Original Research

Critical Key Factors for Thriving Industry 4.0 Implementation

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Abstract
Industry 4.0 (I4.0) is rife with extensive opportunities, and it's been a ubiquitous research topic in multiple academic fields, all of which are trying to explore it and suggest different technologies to solve the complex problems that industries face. Despite the attention given to this field, many organizations still struggle with its successful adoption, and to exploit the expected benefits requires a targeted plan for its implementation. Although academic research on Industry 4.0 is overgrowing, only in recent years has interest shifted to tackle the challenges of its implementation in practice. This paper aims to shed some light on the underlying dynamics of its implementation by exploring the relevance of industry 4.0-related drivers, enablers, and barriers as key factors to consider for a successful implementation. In order to do this, two research questions are addressed: (1) What are the current key areas of interest in research regarding Industry 4.0? and (2) what are the factors that impact its successful implementation?

Keywords - Industry 4.0; Bibliometric Analysis; Implementation; Barriers; Drivers.

INTRODUCTION

The industry has known quite a big transformation throughout history. Starting from the first industrial revolution happened around the eighteenth century and focused on water and steam power as a tool for production. At the same time, the second industrial revolution used electric power and division of work and introduced the concept of mass production. The third industrial revolution brought automation to light by using information technologies. This transformation has multiplied and acted upon the physical, Cyber, and human dimensions in recent years. Its primary focus is the development of self-improving systems and machines [1, 2]. Figure 1 depicts the transformation that took place.

The three industrial revolutions positively affected the quality of life and the standard of living. However, the fourth industrial revolution has a widespread application and covers the entire supply chain. Its leading technologies are used in the product lifecycle and aim to satisfy individualized customer requirements [3]. For instance, CPS, known as Cyber-Physical Systems, is an essential component of I4.0 to build on the other technologies.

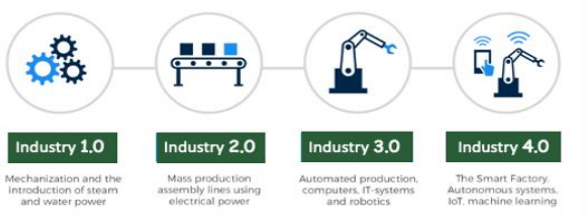

FIGURE 1
THE FOUR INDUSTRIAL REVOLUTIONS

It consists of connected physical objects that can communicate, collaborate and make decisions [4]. Achieving high flexibility to meet customer requirements with utmost efficiency [5]. Similarly, so many novel terms have been introduced to define industry 4.0 but mostly centered around a series of technologies such as IoT, Big data, and additive manufacturing, to name a few. These technologies have been developed for the manufacturing sector using information and communication technologies [6].

Even though this transformation will reduce manufacturing costs, it is rife with risks to be considered. It requires specified skills and competencies to be mastered [7], leading companies to adopt a well thought and structured implementation method. So far in the literature, there is some hands-on experience on the shopfloor concerning a thriving Industry 4.0 implementation, which is still newly studied in research [8].

Even if various studies have shown the good effect of digitization of products and services on the supply chain, these new technological evolutions have made the industrial ecosystem more complex. Therefore, organizations are facing significant risks to attain a successful adoption of Industry 4.0 [9]. Numerous authors [10] state that 'designing & deploying industry 4.0 is a challenging mission, and it will likely take ten or more years to realize'. Implementing this new set of leading technologies in the context of manufacturing involves many conditions to be considered and faces many challenges, including, technological, organizational, economic, and social issues.

In this sense, this article aims to contribute to the state of art of industry 4.0 by studying the different drivers, enablers, and barriers to its implementation. The authors tackled this topic by answering two questions. In the first research question, the authors aim to identify the evolution of themes inherent in industry 4.0 using bibliometric analysis. Its primary purpose is to represent the dynamic of publications in the categories: keywords, authors, publications, and research area. The study will then address a second research question, the authors describe the adoption of Industry 4.0 technologies through different case studies. Articles in this study will describe the performance of Industry 4.0 using in-depth case studies. Moreover, the finding could help organizations understand the drivers and enablers that facilitate the integration of industry 4.0 technologies and recognize the challenges they may face in designing the I4.0 implementation process effectively.

In short, this study will address the following research questions:

(1) What are the current key areas of interest in research regarding Industry 4.0?
(2) What are the factors that have an impact on its successful implementation?

The following sections will introduce how the researchers answered the research questions mentioned above.

RESEARCH TRENDS IN INDUSTRY 4.0

1. Research Methodology

Bibliometric or Scient metric analysis are a set of methods that are used to analyze the trends in a particular research topic and gives researchers insights into the future of research regarding that topic. The first researchers that studied Bibliometrics were [11]. Followed by [12], they developed this approach in the field of accounting by analyzing the trends related to insinuations and authors. Recently, this analysis has expended to tackle topics such as heuristics and other areas [13].

Bibliometric mapping is considered as an important tool in bibliometrics. It helps to visualize academic information through visual representations which makes it easier to comprehend the different correlations between bibliographic objects (fields, affiliations and authors…). In essence, the purpose of this analysis is to assess the major areas of search, its evolution in literature and the different dynamics of transitions from one specialty to another [14]. Moreover, Bibliometric mapping helps also in assessing the evolution of academic research in countries, journals, universities… [15].

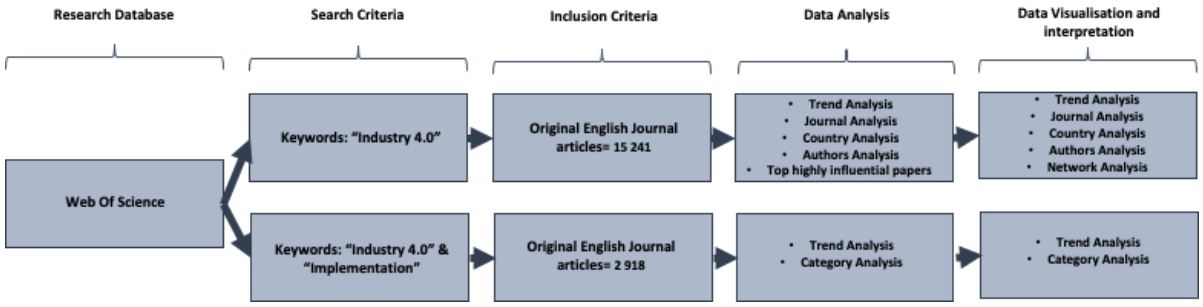

FIGURE 2
RESEARCH METHODOLOGY

This analysis is made using data sources from online databases such as, Web of Science, Scopus, Google Scholar, MEDLINE, ISI, and CiteSeer.

In this section, the research methodology is presented in figure 2. The authors started first by applying bibliometric analysis. For this, the 'Web Of Science'(WOS) database is scanned using the keyword 'Industry 4.0', and later on, the keyword 'implementation'. is added. The data analysis, visualization, and interpretation are carried out using the VOSViewer program, one of the science mapping tools based on the java program, designed primarily to analyze bibliometric networks through graphical representation. VOSViewer creates maps represented in networks, such as co-citation or co-authorship [16].

2. The current trend of Industry 4.0

2.1. Data analysis

According to the results of the query made in the Web Of Science database on 10th June 2022, using headings and keywords, 13.670 publications related to industry 4.0 were made in 2012-2022, which included 6,559 (46%) original research articles, 5,912 (41%) Proceeding papers, 885 (6%) review articles, 363 (3%) editorials, and 528 (4%) other forms of publications including letters, book chapters, etc. Of all the published papers, 15,241 could be indexed in the WOS core database.

- **General Trends of Publications**

The distribution of these publications by year is shown in Figure 3.

It shows that the scientific publications made in the field of Industry 4.0 tend to increase with a rise in the number of publications in 2021, reaching 3349.

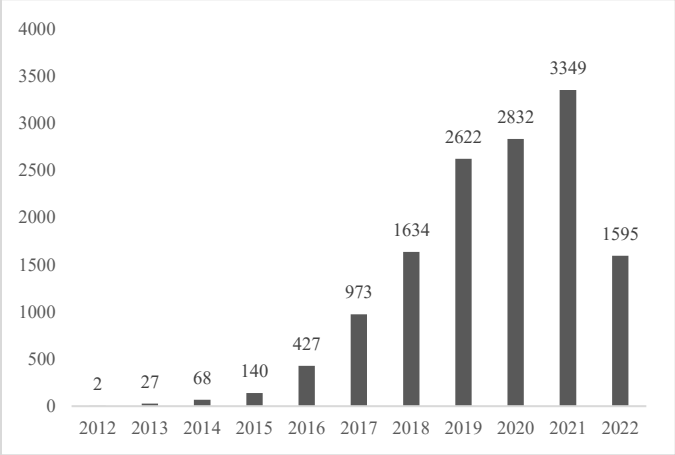

FIGURE 3
INDUSTRY 4.0 PUBLICATIONS PER YEAR

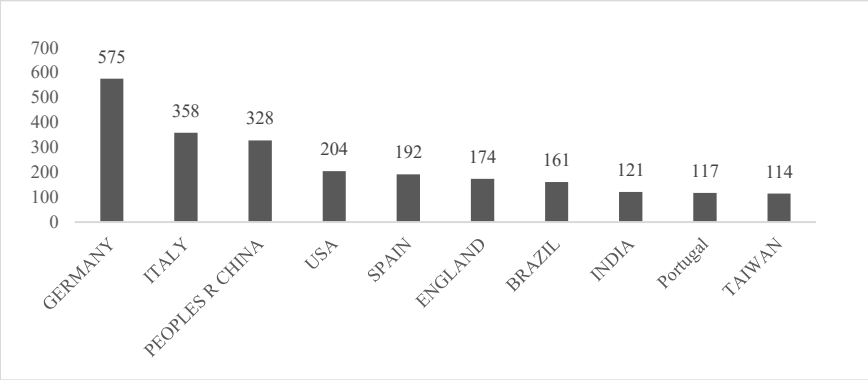

FIGURE 4
INDUSTRY 4.0 PUBLICATIONS BY COUNTRY

- **Academic Performance: Country, Organizations, and Authors**

In this section, the authors analyzed the most active Journals, countries and authors in this field. Two hundred journals have published papers about industry 4.0, and 12 have published over 100 articles. In total, 9,138 papers were published in the top five active journals, which accounted for 70% of the publications in the Web of Science. The highest-ranking journal was « The Institute of Electrical and Electronics Engineers (IEE), » with 3,051 publications. It has an impact factor of 11.648. Table I displays the synthetic results.

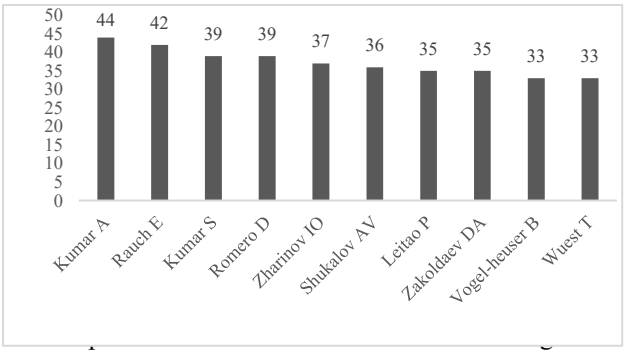

FIGURE 5
INDUSTRY 4.0 PUBLICATIONS BY AUTHORS

TABLE I
THE RANKING OF JOURNALS BASED ON THE NUMBER OF PUBLICATIONS

Journals	Nb of publications	%
IEEE	3051	23%
Elsevier	2482	19%
Springer Nature	1615	12%
Mdpi	1437	11%
Taylor & Francis	553	4%
Emerald Group Publishing	540	4%
Wiley	220	2%
Div Deutscher Industrieverlag Gmbh	206	2%
Iop Publishing Ltd	178	1%
Assoc Computing Machinery	155	1%
Scitepress	118	1%
Int Business Information Management Assoc-Ibima	111	1%

In Figure 4, it is seen that Germany has topped the list as it is the leading country that launched the concept, then Italy, China, and America, respectively.
The top ten most active authors of industry 4.0 publications are shown in figure 5. 44 articles were written by Kumar A from London Metropolitan University.

- **Top highly influential papers**

This section lists the top most highly influential papers in WoS. Table 2 lists the most highly cited articles ranked in WoS. It also contains the name of the authors, the type of document and the year of publication. The paper by Xu, LD; Xu, EL, Li, L in 2018 has got the highest citation count of 1040 as it provides the basic overview of Industry 4.0 as it relates to industries.

Zhong, RY precedes it; Xu, X; Klotz, E; Newman, ST (2017), with 882 citations. Noticeably, there are about 145 papers with a citation count of at least 100.

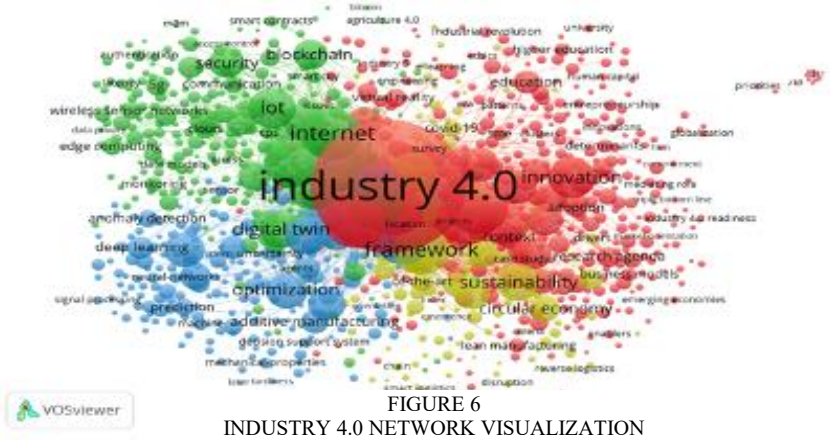

FIGURE 6
INDUSTRY 4.0 NETWORK VISUALIZATION

2.2. Network Analysis

The second step of the literature review is to visualize the essential components of industry 4.0 using the evolution map. The network visualization was examined with the software VOSViewer. The data used were extracted from Web of Science database and the study was made using citation-based networks. This analysis is based on the co-occurrence of keywords that are extracted from titles, abstracts or the assigned keywords by the publisher. The network visualization was examined as each theme which represent a keywork is symbolized by a circle and a label. The circle size for a theme is based on the weight of the theme, which is explained by the number of times a theme appears in the data. The 'density' on the vertical axis in the strategic diagram expresses the abundance of scientific publications. The higher the frequency of a theme, the higher the weight and the larger the size of the circle. Thus, the size of the process is the measure of the significance of a theme. The lines between two keywords represent links between them. Van Eck & Waltman [16] explained that '...for some themes, the label may not be displayed. This happens to avoid overlapping of labels.

TABLE III
THE LIST OF THE TOP CITED PAPERS FOR 'I4.0 IMPLEMENTATION'

Authors	Article Title	Document Type	Times Cited, WoS Core	Publication Year
[17]	"Industry 4.0: state of the art and future trends."	Article	1040	2018
[18]	"Intelligent Manufacturing in the Context of Industry 4.0: A Review"	Review	882	2017
[19]	"Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal."	Article	750	2017
[20]	"Industry 4.0: A survey on technologies, applications, and open research issues."	Review	688	2017
[21]	"Industrial Internet of Things: Challenges, Opportunities, and Directions"	Article	649	2018
[22]	"Industry 4.0 and the current status as well as future prospects on logistics"	Article	639	2017
[23]	"Industry 4.0 technologies: Implementation patterns in manufacturing companies."	Article	631	2019
[24]	"Towards smart factory for industry 4.0: a self-organized multi-agent system with big data-based feedback and coordination"	Article	607	2016
[25]	"Smart Manufacturing: Past Research, Present Findings, and Future Directions"	Review	560	2016
[26]	"Digital Twin in Industry: State-of-the-Art"	Article	515	2019

'Industry 4.0' is presented in the map as the most extensively studied subject (Fig. 6). In the analyzed period, four conceptual clusters were identified from WoS. The coexistence of keywords is visible on the evolution map—the primary clusters are built around IoT, internet, Optimization, Innovation, and sustainability. But again, the analysis shows the nonlinear development of these concepts and the quick changes in scientific research.

For the past ten years, research has been mainly focused on Industry 4.0 and its components. Still, until 2018, the graph shows a significant shift in scientific research that focused more on practically integrating these technologies into existing processes. Although industrial research was the only theme studied in 2012, 3 other themes came forward in 2014 (Industry 4.0, digital factory, IoT, CPS).

In 2018, themes that emerged were (industry 4.0, Management, and big data). In 2020, the following themes emerged (Industry 4.0, Integration, lean production, challenges, barriers, sustainability.

After the network analysis, the authors explore the evolution of research in industry 4.0 implementation.

3. The current trends of Industry 4.0 implementation

As mentioned in the section before, the notion of Industry 4.0 can be seen as a novel topic in the literature and still seems mainly conceptual. A lot of publications have explained the concept of Industry 4.0 and its components [3, 5, 7], and the number of companies that get engaged with this transformation is exponentially on the rise. The industry 4.0 concept is gradually implemented in enterprises through projects that require significant investments and are executed in phases in selected areas of activity [28].

This section aims to explore the other research on industry 4.0 implementation in the literature and discuss findings through bibliometric analysis. To conduct a systematic review of the literature, the general data of the articles available in the Web of Science databases were considered from 2012 to 2022 using the keywords 'Industry 4.0' and 'Implementation'.

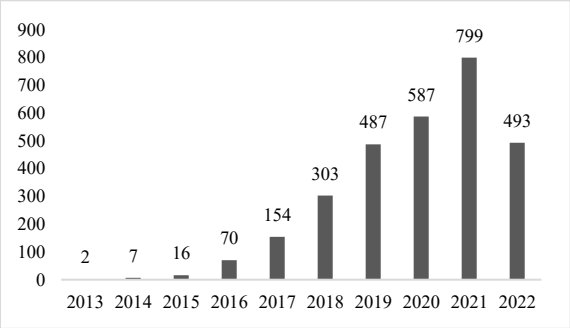

FIGURE 6
TRENDS OF PUBLICATIONS

3.1. Data analysis

The results of the research made in the Web of Science database on 10th June 2022 indicated a total of 2.918 publications were made between 2013 and 2022 on the topic of the implementation of industry 4.0, which included the following:

-1,613 (55%) original research articles,
-1,101 (37%) Proceeding papers,
-213 (7%) review articles, 165 (1%) other publications, including editorials, book chapters, etc.

- **General Trend of Publications**

Looking at Figure 7, it shows the increase in interest regarding the topic of Industry 4.0 implementation, which was growing every year, and is still a trending topic. The graph gives an idea about the growth of publications throughout the years. the massive growth in publications is between 2018 and 2021, which increased by 80%. The first publications from 2013 to 2017 had low growth, as it was a very novel topic in research, mainly because the term industry 4.0 was newly introduced, as explained before. The graph shows that this topic is at the beginning of this new revolution, as the first publications related to industry 4.0 implementation were out in 2013. With only ten years of research in this field, there is much more to study in the coming years. One of the reasons for the growth in research in this field is due to the fast development of the industry to meet

customer fluctuant and customized demands. Therefore, to maintain business growth, companies must keep pace with the latest technologies and develop their business models to integrate industry 4.0.

- **Publications Per Category**

The authors did a further analysis based on the categories of publications. Based on Web of Science analysis (Fig. 8), most articles belong to more than one category, which explains the results obtained. 'Industrial Engineering', 'Manufacturing Engineering', 'Electrical & Electronic Engineering', and 'Management' were the categories with the most publications, with 537, 477, 451, and 379, respectively which represents 63% of the database. The articles published under these categories focus mainly on the technical side of Industry 4.0 transformation while discussing and reviewing the technology available to be implemented and how this transformation impacts the supply chain.

After the literature review using the scientific database, the authors focus on the available studies published in WoS on the different ways of implementing Industry 4.0 for a particular type of enterprise and a large sample of studies.

THE INDUSTRY 4.0 IMPLEMENTATION

In this section, the authors try to answer the second question: 'What factors impact the successful implementation of industry 4.0?' by studying different research papers from the top 10 most cited articles in WoS.

These articles can be divided into two groups. The first group, the case study group, has five articles. The articles explore the different implementation methods in practice by various manufacturing companies. The second group comprises five articles, which will be called the survey/model group. The articles study the different drivers and challenges for Industry 4.0 implementation. It shows how the corporation's size and type can significantly influence the kind of drivers and hinder its performance. Some of this detailed information explains how implementing Industry 4.0 can be accelerated based on well-thought-out preparation.

An overview of the groups is presented in Table III. The authors will discuss the results from each of these groups in more detail.

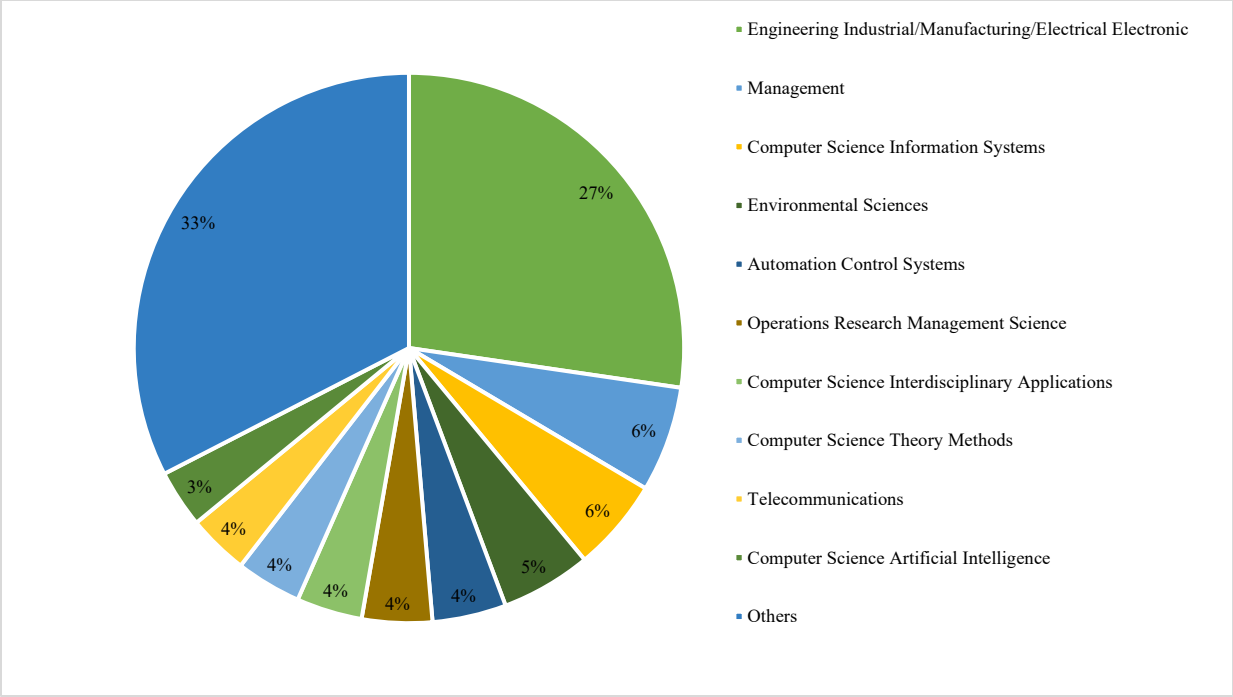

FIGURE 7
PUBLICATIONS PER CATEGORY

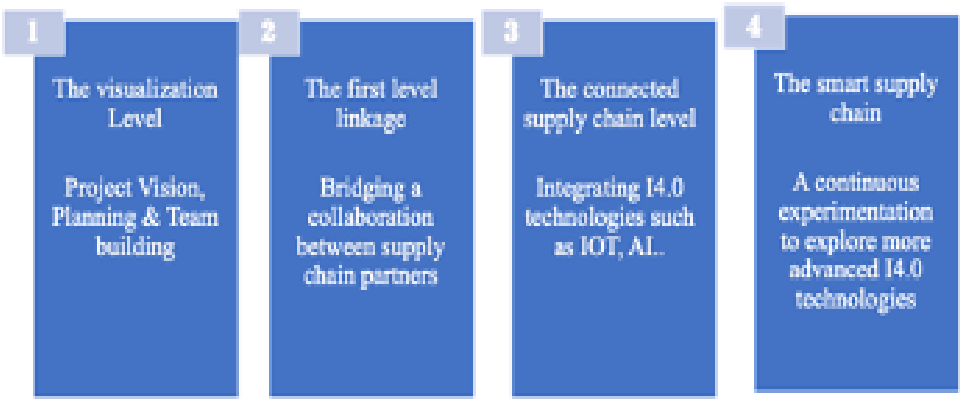

FIGURE 8
I4.0 ADAPTATION STEPS

- **The case-study Group***:*

The next set of articles studies the implementation of Industry 4.0 in practice and the various drivers and challenges faced during the process of integration. These articles focus on study of real cases of implementation. To design an implementation process, all articles build on a standard definition of industry 4.0 and its components before tackling the topic of its implementation.

The first article, "Multistage implementation framework for smart supply chain management under industry 4.0" [29], focuses on supply chain integration in a multinational packaging company in Pakistan. The article studies how to design an integrated supply chain using industry 4.0 concepts to link multiple tiers across the supply chain. This company faced the challenge of problem-solving in real-time at the customer's filling machines. The process took several days to resolve, which led to the loss of several business days dedicated to the production process. In this article, a project team was formed to address and outline a relevant plan for the supply chain digitization project.

The article proposes a phased framework that consists of four subsequent steps to Industry 4.0 adaptation, (1) the Visualization level, (2) The first-level linkage phase, (3) the connected supply chain phase, and (4) the intelligent supply chain phase. The first stage consists of preparing the ground for the implementation based on a clear project vision, well-thought planning, and team building. It was deemed essential to have organizations with a history of cross-functional continuous improvement initiatives. The authors explained that these elements help proceed from one stage to the next with less effort. The latter stages of the implementation suggest integrating technologies such as IoT and AI with bridging a collaboration between supply chain partners. Finally, the last step suggests continuous experimentation to be considered to explore more advanced technologies and ensure the stakeholders' commitment to the development process.

The second article, « Lessons learned from Industry 4.0 implementation in the German manufacturing industry" [30], provides a practical guideline for effectively designing the industry 4.0 implementation process. It shares the hands-on experience on the shop floor of 13 large German companies implementing Industry 4.0. The authors presented the different dimensions before starting any transformational project. They stress the importance of technology as a critical enabler of industry 4.0. Thus, a successful implementation needs to be based on a well-prepared infrastructure. This includes creating standards for the different technical areas (connectivity, secure interfaces…), managing the integration of existing systems such as (ERP and MES…), applying robust security systems, especially with customers and partners interfaces, and giving leading IT positions to highly qualified ICT experts. Another critical enabler mentioned is related to ICT skills, which are essential for this digital transformation.

TABLE III
THE LIST OF THE TOP CITED PAPERS FOR 'I4.0 IMPLEMENTATION'

Authors	Findings	Article Type
[29]	A case study that presents a framework for industry 4.0 implementation with a focus on the organizational culture as a positive influence for this transformation	Case Study
[30]	A case study focusing on implementing industry 4.0 technologies in German manufacturing companies. It tackles the organizational aspects with human resources as its core elements alongside with a structured planning process and a well thought and secured systems	Case study
[31]	A case study that focuses on the technical, organizational and human dimensions to be taken into consideration while implementing the smart factory of the future.	Case Study
[32]	A case study that explores the views of Romanian SME managers on the positive influencers and the hinders of industry 4.0 implementation	Case Study
[33]	A case study that presents a detailed framework of the different phases planned in time to implement the concept of I4.0 in companies.	Case Study
[34]	A research model that presents the different opportunities that enables a successful implementation of industry 4.0 and the different challenges that act as hinders and have to be delt with such as competitiveness, employee skills and competencies.	Survey/Model
[35]	A research model that identifies the difficulties of the implementation of Industry 4.0 in the manufacturing industry in the context of developed and developing economies.	Survey/Model
[36]	A study that describes the process of transformation of European manufacturing companies to attain the smart factory of the future	Survey/Model
[37]	A study based on the implementation of I4.0 in Indian manufacturing companies and the different important factors for its success	Survey/Model
[38]	A study that explores the different management tools and shows their importance in supporting the transformation of the industry 4.0	Survey/Model

On the one hand, employees need skills and competencies matching the integration of the novel technologies offered by i4.0. And on the other hand, companies must assist their employees with adequate training to develop these skills and try to help educational institutions develop suitable programs that go with the need of industry 4.0. In addition, the authors added a company's organizational structure as an enabler when it supports the goals of industry 4.0.

Both articles mentioned before emphasized the importance of a lean and agile organization. It is considered a key factor for successfully adopting this change as it allows for quick ways to put solutions into action. Following these guidelines without neglecting a single dimension paves the way to a successful implementation, as the authors put it.

Another case study presented in the paper: « Smart factory: the requirements for implementation of the industry4.0 solutions in FMCG environment case study» [31] takes the approach of assessing the maturity level as an enabler for the adoption of Industry 4.0. the authors presented a couple of requirements that must be fulfilled before starting the implementation process. These requirements play a significant role in successfully managing this change while avoiding issues and problems that may arise afterward. In this study, authors also distinguished between three dimensions of change (Human/Technical/Organizational) as mentioned in the article before and presented almost the same enablers while proposing an evaluation sheet that acts as a tool to assess the company readiness for this digital transformation. The lessons to be concluded are outlined below:

(1) **Technical:** Firstly, Organization has to determine the most crucial data to be collected to avoid useless information. Secondly, Existing systems must be integrated to help reach the level of adoption of technologies needed. Thirdly, standardized work processes compatible with the appropriate technologies must be implemented.

(2) **Organizational:** Firstly, Organization's structure has to be vertically and horizontally integrated, maintaining an entire corporation within the company and across the supply chain with other companies and partners. Secondly, A well-defined plan must be set to invest in resources (technology and skills).

(3) **Human:** Firstly, employees must be qualified and competent in IT and automation. They need to know how to operate the newly integrated software and hardware. Secondly, the organization must plan training sessions for employees to develop the skills required for this transformation.

The fourth article has title "Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania" [32]. This article focuses on implementing industry 4.0 technologies in SMEs in Romania. In a multiple-case study approach and by applying a survey by sampling the questionnaire as a data collection tool, 176 managers in areas such as automotive, electronics, chemicals and others provided answers. The article explores some barriers to the adoption of industry 4.0. firstly, a Lack of knowledge about industry 4.0 emerged as the top in the list for being a barrier as it is critical to have expertise in this field to develop and integrate the solutions of industry 4.0. Secondly, Corporations put their efforts and concentration solely into

managing day-to-day operations instead of taking some time to create the company. Thirdly, companies lack a comprehensive understanding of the benefits expected from implementing industry 4.0 in the long run. Fourthly, companies have problems hiring a specialist in the domain or competent employees with adequate skills to implement Industry 4.0 technologies. Others do not solicit experts or plan training for their employees to become experts. Fifthly, the Lack of standards to connect the new and existing technologies makes it hard to implement them. The authors show that although all the companies interviewed did not yet reach an advanced level of implementation, they are willing to start the actions while providing all the necessary resources (expertise, technologies...) to create a resilient ecosystem and to ensure economic growth.

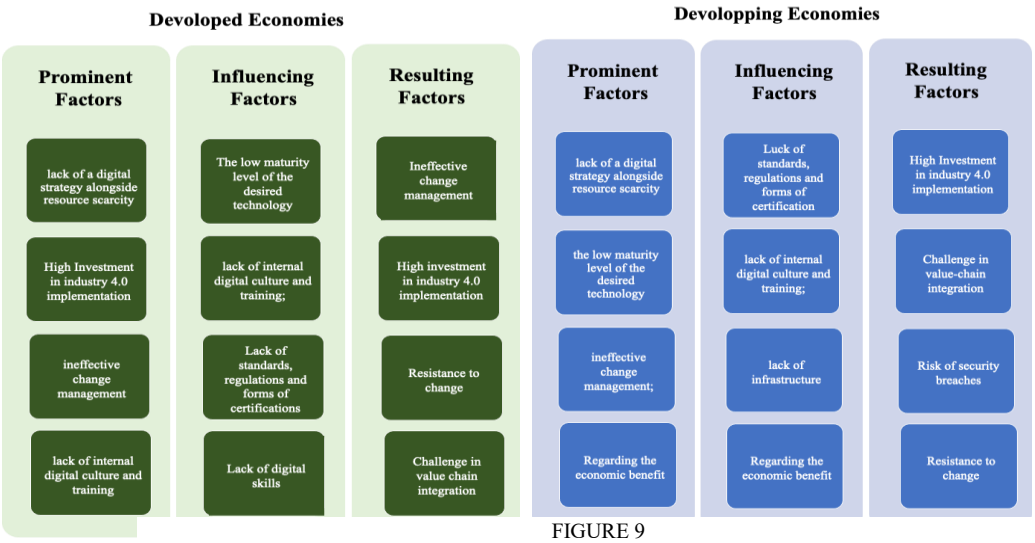

FIGURE 9
I4.0 CHALLENGES

The fifth article is titled “A Theoretical Framework of Industry 4.0 and Its Implementation with Selected Practical Schedules” [33]. The article explores the literature and analyses how 3 different companies have implemented industry 4.0 and conclude with a framework for the primary stages of implementation. The authors stated that companies are working intuitively on the road to transformation. As a common ground, all companies start with preliminary work of setting strategic objectives and then conduct internal audits to assess the readiness of their business processes to develop a pilot project in a delimited area. The framework consists of the following:

-Foundation1: Updated technologies (cyber-physical systems (CPS), cloud manufacturing, IoT, etc.).
-Foundation 2: Strong management system (knowledge and human-machine relations)
-Pillar1: a focus on the critical fields of the core technology of I4.0, Knowledge management, and organization culture and people;
-Pillar 2: A cyclical closed loop of machine-action learning to perform optimally.

- **The survey and model group**

In this group, authors used larger companies' samples, allowing them to explore specific relationships using statistical analysis. This article with the title “What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability” [8] examines the relevance of Industry 4.0-related opportunities and challenges as drivers for Industry 4.0 implementation. The article classifies a set of opportunities as drivers for successful implementation, such as; strategic, operational, environmental, and social opportunities. Yet, challenges such as competitiveness, capability, good organization, and production structure hamper its progress.

The authors show how companies depending on their size, differ in terms of influence regarding opportunities and challenges in the implementation. The article indicates that the companies of a large scale in the sample generally regard strategic opportunities as a relevant element to be considered for Industry 4.0 implementation. While SMEs believe Operational opportunities as a key driver. Large companies such as the automotive and steel industries struggle with adapting the

organization and production structure to this new technological integration. However, the above-cited opportunities can only be exploited if challenges are well addressed.

The notion related to the study of challenges as a basis for industry 4.0 implementation depending on the type of company and its context was also noticed in the article "Barriers to the Adoption of Industry 4.0 Technologies in the Manufacturing Sector: An Inter-Country Comparative Perspective » [34], which examined the implementation of Industry 4.0 in both developing and developed economies.

This article studies the most effective barriers to I4.0 implementation using Grey Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach.

The authors have classified three types of barriers: (1) Prominent Barriers, those factors that significantly impact other barriers. They need special attention and must be put on the top of the list of priorities. (2) Influencing barriers are those factors that have a direct impact on hindering the process of implementation. (3) Resulting barriers are factors most influenced by other barriers. Managers can put them on the final list of priorities. Fifteen barriers (Fig. 10) were identified based on a comprehensive literature review and discussion with experts from both developed and developing economies. The results show that the 'lack of a digital strategy alongside resource scarcity' is the most prominent barrier in developed and developing economies. The influencing barriers identified suggest that standards and government regulation improvements could facilitate the adoption of Industry 4.0 technologies in developing country cases.

In contrast, technological infrastructure is needed to promote the adoption of these technologies in designed country cases.

Similarly, the authors of the following article, "What matters in implementing the factory of the future FoF "[35], conducted a multi-dimensional and multi-sectorial analysis of 92 manufacturing companies to determine the different barriers and prominent drivers for industry 4.0 implementation. The survey has identified the common concern of all companies regarding bridging the gap between the existing business model and the FoF model. Thus, four dimensions that need to be shaped for a systematic transformation have been highlighted. It covers technological, strategic, managerial, and organizational aspects of industry 4.0 adoption. The surveyed companies voiced the need for an organizational reform based on collaboration rather than a centralized one alongside the improvement of managerial capabilities in operations and supply chain management.

This work is based on a study of literature and interviews with experts in Indian manufacturing industries to identify the elements for a successful implementation of Industry 4.0. Motivated by the drivers that facilitate the process of performance, the authors in the following article with the title "Prioritization of important factors towards the status of industry 4.0 implementation utilizing AHP and ANP techniques" [36] have worked on a model that serves as a checklist to help executives understand the crucial factors to consider before any digitization project. The authors have identified four criteria (Cost, Organizational, Environmental, and Innovation) and 16 critical factors confirmed by academic and industry experts. The authors discussed some points of similarities when compared to other articles mentioned before in regards to the different drivers presented, such as the importance of the organizational structure flexibility, the importance of IT expertise, the importance of the technology infrastructure, the well-integrated organization (a good collaboration between departments). At the same time, the authors highlighted some new aspects to be taken into consideration equally.

Regarding costs, understanding the economic advantage and the benefits expected from the implementation of I4.0 technologies acts as an essential enabler for any stakeholder who plans to invest in I4.0. Regarding environmental criteria, organizations must keep up with the ever-changing demands of the markets and the increase of competitiveness and try to find the suitable technology that best answers this pressure, adding to that the importance of exploiting the data to improve the solutions and the product offered to the clients. Concerning the innovation criteria, the importance of having available real-time data for quick decision-making and having an integrated platform accessed by multiple users. This study was restricted to the Indian context, so these factors of success are deemed necessary by experts from this nation. These are the key factors that the management must focus on initially when implementing industry 4.0.

The following article, "Speeding Up the Implementation of Industry 4.0 with Management Tools: Empirical Investigations in Manufacturing Organizations" [37], is focused exclusively on the managerial dimension and presents the primordial tools that promote the readiness for a thriving industry 4.0 implementation. A survey of 323 employees from different manufacturing companies has been conducted. And the results of the study have shown the following:

-Contemporary management tools: these tools, in one way or another, are based on the usage of information technology. Their use seems to have a significant impact in facilitating the implementation of industry 4.0. For example, six sigma; is a tool that helps stabilize the production process, enabling easy technology integration in more standardized and easily modeled methods. TQM total quality management is a concept that allows organizations to achieve excellence through continuous improvement. This acts as an enabler and a basis for integrating industry 4.0 technologies. RFID, radio frequency identification, is a technology that helps track the product through a set of operations. For example, this developed technology is an enabler

for communication between devices and helps with the integration of other industry 4.0 technologies. Rapid prototyping replaces physical prototypes, and it is used as well in the development of IOT.

-Traditional management tools are well known and the most used in organizations, such as; customer segmentation, balanced scorecard, mission and vision statements, and strategic planning. They address the needs of the customer individually. The use of these tools helps in keeping track of their goals and in the management of the implementation projects.

The survey results are more specific to manufacturing companies and present a broad view of the use of management tools to assess the readiness for I4.0 adoption.

CRITICAL SUCCESS FACTORS OF INDUSTRY 4.0 IMPLEMENTATION

The ten articles examined are all interrelated to the factors of a successful implementation of Industry 4.0. These papers pinpoint the different kinds of ways technologies are integrated into the manufacturing industry. Some of them provide an approach based on the challenges and barriers, i.e., factors that hinder the implementation of industry 4.0. Others present drivers and enablers, i.e., elements that promote and facilitate the adoption of industry 4.0 to remain competitive in increasingly demanding markets. Some provide tools to assess the degree of implementation, and others provide a specific implementation process based on sectors and types of companies. These scenarios play a massive role in developing a strategic plan to accelerate the implementation of Industry 4.0. In the following, the authors discuss the most critical similarities of the articles mentioned above and compare them together.

So, the current research comprehensively deals with three main factors, as mentioned before: drivers, enablers, and barriers. The study of these three factors altogether deems essential. By analyzing them, it will be possible to identify and develop strategies that will empower companies to implement i4.0 technologies in their organizational process, thus, allowing them to adapt the factors that facilitate their implementation at a human, technical, and managerial level. In figure 11 is a summary of the key factors collected from the literature.

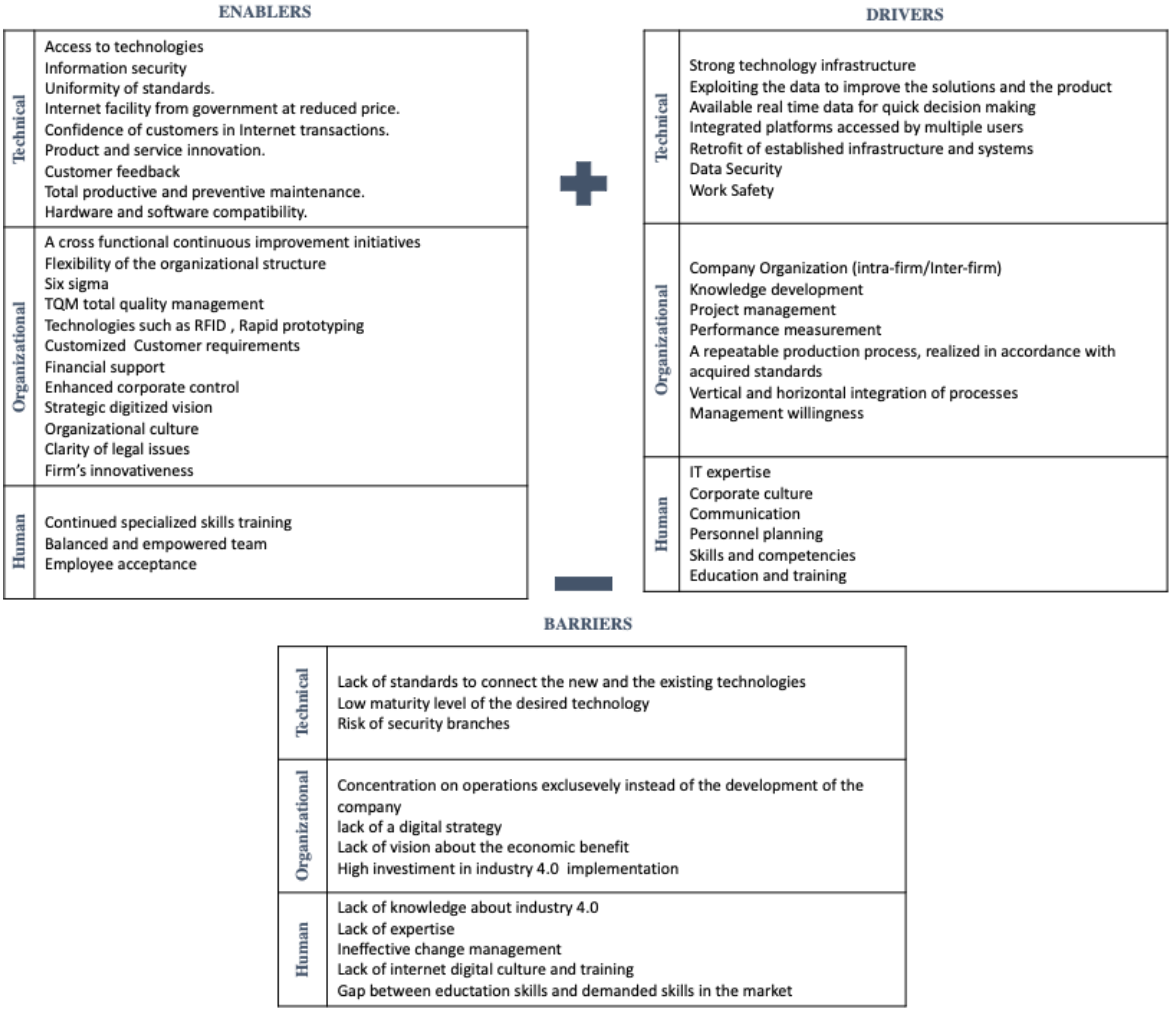

FIGURE 10
OVERVIEW OF I4.0 CHALLENGES, DRIVERS AND ENABLERS

As far as the human factor is concerned, both existing literature and the result from the studies mentioned above illustrates the importance of employees' adherence to this transformation. The studies [29] consider it an enabler for I4.0 implementation. Employees should be willing to adhere to this cultural change and impact it by improving and developing their skills. Moreover, Information and computer technology (ICT) skills are essential to design and integrating I4.0 technologies according to the needs. Adding to that is the knowledge related to supporting security programs to deal with data abuse [38-39]. Companies must work extensively in developing these skills by organizing training. For example, they can implement scenario-based training or e-learning platforms [32, 40]. Companies should work with schools and universities to develop programs suitable to industry needs and acquire adequate skills [30].

Regarding the technical factor, research has emphasized it as a critical challenge in the context of industry 4.0 [32], and others see it as a crucial factor. The challenge lies in how to incorporate it with existing production systems. The usage of new technologies requires the preparation of existing systems. For instance, many technologies, such as sensors and actuators, considered the core components of CPS, can be further developed and integrated with other internet-based technologies to manage data more efficiently.

The existing applications are considered as a basis to build on different technologies, and this will reinforce Industry 4.0 implementation. Industry 4.0 offers flexibility and customization of products, and this needs a robust IT infrastructure that does not get disturbed easily and affects the entire system. Therefore, standards must be applied for the different technical areas, hardware and software compatibility problems must be handled carefully, and data security issues must be treated with the appropriate protection measures. In addition, one of the most important factors to be implemented is the internet's uninterrupted continuous availability, which is the basis for industry 4.0 applications. Other findings stressed the importance of combining existing notions with concepts of lean management, radio frequency identification (RFID), manufacturing execution systems (MES), and enterprise resource planning (ERP) [30].

Regarding the organizational dimension of Industry 4.0 implementation, several aspects have been taken into account regarding its reform. On the one hand, some studies emphasized the importance of a decentralized and agile organizational structure, especially in the process of decision-making to implement I4.0 practices with vertical and horizontal integration [35, 41, 42]. On the other hand, organizations with a history of cross-functional continuous improvement initiatives are better suited to efficiently implementing industry 4.0 with lesser effort [29]. Another critical enabler is the management's willingness to change which is demonstrated through the interest that top management show in implementing i4.0 and how much managers back up the projects. It is essential that complete management work on analyzing the current state of the organization structure and work towards changing it to suit better the new setting required and drive this digital revolution.

- **Implications of research**

Implications for experts and managers: from reviewing the literature, it was noticed that managers are still in the first step of understanding the different dynamics that help in the process of I4.0 implementation. So, this paper will give practitioners in the domain a proper understanding of the underlying drivers and enablers that will help them move on to the next step of the implementation and take suitable actions accordingly. Secondly, managers will have a good reference of the barriers that block the way to an efficient adoption and impact the investment costs. By overcoming these challenges and making use of the full potential of the driving factors, managers can set a clear roadmap on the road towards a successful integration, bringing new business models, having flexible production processes, and improving products and quality service, all of which has a significant impact across the entire value chain.

Implications for researchers: Researchers may carry out studies more focused on mitigating the risks related to the challenges faced during the implementation. They can also study more in-depth the different applications that already exist in practice and in literature and how efficient they are in supporting the process of implementation.

CONCLUSION

A new revolution has seen the light recently, leading to big industry changes. It brought about different technological advancements such as big data, cloud computing, intelligent robots, etc. the impact of this transformation on organizations and the end customer it already noticed. An organization's production processes are more flexible and productive while maintaining a good level of quality. At the same time, customers are more satisfied than ever regarding the improved quality and fast responses to their ever-changing needs. From a business perspective, keeping up with these new advancements while optimizing the investments related to their adoption is critical for any organization to thrive in the market. However, different factors hinder the full adoption of industry 4.0 technologies. These challenges and limitations are to be considered alongside the opportunities that industry 4.0 offers for a successful transformation.

Recently, the research field has shifted to focus more on the enablers for the productive implementation of the industry 4.0 concept. Thus, this study has presented a list of barriers and challenges to adopting Industry 4.0 studied in the literature as well as the different drivers and enablers to consider to facilitate the adoption process. The current findings mainly focus on theoretical and conceptual aspects of industry 4.0 implementation and deal with specific areas within Industry 4.0. This study did not focus on particular tools, such as additive manufacturing, intelligent robots, etc., as few recent studies explore the practical way to adopt these technologies. Therefore, future studies can explore the intercorrelation between the dimensions studied before with a focus on some specific tools to present a practical framework for their implementation. Thus, the primary purpose of this article is to provide a general overview of both examples in theory and practice alongside challenges to tackle and best practices to adopt for a broad range of industrial companies.

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