The effect of digitalization and human-centric on companies' production performances

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Abstract. Industry 5.0 is the inclusion of humans in the production line. This is because human is now considered a prerequisite for any industry to enhance production performances. However, most of the technological enablers still do not consider the human factor in the production system and only a few articles expose the impact of human-centric approaches and digitalization on production performance. Therefore, this study applied a questionnaire-based survey approach to map out the level of digitalization and human-centric in companies of different sizes and identify the impact on production flexibility and throughput performances on the production systems. The survey was conducted using Google Forms. One of the key findings is the level of digitalization should go hand in hand with human centricity. Both the production performances of product throughput and process flexibility have an S-shape tendency where a high level of human-centric can have a positive impact on both production performances. Respondents from different sizes of enterprises in different regions of the world and job nature can have a different perception of both the degree of human-centric and digitalization. Companies should consider different human roles like managers and engineers in the human-centric framework to enhance human-centric in a more holistic approach.

Keywords: Human-centric, Digitalization, Industry 5.0, Survey, Performance.

1   Introduction

From the first Industrial revolution to the fourth, the implementation of automation and machines has increased steadily. This results in production performance improvements such as productivity and quality. One of the reasons is that machines can outlast humans in long-lasting repetitive work, with higher manufacturing speed and accuracy [1]. With the increasing deployment of advanced digital technologies such as artificial intelligence (AI), complex processes are transferred from humans to machines [2].

Till today, humans, particularly operators, are not completely removed from shopfloor despite the using machines and technological tools in production. On the contrary, they are often included in the activities such as the decision-making process,

material handling and assembly due to their flexibility and their cognitive and motor skills that machines cannot imitate economically yet [3]. Automation technologies and digital transformation promise increased productivity and profits to companies, but there is an imbalance or mismatch between the automation level and human capabilities such as human-machine collaboration, and human-machine interface [4].

Industry 5.0 is to solve the mismatch issue between manufacturing and human-social needs which leads to three focus areas of human-centricity, sustainability, and resiliency [5]. After the EU commission published a report on Industry 5.0 in 2021 [6], there is an increase in published work focusing particularly on human-centric in the manufacturing sector to reduce waste and improve overall product quality [7]. Although there is no single definition of a human-centric approach, it denotes a similar concept which is to put focus on humans themselves [7]. Human-centric approaches are not only applied in manufacturing, sectors such as energy [2] and maritime [8] are also shifting their attention towards a better human-machine collaboration to increase their performances.

Although the human component in Industry 5.0 receives high focus due to its better knowledge transfers and flexible capabilities, various literature reviews on human-centric approaches highlight that production systems are still not prioritizing human needs (ergonomics, etc.) and most of the technological enablers still do not consider the human factor in the manufacturing processes and production system to achieve high production performance [9-11]. Currently, only a few articles expose the effect of human-centric approaches and digitalization on production performance. Most of these studies are based on empirical data such as single or multiple case studies and can only demonstrate the impact of human-centric approaches and digital technologies on performance only on a small scale.

This study is to map out the level of digitalization and human-centric of the production systems of various companies as well as to identify the impact on production flexibility and throughput performances. Therefore, this study focuses to answer the following research questions (RQ):
1) What is the relationship between different levels of human-centric and digitalization in companies?
2) What human-centric approaches could companies consider along with digitalization development to improve product throughput and process flexibility performances?

2 Theoretical background

While Industry 4.0 focuses on digitalization and automation, Industry 5.0 re-introduce humans (e.g operators) back to the shop floor to increase the process efficiency of production [5]. In the conference [5], the authors categorized the definition of Industry 5.0 from three different perspectives namely EU proposal-based, intelligent cutting-edge technology-based and human-machine collaboration-based. From the EU proposal perspective, Industry 5.0 is, for example, placing a premium on workers' well-being throughout the manufacturing process and leverages new technologies beyond

development and employment [12]. From the human-machine collaboration perspective, Industry 5.0 focuses on building a synergy between the human workforce and machine to improve process efficiency and designing a human-centric solution which enables human work to rejoin the automated process [13]. Although there is no set definition, Industry 5.0 aims to combine the strengths and capabilities of autonomous decision-making of both humans and technologies to increase production performance [14].

Currently, most published literature on human-centric in Industry 5.0 focuses to increase the collaboration of humans with autonomous technologies in production systems that improve production performance (such as flexibility) and human-centricity (such as reducing fatigue levels among workers). Perizzini and Pellicciari [15] present a novel human-centric factory model that considers crucial aspects (such as ageing workers, and digital technologies) to design factories and improve performance. The study by Kong et al. [16] developed a human–cyber-physical symbiosis and so support real-time, trusting, and dynamic interaction among operators, machines and production system. Pinzon et al. [17] introduce a holistic framework for a human-centric approach and cyber-physical systems to improve operational and social sustainability-related performance impacts. Further, Wanasinghe et al. [18] introduce a human-centric digital transformational framework for the oil and gas industry to deploy existing digital technologies to enhance their workers' health, safety, and working conditions. Dengler et al. [19] develop a system of machine learning to detect errors and present the information in an understandable format to operators to have a colligative decision-making process. Canas et al. [20] suggest to incorporate augmented reality in learning mythology can change which can improve the education and training for operators to work in an industry 4.0 environment.

Human-centric manufacturing is now considered a prerequisite for any industry to enhance flexibility, agility, and robustness [21,22]. The outcomes of human and autonomous technologies collaboration will be a highly effective manufacturing process with added value, thriving trusted autonomy, and decreased waste and expenses [23]. To the best of our knowledge, there are no studies that have investigated, on a large scale, the level of digitalization and human-centric approach in manufacturing companies and identified their impact on product throughput and process flexibility performance.

3   Methodology

This study applied a questionnaire-based survey approach to answering the RQs. The global survey was conducted online mode using Google Forms and the respondents' answers were collected over a timeframe of 6 months. The questionnaire contains 38 closed questions in total with nominal (e.g., choose the company size) and ordinal scales (e.g., rate the human-centric approach in the company). A 5-scale Likert (e.g, "very low, low, medium, high to very high") is used in the questionnaire. To ensure the reliability and validity of the questionnaire, the questionnaire was screened among several critics on web-based questionnaires and sent to experts for pilot testing. The revised and enhanced online questionnaire link (refer to appendix) was sent to 432 subject matter experts. The sampling criteria of the respondents were that they must be working,

practicing, or involved in projects focusing on digital manufacturing and must be working in the manufacturing or service sector.

A total of 120 respondents participated in the survey. The result has a response rate of (31%), which is acceptable in the survey research methodology [12]. The respondents in this survey are located in Asia (29%), Africa (14%), North America (11%), South America, (10%) and Europe (36%) and are working in small (15%), medium-sized (24%) and large enterprises (61%). Most of the respondents are working with production and quality management, have more than 10 years of experience within this field, and identify as top- or middle management.

This study reflects a minor part of the survey results. Nineteen closed questions were included and analyzed to answer the RQs. To map the digitalization level, product throughput and process flexibility performance, several questions were asked. This approach reduces the bias and increases the validity of the survey. To test reliability, Cronbach's alpha coefficient was calculated for each of the summated scales. All the summated scales have values above the recommended threshold of 0.6 [24]. The reliability statistics of this survey has a Cronbach's Alpha of 0.927, and so, deemed reliable for further analysis.

4 Results

In this section, the survey results are presented and visualized in a whisker and box diagram. The survey results are showing five different human-centric levels ranging from very low to medium to very high and their results on digitalization level, product throughput time performance and process flexibility performance.
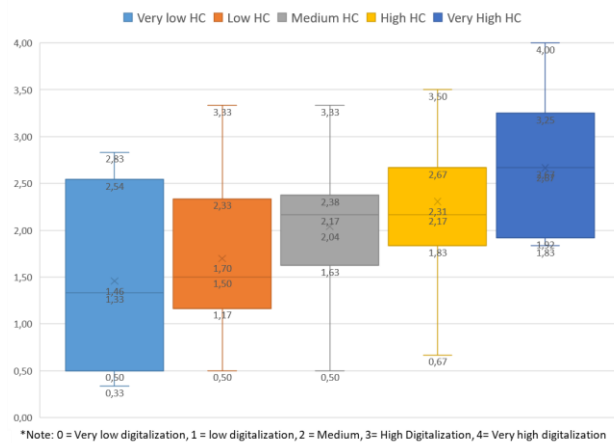

Fig. 1. Digitalization level in production systems with different human-centric approaches

Fig. 2 shows the results of the human-centric approach on product throughput performance, while Fig. 3 presents the results on process flexibility performance. The performance dimensions are an average of five different questions relating to applying

strategies, methods, and tools distinguished by companies with different levels of human-centric approaches. Both the production performances of product throughput and process flexibility have an S-shape tendency.
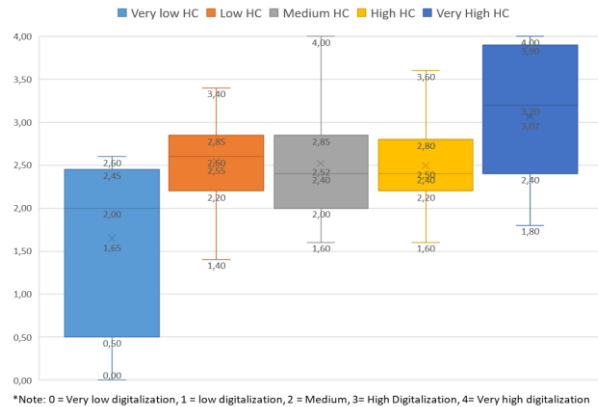

*Note: 0 = Very low digitalization, 1 = low digitalization, 2 = Medium, 3= High Digitalization, 4= Very high digitalization

Fig. 2. Human-centric approaches impacting product throughput performance

*Note: 0 = Very low digitalization, 1 = low digitalization, 2 = Medium, 3= High Digitalization, 4= Very high digitalization
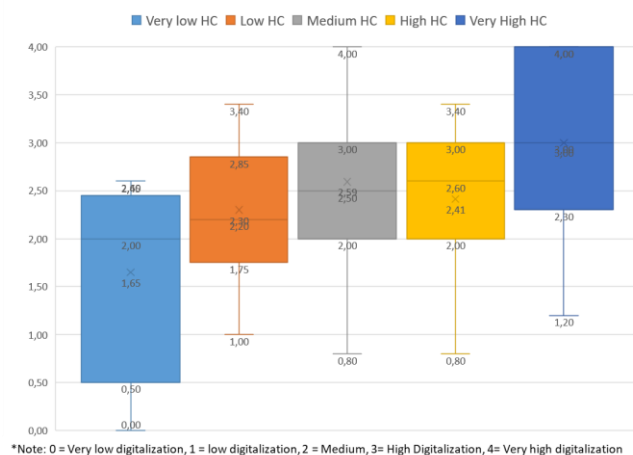
Fig. 3. Human-centric approaches impacting process flexibility performance

In Fig. 2, companies which responded to very low human-centric (mean = 1,65), have a medium throughput performance compared to companies from low to very human-centric where they all have high throughput performances. The impact on throughput performances is small for companies with low to high human-centric as compared to companies with very low and very high human-centric. Fig. 3, companies which responded to very low (mean = 1,65) and low human-centric (mean = 2,30) have a medium flexibility performance, while companies which responded ranging from medium to very human-centric have a higher flexibility performance. Similarly, there is a huge difference between companies with very low and very high human-centric

approaches companies when it comes to the impact on product throughput and process flexibility performance.

5   Discussion and conclusion

In highly digitized production lines, human roles on the shop floor are often substituted by robots and automation [25]. However, the types of human activities that are involved in the production, depending on the level of digitalization. For example, in a production line with a high degree of digitalization where the operators are cooperating closely with robots in the same workspace, companies should focus on developing higher skills activities for operators to work on shopfloor such as day-to-day robot maintenance and learning basic programming knowledge [7]. It is crucial to align the degree of human-centric approach with the level of digitization, as depicted in Fig. 1, to achieve improved production outcomes in terms of product throughput and process flexibility.

Human involvement is crucial during uncertain events in the production line [26]. Given the evident benefits of human-robot collaboration in manufacturing systems [26, 27], it is crucial to adopt a human-centric approach when deploying robots during the early design stage to enhance product output and process flexibility, as depicted in Fig. 2 and 3. However, implementing a human-centered approach in conjunction with industrial robots presents significant challenges in task planning [26]. A challenge is to efficiently allocate tasks and assembly operations to human operators or robots, taking into account the strengths and limitations of both.

Human-centric should always be one of the focus points to elevate into Industry 5.0. It is also important to note that human-centric goes beyond just the operators. Although operators have direct contact on the shop floor, both managers and engineers have roles to play [7]. Managers play a role in advancing the level of a human-centric approach in production. For example, managers, especially in large companies, should facilitate a feedback channel from the operators to understand the needs and challenges faced by them because often some of the decision-making is beyond their control [28].

This study provided new insight into what should be developed and focused on, in parallel with the level of digitalization of companies. The results show that there is a huge impact on both product throughput and process flexibility between companies with very low and very high human-centric approaches companies. One limitation of the questionnaire is the different perceptions and understanding of both the degree of human-centric and digitalization by the respondents from different sizes of enterprises in different regions of the world. We included, therefore, several questions to map a performance dimension to reduce bias. Further, the job nature of the respondents with different knowledge of digitalization can also have an impact on the results.

Nonetheless, this survey provided a new viewpoint on where the industry should position humans when it comes to introducing new technology. The level of human-centric of a company goes hand in hand with the level of digitalization which supports the Industry 5.0 perspective - human involvement in manufacturing. Future research should consider different roles of humans like managers and engineers in the human-centric framework to enhance human-centric in a more holistic approach.

Appendix

Link to the survey and questionnaire: https://forms.office.com/r/AumEsRnPvE

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