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Industry 4.0: Challenges and Opportunities of Digitalisation Manufacturing Systems

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Abstract. Industry 4.0 technologies enable manufacturing companies to efficiently utilise their assets and reach a competitive advantage. These technologies provide new methods of generating revenue from data-driven services and facilitate predictive maintenance through the use of real-time data analytics. Even after more than a decade from the start of the fourth industrial revolution, manufacturing industry still struggles to upgrade to Industry 4.0-compliant technologies and standards. Currently, the barriers and enablers facing manufacturing companies to adopt new technology are not well understood, and there is a significant gap in the available literature. The authors of this paper review the challenges, opportunities, and applications facing manufacturers from an academic and industrial perspective. In order to identify these factors, a literature review and a survey were chosen. Based on the results of this study, the main challenges identified are financial constraints, a lack of knowledge, and the complexity of new technologies. The research also identified opportunities for manufacturing firms, such as improving efficiency, reducing costs, and improving quality. Potential applications for manufacturers include sharing machine status, predictive maintenance and controlling machines remotely. In the current work, these factors have been ranked from an industrial perspective.

Keywords. Challenge, Opportunity, Manufacturing, IoT, CPS, SME, I4.0.

1. Introduction

Industry 4.0 (I4.0) enables manufacturing to enhance their productivity and compete globally through the deployment of cutting-edge technologies such as the Internet of Things (IoT), Cyber-Physical Systems (CPS), cloud computing, and data analytics. I4.0 has been shown to increase efficiency while also increasing customizability and autonomy [1, 2]. The adoption of I4.0 brings new opportunities for industry to innovate and compete in domestic and foreign markets, enabling better decision making, increasing efficiency, and improving business performance [3]. Although the fourth industrial revolution has been underway for more than a decade, manufacturing sector, in particular, small and medium enterprises (SMEs) are still facing challenges with upgrading manufacturing systems and adopting Industry 4.0 technologies [4]. In order to transition to Industry 4.0, companies must either replace or upgrade legacy assets. This is not a trivial task since industry maintains a considerable amount of legacy assets [5]. As a result, there are challenges in adopting new technologies that originate from inside or outside of the organisation, however, few challenges are more frequently mentioned

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in articles as the main. Likewise, when I4.0 technologies are adopted, a number of opportunities and applications are created for companies to utilise. This study seeks to identify and rank the main challenges, opportunities, and applications associated with the adaptation of I4.0 technology by manufacturing enterprises from academic and industry perspectives. It aims to answer the following questions:

I. What are the main challenges, opportunities and applications that manufacturing companies face in adopting I4.0?
II. What is the ranking of these factors from an industrial perspective?

In order to answer these questions, a literature review and a survey are conducted. The remainder of the paper is arranged as follows. Section 2 summarises the study's methodology. In Section 3, the results and discussion are presented in terms of research questions. The conclusion is presented in Section 4.

2. Methodology

In order to answer the research questions of the current work, two methods are employed. First, a literature review is conducted to identify the main challenges and opportunities of adopting new technologies. In a second method, a survey is conducted to confirm and rank the findings of the literature review from an industry perspective. This two-step approach is selected to gather information from both academic and industry perspectives.

2.1 Literature Review

In this study, the literature published between 2017 and 2022 on the topic of I4.0 challenges and opportunities are reviewed. Three databases are searched, including Compendex, Web of Science, and Google Scholar. Boolean logical search operator (OR, AND, NOT) are also applied to narrow or extend the research scoop. The following keywords and phrases are used to search relevant articles: (challenge* opportunit* barrier* application, I4.0, adopt*, Industry 4.0, SME, CPS, IoT). The search is restricted to English articles in the field of manufacturing.

Figure 1 indicates the search strings and keywords used to conduct the literature search. After removing the papers that did not meet the search criteria, 24 papers remained which were reviewed to answer the research questions.

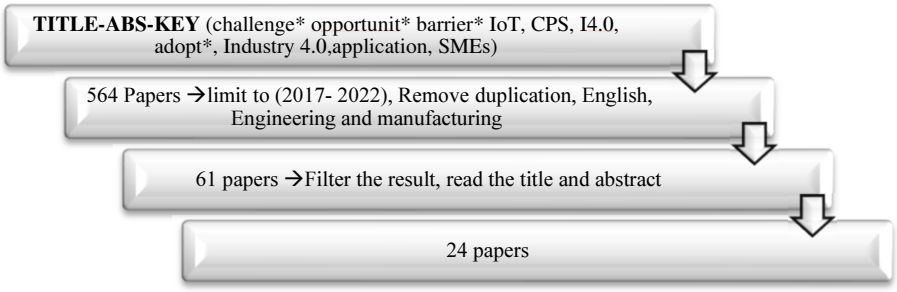

Figure 1. Literature review search process.

2.2 Online Survey

A cross-sectional study is conducted using an online survey with the aim of confirming and ranking gathered factors from the literature review. The survey consisted of two techniques for collecting data: closed-ended and open-ended questionnaires.

A. Close-ended questions:

Close-ended questions ask respondents to select an appropriate answer based on their experience. A Likert scale is used with five points ranging from strongly agree (5), to strongly disagree (1). The use of this technique helps to rank and prioritise factors from the participants' perspective.

B. Open-ended questions

Open-ended questions enable respondents to answer in their own words if the provided answers are incorrect or if they want to provide more information. It allows researchers to explore ideas and obtain additional insights.

The target population for this study is in the manufacturing sector, as shown in Table 1, which outlines the inclusion and exclusion criteria for participants.

Table 1. Participants' inclusion and exclusion criteria

Inclusion	Exclusion
People who work in the manufacturing sector	People who do not work in the manufacturing sector or who have no experience in digitalisation of factories
People who work as digitalisation solution providers for manufacturers	
People who have experience in digital transformation to Industry 4.0	People under 18 years old
Aged above 18, both genders	

3. Results and Discussion

In accordance with the proposed methodology, the results of the study are arranged in the following order: results of the literature review followed by results of the online survey.

3.1 Result of Literature Review

In light of the findings of the literature review (see Table 2), three major challenges are identified: financial constraints, a lack of knowledge, and the complexity of the new technology. The main opportunities identified are reduced costs, increased efficiency, and improved quality. It is also found that manufacturing firms can benefit from the following three core applications: real-time machine status, remote control of the machines, and predictive maintenance.

Table 2. Summary of literature review result

Factors		Authors
Challenges	Financial constraints	[6-8]
	Lack of knowledge	[9-11]
	Complexity	[12-14]
Applications	Share machine status	[2, 15-18]
	Predictive maintenance	[19-23]
	Remotely control machine	[5, 24-27]
Opportunities	Reduce cost	[24, 28, 29]
	Improve efficiency	[3, 29-31]
	Improve quality	[22, 26, 31]

3.2 Result of Online Survey

Based on the survey results, 57 out of 100 responses were collected for descriptive analysis. The results of five demographic questions that illustrate the background of the participants are provided in Table 3.

Table 3. Participants' background

Questions	Options				
Which industry is your company working in?	Metals 17.5%	Food 12%	Chemicals 10.5%	Plastic 17.5%	Research 37%
Your role in the company	Top-level managers 10.5%	Middle 37%	Supervision 28%	Machinist 21%	Other 3.5%
How many years of experience do you have?	Less than 2 years 9%	2-5 years 32%	6- 10 years 32%	More than 10 years 28%	
Number of employees in the company	1-9 5%	10-49 68%	50-249 17.5%	More than 250 9%	
Where is the company located?	The UK 51%	European 25%	The USA 7%	Other 15%	

The survey method is used to analyse and rank 57 responses in order to determine participants' preferences regarding the challenges, opportunities, and applications associated with the adoption of I4.0. The ranking of previous factors from participants' points of view is presented in Table 4.

Through the analysis of participants' data, the majority of participants agreed that adopting I4.0 technology is complex. An interesting finding is that top-level managers do not view financial obstacles as challenges, while low-level employees do. As for the lack of knowledge, most of the shopfloor employees denied that, and they are against controlling machines remotely. In general, manufacturing enterprises look to more interested in utilising the efficiency of the current system first, then find ways to reduce costs, and finally, improve quality.

Table 4. Result of participants ranking

Challenge	
Luck of investment	0.30 = 3rd
Lack of knowledge	0.34 = 2nd
Complexity	0.36 = 1st
Opportunity	
Reduce cost	0.30 = 2nd
Increase efficiency	0.42 = 1st
Improve quality	0.28 = 3rd
Application	
Share machine status	0.43 = 1st
Perform predictive maintenance	0.37 = 2nd
Control machines remotely	0.21 =3rd

4. Conclusion

In conclusion, the adoption of I4.0 technology can improve efficiency and business performance of manufacturing enterprises, which in turn can enhance competitive advantage in domestic and international markets. As a result, factories have a great opportunity to integrate new technologies to improve efficiency, reduce costs and improve product quality. However, financial constraints, lack of knowledge, and the complexity of adopting new technologies are considered to be major challenges for manufacturing companies. Digitalisation of assets is a strategic decision that manufacturing companies should evaluate against the opportunity and associated risk. The findings of the study lead to a better understanding and prioritisation of the main factors affecting the digitalisation journey.

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