 and are still trying to identify Industry 4.0 implications and challenges and what the required competencies are (Sanders et al., 2016). Moreover, it is often difficult for companies to establish their current state concerning Industry 4.0 development, failing to identify specific priorities, actions, and projects (Erol, Schumacher, Sihn, 2016). Nevertheless, several few roadmaps or maturity models have been proposed by academics, practitioners, and consultants, to support Industry 4.0 successful adoption. Namely Lee, Bagheri, and Kao (2015), Anderl (2014), the German Government (Schumacher, Erol, Sihn, 2016); Leyh et al. (2016); Ganzarain and Errasti (2016), Leyh et al. (2016), Pessl et al. (2017), Akdil et al. (2018), and PwC (2020).

However, the successful adoption of Industry 4.0 faces several challenges. Namely, the need for adequate training and education to overcome resistance to change (Yaseen et al., 2017), increased capital requirements and issues of data ownership (Brous et al., 2020), and to address privacy and security concerns (Oesterreich, Teuteberg, 2016). Moreover, academic research indicates that a lack of Industry 4.0 integration with the overall business strategy can negatively impact environmental performance (Oláh et al., 2020; World Economic Forum, 2018). Therefore, Industry 4.0 successful adoption requires strong leadership, the right human competencies, work ethics, and suitable management systems (Fonseca, 2017; World Economic Forum, 2018).

Several researchers investigated the application of Industry 4.0 in companies in specific countries. For example, Hamzeh, Zhong, and Xu (2018) present the results of a survey conducted in the New Zealand industry, where Industry 4.0 will be implemented to update and transform small and medium-sized enterprises (SMEs) in the future. Other researchers that studied this theme include Dalenogare, Benitez, Ayala, Frank (2018) in Brazil; Kim (2018) in South Korea; and Müller, Buliga, and Voigt (2018) in Germany. Furthermore, the consultancy firms Deloitte ("Industry 4.0 – at the intersection of readiness and responsibility", 2019) and PwC ("Global Industry 4.0", 2016) made relevant contributions to this topic. Specifically, Hamzeh, Zhong, and Xu (2018) analysed the contribution of Industry 4.0 to the business of the participants, the application of IT tools, and what are these tools, the window of possible implementation, the benefits, and obstacles of it, and thus determined the level of perception. Hence, this work provides valuable insights for the present research encompassing the adoption of Industry 4.0 in Portugal.

3. Research Questions / Aims of the Research

To successfully start the digital transformation process, companies must have a clear view of their current situation, their desired future state, and a strategic plan to achieve their goals (Rajnai, Kocsis, 2018). Therefore, it is essential to support corporations by providing them with guidelines for the required digital changes. However, due to the lack of research encompassing the adoption of Industry 4.0 in Portugal, namely empirical studies on the perception, knowledge, application and maturity of Industry 4.0 in Portuguese companies, the authors ask the following research questions: Q1: What is the perception and knowledge about Industry 4.0 by companies operating in Portugal?; Q2: What is the state of application of the tools and methods of Industry 4.0 by Portuguese companies?; Q3: What are the most critical factors for defining the maturity level of the implementation of Industry 4.0 in Portugal.

4. Research Methods

This study is framed with a quantitative methodology supported by an email survey encompassing a sample of 50 Portuguese companies. The survey featured distinct parts: Company characterisation; Industry 4.0 with six related companies' dimensions: Strategy and Leadership (SL); Customer Experience (CE); Operations (O); Products and Innovations (PI); Information Technology (IT); Human Resources (HR). After the survey validation, an email was sent to a total of 700 companies identified through a ranking of the largest companies in Portugal in 2019 and contacts made available by this research author(s). The data collection period was active between July and August 2020, and in total, 50 valid answers were obtained (response rate of 7.1%). Furthermore, the analysis of the sample survey results according to the company's characteristics suggests that this distribution is consistent with the distribution of the population. According to the proposed research questions, descriptive statistics were performed.

5. Findings

5.1 Characterisation of the Companies

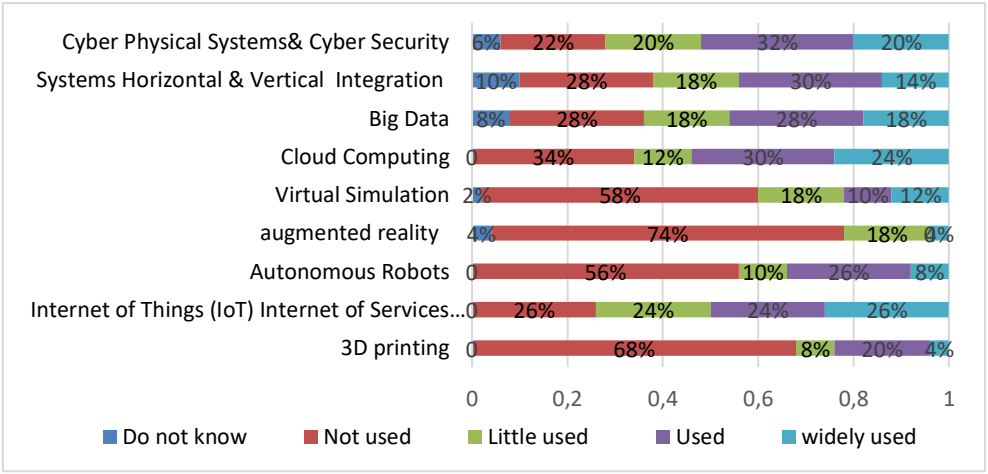
In the 50 responses obtained, it was possible to observe a wide range of business branches, such as Services (20%), Metalworking (16%), and Automobile (12%) 72% of the companies were in the North of Portugal. More than 75% of employ more than 50 employees, and around 78% had a turnover greater than €1 million in 2019, of which 60% exceeded €5 million. Regarding the respondent's positions in the company, 30% hold Administration positions. These positions are closely followed by Owners, who represent 20% of respondents and Operations Managers, with 18%. Lean Manager and i4.0 Manager positions only represent 2% and 4% of respondents, respectively.

5.2 Industry 4.0 Companies' Tools Investments Analysis

Regarding the second part of the questionnaire, 60% of the respondents consider that the Industry 4.0 tools will have a contribution to the improvement of Production: more than 68% of the companies said that they use IT tools in Production Planning, Quality Management, Accounting and Finance and in Purchasing and Inventory Management, the latter having the highest usage rate (82%). Concerning the potential benefits of applying Industry 4.0, Increased Agility in Operations with 76% was chosen as the main benefit, followed, with 64%, by companies considering Improved Services to be offered to customers, and Reduced Production Costs as the second most significant benefit. In the opposite direction, when questioning companies about potential obstacles to implementing Industry 4.0, we can observe that the great focus is on the possible high-time investments and funds, being the options on which more than 60% of the companies focused. Furthermore, almost half of the respondents have difficulty accessing collaborators with the necessary knowledge to apply the changes implicit in the digitalisation of processes.

22% of the respondent companies have already implemented Industry 4.0 concepts, 26% have implementation forecast for the near future, up to 24 months, and almost one-third of the organisations have no plans for future implementation now. Regarding Industry 4.0 pillars, Augmented Reality, 3D Printing, Autonomous Robots, and Virtual Simulation are the least used in the companies participating in the study. Conversely, IoT/IoS (26%), Cloud Computing (24%), and Cybersecurity (20%) have the highest percentages of high usage (Figure 1). IoT/IoS and Cyber Security have usage rates above 72%. Horizontal and vertical integration of systems is the pillar more unfamiliar to the respondents.

Figure 1. Level (%) of use of the tools of the Industry 4.0 Pillars

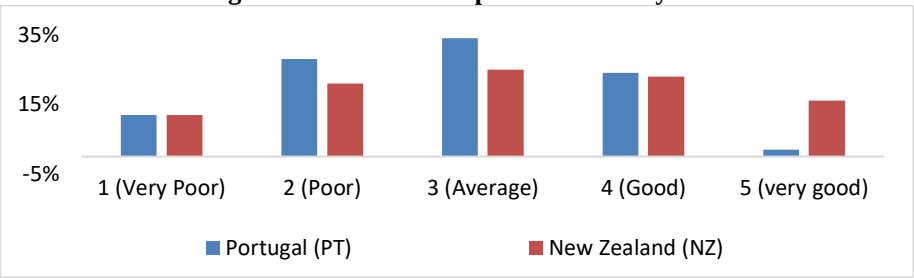


Source: authors' own elaboration based on data.

5.3 Level of Perception of Industry 4.0

Considering Hamzeh et al. (2018)' survey, when comparing the Portuguese self-assess level of maturity perception of Industry 4.0 with the results obtained from the survey conducted in New Zealand, as shown in Figure 2, the level of perception observed in the New Zealand study is higher than the Portuguese one.

Figure 2. Level of Perception of Industry 4.0

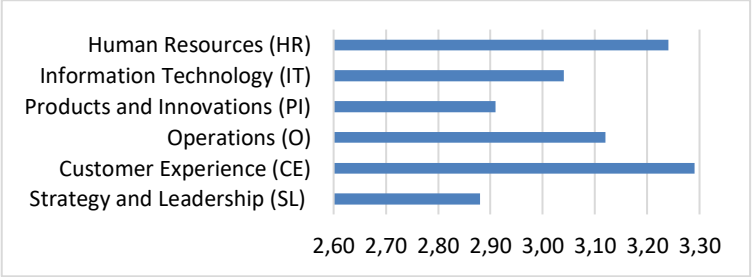


Source: authors' own elaboration based on data and compared.

5.4 Industry 4.0 Companies' Dimensions Analysis

Companies were analysed with six related company dimensions: Strategy and Leadership (SL); Customer Experience (CE); Operations (O); Products and Innovations (PI); Information Technology (IT); Human Resources (see Figure 3).

Figure 3. Mean assessment average of the surveyed companies



Source: authors' own elaboration based on data.

6. Conclusions

Overall, the research objectives were achieved by analysing the perception and knowledge about Industry 4.0 by companies operating in Portugal, ascertaining the state of application of its tools and methods in the national panorama, and determining the essential factors for defining the maturity level of the implementation of Industry 4.0.

Concerning the Research Question (RQ) 1 "What is the perception and knowledge about Industry 4.0 by companies operating in Portugal?" the Portuguese organisations will have to adapt to the impact of the Fourth Industrial Revolution on how their business is being developed. Furthermore, considering that the

industrial revolution is promoted with a solid technological base, organisations will need to enter the new reality of digitisation with new technologies.

Regarding RQ2, "What is the state of application of the tools and methods of Industry 4.0 by Portuguese companies? Unfortunately, the adoption of the concepts and methodologies inherent to Industry 4.0 is still incipient in Portugal, suggesting a possible lack of knowledge and poor leadership".

Finally, concerning RQ3, "What are the most critical factors for defining the maturity level of the implementation of Industry 4.0 in Portugal?" it is required to prepare and adapt to the successful adoption of Industry 4.0. E.g., by strategic change towards models that are more flexible to the potential of technology and have a closer relationship with customers who should be integrated into these services. Furthermore, greater autonomy and decentralisation will be needed at the level of operations. In addition, the adoption of the I4.0 paradigm also presupposes the repositioning of products and services.

In conclusion, although respondent organisations are aware of the potential benefits of Industry 4.0 implementation, they still look at this paradigm shift with some reticence. Namely, concerns with high monetary and time investments and insufficient human resources knowledge are difficult to obtain, which aligns with Sony's (2020) literature review. Therefore, there is a need to support the business case for I4.0. Furthermore, employees will have to develop new skills and qualifications since companies will demand a different employee, much more versatile, agile, and connected.

Nevertheless, the research results indicate that their actual Industry 4.0 level of knowledge is slightly higher than they initially assumed. This finding should be linked to the fact that, although they know and use industry 4.0 methodologies, they do not associate them with Industry 4.0 because they are unaware of their basic concepts.

Additionally, factor analysis and comparison of averages were performed, concluding that companies with a team dedicated to digitisation at the strategic level and making a cross-cutting effort to translate this digitisation at all levels increased their Industry 4.0 maturity. Furthermore, companies with a medium/high customer experience maturity level have a higher level of perception based on interaction with customers across multiple digital channels, continuously collecting information to improve products and services. At the level of Operations, the respondent organisations surveyed that have integrated management software for monitoring and process control with remote access increased their level of maturity in Industry 4.0 in this factor. This dimension causes a significant difference between companies with high maturity and low maturities. Moreover, the organisations with a medium/high product and innovation maturity level have a higher level of perception based on their innovation capacity, supported by new digital models and tools. Concerning Human Resources, the digitisation of knowledge management and the promotion of new ideas of transformation increases the level of maturity I4.0 of the Human Resources block. However, most companies do not have a dedicated team to do so.

Comparing this research results with Hamzeh et al. (2018), Portuguese companies report lower perceptions of Industry 4.0 than New Zealanders. However, companies in both countries have very similar hopes and fears regarding the implementation of digitisation. Finally, when comparing the results with previous studies by PWC and Deloitte, it was possible to conclude that Portuguese companies have not yet reached the scanning levels expected for 2020. Despite the increasing allocation of monetary and human resources to digital development.

The author(s) acknowledge that, despite their efforts, this research may suffer from the limitations inherent to the limited sample size and the survey methodology (e.g., possible bias). Concerning suggestions for future research, additional studies with increased sample sizes and further statistical analysis (e.g., the difference between sectors or organisation size) are proposed.

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