Drivers and Barriers to Implement Industry 4.0 in Manufacturing Sectors, Systematic Literature Review

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***Abstract*: The Fourth Industrial Revolution (IR 4.0) nowadays has attracted more and more attention around the world to different kinds of sectors especially the manufacturing sector. In the published literature, there is still a lack of systematic information about the drivers and barriers to implement industry 4.0 in the manufacturing sector. This study addresses the gap in this area to support the managers and practitioners to well-understand the key aspects to implement IR 4.0. A systematic literature review has been carried out, twenty-two articles and one electronic book are selected from leading database (Scopus, WoS and Google Scholar) from 2015 to 2020. The result identified sets of eighteen drivers and twenty-three barriers and obstacles. The identified drivers and obstacles were further classified into seven categories: economic, strategy, legislation, operation and process, organization and cultural, people and competencies and environment and safety. The outcome of this study will contribute theoretically to the development of literature on the implementation of Industry 4.0 from a managerial perspective and it could support decision makers and practitioners to address the drivers and the barriers that will eventually pave the way for successful implementation of Industry 4.0 across the manufacturing sectors.**

***Keywords*: Industrial Revolution, Manufacturing, IR 4.0**

1. INTRODUCTION

Nowadays, the manufacturing companies all over the world utilize the advance science and technology to support the whole value chain in their organization. The initiative of implementing this high tech comes from Germany government when they announce in 2011, the 'High-Tech Strategy 2020' action plan. This strategy known after that IR 4.0, which is represents the German ambitions in the manufacturing sector, and was intended to support national growth by promoting manufacturing development [1,21]. Following this, different countries come with their own initiatives with different names to promote this progression, such as "Smart Manufacturing" in the USA, "Future of Manufacturing" in the UK, and "Made in China 2025" in China, additional to that there are more than 30 national and regional initiatives at Europe [2, 3].

Implementation of this new era (IR 4.0) in the manufacturing sector, imperative for the decision-makers to have sufficient knowledge and clear understanding of two aspects. The first one to know the implementation results in terms of economic, technical and quality wise and the second aspect, what are the limitations and barriers that limit that. However, there is successful adoption in different countries and also there is still lack of studies in the data base providing empirical evidence about the way these technologies are adopted in manufacturing companies. Thus, there is a need for more investigation to identify the drivers and barriers to implement I4.0 in the manufacturing sector, which could help the decision maker and practitioners to make mitigation strategy, which may lead to smoother adoption of Industry 4.0 [12].

There are multiple reasons that drive the use of digital production technologies (IR 4.0) forward. In contrast, there are many barriers that affect its adoption. A well understanding of the mechanism to implement IR 4.0 processes definitely will assist the enterprises to prepare the application duly in order to make it a successful project. The objective of this paper is to conduct systematic literature review to identify the drivers and barriers to implement IR 4.0. The research gap enables to contribute to the following research question: *Which drivers foster the adoption of IR 4.0?" and Which barriers hindering the adoption of IR 4.0?"* [13]. This paper started with section 1 introduction section 2 about the era IR 4.0. The remaining of the research is organized as follows. Section 3 describes the materials and methodology. Section 4 presents the results and discussion. Section 5 concludes this paper.

2. INDUSTRY 4.0

2.1 INDUSTRY 4.0 HISTORICAL BACKGROUND

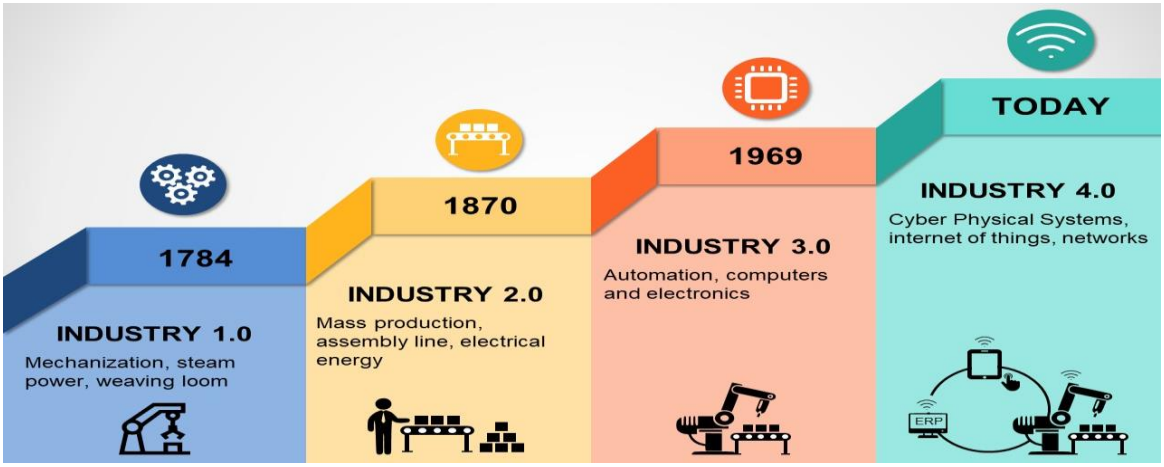
Stages in the development of industrial manufacturing systems from manual work towards Industry 4.0 concept presented by different researchers as a path through the four industrial revolutions. The stages of the development are illustrated in Figure (2.1). The first industrial revolution (IR 1.0) or industry 1.0 began from 1760 and 1820, with the mechanization and mechanical power generation. It brought the transition from manual work to the first manufacturing processes and it was adopted first mostly in textile industry as well as iron industry, agriculture, and mining.

The second industrial revolution (IR 2.0) or industry 2.0 also known as the technological revolution began in the period between 1870 and 1914 and was triggered by electrification that enabled industrialization and mass production [2]. The best-known examples for the second industrial revolution are the increasing use of electric energy. This revolution enabled low costs mass production and increase productivity and the great benefits of it was the present of electricity which allowed for factory electrification and the modern production line [2, 20]. The third industrial revolution (IR 3.0) or industry 3.0 or digital revolution, started in the late 20th century,

after the end of the two big wars, as a result of a slowdown with the industrialization and technological advancement compared to the previous periods. There were many technologies in different sectors introduced in this revolution, generally like industrial robots, computer aided management processes, computer aided manufacturing, and automated assembly lines. This revolution was characterized by the digitalization and has significant impact to different sectors like aerospace, IT, energy and other sectors. The first three industrial revolutions can be summarised, in respective order, as the results of mechanisation, electricity and lastly information technology (IT) [20, 3].

Today we are in the fourth industrial revolution (IR 4.0) or industry 4.0 that was triggered by the development of Information and Communications Technologies (ICT). Industry 4.0, its technological basis, combines and captures contemporary automation, data exchange and manufacturing technologies.

Fig. 2.1. Industrial Revolution Stages (Source: slide model.com)



2.2 INDUSTRY 4.0 DEFINITION

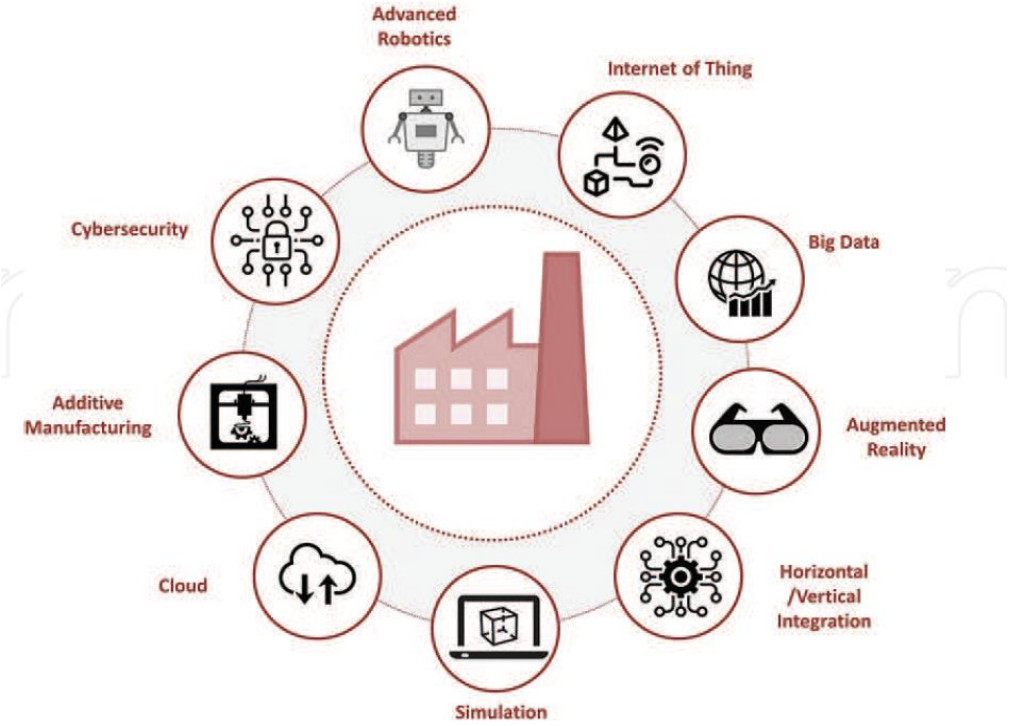
The term Industry 4.0 originates and invented from the Germany in 2011. The German Federal Government initiative to strengthen the competitiveness of the German manufacturing industry [20, 24]. In some sources the expression digital transformation also stands for IR 4.0. Many definitions of Industry 4.0 are proposed from different researchers [13]. In this paper, we rely on the following understanding and definitions of Industry 4.0. One of the definitions is integration of cyber-physical systems in production and logistics as well as the application of the Internet of Things in industrial processes [7]. According to [2, 15, 23] I4.0 is a new concept of the market characterized by the wide integration of information, communication and Cyber-Physical Systems (CPS) in the industrial environment. So, it involves the technical integration of Cyber-Physical Systems into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. Some authors refer IR 4.0 to a new global wave that aims to seamlessly combine manufacturing, automation and Information & Communication Technology (ICT) into a vertical network within an organization by connecting two or more of these organizations in a horizontal chain. Furthermore, Industry 4.0 technologies are under rapid development and consequently the theoretical and conceptual understanding. As a result of this, from this context it is defined by causes of rapid technological advancements in recent times. Digital transformation is defined in manufacturing as "the use of new digital technologies (social media, mobile, analytics or embedded devices) to enable major business improvements (such as enhancing customer experience, streamlining operations or creating new business models" [13].

From the above definitions and different contexts, the main technology used in Industry 4.0 is cyber-physical systems (CPS). CPS are considered a Key Enabling Technology (KET) in the fourth industrial revolution [18].

2.3 KEY TECHNOLOGY OF INDUSTRY 4.0

The change of processes in the organization by adopting IR 4.0 needs strong supporting tools, several authors described nine pillars or key technologies or sometimes known as building blocks. These nine key technologies are big data and analytics, autonomous robots, simulation, horizontal and vertical system integration, internet of things (IoT) (including sensors), cyber-security, the cloud, additive manufacturing and augmented reality [2, 4]. The nine key technologies are illustrated below in Figure 2.2. While some of these digital technologies are already in use in industrial applications, some others are still not ready for application at scale. Manufacturers need to carefully pick the right mix of technologies that would maximize returns on investment [9]. The integration of all of these key technologies will transform industry and lead to implementation of Industry 4.0.

Figure 2.2 Key enabling technology for industry 4.0 (source 18)



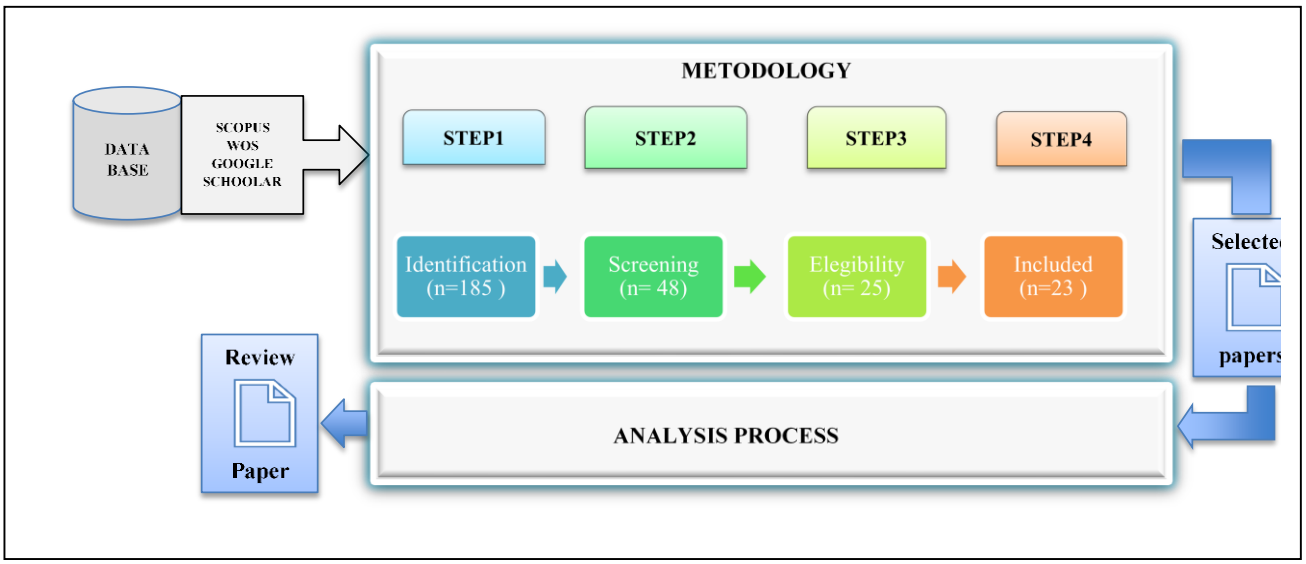
3. MATERIALS AND METHOD

3.1 SYSTEMATIC LITERATURE REVIEW

Considering the novelty of the topic, systematic literature review was used to insure a good result. The systematic literature review methodology was developed in the field of medicine in order to improve research performance and the quality of review processes; it could also inform government bodies more precisely in order to improve health system interventions [17]. For all these mentioned reasons, the same method was selected and applied to different managerial studies, and was chosen by the author as the research methodology for this paper [17]. The systematic literature review was conducted between July and November 2020.

The research began by identifying three scientific databases, Scopus-Elsevier, the Web of Science—WoS and one search engine (Google Scholar) from which the papers were extracted. The following keywords were used in the search: 'Industry 4.0', 'drivers' and 'barriers'. Figure 3.1 illustrates the research process.

Figure 3.1 Research process (source adopted from (17) and modified by author)



3.2 RESEARCH FINDING

The three scientific databases (Scopus-Elsevier, the Web of Science—WoS and one search engine, Google Scholar) were used to search for the industry 4.0 drivers. Twenty industry 4.0 implementation drivers were identified. There are many similar literatures about the industry 4.0, the main drivers to implement it in manufacturing sector and also the different published papers illustrated the barriers hindering the implementation [17]. The summary of the search is listed below:

3.2.1 INDUSTRY 4.0 IMPLEMENTATION DRIVERS

From the 22 articles and one electronic book the below drivers were identified:

1. Applying information and communications technology to digitize information and integrate systems into conception, development, manufacturing and use of products.
2. Increase innovation capacity.
3. Increase productivity.
4. Develop new standards and regulations.
5. New software technologies for modeling, simulation, virtualization and digital manufacturing.
6. Development of cyber-physical systems to monitor and control physical processes.
7. The evolution of 3D printers and additive manufacturing to simplify manufacturing.
8. Savings of raw materials and energy.
9. Decision support for human operators, the emergence of intelligent tools and assistance using augmented reality.
10. Integration of customer through network (cyber-physical systems).
11. Human-Robot Collaboration.
12. Raise up the employee technical and non-technical skills to adapt with new technology.
13. Digital Computing Assistance Systems and Virtual Training.
14. Decentralization: faster and data-driven decision-making.
15. Efficiency increases and cost reductions.
16. Role of government as enabler facilitator and policy makers.
17. Improving the work environment.
18. Decrease documentation and administration.
19. Increase traceability.
20. Increase people safety in the dangerous work places.

3.2.2 INDUSTRY 4.0 IMPLEMENTATION BARRIERS

Barriers to the successful implementation of Industry 4.0 in the manufacturing sector were identified based on the literature review and experts' input (5), From the 22 articles and one electronic book the barriers to implement industry 4.0 were listed below:

1. High Investment in Industry 4.0 Implementation.
2. Lack of Clarity Regarding Economic Benefit and excessive investments.
3. Challenges in Value-chain Integration.
4. Low Maturity Level of Preferred Technology.
5. Disruption to Existing Jobs.
6. Lack of Standards, Regulations, Forms of Certification and operation procedures.
7. Lack of Digital Skills.
8. Lack of Internal Digital Culture and Training.
9. Ineffective Change Management.
10. Resistance to Change.
11. Lack of Infrastructure.
12. Data security risks.
13. High Cost of Digital Technologies.
14. Insufficient qualifications of employees.
15. Lack of a clear digital vision.
16. Lack of data analytical capabilities.
17. Leadership Skill Gap.
18. Workforce Skill Gap.
19. Lack of a Digital Strategy Alongside Resource Scarcity.
20. Top management has no awareness in Industry 4.0.
21. Integration of new technology with old equipment.
22. Lack of formalized information on Industry 4.0 implementation.
23. Lack of methodical approach for implementation.

4. RESULT AND DISCUSSION

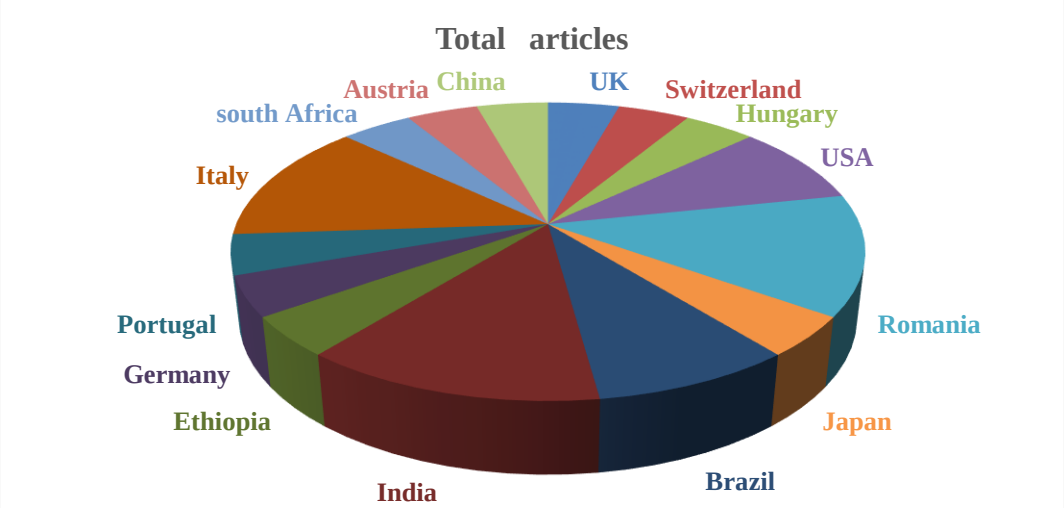
The main objective of this paper is to identify and investigate the main drivers and barriers to implement IR 4.0 in manufacturing sector through systematic literature review. To ensure a comprehensive result the articles were selected according to keywords from

different countries to cover the research gap from different perspectives. Table 4.1 shows the articles according to their origin countries. Fig. 4.1 shows distribution of articles per country.

Table No 4.1 Distribution of articles per country

No	Country	Total No of Articles	% from 23
1	UK	1	4.3
2	Switzerland	1	4.3
3	Hungary	1	4.3
4	USA	2	8.7
5	Romania	3	13
6	Japan	1	4.3
7	Brazil	2	8.7
8	India	3	13
9	Ethiopia	1	4.3
10	Germany	1	4.3
11	Portugal	1	4.3
12	Italy	3	13
13	south Africa	1	4.3
14	Austria	1	4.3
15	China	1	4.3
Total		**23**	**100%**

Figure No 4.1 Distribution of articles per country

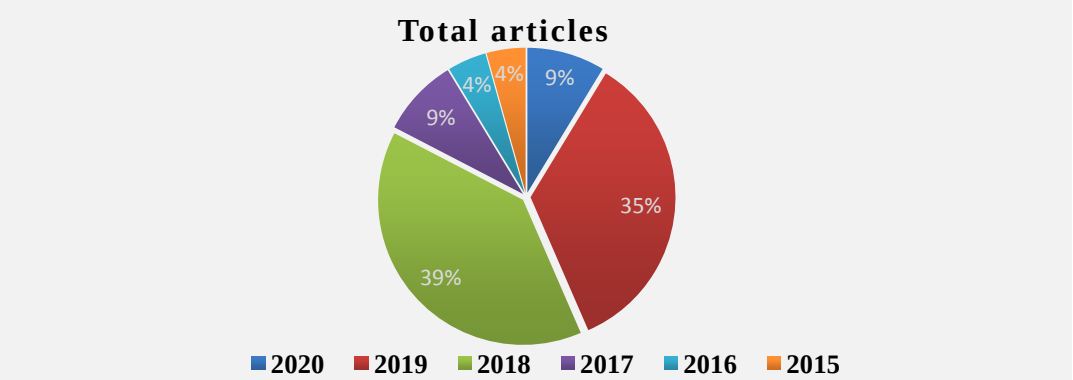


To insure also the data are up to date the search was on the articles that has been published in the last five years (2015-2020). Table 4.2 shows the selected articles in chronological order.

Table 4.2 Distribution of articles according to the year of publication

NO	Year	Total articles	% from 23
1	2020	2	8.7
2	2019	8	34.8
3	2018	9	39.1
4	2017	2	8.7
5	2016	1	4.3
6	2015	1	4.3
Total		**23**	**100%**

Figure 4.2 Distribution of articles according to year of publication

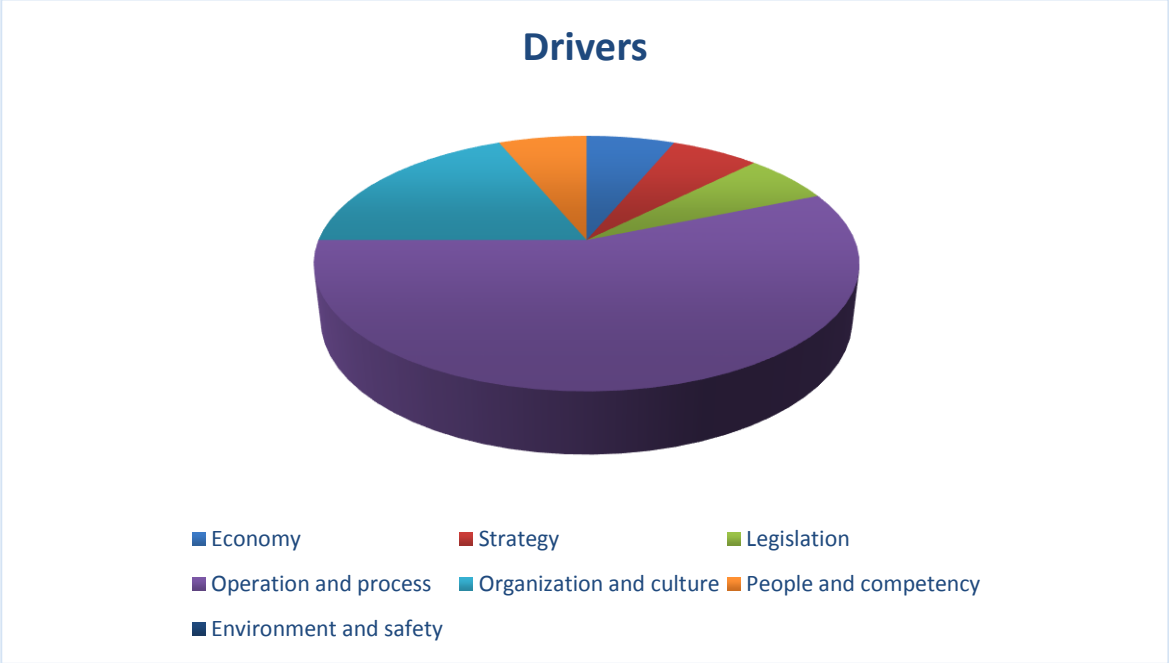


The eighteen drivers, to implement industry 4.0 in manufacturing sector, later were categorized into seven groups: economy, strategy, legislation, operation and process, organization and culture, people and competency and environment and safety. Table 4.3 illustrates these drivers with their respective categories.

Table 4.3 The drivers to implement industry 4.0 in manufacturing sectors (develop by author)

No	Category	Drivers
1	Economy	Efficiency increases and cost reductions
2	Strategy	Role of government as enabler, facilitator and policy makers
3	Legislation	Develop new standards and regulations
4	Operation and process	Applying information and communications technology to digitize information and integrate systems into conception, development, manufacturing and use of products.
		Increase innovation capacity
		Increase productivity.
		New software technologies for modeling, simulation, virtualization and digital manufacturing.
		Development of cyber-physical systems to monitor and control physical processes.
		Savings of raw materials and energy.
		Decision support for human operators, the emergence of intelligent tools and assistance using augmented reality
		Integration of customer through network (cyber-physical systems).
		Human-Robot Collaboration
5	Organization and culture	Decentralization: faster and data-driven decision-making
		Decrease documentation and administration
		Increase traceability
6	People & competency	Raise up the employee technical and non-technical skills to adapt with new technology.
7	Environment & safety	Improving the work environment.
		Increase people safety in the dangerous work places

Figure 4.3 The drivers to implement industry 4.0 in manufacturing sectors

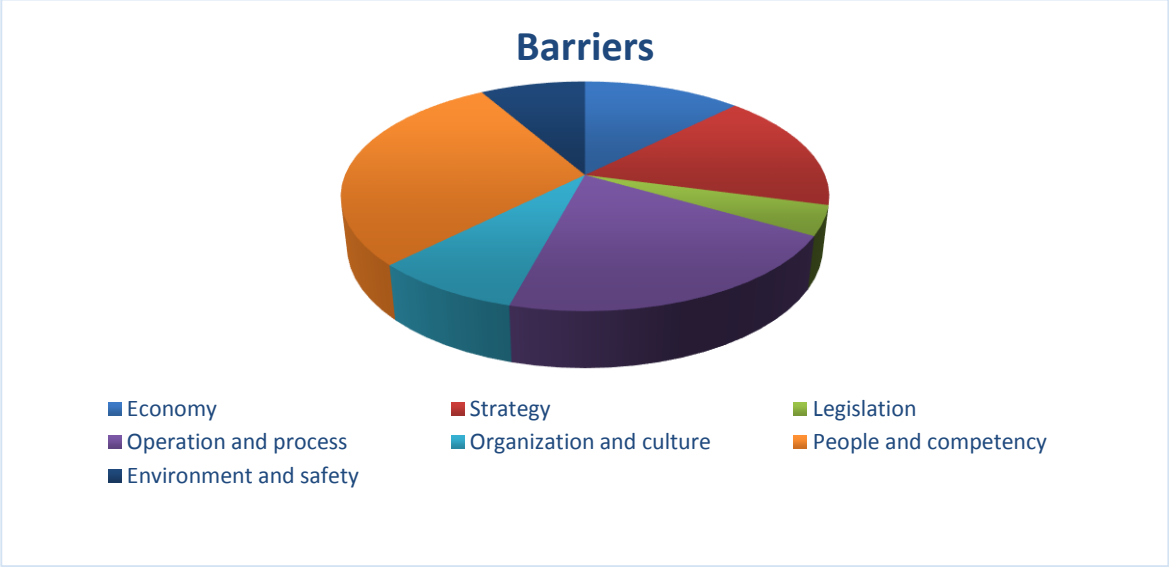


The following part represents the second objective of this paper. The 23 barriers, to implement industry 4.0 in manufacturing sectors, were further critically analyzed. The outcome of the further analysis is the categorization of the barriers. The barriers, to implement industry 4.0 in manufacturing sectors, are categorized in seven groups. Table 4.4 illustrates these barriers with their respective categories.

Table 4.4 The barriers hindering to implement industry 4.0 in manufacturing sectors (develop by author)

No	Category	Barriers
1	Economy	High Investment in Industry 4.0 Implementation
		Lack of Clarity Regarding Economic Benefit and excessive investments
		High Cost of Digital Technologies
2	Strategy	Lack of a clear digital vision
		Lack of a Digital Strategy Alongside Resource Scarcity
		Lack of formalized information on Industry 4.0 implementation
		Lack of methodical approach for implementation
3	Legislation	Lack of Standards, Regulations, Forms of Certification and operation procedures
4	Operation and process	Challenges in Value-chain Integration
		Low Maturity Level of Preferred Technology
		Lack of Infrastructure
		Lack of data analytical capabilities
		Integration of new technology with old equipment
5	Organization and culture	Ineffective Change Management
		Resistance to Change
6	People & competency	Disruption to Existing Jobs
		Insufficient qualifications of employees
		Leadership Skill Gap
		Top management has no awareness in Industry 4.0
		Workforce Skill Gap
		Lack of Digital Skills
		Lack of Internal Digital Culture and Training
7	Environment & safety	Data security risks

Figure 4.4 The barriers hindering to implement industry 4.0 in manufacturing sectors



The number of companies in the manufacturing sector implementing IR 4.0 is increasing all over the world due to their understanding of the necessity of that era to keep them compete with other companies in the same field. Currently, there is a lack in the literature review that addressing the implementation of industry 4.0 in the manufacturing sectors and more specifically the drivers and barriers. Most of the manufacturing companies still seeking to well understand the drivers that encouraging them to implement the IR 4.0 and what benefits they can gain from it. On the other hand, the barriers to implement the IR 4.0 are still another challenges to the companies who want to implement the IR 4.0. Therefore, many companies selecting not to take the risk in implementing the IR 4.0.

5. CONCLUSION

In this paper the researcher has identified and shed the light on the drivers and barriers. Knowing the drivers will motivate companies to implement IR 4.0. Moreover, knowing the barriers will help companies to mitigate the risk before they implement IR 4.0. The relevant literature were reviewed and to consider the novelty of the topic, not only referring to the leading data base like (WoS, Google scholar and Scopus-Elsevier) to extract the driver and barriers, diversifying literature from different countries were reviewed. Through a systematic literature review, 22 articles and one electronics book were considered. The outcome of the critical analysis are 20 drivers and 23 barriers which were further categorized into relevant groups.

The expecting contribution of this paper, is to fill in the gap of the knowledge in implementing IR 4.0, particularly, in the manufacturing sectors. In addition, the identified barriers could be used to develop a mitigation plan that could help managers to implement IR 4.0 into their firms. The findings also have strong implication for policymakers, managers and practitioners.

In future, further efforts from researchers will be needed to provide a framework that help to mitigate the barriers and facilitate the implementation of IR 4.0 in manufacturing sectors.

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REFERENCES

[1] Tariq Masooda, Paul Sonnta, International Journal of Production Research, “Industry 4.0: Adoption challenges and benefits for SMEs”, Computers in Industry 121 (2020) 1032
[2] Dominik T Matt, Vladimír Modrák, Helmut Zsifkovits, “Industry 4.0 for SMEs Challenges, Opportunities and Requirements”, ISBN 978-3-030-25425-4 (eBook) May 2019
[3] Dóra Horvàth', Roland Zs. Szabó, “Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities”, Technological forecasting & social change 146 (2019) 119-132
[4] Jan Stentoft, Kent Wickstrøm Jensen, Kristian Philipsen, Anders Haug, “Drivers and Barriers for Industry 4.0 Readiness and Practice: A SME Perspective with Empirical Evidence”, Proceedings of the 52nd Hawaii International Conference on System Sciences (2019)
[5] Mirela Catalina Türkes, Ionica Oncioiu, Hassan Danial Aslam, Andreea Marin-Pantelescu, Dan Ioan Topor, Sorinel Capus Neanu, “Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania”, MDPI, Processes 2019, 7, 153
[6] Jen Ling Gan, Halimah Mohd Yusof, “Industrial Revolution 4.0: The Human Resource Practices” International Journal of Recent Technology and Engineering (IJRTE) 2277-3878, Volume-8, Issue-3S2, October 2019
[7] Martin Prause, “Challenges of Industry 4.0 Technology Adoption for SMEs: The Case of Japan”, MDPI, Sustainability 2019, 11, 5807

[8] Alejandro Germán Frank, Lucas Santos Dalenogare, Néstor Fabián Ayala, "Industry 4.0 technologies: Implementation patterns in manufacturing companies", International Journal of Production Economics, January 2019
[9] Viraj Vijay Jadhav, Ravindra Mahadeokar, "The Fourth Industrial Revolution (I4.0) in India: Challenges & Opportunities", International Journal of Trend in Scientific Research and Development (IJTSRD), March 2019, 23076
[10] Dr Ravindra Pathak, Allene Endayilalu Zewdie, "Implementation Aspect of Industry 4.0 in Ethiopian Manufacturing Industry", IJTRS-V4-I5-021, Volume IV Issue V, May 2019
[11] Monica Nedelcu, Adriana Dima B, Ruxandra Dinulescu, "Digital Factory – A Prerequisite for Revitalizing the Production Sector", Proceedings of the 12th International Management Conference "Management Perspectives in the Digital Era" November 1st-2nd, 2018, Bucharest, Romania
[12] Alok Raj, Gourav Dwivedi, Ankit Sharma, Ana Beatriz Lopes de Sousa Jabbour, Sonu Rajak, "Drivers and Barriers for Industry 4.0 Readiness and Practice: A SME Perspective with Empirical Evidence" International Journal of Production Economics, 29 October 2019
[13] Kirsten Liere-Netheler, Sven Packmohr, Kristin Vogelsang, "Drivers of Digital Transformation in Manufacturing", Proceedings of the 51st Hawaii International Conference on System Sciences, 2018
[14] Julian Marius Müller, Daniel Kiel, Kai-Ingo Voigt, "What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability", MDPI, Sustainability 2018, 10, 247
[15] João Reis, Marlene Amorim, Nuno Melão, Patrícia Matos, "Digital Transformation: A Literature Review and Guidelines for Future Research", World CIST'18 2018, AISC 745, pp. 411–421, 2018
[16] Sachin S Kamblea, Angappa Gunasekaranb, Shradha A Gawankaraa, "Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives" Process Safety and Environmental Protection 117 (2018) 408–425
[17] Michela Piccarozzi, Barbara Aquilani, Corrado Gatt, "Industry 4.0 in Management Studies: A Systematic Literature Review", MDPI, Sustainability 2018, 10, 3821
[18] Antonella Petrillo, Fabio De Felice, Raffaele Cioffi, Federico Zomparelli, "Fourth Industrial Revolution: Current Practices, Challenges, and Opportunities", 2018, DOI: 10.5772/intechopen.72304
[19] G. Orzes, E. Rauch, S. Bednar, R. Poklemba, "Industry 4.0 Implementation Barriers in Small and Medium Sized Enterprises: A Focus Group Study", 2018 IEEE
[20] Carl Jan du Plessis, "A framework for implementing Industrie 4.0 in learning factories", 2017 Stellenbosch University
[21] Yongxin Liao, Fernando Deschampsa, Eduardo de Freitas Rocha Louresa, Luiz Felipe Pierin Ramosa, "Past, present and future of Industry 4.0 – a systematic literature review and research agenda proposal", International Journal of Production Research, 2017
[22] Dr Sorko S R, Rabel B, Dr Richter H M, "The Future of Employment - Challenges in Human Resources Through Digitalization", International Scientific Journal "Industry 4.0", Year I, Issue 2, P.P. 128-131 (2016)
[23] Keliang Zhou, Taigang Liu, Lifeng Zhou, "Industry 4.0: Towards Future Industrial Opportunities and Challenges", 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)