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Human Factor in Smart Industry: A Literature Review

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Abstract

Purpose of the study: The objective of this study is to identify the benefits and challenges of smart industry concept to the human factor, based on the concept of Industry 4.0.

Methodology/approach: A systematic literature review was elaborated, based on structured protocols for the selection of a bibliographic portfolio of articles. A bibliometric analysis of the data and content analysis was performed.

Originality/relevance: The article discusses human work, focusing on theoretical and practical contributions of international literature. The focus scenario is smart industry, a concept in constant improvement, which currently has acquired influences from Industry 4.0.

Main results: The discussions lead us to ponder on human factor in smart industries in the categories physical and mental health at work, human performance and professional career in general. The conclusions points to the need to ensure adequate working conditions in cognitive and psychic aspects, among others.

Theoretical and methodological contributions: We present major literature articles, smart industry definitions, main technologies, and grouping benefits and challenges to the human factor.

Keywords: Industry 4.0. Human factor. Work. Management.

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Fator Humano em Indústria Inteligente: Uma Revisão de Literatura

Resumo

Objetivo do estudo: O objetivo deste estudo é identificar os benefícios e desafios do conceito de indústria inteligente para o fator humano, com base no conceito da Indústria 4.0.

Metodologia/abordagem: Foi elaborada uma revisão sistemática da literatura, baseando-se em protocolos estruturados para a seleção de um portfólio bibliográfico de artigos. Foi realizada uma análise bibliométrica dos dados e análise de conteúdo.

Originalidade/relevância: O artigo aborda sobre o trabalho humano, concentrando-se em contribuições teóricas e práticas da literatura internacional. O cenário foco é indústria inteligente, um conceito em constante aperfeiçoamento, que atualmente tem adquirido influências da Indústria 4.0.

Principais resultados: As discussões geram reflexões sobre o fator humano nas indústrias inteligentes nas categorias saúde física e mental no trabalho, desempenho humano e carreira profissional em geral. As conclusões apontam para a necessidade de garantir condições adequadas de trabalho em aspectos cognitivos e psíquicos, entre outros.

Contribuições teóricas e metodológicas: Nós apresentamos principais artigos da literatura, definições de indústria inteligente, principais tecnologias e agrupamento de benefícios e de desafios ao fator humano.

Palavras-chave: Indústria 4.0. Fator humano. Trabalho. Gestão.

Como Citar:

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Introduction

Industrial revolutions were marked by scientific / technological developments, notably the discovery of the steam machine in the industry, mass production, electricity use and industrial automation. With the emergence of new technologies, such as Cyber Physical Systems and approaches like Internet of Things, a next revolution is projected (Kazancoglu; Ozkan-Ozen, 2018).

The concept of Industry 4.0 has presented reference to the Fourth Industrial Revolution (Park; Lee, 2017) and is configured as a smart factory. It is evidenced by several research and strategic initiatives, proposed mainly in developed countries, which seek to develop smarter and more sustainable industrial systems for the production of goods and services (Dragicevic et al., 2019). This concept affects not only the production systems, but the ways in which people organize themselves and act at work (Benešová; Tupa, 2017, Kazancoglu; Ozkan-Ozen, 2018).

In the Industry 4.0 Scenario, the human factor needs to be studied, once the participation of people in the work will still be necessary, and there is no perspective of total replacement of them by artificial intelligence (Spath et al., 2013). At work, tacit knowledge about an individual's experience over the years cannot be transferred to robots and computers (Postelnicu; Calea, 2019). Faced with tacit knowledge, learning has been the main vehicle for technology transfer and knowledge through generations (Gorman, 2002). Therefore, the human factor is needed in the smart industry and is a great source of competitive advantages, as people can rely on their natural senses to create solutions (Simões et al., 2019).

The adoption of the smart industry concept, including operating procedures, technologies and systems, relies on the human factor. Therefore, it is necessary to investigate the implications of such important factor in terms of benefits, challenges and negative consequences for people and also for the human resources managers.

Training, professional career, well-being, human performance and physical and mental health are elements influenced by decisions and actions of one or more productive organizations. Therefore, multidisciplinary areas are useful to assist the worker in achieving success in the labor market and industry, such as human resources management, psychology, ergonomics, anthropotechnology (effects of technology on people) and education. Each of them can provide support to the worker, observed as a protagonist in a scenario in constant scientific and technological evolution. Both the worker and company representatives are interested in pertinent questions about the development of activities and work tasks. Human workers want to enter and remain in the market, building their career and obtaining equitative wages, stability, intellectual growth, learning and/or professional achievement. Companies, on the other hand, generally seek the best possible human performance to increase productivity.

In smart industries human tasks will be redirected, or reconceived (Singh; Sellappan; Kumaradhas, 2013), and also the creation of new jobs (Ghani; Muhammad, 2019), allowing people to perform routine functions along with new technologies, mainly in a more dynamic routine.

In this context, the objective of this study is to identify the main benefits and challenges of smart industry concept to the human factor, based on the concept of Industry 4.0. The benefits infer in the better performance of human work, well-being and health, and the challenges govern elements of insertion and permanence of people within industries (physical and mental health management and professional career, in general).

In the extant literature, much is discussed about the human factor in companies - the focus is not on people, but on the development of skills and activities in favor of organizational competitiveness. No modification of industrial manufacturing system should be contemplated without discussing at length the potential effects on worker health and safety (Badri et al., 2018) and career management.

Methodology

A systematic literature review was done, following protocols structured by Pagani, Kovaleski, and Resende (2015; 2018), which consists of nine steps. Differently from all the other existent in the literature, this methodology allows the researcher to ponder on the scientific relevance of a paper using three variables: impact factor, number of citations, and year of publication. The pondering on these variables generates an index, the InOrdinatio, which indicates the scientific relevance of the paper. From this index, it is possible to rank the papers individually.

The developing of the review followed these steps:

Step 1, 2 and 3: Establishing the intention of research, definition of keywords, bibliographic databases, and making the final search. Three similar terms were defined (Smart factory, Industry 4.0 and Fourth Industrial Revolution) and individually combined with the keyword Human. The selected databases were Scopus and Web of Science, as they are two important scientific bases at international level. They have two metrics to measure the relevance of journals, CiteScore and Impact factor, respectively.

After defining the combinations of keywords and aligning them with the research proposal, definitive searches were carried out, adopting three basic criteria, applied in the platforms of each database: i) Keywords inserted in abstract-title-keywords; ii) Journal articles, and; iii) All year's period ≤ November, 2019. A total of six searches were executed, three combinations in each database.

In step 4, a gross portfolio of articles was found and stored in bibtex file format: Collecting the papers, using the reference manager Mendeley. The results are in Table 1, Section of Results.

Step 5: Filtering out the papers: gross portfolio was subjected to filtering procedures: i) eliminating articles that were in duplicate, using the JabRef® software, and; ii) articles not related to the topic under study (exclusion of articles by means preliminary readings of titles and abstracts).

In addition to the scope of the research, another selection criterion was applied, ordering based on the relevance of scientific indicators, inserted in steps 6 and 7 below.

Step 6: Finding the impact factor (metrics of the journal) and the number of citations: the data collected by the reference manager were then exported to an electronic spreadsheet. In the spreadsheet, the year of publication, the number of citations (obtained from Google Scholar) and the metrics of the paper (impact factor) are added. The metrics of the papers (impact factor) was also manually obtained from the Clarivate Analytics list from 2018, in Web of Science database. This information along with the year of publication is necessary to calculate the InOrdinatio (1) index (Pagani, Kovaleski, and Resende, 2015; 2018).

Step 7: Establishing the rank for the papers: this step is designed to rank the papers according to its scientific relevance, determined by the pondering of the most important elements in a paper: year of publication (once new researches means new contributions and advancements of science); the metrics, which show the significance of a scientific journal; and, the number of citations, which proves the recognition of the work in the scientific community (Pagani; Kovaleski; Resende, 2015; 2018).

$$\text{InOrdinatio} = (IF / 1000) + (\alpha * (10 - (\text{ResearchYear} - \text{PublishYear}))) + (Ci) \quad (1)$$

The IF is the impact factor, ɑ (alfa value) is a weighting factor ranging from 1 to 10 to be attributed by the researcher; Research Year is the year which the bibliographic research was developed; Publish Year is the year which the selected paper was published; and, Ci is the number of times the paper has been cited on Google Scholar (Pagani; Kovaleski; Resende, 2015; 2018).

Therefore, from the application of the filtering procedures, for selecting the final portfolio of articles, step 7 of the Methodi Ordinatio, called InOrdinatio, was applied. This phase allows qualifying and sorting the articles according to scientific relevance, equating the impact factor, year of publication and number of citations for each article. Thus, it is possible to obtain relevant studies regarding the scientific factors mentioned. It should be emphasized that together with the method application (articles with best InOrdinatio results of Methodi Ordinatio), it was used the relevance criterion of the themes addressed.

Step 8 and 9: finding full papers and systematic reading: after finding the full versions of the papers, the final reading, and the bibliometric and content analysis were performed.

The software Vosviewer® was used for the bibliometric mapping. The software allows creating a network with keywords and authors, to show tendencies and connections.

Result and discussion

Bibliometrics

In the two international databases, using three keywords combinations, a gross portfolio of 754 articles was obtained (Table 1).

Table 1. Gross total of articles for literature review.

Keywords	Database	
	Scopus	**Web of Science**
"Smart factory" and "Human"	69 articles	22 articles
"Industry 4.0" and "Human"	301 articles	161 articles
"Fourth Industrial Revolution and "Human"	117 articles	84 articles
Total	487 articles	267 articles

We opted for a keyword that best expressed the research proposal, "Human". This includes "human factor", "human resource", "human and machine cooperation", among others. The combination of these with the term Industry 4.0 was responsible for the higher gross return of articles, compared to the other terms used, in both databases.

The Scopus database presented a gross total of 487 articles of journals, followed by the Web of Science, with 267 articles. Only articles published in journals were considered. It was necessary to eliminate duplicate articles and, therefore, a portfolio of 482 was obtained (Table 2).

Table 2. Article filtering procedure.

Procedure		Frequency of articles
Articles on Scopus database	(+)	487
Articles on Web of Science database	(+)	267
Gross portfolio	(=)	754
Duplicates	(−)	272
Total articles after filtering	(=)	482

In the same database, duplicates of articles were found, due to three combinations of keywords being used. In addition, duplicates are also generated because the same article is indexed in more than one database.

After eliminating duplicities, a portfolio of 482 distinct articles was submitted to bibliometric analysis. The bibliometric data of articles are oriented to human work and equivalent approaches in smart industries, presented below, years of publications, major journals, and authors with higher numbers of publications, frequent terms and articles most cited in other studies.

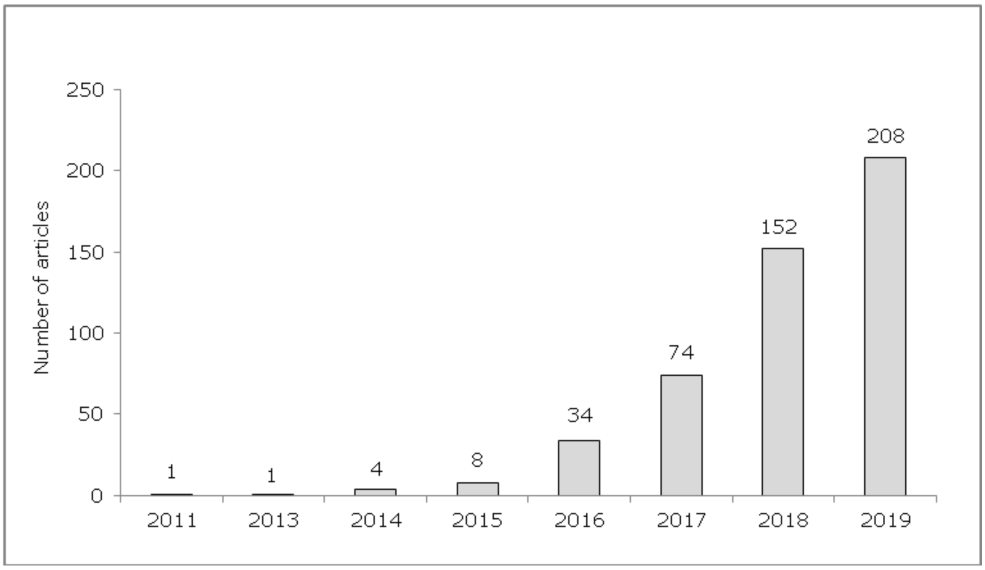

Figure 1. Years of publication of articles on human labor in smart industries.
Source: Data from Scopus and Web of Science (2019).

The years with a higher number of publications were 2019 (208 articles), 2018 (152 articles) and 2017 (74 articles). In the period surveyed, 2019 remained limited until November.

The main journals of publications of the articles are presented in Table 3. The frequency of articles per Journal is low due to the high number of available scientific sources.

Table 3. Main scientific journals.

Journal	Number of articles
IFAC-PapersOnLine	19
Procedia Manufacturing	15
ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb	14
IEEE Access	11
International Journal of Advanced Manufacturing Technology	10
International Journal of Production Research	8
Sensors (Basel, Switzerland)	8
Computers and Industrial Engineering	7
International Journal of Computer Integrated Manufacturing	7
International Journal of Recent Technology and Engineering	7
International Journal of Innovative Technology and Exploring Engineering	7
Fme Transactions	6
AI and Society	6
Elektrotechnik und Informationstechnik	5
IEEE Transactions on Industrial Informatics	5
Sustainability (Switzerland)	5

Source: Data from Scopus and Web of Science (2019).

The main authors, according to the involvement in articles, and the most frequent terms included in the articles, are presented in Figures 2 and 3, respectively.

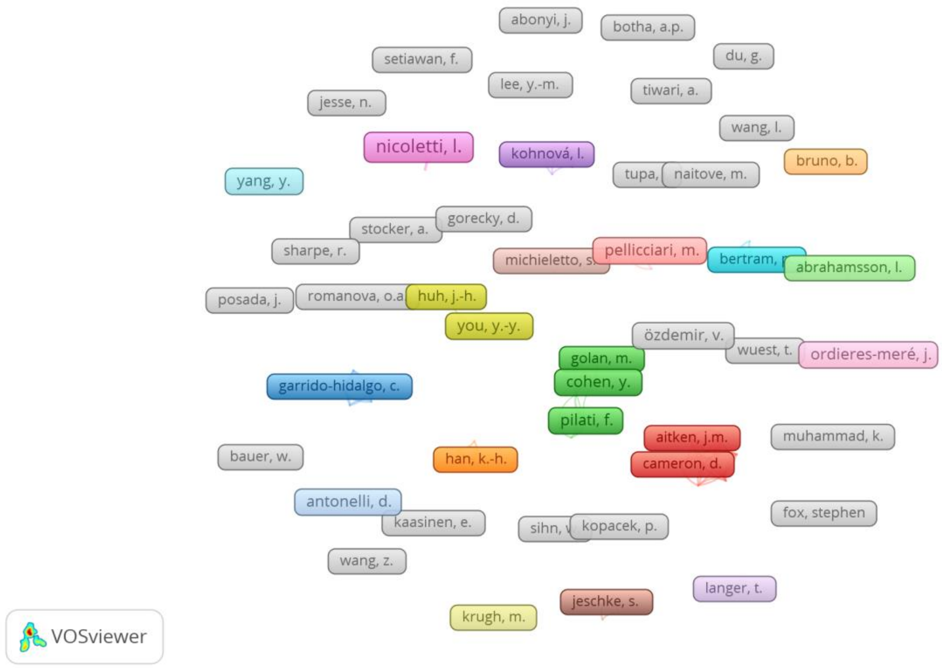

Figure 2. Main authors on human labor in smart industries.
Source: Data from Scopus and Web of Science (2019).

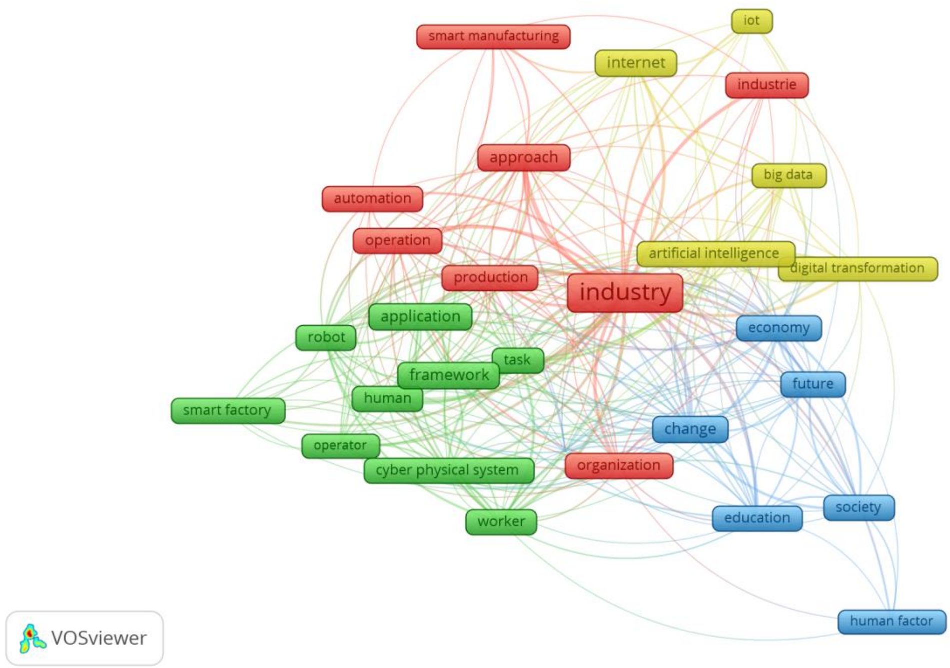

Figure 3. Frequent terms included in selected articles.
Source: Data from Scopus and Web of Science (2019).

Prominent words associated with "human" were Worker and Operator, working in smart manufacturing, smart factory and industries in general.

For content analysis, it was necessary to limit the number of articles, prioritizing studies with greater proximity to the research focus and scientific relevance. Therefore, out of 482 distinct articles, 59 were selected for full readings, through the procedures of Table 4.

Table 4. Total articles selected for content analysis

Procedure	Frequency of articles
Total distinct articles	482
Total articles after preliminary readings of titles	177
Total articles after preliminary readings of abstracts	94
Selected articles for content analysis (articles with higher InOrdinatio values of the Methodi Ordinatio)	59

After filtering articles - based on two criteria (researched scope and relevance of themes), articles with higher values of InOrdinatio were selected. In this context, another criterion was decisive, the scientific relevance. Main information and data from these articles are described in Appendix 1.

The articles with greater similarities to our proposed research objective are briefly addressed in Table 5.

Table 5. Main studies on human factor in the Smart Industry scenario.

Author	Title	InOrdinatio value	Study focus	Methodological procedure
Benešová and Tupa (2017)	Requirements for Education and Qualification of People in Industry 4.0	193	Identify the competencies of IT professionals in Industry 4.0	Case studies in companies
Badri et al. (2018)	Occupational health and safety in the industry 4.0 era: A cause for major concern?	129	Discuss the effects of Industry 4.0 on occupational health and safety of workers	Literature review
Sackey and Bester (2016)	Industrial Engineering Curriculum In Industry 4.0 In A South African Context	107	Analyze the likely impacts of the concept of Industry 4.0 on academic curricula	Literature review and case study in educational institutions in industrial engineering
Ruppert et al. (2018)	Enabling technologies for operator 4.0: A survey	107	Analysis of the relationship between technologies of Industry 4.0 (facilitators of human labor) and worker	Literature review
Whysall, Owtram, and Brittain (2019)	The new talent management challenges of Industry 4.0	103	Discuss the impact of Industry 4.0 on contemporary human resource management practice, focusing on recruitment, training and career development	Interviews with human resources directors at UK companies
Kadir, Broberg, and Conceição (2019)	Current research and future perspectives on human factors and ergonomics in Industry 4.0	102	Identify human resources approaches in the scientific studies of Industry 4.0	Literature review, relating excerpts addressed in articles with contributions to workers in ergonomic physical, cognitive and organizational categories

Discussion

The Industry 4.0, a concept of smart industry, had its discussions begun in 2011 at the Hannover technology fair in Germany (Kazancoglu; Ozkan-Ozen 2018). It was proposed by a group of business representatives, the government and academia to increase competitiveness of German companies (Jeganathan et al., 2018).

In Table 6 some of the definitions of smart factory/industry as well as of a more specific concept (Industry 4.0) are presented.

Table 6. Smart industry definitions.

Definition	Source / author
The smart factory is a manufacturing solution that provides flexible and adaptable production processes for solving complex problems.	Radziwon et al. (2014)
The smart factory is a production solution in a flexible and efficient way to meet the needs of today's market. It links the physical components of the production system and the digital, abstract, and virtual components.	Hozdić (2015)
Smart Factory is the integration of all recent technological advances in computer networks and physical processes.	Lee (2015)
The smart factory is a virtual, planned and real scenario model for design, planning, and management of operations.	Shariatzadeh et al. (2016)
Smart Factory is a set of intelligent production systems that integrates communication, computing and control processes to meet industrial demands.	Chen et al. (2017)
Industry 4.0 is a broad concept covering a variety of systems, technologies, principles and procedures designed to make production processes more autonomous, dynamic, flexible and precise.	Tortorella and Fettermann (2017)
"Industry 4.0 describes the transition from centralized production towards one that is very flexible and self-controlled. Within this production the products and all affected systems, as well as all process steps of the engineering, are digitized and interconnected to share and pass information and to distribute this along the vertical and the horizontal value chains, and even beyond that in extensive value networks."	Leyh et al. (2017)
Industry 4.0 is defined as an intelligent network of machines and industrial processes, which is formed with the aid of information and communication technologies for physical and digital connectivity's of resources.	BMWi (2018)

The concept of Industry 4.0 encompasses a new generation of technologies, existing or under tests, through technological advances in Information and Communication Technologies, Robotics and other areas (Robla-Gómez et al., 2017).

Silva et al. (2019) addressed empirical evidence in Industry 4.0, highlighting the technologies of this concept, as described in Table 7. These technologies have also been found in articles on human labor in smart industries.

Table 7. Key technological requirements for Industry 4.0.

Tecnological requirement
- Robots
- RFID technologies
- Advanced traceability systems
- Generation of wireless sensors and actuators
- Mobile Technologies
- Complex network protocol, IPv6.
- Cyber-Physical System (CPS)
- Internet of Things (IoT) e Internet of Services (IoS).
- Artificial intelligence (software), Big Data and IoT are core technologies for automating operational activities.
- Cloud platform and cloud services
- Cyber security systems
- Augmented reality systems
- Virtual reality systems
- Simulation of technologies and resources
- Digital Twins technologies
- Real Time Location System (RTLS)

Source: Silva et al. (2019).

A marked change in the industrial sector corresponds to an advanced process of automation and digitization, combining physical and virtual resources and internet (Belli et al., 2019). Smart factory defines a new approach to manufacturing by introducing recent industrial Internet technologies, intelligent sensors, cloud computing, predictive analytics of data and scenarios by Big Data, simulations, and resilient control technologies (Lee, 2015).

In particular, technologies and core approaches of Industry 4.0 are Physical Cyber Systems (CPSs), Internet of Things (IoT), artificial intelligence and software (Jeganathan et al., 2018; Pejic-Bach et al., 2019), virtual reality, augmented reality, simulation (Aromaa et al., 2018), Big Data (Belli et al., 2019; Pejic-Bach et al., 2019), cloud computing (Pejic-Bach et al., 2019) and Cyber security (Carías et al., 2019).

Therefore, the adoption of the concept of smart industry, based on the concept of Industry 4.0, presents advantages to companies (Table 8).

Table 8. Advantages of smart industry concept to companies.

Advantage	Source / author
Greater efficiency in resources processing	Albers et al. (2016), Gökalp, Şener, and Eren (2017), Jasiulewicz-Kaczmarek, Saniuk, and Nowicki (2017), Belli et al. (2019)
Flexibility in production	Radziwon et al. (2014), Gökalp, Şener, and Eren (2017)
Production cost reduction	Belli et al. (2019)
Better product quality and control	Albers et al. (2016), Belli et al. (2019)
Real-time fault detection	Jasiulewicz-Kaczmarek, Saniuk, and Nowicki (2017), Belli et al. (2019)
Production optimization	Chen et al. (2017), Rajnai and Kocsis (2018), Bányai et al. (2019), Belli et al. (2019)
Industrial process transparency	Kambatla et al. (2014), Avventuroso, Silvestri, and Pedrazzoli (2017)
More consistent and real-time decisions	Chen et al. (2017), Kiel et al. (2017), Ardito et al. (2018)
Self-organization and self-adaptability in data and product processing	Chen et al. (2017)
Autonomous control and sustainable manufacturing.	Radziwon et al. (2014)

Industry 4.0 combines intelligent sensors, artificial intelligence and data analysis to optimize real time manufacturing (Xu; Xu, and Li, 2018). Information systems and technologies such as the Internet of Things are used to improve resource management (Chen et al., 2017) and reduce unnecessary work and waste (Radziwon et al., 2014).

High variability and reduced product life cycles require agile and flexible production structures that can be quickly reconfigured in companies (Gorecky; Khamis, and Mura, 2017). Smart factory modeling can provide the capacity for self-organizing, self-learning and self-adapting production processes (Chen et al., 2017), allowing flexibility in development, diagnosis and maintenance, operationalization and control of systems. Also in terms of flexibility, products can be tailored to the specific and individual needs of customers (Jazdi, 2014).

Industry 4.0 requires effective integration between equipment, people, processes and products (Gebhardt; Grimm; Neugebauer, 2015; Haddara and Elraga 2015), providing competitive advantages such as cost efficiency and time in production and improved product quality (Albers et al., 2016). The smart factory integrates technologies to improve the performance, quality and transparency of manufacturing processes because its systems assist people and machines in the execution and control of their tasks based on data and information from the physical and virtual scenarios (Mabkhot et al., 2018).

In addition, another advantage is that Big Data analytics can provide support for decision making (Chen et al., 2017).

Manufacturing systems are now able to monitor physical processes, and make smart decisions through real-time communication and cooperation (Zhong et al. 2017). Intelligent processes provide rapid responses to changes in production and failures along the industrial production chain (Jasiulewicz-Kaczmarek; Saniuk; Nowicki, 2017; Haddara; Elraga, 2015).

As explained by researchers and experts, the concept of Industry 4.0 has advantages, but in addition to the technology dimension, other dimensions must be considered in smart industries (Table 9).

Table 9. Key dimensions in the adoption and development of smart industries.

Dimension	Source / author
- Technology, - Organizational management	De Carolis et al. (2017) and Rajnai and Kocsis (2018)
- Strategy, - Client, - Product, - Leadership, - Employees, - Organizational culture, - Governance, - Technology	Schumacher, Erol, and Sihn (2016)
People, - Strategies, - Processes, - Technologies - Products	Canetta, Barni, and Montini (2018)
- Technology, - Organizational management, - People	Kravčík, Ullrich, and Igel (2017)
- Finance, - Employees, - Strategy, - Process, - Products	Mittal, Romero, and Wuest (2018)
- Strategy, - Technology, - Organizational management	Biegler et al. (2018)

Focusing on Human dimension, it is necessary that companies and institutions ponder on developing the human resources sincetheir participation in the work will still be necessary and source of competitive advantages; moreover, there is not a perpective for total replacement of human labor by artificial intelligence (Spath et al. 2013). In face of this situation, this important resource must be managed adequately.

In smart industries, in addition to competitive advantages generated for companies, people will also provide other benefits in terms of human performance, well-being and health at work (Table 10).

Table 10. Benefits of smart industry concept to the human factor.

Category	Benefit	Source / author
Human performance	Facilitate communication between workers	Simões et al. (2019)
	Assist in human empowerment	
	Improved production efficiency	
	Creating interactive environments between humans and robots	Vysocky and Novak (2016)
	Decision making processes	Aromaa et al. (2018)
Human health at work	Reduced physical workload (weight, speed and other aspects)	Adam, Aringer-Walch, and Bengler (2018), Simões et al. (2019)
	Reduced dangerous and repetitive human tasks	Robla-Gómez et al. (2017)
	Data processing and information with analytical complexities, facilitated.	Robla-Gómez et al. (2017), Simões et al. (2019)
	Monitoring of physical activities and health conditions of workers in real time	Ruppert et al. (2018)

Technologies such as robots and intelligent systems provide changes in work. One of them is the redirection of human activities and the creation of new jobs. It is expected an intensification of activities with intellectual nature (Ghislieri; Molino; Cortese, 2018). Changes in technology and work configurations present the main purpose of improving production efficiency (Simões et al., 2019).

In large corporations, the higher degree of process digitization implies in lower quantitative workload and better operational benefits to workers (Adam; Aringer-Walch; and Bengler, 2018). Specific technologies, in addition to reducing the physical workload (weight, speed and other aspects), facilitate the execution of operational activities on human labor, communication between workers and machines, detailed analytical analyses, among other advantages (Simões et al., 2019).

Industrial robots, for example, are widely used in companies, replacing dangerous human and repetitive tasks or difficult processing or with greater analytical complexities (Robla-Gómez et al., 2017). Increasingly flexible robots are desired for industrial work, from sensors, devices, software and hardware modules and advanced interfaces (Gonçalves et al., 2019). Human and machine collaboration emerges as an innovative strategy to build interactive environments between humans and robots, safely (Vysocky; Novak, 2016).

Augmented reality and virtual reality approaches have the potential to empower workers, generating information and knowledge about processes, products, manufacturing and assembly (Simões et al., 2019). In addition to better human performance, they can support less stressful work by removing information that is not currently applicable and facilitating assimilation and learning (Kadir; Broberg; Conceição, 2019).

New technology frameworks, such as Big Data and analytical tools, for instance, generate large volumes of data for monitoring, analysis and improvement of production processes (Faccio et al., 2019).

In practice, successive industrial revolutions decrease physical loads of human work, but the cognitive burden is increased due to the complexity of information and tasks (Kumar; Kumar, 2019). Intelligent technologies can help workers in cognitive terms, one of which makes decisions by sharing information on platforms (Aromaa et al., 2018).

Solutions through activity monitoring are also achievable, such as specific technologies measure activity complexity, heart rate, ergonomic postures, among other important metrics for human health management (Ruppert et al., 2018).

Despite the benefits, human resources are exposed to the challenges of insertion and permanence in smart industries, associated with training, professional career and physical and mental health aspects at work. This includes both the worker and the manager.

Table 11. Categories of human challenges in the context of smart industry

Category	Requirement
Education and formation	Promising knowledge areas and new competences development
Professional career	Positions and functions Human motivation, satisfaction, leadership and instability
Physical and mental health management at work	Worker's role in the intelligent industrial environment. Important aspects of studies are - security of data and personal information, - Physical security in contact with collaborative robots and other technologies, - Social relationship at work - Intellectual management - Challenges in cognitive and mental health

People can adapt to changes in companies without interrupting production, but it is necessary to empower them in terms of intellectual, cognitive and emotional aspects (Simões et al., 2019). It is important to create and improve knowledge about digital technologies. A promising area for the human learning is Information Technology - IT (Ghislieri; Molino; and Cortese, 2018). In addition to the area of Information and Communication Technology, other promising areas for companies are the industrial automation, robotics, nanotechnology, biotechnology, materials science and engineering (Postelnicu; Calea, 2019).

The academy presents a vital role in meeting demands for knowledge and human skills development in Industry 4.0 (Jeganathan et al., 2018). The complexity of the information generated and its influence on production is a multidisciplinary challenge. In human resources management, knowledge is needed in cognitive psychology, ergonomics, operations management, communication technology and computer science, industrial design, manufacturing technologies, instrumentation engineering and others (Kumar; Kumar, 2019).

To ensure that workers perform their tasks efficiently in increasingly complex environments, the implementation of qualification measures is necessary, at the technological and organizational management levels (Gorecky; Khamis; Mura, 2017). Qualification of people for work is one of the challenge requirements for industries, educational institutions and government, which must create policies and actions directed to work issues in smart industries (Silva; Kovaleski; Pagani, 2019a).

Hecklau et al. (2016) identified human competencies for work in the Industry 4.0, classifying them into four categories, technical (in-depth knowledge of technologies, understanding of the intelligent process, technical, media and system coding skills and security understanding of Information Technology - IT), methodological competences (creativity, business perspective, problem solving, decision making, conflict resolution ability, research skills, and analytical skills), social skills (intellectual skills, language and communication skills, networking skills, commitment, ability to transfer knowledge and leadership) and personal competencies (flexibility, motivation to learn, ability to work under pressure and sustainable mindset).

Silva, Kovaleski and Pagani (2019b) identified basic competencies for the Industry 4.0, communication, creativity, innovation, leadership, decision making facility and analytical skills. They are fundamental to diversity of different professions and positions, this is, technology development, project management, management and supervision of systems and people, among others.

Gebhardt, Grimm, and Neugebauer (2015) discuss the importance of developing Information Technologies skills and interdisciplinary human thought ability as basic curricular elements for people in Industry 4.0.

For work in Industry 4.0, Kazancoglu, and Ozkan-Ozen (2018) mention human skills, ability to act in complex situations, critical thinking, flexibility at work, interdisciplinary learning, IT knowledge, knowledge of technologies, ability to interact with modern interfaces and analytical skills. Ghislieri, Molino, and Cortese (2018) highlight social human skills, flexibility, and ability to work in multifunctional teams, and deal with complex situations, leadership, efficient communication and innovation (Silva; Kovaleski; Pagani, 2019a).

People should gain knowledge and learn new daily tasks, as well as understand and know how to use high-tech devices (Trstenjak; Cosic, 2017) and manage smart systems. Educational programs will be designed to meet current demands, new content, skills and knowledge (Azahari; Ismail; Susanto, 2019).

Promising human professions in smart industries are project management, product development, computational systems development, engineering (mechanics, industrial, electronics and software), industrial automation, quality management, production management (business, data, production processes, advanced technologies and software) and predictive maintenance (Pejic-Bach et al., 2019). Other professions are strategic corporate manager, software developer, systems programmer, process supervisor and manager and operator of technologies and devices (Silva; Kovaleski; Pagani, 2019a).

On the other hand, the widespread use of different technologies for work execution can result in negative implications such as reducing human relationships in the environment, informal learning of interrupted people, dissatisfaction, demotivation and stress. One of the reasons is the greater sense of control and oppression of workers by technologies (Ghislieri; Molino; Cortese, 2018).

It should be ensured that the worker feels comfortable and safe when interacting with digital devices, robots and systems. The psychological factor must be preserved and managed (Robla-Gómez et al., 2017). In Industry 4.0, the organization of work should be fully reviewed and any loss of quality and safety to workers, who may arise, should be carefully managed (Stadnicka; Litwin; Antonelli, 2019).

Conclusion

The smart industry is widely influenced by the concept of Industry 4.0 and other concepts and principles such as lean production, resource efficiency such as energy, sustainable development, smart manufacturing and advanced manufacturing, among others. As noted in the literature, human work will be indispensable in smart industries, both for the development of this concept as the management and operationalization of advanced production systems, technologies and processes.

In this intelligent environment, workers will have reduced physical efforts, more efficient internal and external communication by artificial intelligence, companies and people, decision-making processes based on sets of criteria, tools and data other positive implications.

It is necessary to ensure adequate conditions of human work, interventions and actions in cognitive, emotional and psychic aspects, mainly. Changes are projected not only to the operator, but to technicians, managers and other employees at operational, tactical and strategic levels.

Studies with worker-centered focuses are suggested, seen from the perspective of protagonists, regarding professional career, challenges in the labor market, performance and health management in the context of smart industry.

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Appendix 1

Table 12. Main information and data of articles analyzed.

N.	Source / Author	Article title	Year	Citation	Impact factor	InOrdinatio value
1	Benešová, A. and Tupa, J.	Requirements for Education and Qualification of People in Industry 4.0	2017	113	0	193
2	Longo, F., Nicoletti, L. and Padovano, A.	Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context	2017	101	3,518	181
3	Gorecky, D., Khamis, M. and Mura, K.	Introduction and establishment of virtual training in the factory of the future	2017	59	2,09	139
4	Badri, A., Boudreau-Trudel, B. and Souissi, A.S.	Occupational health and safety in the industry 4.0 era: A cause for major concern?	2018	39	3,619	129
5	Peruzzini, M. and Pellicciari, M.	A framework to design a human-centred adaptive manufacturing system for aging workers	2017	46	3,772	126
6	Richter, A., Heinrich, P., Stocker, A. and Schwabe, G.	Digital Work Design: The Interplay of Human and Computer in Future Work Practices as an Interdisciplinary (Grand) Challenge	2018	23	3,6	113
7	Pinzone, M., Albè, F., Orlandelli, D., Barletta, I., Berlin, C., Johansson, B. and Taisch, M.	A framework for operative and social sustainability functionalities in Human-Centric Cyber-Physical Production Systems	2019	12	3,518	112
8	Kaasinen, E. et al.	Empowering and engaging industrial workers with Operator 4.0 solutions	2019	10	3,518	110
9	Ruppert, T., Jaskó, S., Holczinger, T. and Abonyi, J.	Enabling technologies for operator 4.0: A survey	2018	17	2,217	107
10	Sackey, S.M. and Bester, A.	Industrial Engineering Curriculum In Industry 4.0	2016	37	0,547	107

		In A South African Context				
11	Ansari, F., Khobreh, M., Seidenberg, U. and Sihn, W.	A problem-solving ontology for human-centered cyber physical production systems	2018	15	2,333	105
12	Longo, F., Nicoletti, L. and Padovano, A.	Ubiquitous knowledge empowers the Smart Factory: The impacts of a Service-oriented Digital Twin on enterprises' performance	2019	3	4,759	103
13	Whysall, Z., Owtram, M. and Brittain, S.	The new talent management challenges of Industry 4.0	2019	3	0	103
14	Faccio, M., Ferrari, E., Gamberi, M. and Pilati, F.	Human Factor Analyser for work measurement of manual manufacturing and assembly processes	2019	3	2,496	103
15	Du, G., Chen, M., Liu, C., Zhang, B. and Zhang, P.	Online robot teaching with natural human-robot interaction	2018	12	7,503	102,01
16	Ghani, E. and Muhammad, K.	Industry 4.0: Employers' expectations of accounting graduates and its implications on teaching and learning practices	2019	2	0	102
17	Pérez, L., Diez, E., Usamentiaga, R. and García, D.	Industrial robot control and operator training using virtual reality interfaces	2019	2	4,769	102
18	Mohelska, H. and Sokolova, M.	Management approaches for industry 4.0 - The organizational culture perspective	2018	12	4,344	102
19	García de Soto, B., Agustí-Juan, I., Joss, S. and Hunhevicz, J.	Implications of Construction 4.0 to the workforce and organizational structures	2019	2	0	102
20	Kadir, B., Broberg, O. and Conceição, C.	Current research and future perspectives on human factors and ergonomics in Industry 4.0	2019	2	3,518	102
21	Ramingwong, S., Manopiniwes, W. and Jangkrajarng, V.	Human Factors of Thailand Toward Industry 4.0	2019	2	0	102
22	Vysocky, A. and Novak, P.	Human - Robot collaboration in industry	2016	32	0	102
23	Umachandran, K. et al.	Designing learning-skills towards industry 4.0	2019	1	0	101
24	Longo, F., Nicoletti, L. and Padovano, A.	Modeling workers' behavior: A human factors taxonomy and a fuzzy analysis in the case of industrial accidents	2019	1	1,517	101
25	Ahmad, A., Segaran, Soon, N., Sapry, H. and Omar, S.	Factors influence the students readiness on industrial revolution 4.0	2019	0	0	100
26	Azahari, M., Ismail, A. and Susanto, S.	The significance of photographic education in the contemporary creative industry 4.0	2019	0	0	100
27	Azmi, A., Kamin, Y., Md Nasir, A. and Noordin, M.	The engineering undergraduates industrial training programme in Malaysia: Issues and resolutions	2019	0	0	100
28	Badaruddin, Noni, N. and Jabu, B.	The potential of ICT in blended learning model toward education 4.0 need analysis-based learning design for ELT	2019	0	0	100

29	Gerasimova, E., Kurashova, A., Tipalina, M., Bulatenko, M. and Tarasova, N.	New state standards of higher education for training of digital personnel in the conditions of Industry 4.0	2019	0	0	100
30	Jancikova, K. and Milichovsky, F.	HR Marketing as a Supporting Tool of New Managerial Staff in Industry 4.0	2019	0	0	100
31	Martínez-González, M., Olid, C. and Crespo, J.	Evolution of HR competences in organizations immersed in the fourth industrial revolution	2019	0	0	100
32	Mokhtar, M. and Noordin, N.	An exploratory study of industry 4.0 in Malaysia: A case study of higher education institution in Malaysia	2019	0	0	100
33	Mpofu, R. and Nicolaides, A.	Frankenstein and the Fourth Industrial Revolution (4IR): Ethics and human rights considerations	2019	0	0	100
34	Ovinova, L. and Shraiber, E.	Pedagogical model to train specialists for Industry 4.0 at University	2019	0	0	100
35	Popkova, E. and Zmiyak, K.	Priorities of training of digital personnel for industry 4.0: social competencies vs technical competencies	2019	0	0	100
36	Postelnicu, C. and Câlea, S.	The fourth industrial revolution. Global risks, local challenges for employment	2019	0	0	100
37	Riveros Valdes, B.A. and Bustos Baez, S.S.	Training programs linked to technological management in Argentina, Colombia, Mexico and Chile: Challenges for the academy and its relationship with the socio productive sector	2019	0	0	100
38	Tan, S. and Rajah, S.	Evoking Work Motivation in Industry 4.0	2019	0	0	100
39	Tinz, J., Tinz, P. and Zander, S.	Knowledge management models for smart manufacturing - A comparison of current approaches	2019	0	0	100
40	Ullah, A.	Fundamental issues of concept mapping relevant to discipline-based education: A perspective of manufacturing engineering	2019	0	0	100
41	Antonelli, D. and Bruno, G.	Dynamic distribution of assembly tasks in a collaborative workcell of humans and robots	2019	0	0	100
42	Dannapfel, M., Wissing, T., Förstmann, R. and Burggräf, P.	Human machine cooperation in smart production: Evaluation of the organizational readiness	2019	0	0	100
43	Havard, V., Jeanne, B., Lacomblez, M. and Baudry, D.	Digital twin and virtual reality: a co-simulation environment for design and assessment of industrial workstations	2019	0	0	100
44	Kolbeinsson, A., Lagerstedt, E. and Lindblom, J.	Foundation for a classification of collaboration levels for human-robot cooperation in manufacturing	2019	0	0	100

45	Nicoletti, L. and Padovano, A.	Human factors in occupational health and safety 4.0: A cross-sectional correlation study of workload, stress and outcomes of an industrial emergency response	2019	0	0	100
46	Pardi, T.	Fourth industrial revolution concepts in the automotive sector: performativity, work and employment	2019	0	0	100
47	Kinzel, H.	Industry 4.0 - Where Does This Leave the Human Factor?	2017	20	0	100
48	Posada, J., Zorrilla, M., Dominguez, A., Simoes, B., Eisert, P., Stricker, D., Rambach, J., Dollner, J. and Guevara, M.	Graphics and Media Technologies for Operators in Industry 4.0	2018	7	1,725	97
49	Richert, A., Müller, S., Schröder, S. and Jeschke, S.	Anthropomorphism in social robotics: empirical results on human–robot interaction in hybrid production workplaces	2018	7	0	97
50	Laudante, E.	Industry 4.0, Innovation and Design. A new approach for ergonomic analysis in manufacturing system	2017	16	0	96
51	Johansson, J., Abrahamsson, L., Kåreborn, B., Fältholm, Y., Grane, C. and Wykowska, A.	Work and organization in a digital industrial context	2017	16	0	96
52	Birtel, M., Mohr, F., Hermann, J., Bertram, P. and Ruskowski, M.	Requirements for a Human-Centered Condition Monitoring in Modular Production Environments	2018	5	0	95
53	Jerman, A., Bach, M. and Bertoncelj, A.	A bibliometric and topic analysis on future competences at smart factories	2018	4	0	94
54	Arena, D., Tsolakis, A., Zikos, S., Krinidis, S., Ziogou, C., Ioannidis, D., Voutetakis, S., Tzovaras, D. and Kiritsis, D.	Human resource optimisation through semantically enriched data	2018	4	3,199	94
55	Müller, S., Shehadeh, M., Schröder, S., Richert, A. and Jeschke, S.	An overview of work analysis instruments for hybrid production workplaces	2018	4	0	94
56	Rasca, L.	Employee experience – An answer to the deficit of talents, in the fourth industrial revolution	2018	2	0	92
57	Koch, P., van Amstel, M., Dębska, P., Thormann, M., Tetzlaff, A., Bøgh, S. and Chrysostomou, D.	A Skill-based Robot Co-worker for Industrial Maintenance Tasks	2017	9	0	89
58	Richert, A., Shehadeh, M.,	Digital Transformation of Engineering Education	2016	11	0	81

	Willicks, F. and Jeschke, S.	Empirical Insights from Virtual Worlds and Human-Robot-Collaboration				
59	Binner, H.	Industry 4.0: defining the working world of the future	2014	15	0	65