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• **Abstract** (see below):

This study aims to provide a systemic and integrated view of how Industry 4.0 and its enabling technologies affect companies' internal and external environments. It offers a comprehensive view of the contribution about ten years after the start of the Fourth Industrial Revolution.
The study performs a systematic literature review based on Industry 4.0 management literature. Analyzing the results of the 308 final papers in the sample made it possible to build a theoretical model to explain the contribution of Industry 4.0 to the internal and external environment of the company. The results highlight the contribution of Industry 4.0 to the processes and environment of the company by providing a systemic and integrated view, highlighting the most applied enabling technologies and their internal, external, and combined usefulness in business processes.
Finally, the paper provides a broad view of the Industry 4.0 topic ten years after its origin through an extensive literature analysis that allows us to highlight the significant studies and the areas still under-researched by researchers and opens the debate on the Industry 5.0 scenario.
The model makes it possible to appreciate the role of Industry 4.0 and its enabling technologies in companies in a broad and systemic view and to understand, from a managerial point of view, the interactions, synergies, and possibilities within processes and the reflection on the external environment.

Ten years of Industry 4.0 adoption: external and internal perspective in a systemic model towards Industry 5.0

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Abstract

Purpose – This study aims to provide a systemic and integrated view of how Industry 4.0 and its enabling technologies affect companies' internal and external environments. It offers a comprehensive view of the contribution about ten years after the start of the Fourth Industrial Revolution.

Design/methodology/approach – The study performs a systematic literature review based on Industry 4.0 management literature. Analyzing the results of the 308 final papers in the sample made it possible to build a theoretical model to explain the contribution of Industry 4.0 to the internal and external environment of the company.

Findings – The results highlight the contribution of Industry 4.0 to the processes and environment of the company by providing a systemic and integrated view, highlighting the most applied enabling technologies and their internal, external, and combined usefulness in business processes.

Research limitations/implications – Finally, the paper provides a broad view of the Industry 4.0 topic ten years after its origin through an extensive literature analysis that allows us to highlight the significant studies and the areas still under-researched by researchers and opens the debate on the Industry 5.0 scenario.

Originality/value – The model makes it possible to appreciate the role of Industry 4.0 and its enabling technologies in companies in a broad and systemic view and to understand, from a managerial point of view, the interactions, synergies, and possibilities within processes and the reflection on the external environment.

Keywords Industry 4.0, Enablers technologies, Tools, Internal and external environment, Model

Paper type Literature review

1. Introduction

Only half a century after the Third Industrial Revolution in the 1950s, with the development of semiconductors that gave rise to computerization, the subsequent Internet, and mobile phone technologies (Nazarov and Klarin, 2020), the German government, 2011 presented the concept of "Industry 4.0" (I4.0), which quickly became the focus of both the government in Germany and many other European countries (Ghobakhloo, 2018). I4.0 refers to a new industrial model "based on cyber-physical systems and the Internet of things, which represent technological enablers of this digital industrial transformation" (Lassnig *et al.*, 2018, p. 162). I4.0 proposes smart factories (Nazarov and Klarin, 2020) in which machines and products interact without human control (Ivanov *et al.*, 2016), and by changing current processes/systems, manufacturing is based on intelligent machines capable of producing innovative products.

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Based on horizontal integration, value networks, and vertical integration, I4.0 provides networked manufacturing systems with end-to-end digital integration of engineering along the entire value chain (Wang *et al.*, 2016, 2017; Shi *et al.*, 2020). Finally, it integrates production facilities, warehouse systems, logistics, and social requirements to establish global value-creation networks (Frazzon *et al.*, 2013).

The use of new advanced technological techniques, such as Big data, Cloud computing, Virtual Reality, Internet of Things (IoT), additive manufacturing and robotics, etc., will enable the creation of cyber-physical systems (CPS) in logistics and manufacturing (Acemoglu, 2002; Jain and Ajmera, 2020; Stornelli *et al.*, 2021). These technologies are called the enabling technologies of I4.0, supported by new horizontal and vertical integration techniques that help transform traditional systems into I4.0-enabled systems (Thoben *et al.*, 2017; Oztemel and Gursev, 2020; Salunkhe and Berglund, 2022).

Shi *et al.* (2020) define I4.0 as "a strategy aiming for constructing a communication system between production equipment and products based on hyper-connected technology and integrating the entire production processes" (p.608) to increasingly shorten product life cycles and ensure extreme and economically sustainable mass customization (Veza *et al.*, 2015).

However, the transition to I4.0 is not simple as it requires the definition of strategies and implementation of organizational models capable of making radical changes, involving the entire organization in terms of physical infrastructure, production operations and technologies, human resources, capabilities and process management (Gilchrist, 2016; Pirola *et al.*, 2020; Ciarli *et al.*, 2021; Peerally *et al.*, 2022). This situation justifies why, although I4.0 has several potentials, many companies struggle with its implementation (Lassnig *et al.*, 2018; Ghobakhloo and Fathi, 2020).

Thus, several studies have been proposed in the literature on the topic of I4.0 aimed primarily at supporting companies in this new transition. Several authors have developed research to define obstacles to implementing I4.0 (i.e. Caiado *et al.*, 2017; Ghobakhloo, 2020; Liu *et al.*, 2021; Machado *et al.*, 2021; Razak *et al.*, 2021). In contrast, others have tried to describe how human resources can critically contribute to the success of the new organizational model (i.e. Chang and Yeh, 2018; Mariani and Borghi, 2019; Li *et al.*, 2021; Singh *et al.*, 2022). Authors such as Kohtamäki *et al.* (2019), Flores *et al.* (2020), and Gupta *et al.* (2021), on the other hand, have proposed possible business models capable of accommodating the changes of the fourth industrial revolution. In contrast, others such as, i.e. Ghobakhloo (2018), Santos and Martinho (2020), and Ito *et al.* (2021) have focused on possible managerial strategies to manage the changes resulting from I4.0 efficiently. Finally, other research has sought to understand the possible relationships and interactions between I4.0 and its tools (i.e. Islam *et al.*, 2020; Dos Santos *et al.*, 2021; Klingenberg *et al.*, 2021; Newman *et al.*, 2021) with the internal (processes, organization)/external (stakeholder) environment (i.e. Garay-Rondero *et al.*, 2020; Núñez-Merino *et al.*, 2020) and new issues such as Circular Economy and sustainability (Cwiklicki and Wojnarowska, 2020; Ciliberto *et al.*, 2021; Piccarozzi *et al.*, 2022, 2023; Minashkina and Happonen, 2023).

More than 2,300 reviews have been published on I4.0, all aiming to provide a comprehensive picture of the different aspects characterizing this fourth industrial revolution, demonstrating how academics perceive the topic to be significant. However, there is a lack of analysis to provide an overview of I4.0 concerning the company, considering both the internal and external environment. Various models are in the literature, but they do not allow for a joint analysis of the external and internal environment of the company, highlighting synergetic interactions and opportunities.

For instance, Ghobakhloo (2018) highlighted a model that defines crucial design principles and technology trends and offered a practical "strategic roadmap" to guide companies through the transition process toward I4.0. This model expresses in great detail the application of I4.0 in the internal context of companies but does not outline, except for some consumer-related aspects, the characteristics and interaction of technologies with the external context. Also, Mariani and Borghi (2019) propose a model based on the most recurring issues emerging from the application of I4.0 in service companies. The sustainability goals focus on the external context by applying I4.0 without describing external actors or processes in detail. Bagnoli *et al.* (2019) developed a literature-based model highlighting the impact and the use of I4.0 enabling technologies on the definition of business models with a specific focus, therefore, on activities and processes within the company. An exciting contribution is that of Hizam-Hanafiah *et al.* (2020), who identified I4.0 readiness models and proposed six dimensions (Technology, People, Strategy, Leadership, Process, and Innovation) that can be considered the most critical dimensions for organizations. However, there is no overall, joined-up view of the phenomenon between internal and external aspects.

So, starting from gap analysis in the literature, the present research aims to provide a comprehensive overview of all the studies. Through literature review, it studies the topic of I4.0. It proposes a model capable of systemizing the main results obtained from the analysis by highlighting the interactions between I4.0, its tools, and the internal and external environment with which the company itself relates, trying to give a comprehensive and holistic view of what is stated in the literature.

Within this background, the research question that the paper poses is:

> Is it possible to synthesize, in a holistic model, the relationships between I4.0 enabling technologies and companies' internal and external environment?.

The literature reviews on I4.0 have analyzed the relationships between the enabling technologies and the internal and external environment but without offering a holistic synthesis that brings tools and environments together in a synergetic manner.

Compared to the systematic reviews analyzed, which jointly study the internal and external environment, the present research differs in that it further investigates the relationships with the enabling technologies, integrating them into a single macro model that highlights their interactions and possible synergies in a single vision that summarizes what has been affirmed by the various authors over the last ten years.

Furthermore, in the present work, both the external and internal environments were further investigated by investigating them respectively from the perspective of Porter's Value Chain (Porter, 1998) and Macro (McConville *et al.*, 2014, p. 4; Georgiadou *et al.*, 2019; Richter *et al.*, 2022), and Microenvironment (Bonechi *et al.*, 2004) in order to extract more detailed information and elaborate the synthesis model (see Table 2 for further details).

The article will then be structured as follows: in paragraph 2, the methodology is explained; paragraph 3 describes the main results that enabled the description of the final model; paragraph 4 introduces the model and the discussions. Finally, paragraph 5 contains conclusions with both managerial and scientific implications.

2. Materials and method

To provide the framework capable of providing an overview of I4.0 and related enabling technologies concerning the company, considering both the internal and external environment, it develops a Systematic Literature Review (SLR). The aim of SLR is "to identify, evaluate and interpret research relevant to a determined topic area, research question or phenomenon of interest" (Kitchenham and Charters, 2007; Muller *et al.*, 2019) (p. 398). According to Muller *et al.* (2019), the SLR allows one to (1) summarize the existing evidence in a topic, (2) identify gaps in the state-of-art, proposing areas for further investigation, and (3) provide a framework as support for further research activities. In this contest, the SLR provided information and data imported to create the conceptual framework (Machado Fagundes da Silva *et al.*, 2022).

Based on the systematic literature review work previously conducted by Budgen and Brereton (2006) and Klingenberg *et al.* (2021), a three-stage procedure was adopted as the methodology in this study, namely Stage 1 (search), Stage 2 (selection) and Stage 3 (analysis). The research team, consisting of four researchers (one professor, one senior researcher, and two Ph.D. students), collaborated continuously and discussed all aspects of SLR (Kalaiarasan *et al.*, 2022).

Phase 1- Search. The Scopus database was used for the material collection. Scopus is used for research because scholars consider it among the best databases for producing a reliable bibliometric survey (Durán-Sánchez *et al.*, 2018; Silvestri *et al.*, 2022). Scopus possesses a high level of singularity (Sánchez *et al.*, 2017) and broad data coverage (Salim *et al.*, 2019), making it one of the most comprehensive and comprehensive scientific databases (Chadegani *et al.*, 2017). Table 1 shows the four parameters (what, where, when, and how to search for papers) used in the research phase (vom Brocke *et al.*, 2009; Klingenberg *et al.*, 2021).

For research purposes, this analysis focused only on papers in peer-reviewed scientific journals in English (Seuring and Muller, 2008; Adjei-Bamfo *et al.*, 2019; Alshqaqeeq *et al.*, 2020; Merli *et al.*, 2020). The extraction of the papers from the databases was carried out on 31 October 2023. The initial amount of collected papers from Scopus was 2,338.

Phase 2 - Selection. In this phase, the authors applied different selection criteria to arrive at a sample of articles in line with the aim of the research. The filter applied covered the Subject area by selecting only those articles that fall into the following Fields:

(1) Business, Management, and Accounting;

(2) Decision Sciences;

(3) Social Science.

Finally, to assess how relevant the selected paper is in response to the research question (Xavier *et al.*, 2017), the C-I-M-O (context-intervention-mechanism-outcome) framework was applied (Briner *et al.*, 2009; Briner and Denyer, 2012). The C-I-M-O framework, relying on the criterion of inclusion and exclusion, made it possible to define the specific focus of the research, excluding articles that did not correspond to the purpose of the review.

The C-I-M-O framework consists of the following inclusion/exclusion criteria:

(1) Inclusion criteria: all the papers that analyze I4.0 in the companies.

(2) Exclusion criteria: all the papers that do not analyze I4.0 in the companies.

In particular, through the C-I-M-O framework, the research can be schematized as follows (Kearney *et al.*, 2023):

(1) Context (C): Context assesses central individuals, relationships and broader systems.

- Analysis of I4.0 and its enabling technologies in the internal and external business context/environment.

(2) Intervention (I): Intervention investigates the actions taken.

Table 1.
Search parameters

What	Where	When	How
"Industr* 4.0" AND "Review"	Scopus	October 31, 2023	"Article title, Abstract, Keywords" Document Type: Articles Source Type: Journal Fields: Business, Management and Accounting; Decision Sciences; Social Science

Source(s): Our elaboration

- Relationship between I4.0 and its enabling technologies in specific internal (Porter's value chain) and external environments (STEEPLED Analysis and the operating environment model for studying the microenvironment).

(3) Mechanism (M): Mechanism appraises the theory framing the previous studies.

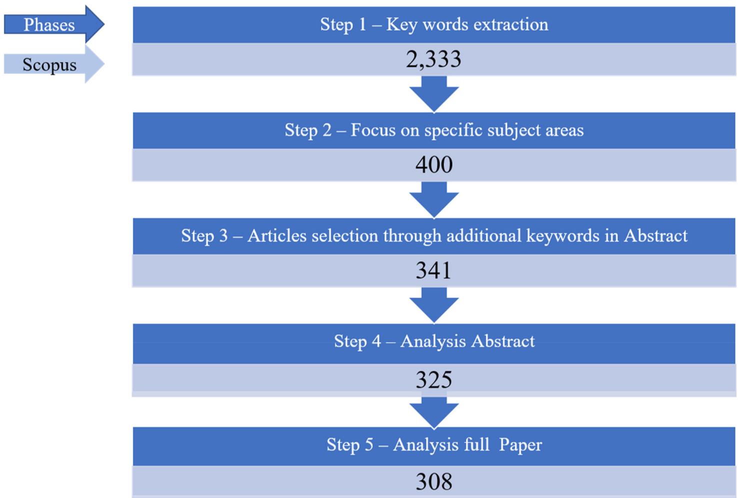
- There is an existing relationship/impact between enabling technology and enterprises' internal/external environments. Articles analyzing this relationship in the non-business environment were excluded.

(4) Outcome (O): Outcome analyses the impacts of the intervention as both intended and unintended end states.

- The result was measured in terms of recurrence and, thus, frequency calculations between the enabling technologies analyzed by the reviews and different internal and external environment components.

Applying the above selection criteria, the analysis sample was 341 articles. Next, the abstracts and the entire articles were read, resulting in a sample of 308. Figure 1 summarizes the stages of article search and selection.

Phase 3 - Analysis. Each stage analysis highlights the main contributions of enabling technologies to view the evidence and consistently simplify the model's reading. Specifically, the content analysis provided an understanding of the relationships between I4.0 and the company regarding the internal/external environment, and a better understanding of which enabling technologies facilitate their relationships and interaction. Specifically, the analysis first involved searching the papers for the nine enabling technologies (Additive Manufacturing, Augmented Reality, Autonomous Robots; Big Data, The Cloud, Cybersecurity Horizontal, and Vertical System Integration, The Industrial Internet of Things, and Simulation) following the literature (Rüßmann *et al.*, 2015; Brunelli *et al.*, 2017; Bortolini *et al.*, 2018; Büchi *et al.*, 2020; Leong *et al.*, 2020; Mubarak and Petraite, 2020). The second aspect investigated was the focus of the paper, whether related to applications/observations of Industry 4.0 in the internal context of the company or the external context. Regarding impact on the internal context, Porter's value chain (Porter, 1998; Koc and Bozdag, 2017) was used as a reference model to identify the specific functions (primary



Source(s): Our elaboration

Figure 1.
Summary of the stages of papers search and selection

and/or supporting) in which I4.0 and its technologies intervene. The analysis of the external context was based on the application of the STEEPLED Analysis (Social, Technological, Economical, Ecological, Political, Legal, Ethical, and Demographical) model for the study of the macro environment (Georgiadou *et al.*, 2019; Richter *et al.*, 2022), and the operating environment model for the study of the microenvironment (Bonechi *et al.*, 2004) (Table 2).

Figure 2 shows the schematization of the methodology used for Phase 3.

The structured database is preparatory to a comprehensive and synergistic analysis of what emerges from the articles. It lays the foundation for the definition of the theoretical model.

3. Results

3.1 General results - an overview

The analysis of the results from the database follows the methodology described above. In particular, the aspects studied were the enabling technologies and the internal and external environment of the company.

Contes	Focus	Name	Definition	Rif
External environment	Macroenvironmental	STEEPLED analysis	"STEEPLED is a framework for describing external macroenvironmental factors commonly used in market research or strategic analysis (originally known as PEST analysis19). It covers Social, Technological, Economic, Environmental, Political, Legal, Ethical, and Demographic factors" (McConville *et al.*, 2014, p. 4)	McConville *et al.* (2014, p. 4), Georgiadou *et al.* (2019), Richter *et al.* (2022)
	Microenvironment	Operating environment	"The microenvironment is represented by the set of all those groups of people who have some interest in the activities carried out by the company (stakeholders), with whom it continuously interacts, and by the other economic operators in the area of influence, including competitors" (Bonechi *et al.*, 2004, p. 156)	Bonechi *et al.* (2004)
Internal environment	Porter value chain	Primary activities	"Activities involved in the physical creation of the product and its sale and transfer to the buyer as well as after sales assistance" (Porter, 1998, p. 38)	Porter (1998)
		Support activities	"Support the primary activities and each other by providing purchased, inputs, technologies, human resources and various firmwide functions" (Porter, 1998, p. 38)	

Source(s): Our elaboration

Table 2.
Definitions of external and internal environment

Table 3 shows the digital tools of I4.0 mentioned in the papers. “IoT” (18.7%) followed by “Big Data and Analytics” (15.8%) are the most analyzed.

Based on the theories mentioned in Table 2, the papers were analyzed from the perspective of the internal and external environment and their sub-scope according to the literature.

107 authors (37.7%) analyzed the internal environment, 17 (6.0%) the external environment, and 160 (56.3%) both environments (Table 4).

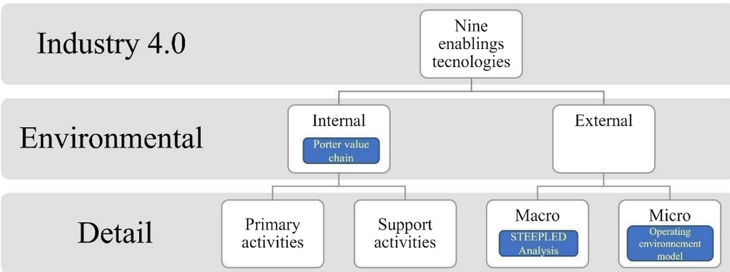
Considering the primary and support activities, the most mentioned activity is “Technology Development” (19.8%) (Support activity), followed by “Infrastructure/data information technologies” (Support activity) (19.2%) and “Operations” (production) (18.4%) (Primary activity) (Table 5).

Table 6 concerns the STEEPLED analysis (macro environment), and it is possible to understand that the aspect most analyzed by the authors concerning the theme of I4.0 is “Economical” (25.2%), followed by “Sociocultural” (22.4%) and “Environmental” (21.2%).

Relative to the second dimension of the external environment (micro), “Suppliers” (36.9%) and “Consumers” (25.1%) represent the most analyzed stakeholders about I4.0 (Table 7).

3.2 Results in depth

The second analysis step compares enabling technologies, the primary and supporting activities of the internal environment, and the Steepled and “Operation environment” models for the external environment. This step made it possible to understand which, depending on



Source(s): Our elaboration

Figure 2. Schematization of the methodology Phase 3 – analysis

Nine enabling technologies	*f*	%
IoT	150	18.7%
Big Data and Analytics	127	15.8%
The Cloud	94	11.7%
Industry 4.0 general concept*	87	10.8%
Cybersecurity	74	9.2%
Additive Manufacturing	67	8.4%
Augmented Reality	63	7.9%
Autonomous Robots	61	7.6%
Simulation	47	5.9%
Horizontal and Vertical System Integration	32	4.0%
Total	802	100%

Note(s): *Discrete Event Simulation, Virtual Reality, Artificial Intelligence, RFID, Information systems, Fintech and Blockchain, Automation, Wireless Sensors Networks (WSN), Machine Learning
Source(s): Our elaboration

Table 3. Nine enabling technologies

the activity considered (primary or support) and the elements of the STEEPLED and the "Operation environment" of the external environment, are the enabling technologies most used/mentioned by the authors.

Considering the primary activities of the internal environment (Inbound Logistics, Operations (procurement), Outbound Logistics, Marketing and Sales, and Service), it notes that "IoT" and "Big Data and Analytics" are the main pillars mentioned by the sample authors in all the individual primary activities (Table 8). "IoT" and "Big Data and Analytics" have the highest percentage in Marketing and Sales activity (21.3% and 17.0% respectively).

Considering the activities supporting the internal environment, "IoT" is again the most frequently mentioned technology, depending on the activity considered. "IoT" and "Big Data

Internal and external environmental	*f*	%
Internal and External	173	56.1%
Internal	115	37.3%
External	20	6.6%
Total	308	100%

Note(s): *The term External includes both the macro and micro environments
Source(s): Our elaboration

Table 4.
Firm focus

Internal environmental	Primary and support activities	*f*	%
Technological Development	Support	129	19.8%
Infrastructure/data information technologies	Support	125	19.2%
Operations (production)	Primary	120	18.4%
Human Resource Management	Support	108	16.6%
Inbound Logistics	Primary	53	8.1%
Procurement	Support	43	6.6%
Outbound Logistics	Primary	42	6.4%
Service	Primary	18	2.8%
Marketing and Sales	Primary	14	2.1%
Total		652	100.0%

Source(s): Our elaboration

Table 5.
Primary and support activities

Steepled	*f*	%
Economic	81	25.2%
Sociocultural	72	22.4%
Environmental	68	21.2%
Ethical	33	10.3%
Political	28	8.7%
Technical	21	6.5%
Legal	14	4.4%
Demographic	4	1.2%
Total*	321	100.0%

Note(s): *The total is more than the 161 papers (see Table 4) in the sample because several authors analyzed multiple aspects simultaneously
Source(s): Our elaboration

Table 6.
STEEPLED or macro environmental

Operation environmental	*f*	%
Suppliers	75	36.9%
Consumer	51	25.1%
Competitors	43	21.2%
Labor market	22	10.8%
Finance facilities	12	5.9%
Total	203	100%

Note(s): *The total is more than the 161 papers (see Table 4) in the sample because several authors analyzed multiple aspects simultaneously
Source(s): Our elaboration

Table 7.
Microenvironment

and Analytics" have the highest percentage in "Procurement" activity (23.4% and 20.3% respectively). (Table 9).

Analyzing the external environment regarding STEEPLED, "IoT," and "Big Data and Analytics" are the authors' most used/cited technologies. In particular, "IoT" has the highest percentage in "Demographics" (33%) and also "Big Data and Analytics" (25%) (Table 10).

Finally, considering the "Operation Environment" of the external environment at the micro level, once again, "IoT" and "Big Data and Analytics" are the technologies that the authors most use/cite. "IoT" has the highest percentage of "Competitors" (22.2%) and "Big Data and Analytics" (21.5%) (Table 11).

4. Discussion

The following theoretical model derives from the methodology described and the results obtained from the document analysis. The model structure provides for a progressive aggregation of the levels of analysis to have a partial and aggregated view of the intervention of I4.0 and its enabling technologies on companies' internal and external environments. The analysis starts by representing the internal environment, then details the external environment, in micro and macro, and finally has an overall and integrated picture of the previous three steps. Each stage analyzed highlights the main contributions of the enabling technologies to have a consistent view of the evidence and simplify the model's reading.

4.1 Step 1 - internal environment – Porter value chain

The first step focuses on the relationship between the company's internal environment and I4.0 technologies.

As outlined in the results, the primary activities see support from "IoT", "Big Data and Analytics", and "Cloud" technologies. In particular, the contribution of these technologies helps improve manufacturing effectiveness and efficiency (Ghobakhloo, 2018). "IoT" improves business operations and assets by integrating machine sensors and "Cloud" technologies, contributing not only to technical improvements in manufacturing but also to green manufacturing initiatives, product quality efficiency, energy optimization, and design optimization (Ghobakhloo, 2018; Runji *et al.*, 2023). "Big Data and Analytics" contributes to rapid decision-making to improve business flexibility (Ryabchikov and Ryabchikova, 2022), making companies more efficient as it not only anticipates and directs activities but also facilitates innovations and the deployment of resources (Ogbuke *et al.*, 2022). Rahman *et al.* (2018) discuss "Cloud Manufacturing," the latest manufacturing paradigm that allows manufacturing to be considered a service industry, providing cost and flexibility advantages.

Interestingly, the contribution of these technologies enables companies to implement agile and sustainable processes (Mrugalska and Ahmed, 2021). Although introducing new

Table 8. Nine enabling technologies in the internal environment (primary activities)

Inbound logistics	f	%	Operations (production)	f	%	Outbound logistics	f	%	Marketing and sales	f	%	Service	f	%
IoT	35	19.2%	IoT	65	18.7%	IoT	26	17.8%	IoT	10	21.3%	IoT	13	17.8%
Big Data and Analytics	28	15.4%	Big Data and Analytics	54	15.5%	Big Data and Analytics	23	15.8%	Big Data and Analytics	8	17.0%	Big Data and Analytics	12	16.4%
The Cloud	22	12.1%	The Cloud	40	11.5%	The Cloud	19	13.0%	Augmented reality	6	12.8%	The Cloud	9	12.3%
Industry 4.0 general concept	20	11%	Industry 4.0 general concept	40	11.5%	Industry 4.0 general concept	18	12.3%	Additive manufacturing	4	8.5%	Augmented reality	7	9.6%
Additive manufacturing	16	8.8%	Additive manufacturing	32	9.2%	Cybersecurity	13	8.9%	The Cloud	4	8.5%	Additive manufacturing	6	8.2%
Cybersecurity	15	8.2	Cybersecurity	31	8.9%	Augmented reality	12	8.2%	Industry 4.0 general concept	4	8.5%	Cybersecurity	6	8.2%
Augmented reality	15	8.2%	Augmented reality	27	7.8%	Additive manufacturing	12	8.2%	Autonoumus robots	3	6.4%	Horizontal and Vertical System Integration	6	8.2%
Autonoumus robots	12	6.6%	Autonoumus robots	25	7.2%	Simulation	9	6.2%	Cybersecurity	3	6.4%	Autonoumus robots	5	6.8%
Simulation	11	6%	Simulation	21	6.8%	Autonoumus robots	8	5.5%	Simulation	3	6.4%	Industry 4.0 general concept	5	6.8%
Horizontal and Vertical System Integration	8	4.4%	Horizontal and Vertical System Integration	13	3.7%	Horizontal and Vertical System Integration	6	4.1%	Horizontal and Vertical System Integration	2	4.3%	Simulation	4	5.5%
Total	182	100%	Total	348	100%	Total	146	100%	Total	47	100%	Total	73	100%

Source(s): Our elaboration

Table 9. Nine enabling technologies in the internal environment (support activities)

Procurement	*f*	%	Human resource management	*f*	%	Technological development	*f*	%	Infrastructure/data information technologies	*f*	%
IoT	30	23.4%	IoT	47	16.8%	IoT	79	21.0%	IoT	65	18.6%
Big Data and Analytics	26	20.3%	Big Data and Analytics	41	14.7%	Big Data and Analytics	69	18.3%	Big Data and Analytics	64	18.3%
The Cloud	14	10.9%	The Cloud	33	11.8%	The Cloud	46	12.2%	The Cloud	45	12.9%
Industry 4.0 general concept	12	9.4%	Cybersecurity	30	10.8%	Augmented reality	31	8.2%	Industry 4.0 general concept	37	10.6%
Cybersecurity	11	8.6%	Industry 4.0 general concept	27	9.7%	Autonoumus robots	30	8.0%	Cybersecurity	28	8.0%
Additive manufacturing	11	8.6%	Augmented reality	26	9.3%	Additive manufacturing	30	8.0%	Autonoumus robots	27	7.7%
Augmented reality	8	6.3%	Autonoumus robots	24	8.6%	Cybersecurity	29	7.7%	Augmented reality	26	7.4%
Simulation	7	5.5	Additive manufacturing	23	8.2%	Industry 4.0 general concept	28	7.4%	Additive manufacturing	23	6.6%
Autonoumus robots	6	4.7%	Simulation	15	5.4%	Simulation	19	5.0%	Simulation	21	6.0%
Horizontal and Vertical System Integration	3	2.3%	Horizontal and Vertical System Integration	13	4.7%	Horizontal and Vertical System Integration	16	4.2%	Horizontal and Vertical System Integration	13	3.7%
Total	128	100%	Total	279	100%	Total	377	100%	Total	349	100%

Source(s): Our elaboration

Table 10. Nine enabling technologies in the external environment (STEEPLED)

Sociocultural	*f*	%	Technical	*f*	%	Economic	*f*	%	Environmental	*f*	%	Political	*f*	%	Legal	*f*	%	Ethical	*f*	%	Demographic	*f*	%
IoT	28	14.9%	IoT	11	16.4%	IoT	51	19.5%	IoT	44	18.6%	Big Data and Analytics	15	15.2%	Big Data and Analytics	6	16.7%	IoT	20	17.7%	IoT	4	33%
Big Data and Analytics	24	12.8%	The Cloud	10	14.9%	Big Data and Analytics	47	17.9%	Big Data and Analytics	37	15.7%	IoT	13	13.1%	The Cloud	6	16.7%	Big Data and Analytics	19	16.8%	Big Data and Analytics	3	25%
Cybersecurity	23	12.2%	Big Data and Analytics	8	11.9%	The Cloud	31	11.8%	The Cloud	27	11.4%	The Cloud	11	11.1%	IoT	6	16.7%	Augmented reality	14	12.4%	Augmented reality	2	17%
The Cloud	21	11.2%	Others	8	11.9%	Additive manufacturing	25	9.5%	Additive manufacturing	25	10.6%	Additive manufacturing	10	10.1%	Cybersecurity	4	11.1%	Additive manufacturing	12	10.6%	Industry 4.0 general concept	2	17%
Industry 4.0 general concept	21	11.2%	Additive manufacturing	6	9.0%	Augmented reality	23	8.8%	Industry 4.0 general concept	25	10.6%	Cybersecurity	10	10.1%	Industry 4.0 general concept	4	11.1%	Autonoumus robots	10	8.8%	Additive manufacturing	1	8%
Autonoumus robots	18	9.6%	Simulation	6	9.0%	Industry 4.0 general concept	20	7.6%	Cybersecurity	22	9.3%	Autonoumus robots	9	9.1%	Augmented reality	3	8.3%	The Cloud	10	8.8%	Autonoumus robots	0	0%
Additive manufacturing	18	9.6%	Cybersecurity	5	7.5%	Autonoumus robots	19	7.3%	Augmented reality	21	8.9%	Augmented reality	9	9.1%	Additive manufacturing	3	8.3%	Cybersecurity	9	8.0%	The Cloud	0	0%
Augmented reality	17	9.0%	Augmented reality	5	7.5%	Cybersecurity	19	7.3%	Autonoumus robots	14	5.9%	Simulation	8	8.1%	Autonoumus robots	2	5.6%	Industry 4.0 general concept	9	8.0%	Cybersecurity	0	0%
Simulation	11	5.9%	Horizontal and Vertical System Integration	4	6.0%	Simulation	17	6.5%	Simulation	14	5.9%	Horizontal and Vertical System Integration	7	7.1%	Horizontal and Vertical System Integration	1	2.8%	Simulation	6	5.3%	Horizontal and Vertical System Integration	0	0%
Horizontal and Vertical System Integration	7	3.7%	Autonoumus robots	4	6.0%	Horizontal and Vertical System Integration	10	3.8%	Horizontal and Vertical System Integration	7	3.0%	Industry 4.0 general concept	7	7.1%	Simulation	1	2.8%	Horizontal and Vertical System Integration	4	3.5%	Simulation	0	0%
Total	188	100%	Total	67	100%	Total	265	100%	Total	236	100%	Total	99	100%	Total	36	100%	Total	113	100%	Total	12	100%

Source(s): Our elaboration

Suppliers	f	%	Competitors	f	%	Labor market	f	%	Consumer	f	%	Finance facilities	f	%
IoT	50	20.0%	IoT	30	22.2%	IoT	9	17.3%	IoT	30	15.7%	IoT	8	20.0%
Big Data and Analytics	44	17.6%	Big Data and Analytics	29	21.5%	Big Data and Analytics	8	15.4%	Big Data and Analytics	30	15.7%	The Cloud	7	17.5%
The Cloud	26	10.4%	The Cloud	15	11.1%	Additive manufacturing	5	9.6%	The Cloud	23	12.0%	Cybersecurity	6	15.0%
Cybersecurity	26	10.4%	Additive manufacturing	13	9.6%	The Cloud	5	9.6%	Augmented reality	19	9.9%	Big Data and Analytics	5	12.5%
Additive manufacturing	24	9.6%	Autonoumus robots	11	8.1%	Industry 4.0 general concept	6	7.7%	Cybersecurity	18	9.4%	Simulation	3	7.5%
Industry 4.0 general concept	23	9.3%	Augmented reality	10	7.4%	Augmented reality	4	7.7%	Additive manufacturing	16	8.4%	Industry 4.0 general concept	3	7.5%
Autonoumus robots	18	7.2%	Cybersecurity	9	6.7%	Autonoumus robots	4	7.7%	Industry 4.0 general concept	16	8.4%	Additive manufacturing	2	5.0%
Simulation	15	6.0%	Industry 4.0 general concept	7	5.2%	Cybersecurity	4	7.7%	Autonoumus robots	15	7.9%	Augmented reality	2	5.0%
Autonoumus robots	14	5.6%	Horizontal and Vertical System Integration	6	4.4%	Horizontal and Vertical System Integration	4	7.7%	Horizontal and Vertical System Integration	12	6.3%	Autonoumus robots	2	5.0%
Horizontal and Vertical System Integration	10	4.0%	Simulation	5	3.7%	Simulation	3	5.8%	Simulation	12	6.3%	Horizontal and Vertical System Integration	2	5.0
Total	250	100%	Total	135	100%	Total	52	100%	Total	191	100%	Total	40	100%

Source(s): Our elaboration

Table 11. Nine enabling technologies in the external environment (micro environment)

technologies represents a significant effort in economics, organization, and human resources, inbound and outbound logistics production processes supported by I4.0 technologies tend to have greater flexibility to adapt to changes in the external environment. So this makes it possible to begin to perceive the connection between internal processes and technology's link to the external context (Jiang *et al.*, 2022). The flexibility provided to internal processes, particularly primary activities, allows for a prompt response to changes in the external environment, particularly regarding consumer needs and the growing interest in sustainability (Gupta *et al.*, 2021).

Similarly, the contribution of the three leading technologies also spills over to the other primary activities most closely related to the customer, marketing, and services. First, customer quality and satisfaction improvement are found precisely from applying I4.0, particularly from the storage and analysis of "Big Data and Analytics" (Efimova and Briš, 2021). In synergy with virtual reality, "Big Data and Analytics" enables improvement in product definition at both production and marketing levels (Turner *et al.*, 2016), particularly in the retail sector (Bruni and Piccarozzi, 2022). In addition, "Big Data and Analytics" in integration with the "Cloud" brings benefits not only to production but also to the customer, as the cost benefits resulting from better utilization of resources will be cost benefits passed on to the customer (Rahman *et al.*, 2018). Some authors express this contribution to the customer relationship by analyzing lean manufacturing about I4.0 innovations that allow a better approach and connection with customer needs (Saad *et al.*, 2023; Bauer *et al.*, 2018). In addition, Escobar-Sierra *et al.* (2021) also point out how companies that adopt I4.0 technologies can initiate value co-creation processes with their customers to initiate sustainable practices while simultaneously improving customer satisfaction and corporate focus on sustainability.

The improvements and benefits of applying these three leading technologies are evident in large, small, and medium-sized companies. So, this helps affirm the incredible versatility of I4.0 as an accessible innovation vehicle even when resources show limitations or SMEs limit the application and exploitation of these technologies only for production and not from a broader perspective (Moeuf *et al.*, 2018).

In addition to the three leading technologies highlighted, "Augmented Reality" (AR) also deserves attention. AR is a relevant tool in marketing and sales activities. Since the advent of the pandemic, there has been a very important use, especially in the retail sector, with numerous positive impacts. Bruni and Piccarozzi (2022) highlight how AR improves consumer interaction, consumer experience, behavior, and loyalty. At the same time, AR becomes an element of strength for brand management and the organization of the entire retail structure.

Analyzing the support activities again shows a significant contribution of the technologies mentioned above.

To summarize this first step, it is essential to emphasize the strong correlation between adopting I4.0 technologies and sustainability (Varela *et al.*, 2019). I4.0 allows companies a better propensity for process sustainability, which inevitably positively affects the operating and macro environments (Laskurain-Iturbe *et al.*, 2021).

4.2 Step 2 – micro-environment

The second step focuses on the micro-environment dynamics through the operating environment analysis.

Again, the wide application and analysis of "Big Data and Analytics", "IoT," and "Cloud" is confirmed, while tools such as Cybersecurity and Additive Manufacturing emerge. The business operating environment reflects the usefulness and focuses on technologies. "Big Data and Analytics" helps support the analysis of the operating context by providing information on key stakeholders, especially suppliers, consumers, and competitors. As seen in the previous step, this analysis enables the improvement of primary activities especially.

"Big Data and Analytics" is essential to the business world. The wealth of information makes it possible to monitor not only the internal context and thus the satisfaction and working conditions of employees (Erol, 2019) but also to manage the demands and attentions arising from the operational context while trying to adapt to the changing world of work. In support of "Big Data and Analytics", "AR" also contributes. "AR" supports the construction of an appropriate work environment that improves and protects employees' health and performance (Kamble *et al.*, 2020), supporting training and growth while reducing stress (Uva *et al.*, 2018). This focus and support provided by enabling technologies are especially evident in the context of manufacturing firms (Devi *et al.*, 2021; Kumar *et al.*, 2023). This focus on well-being and human values is today firmly taken up not only by companies but especially by policymakers (e.g. the European Union) to initiate the transition process to Industry 5.0, which is understood as an industry that focuses not only on efficiency and productivity but includes human values and vital societal needs (Longo *et al.*, 2020).

Another relevant topic in the literature is the supply chain. As the model shows, "IoT" and "Big Data and Analytics" help provide opportunities to meet customer needs and contribute to the development of supply chain management (Witkowski, 2017; da Silva *et al.*, 2023; Schmidt *et al.*, 2023), and other technologies also come alongside. "Blockchain" is a critical technology in supply chain management, especially for agribusinesses, and improves traceability, trust, and accountability (i.e. Vu *et al.*, 2021; Kayikci *et al.*, 2022).

Also of interest is the focus on competitors. Here again, "Big Data and Analytics", "Cloud", and "IoT" technologies help companies provide helpful information and analysis to manage and improve knowledge and impact with competing companies. These technologies enable companies to operate based on cooperation networks in the real and virtual environment, with remote partners and close and remote competitors (Adamik and Nowicki, 2019). There is an emphasis on a value co-creation approach related to collaboration for the joint development and application of I4.0 technologies with competitors. Furthermore, from the study of competitors, many authors focus on achieving a competitive advantage in the I4.0 scenario (Ding *et al.*, 2023; Mefi and Asoba, 2020). The analysis of competitive advantage through I4.0 and its tools see the joint study of all actors in the external context, starting from the search for critical competencies in workers helpful to preside over enabling technologies (García-Pérez *et al.*, 2021) to redefine the relationship with the consumer, passing through the redefinition of the supply chain and a new approach with competitors, also to value co-creation.

Finally, in finance, it is crucial to consider the impacts of "IoT" and especially "Cybersecurity". This support is explicit regarding the security and reliability of financial management, with a positive impact on the consumer and suppliers (Nazarov and Klarin, 2020).

In brief, the first two steps of the model show the contribution of enabling technologies to create a synergy between the internal business environment and the microenvironment, highlighting reflections and concatenations of results from the inside to the outside and vice versa. Thus, various areas and directions in and out of the company environment define support.

4.3 Step 3 – macro environmental

The third step shifts the focus to the factors of the macro environment.

Again, the most recurring technologies are "IoT", "Big Data and Analytics", and "Cloud", also highlighting the importance of AR in specific areas such as demography and ethics.

The socio-cultural aspect affected and supported by new technologies is an exciting element. Technology, particularly I4.0, is often analyzed from a technical, operational perspective, while the reflections on intangible aspects not strictly related to production processes can be numerous. Focusing on workers is essential because it identifies a thread created with the previous steps and highlights the importance of including the differently abled. This aspect represents a sociocultural and ethical element. It elevates I4.0 to a level defined as "Human-Centered Production 4.0" (Rauch *et al.*, 2020) strongly linked to the Industry 5.0 topic (Enang *et al.*, 2023; Golovianko *et al.*, 2023; Konstantinidis *et al.*, 2023; Adel, 2022). Indeed, technologies offer the potential for including people with disabilities and, in any case, enable better management and attention to human resources at all organizational levels. For this reason, there is a reflection on ethics and attention to social sustainability. The focus of I4.0 and its technologies on the ethical and social aspects is a direct link between the macro environment, the microenvironment, and the internal environment of the enterprise. It projects attention to the new Industry 5.0 debate that wants to focus on the man with his well-being and values at the center of the manufacturing/production processes (Demir and Cicibaş, 2019).

The focus on social sustainability emphasizes the study of innovations and helps develop a focus on the labor market and the skills needed to master technologies. In turn, developing new skills and training paths for staff also pervades the internal context of companies by highlighting a necessary ongoing training of staff and a continuous dialogue with them to understand opportunities and inconveniences/threats arising from using technologies.

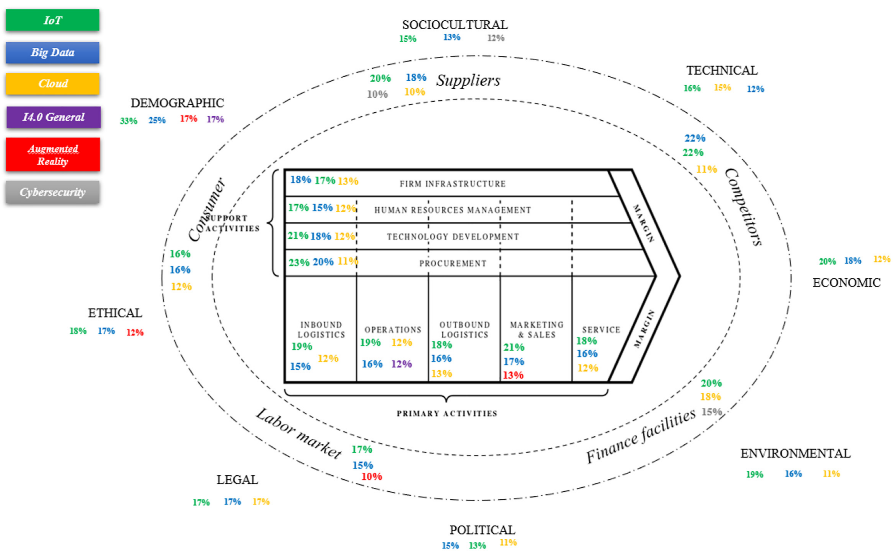
Indeed, Fernández *et al.* (2021) bring I4.0 and its analysis into an ethical and social dimension by highlighting the necessary technological and digital transition while emphasizing the necessary attention to social, human, and ethical values for a proper human-machine integration functional to the success of businesses. Training and enhancing competencies and skills are essential to achieve this objective (Santos *et al.*, 2021).

The remaining factors in the macro environment represent technical elements related to developing and introducing I4.0. In this case, they are factors from outside to inside the company that determine pressures and create opportunities for the development and transition to new technologies. For instance, critical factors that induce firms to adopt technologies include technical, economic, legal, and political factors (Hoyer *et al.*, 2020). The impetus dictated by, for example, political support or economic incentive (Muller *et al.*, 2019) or adaptation to the external technical environment are relevant elements and create inward pressure on firms (Szymańska *et al.*, 2018). Of course, it is essential to consider that these factors cannot be generalized and highly depend on the countries' relevant economic and technological environments worldwide (Melnyk *et al.*, 2019). Simply, we must think about the different levels of technological development of the Internet in different contexts and from the contribution of, for example, 5G to the optimal use of enabling technologies (Attaran and Attaran, 2020). In addition, the issue of security and privacy is considered legal aspects. The significant amount of data companies collect and reprocess with enabling technologies requires constant adaptation of regulations on the security and protection of subjects, especially consumers, whether B2C or B2B (Ogbuke *et al.*, 2022).

In summary, this third step of the model induces reflection on how the considerations made in the first two steps are closely related to the macro environment. I4.0 and its introduction in companies receive a strong incentive push from the macro environment in some of its factors. The technical environment triggers the virtuous mechanism. The more companies receive a push from outside to raise their technological level, the more the external environment (macro and micro) is positively affected and increases its potential and growth. Figure 3 shows the synthesis of the three steps of analysis previously described.

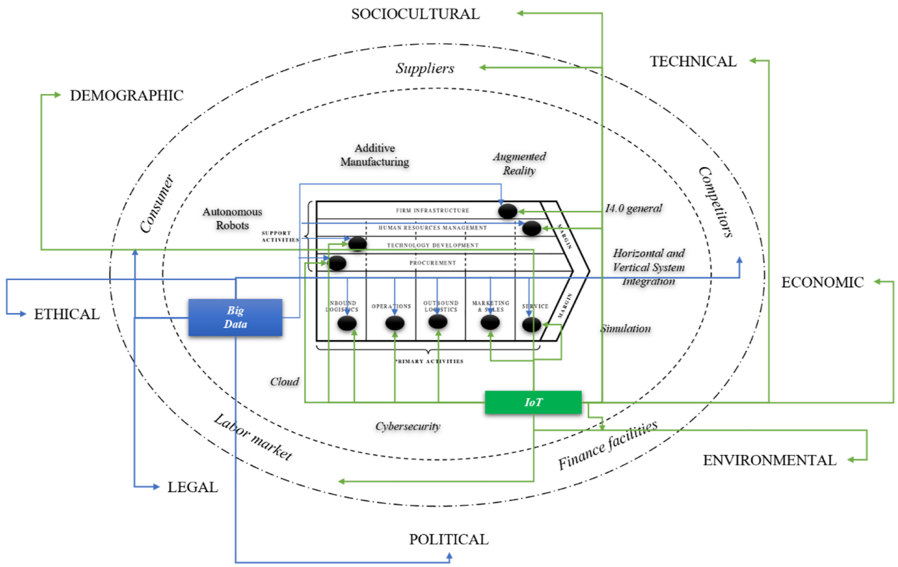
4.4 Step 4 - final model

The final step involves aggregating the previous analyses to highlight the treated topic synergistically and systemically (Figure 4). Only the first three enabling technologies applied



Source(s): Our elaboration

Figure 3.
Synthesis of the three steps of analysis



Source(s): Authors elaboration

Figure 4.
Final model – overview of I4.0 and macro/micro/internal environmental

to the enabling results of the analysis constitute the final model. The arrows indicate the link highlighted in the results between the leading enabling technologies of Industry 4.0 and the aspects characterizing the internal and external environment.

In summary, the technologies that have the most application and interest from researchers are "Big Data" and "IoT". Both technologies significantly contribute to the company's primary and secondary activities. IoT focuses on the operational environment, significantly contributing to the definition of the supply chain and improving companies' functional and business capabilities (Ghadge *et al.*, 2020).

At the same time, it does not neglect attention to human resources by contributing to developing a labor market that is in line with the principles of ethics and sociocultural respect. The influence of the ethical aspect is vital and contributes to better human-machine integration, making the transition to I4.0 consistent with the dynamics of sustainable market development (Berawi, 2019).

"Big Data and Analytics", on the other hand, also supports primary and secondary activities focusing on manufacturing and input and output contributions. Inbound information helps to deepen and monitor consumer preferences and behavior. On the output side, "Big Data and Analytics" support products and services that are qualitatively more relevant to market demands. In addition, such technology enables continuous monitoring of competitors, again improving the overall market and competitiveness. In addition to the purely technical aspects, big data supports the attention to human resources, which is an ethical factor in their training and protection.

The strong and combined focus of the analyzed research on factors such as economic, sociocultural, environmental, and ethics through I4.0 allows us to understand how fundamental the role of sustainability is in such a scenario (Bonilla *et al.*, 2018; Dionisio *et al.*, 2023). I4.0 and its enabling technologies arise in a context where the three pillars of sustainability are established and inescapable, and this, compared to even previous industrial revolutions, allows us to appreciate a new face of technology, that is, one aimed at supporting businesses but at the same time strengthening and meeting the challenge of sustainable development (Piccarozzi *et al.*, 2022). At the same time, the interaction between the various factors and the impact in terms of sustainability is studied a lot in academia, and consequently, there are no concrete parameters that can specify the positive correlation between I4.0 and sustainability (Oláh *et al.*, 2020; Stefanini and Vignali, 2023).

In conclusion, the interaction between the three contexts (internal, micro, and macro) emerges from this aggregate model in various directions to support and incentivize the adoption of I4.0 and its technologies. Some signals come directly from the external context, from the macro environment, and push (especially in the post-pandemic international political and legal environment) companies to invest in innovation. On the other hand, the companies themselves, with improvements in operations, processes, and management in general, induce the internal and microenvironment and, subsequently, the macro environment to evolve even more, seeking to provide new incentives and push for innovation. As pointed out in the previous stage of the model, it is crucial for a complete understanding to identify the differences in the various countries to understand the different focus on the macro environment factors. Different political, economic, and legal approaches and a different underlying technological environment can profoundly alter the dynamics of model interaction across stages in different directions.

5. Conclusions

What emerges from the literature analysis and its translation into the proposed model is that I4.0 represents, with its enabling technologies, a wave of revolution in the entire economic system. The changes primarily pervade business management and processes, but they highlight a driving force that also branches out to the external environment, both micro and macro. The applications and benefits derived from the various enabling technologies analyzed by the researchers are numerous and contribute to improving productivity, skills, customer relations, suppliers, and the entire community understood ethically and culturally. "IoT", "Big Data and Analytics", and "Cloud" seem to be the leading promoters of such a revolution from both a technical and social perspective. Some authors have used the term "BIC" to indicate the three technologies (Chai *et al.*, 2021; Manimuthu *et al.*, 2021). The negative connotation often associated with industrial revolutions regarding their impact on humans seems unrelated to I4.0. Indeed, Szabó-Szentgróti *et al.* (2021) affirm that I 4.0 opens many opportunities for a more humane life. From an economic point of view, digitization will become an inescapable element of competition by reducing marginal costs. An orientation and centrality of man versus machine persists and is strongly supported (Rauch *et al.*, 2020). The machine becomes a means to meet both productive and social, cultural, and ethical goals of effectiveness and efficiency. The proposed model intends to lay the foundations for developing synergy between the three levels, to varying degrees, but simultaneously in the context of I4.0. As the operational arm, the enabling technologies help to hold together and reconcile purely organizational needs with those of the external context and society, first and foremost, sustainability. A synthesized and encompassing model is crucial when practice and literature focus on an even more advanced model of the Industrial Revolution called Industry 5.0 (Nahavandi, 2019). Indeed, after the entry of enabling technologies into all business environments and functions, today we are moving towards a reflection on the proper placement and function of machines and a resumption of human dominance in critical, and thinking functions "to leverage the creativity of human experts in collaboration with efficient, intelligent and accurate machines, in order to obtain resource-efficient and user-preferred manufacturing solutions compared to Industry 4.0" (Maddikunta *et al.*, 2022, p. 1). From this perspective, this model can contribute to understanding the future development and the transition to the new industrial revolution, Industry 5.0.

5.1 Theoretical and managerial implications

This work fits theoretically into the debate on I4.0 in management. The proposed model allows a broad synthesis of what has been published and analyzed to date, seeking a systemic and synergistic key that can create a link between the numerous bibliographies and synthesize in a clear vision the impacts and reflections of I4.0 primarily through the enabling technologies in an internal and external context and creates a strong starting point to launch the new Industry 5.0 scenario with the interactions, strengths and weaknesses of the previous industrial revolution in mind.

From a managerial point of view, the paper allows an overall view of the connection and interaction of business activities of I4.0 technology while matching the external context. Companies can understand what opportunities arise from enabling technologies without neglecting the joint reflections on other actors and additional opportunities that may arise in the macro environment. One can then maximize the investment in innovation by considering it in a single application in a primary or secondary activity and taking full advantage of other interactions.

The model highlights interactions with the micro and macro environment and between the various technologies adopted, often used together and in synergy. As emphasized in the model, Big Data and IoT represent the leading enabling technologies that emerged from the analysis, but Cloud also contributes in many areas. These enabling technologies can work together to support business processes internally, in specific primary and/or support functions (Figure 3) and the external context (Figure 4). IoT can generate fundamental data, which is then processed through Big Data and stored in the Cloud, guaranteeing rapid access, analysis, and use. Big Data and IoT share common goals, as they can examine inputs to show hidden correlations and unidentified patterns and expose new trends in the data. IoT collects immediate analytical data to support real-time decision-making, e.g. machine-generated data, to produce optimal performance or determine predictive maintenance. Big Data helps this function by acting as an integration solution for predictive analysis to anticipate future problems and create solutions. The Cloud, in turn, supports this reciprocity between Big Data and IoT by enabling real-time storage control and data monitoring. The benefits of this interaction are numerous: better connectivity, data flow and communication between different devices, accurate and cross-referenced analysis and data. This convergence can anchor a new range of business decision-making systems, providing input from and integrating with the internal context to create optimal solutions in both domains.

The synergy between these technologies and augmented reality also emerges in the model. Augmented reality allows greater interaction by providing information, visualizations, or instructions and integrating the real world with the digital one. This instrument, together with other technologies, allows for even greater depth in the production of data and its utilization. It also increases the personalization of the information produced (e.g. in the consumer relationship and thus in the marketing field). It supports companies in the external context and the internal context.

Finally, the large and increasingly complex amount of data these technologies produce poses a security problem. Another synergy that has emerged is cybersecurity, a fundamental tool for ensuring privacy, data security and protection from cyber threats. The connection dictated by IoT and the management of Big Data, in particular, implies a barrier that protects against intrusions and regulates the management of access to the enterprise platforms while also protecting and securing relevant data and information from the external context.

At the same time, the model draws attention to the external environment, understood as the ethical and social environment, as well as the context's legal, economic, and technological aspects. Through this aspect, companies understand how the real opportunities of these technologies are not only technical but also embedded in the sustainable growth and development process of companies, which is now essential for competitiveness.

This model suggests to companies how, when faced with a significant and challenging investment in I4.0 technologies, the efficiency and effectiveness benefits are considerable while reflecting a positive impact on the market and consumers who benefit from these savings. I4.0 also allows for a new and more fruitful approach to customers, which takes into account the influences of the macro and micro context and, above all, the company's internal environment. However, all the above is possible because of the constant focus on human resources regarding training and well-being in general. Technologies can improve employees' lives and work environments if they are correctly integrated into business processes and known by workers. In this case, staff training on the new skills required by I4.0 is indispensable (Santos *et al.*, 2021). Kannan and Garad (2021) point out that the skills required for I4.0 are technical, interpreting large amounts of data from processes to make strategic decisions, and methodological required to use data to identify the source of problems. Finally, social media must communicate across multiple locations, suppliers, and customers in a new collaborative virtual space.

This analysis also leads companies to look at I4.0 technology from a Society 5.0 perspective (Fukuyama, 2018). To exploit the opportunities of this fourth industrial revolution, it is crucial not to dwell on mere technical aspects and related benefits but to adopt a broader perspective that allows one to see the changes as a whole in the macro context in which businesses operate. Therefore, businesses must reinterpret their sustainability orientation corporate social responsibility practices and, focus on the whole community from a technological perspective and adopt I4.0 and its technologies for general well-being that starts with the activities of the business and benefits the outside and vice versa, moving towards Industry 5.0 perspective. An interesting key in this transition is the United Nations Development Goals (SDGs). Indeed, if Industry 4.0 (Dantas *et al.*, 2021) has already defined a path of innovation in the achievement of sustainability goals (e.g. Goal 7: Affordable and clean energy; Goal 8: Decent work and economic growth; Goal 9: Industry, innovation and infrastructure; Goal 12: Responsible consumption and production; Goal 13: Climate action), the new direction towards Industry 5.0 sees these goals as fundamental and central in the use of new technologies and necessarily to be achieved entirely (Zengin *et al.*, 2021). Industry 5.0 and Society 5.0 concepts can proactively support the SDGs by creating prosperity, ending poverty and protecting the planet (Shiroishi *et al.*, 2018). For instance, both Industry 5.0 and Society 5.0 will be able to emphasize implementation processes to achieve human craftsmanship and creativity. Considering the environment as the new priority for the future (Kasinathan *et al.*, 2022).

Finally, the paper can provide food for thought for institutions and policymakers to understand the scope of the innovation phenomenon in the economic system and all societal actors. These reflections can support strategic investment choices and those supporting the business world to benefit as much as possible from the innovations dictated by I4.0. Many are already moving in this direction. For example, more than ten years after introducing Industry 4.0, the European Commission has moved towards Industry 5.0 to counter emerging societal challenges (Breque *et al.*, 2021). In such a scenario, institutions, even at the level of individual regions, can use this model to understand the importance of support in terms of skills and knowledge to equip the world of work to maximize labor demand and supply.

5.2 Limitations and future research avenues

At the same time, it is essential to note that the paper has limitations.

The first limitation is the choice of the Scopus database. Although Scopus is the central reference database for research, especially in management, other databases such as Jstore, Google Scholar, or Web of Science could broaden the search. Moreover, the selection of keywords may have delimited the paper extraction by providing a broad but partial view of the literature. Indeed, the main keyword of the research was "Industry 4.0". So, this may have limited the selection of papers using synonyms or other terms to define the concept (i.e. digital transformation, the fourth industrial revolution, digitization, etc.). The selection of papers was also limited to English and international journals only. So this amplifies the scientific relevance of the selected papers while narrowing the analysis fields. Including papers in other languages, conference proceedings, chapters, or books in future research steps will help create an even broader and more detailed view.

Furthermore, the model is based on the existing literature and thus on what is most addressed by researchers. A possible generalization of the model may not be helpful or possible in different fields and sectors, so the model should be tested in specific contexts to understand its effectiveness and correspondence. Production companies orientate the final model of the analysis. In this sense, it is more difficult to read in the case of service companies. Furthermore, to simplify the analysis, the fields of observation are restricted to only the most critical aspects of the research.

Finally, the lack of an empirical test of the model is a further limitation of the paper.

Future research development may involve a comprehensive analysis of all results by trying to tie not only the enabling technologies of I4.0 but also those defined as "I4.0 general" to understand how new technologies can integrate and maximize results with older technologies (i.e. artificial intelligence). In addition, the model could be tested in different business realities to understand how size, geographic location, or industry may affect the dynamics of application and interaction of the model in its three levels. The application of the model with a methodology of multiple case studies could allow for a more in-depth investigation of the concrete and different application of technologies or Industry 4.0 in general to the company contexts analyzed, highlighting whether other enabling technologies not revealed by the research are present in practice and used to a greater extent. Such an application could refine the model by highlighting a possible difference between the theoretical model and empirical application. At the same time, different sectors and geographical contexts can bring out different and heterogeneous Industry 4.0 characteristics, highlighting more or less profound but also different applications motivated by the influence of the external context (e.g. government, policies, incentives). The size of the companies being analyzed can also change the composition of the model, which can, therefore, be adapted and reinterpreted to understand and explain not only Industry 4.0 in its overall and holistic view but also reinterpreted in a more specific and useful comparative key. Comparing applications in small, medium-sized, and large companies can allow reflections on challenges and opportunities that have been investigated in the literature but have not yet fully emerged. It can also broaden the knowledge and debate on the concrete implementation of Industry 4.0 in various contexts.

Furthermore, as emerged from the discussion, the link between Industry 4.0 and sustainability is also a critical factor in the model, which is evident in numerous links (see section 4). In a future analysis, the model can also be appropriately supplemented with the logic of the Triple Bottom line (Brundtland, 1987; Elkington, 1997) by making explicit pillars of economic, social and environmental sustainability and investigating even more in-depth tools and areas in which Industry 4.0 supports or is still lacking in achieving sustainable development goals.

This last aspect is all the more significant when the transition to the new Industry 5.0 model is underway and growing stronger (Cillo *et al.*, 2022). Indeed, given the ongoing transition to the new Industry 5.0 scenario, this model can be a starting point for budding new areas of study. It may allow a deeper analysis of the internal and external environment of the new social and technological background. Based on these considerations, it is possible to identify two main strands of research: (1) to introduce indicators into the described model capable of quantitatively measuring the impact of I4.0 enabling technologies on the studied environmental dimensions (Internal and External Environment); (2) to create a model with dimensions and indicators proper to the new Industry 5.0 paradigm and to analyze the gap with the I4.0 model (dimensions and indicators).

Not only that, the model outlined in Industry 4.0 can also be appropriately integrated in light of the new technologies emerging with Industry 5.0 (e.g. edge computing, digital twins, collaborative robots, Internet of everything) and the new opportunities arising both about the internal context and external both about sustainability and its achievement from a more markedly human-centric perspective.

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