Assessment and implementation of Industry 4.0 paradigm: research topics and trends

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Abstract: The paradigm of Industry 4.0 (I4.0) is bringing about a relevant change in worldwide companies at the organizational and technological levels in terms of operations management, development of new products and services, definition of strategic plans, introduction of new technologies, and creation of new skills. Thus, companies are called to face significant challenges and they need a concrete methodology that allows them to define their digital and technological strategy and to identify the actions and technologies necessary for the complete transformation in the I4.0 perspective. Several readiness and maturity models have been proposed in recent years, but an accurate analysis and classification of these models are not yet available. For this reason, the paper aims to summarize the body of existing scientific literature on this subject and to identify the research trends of literature concerning the assessment and implementation of the I4.0 paradigm. A Systematic Literature Review (SLR) was conducted to identify and analyse the papers proposing methods and/or tools developed to assess the I4.0 maturity level of the companies and to identify the strategy necessary for the implementation of the I4.0 paradigm. Then, the Latent Dirichlet Allocation (LDA) statistical method was used for detecting the main topics of the selected papers, in order to identify the research trends of the subject. The combined analysis of the contents of the papers and topics through the LDA method has allowed us to define nine research topics on the subject and to identify three research trends underlining the current literature gaps and research opportunities.

Keywords: industry 4.0; smart industry; maturity model; strategic roadmap, systematic literature review.

1.Background and Motivation

The Industry 4.0 paradigm is spreading rapidly in the academic and industrial contexts, attracting the interest of researchers, practitioners, and managers. This fourth industrial revolution is considered as a process that will culminate in a new conception of industry, from the development of new products and services to research and innovation to validation and production, with the lowest common denominator consisting of a high degree of automation and interconnection (Lasi et al. 2014). The definition of the "German Industry 4.0 Platform Steering Committee" considers as the most important attributes of Industry 4.0 (Rajnai and Kocsis 2018): a new level of organization and control of the entire cross-enterprise value-adding network throughout the product lifecycle, forming a real-time optimized, self-organizing system; a lifecycle that includes concept, development, production, order, shipping, recycling; the focus on personalized customer wishes; and the capability of optimizing various conditions, like cost, resource usage, availability.

The introduction of intelligent systems in production, logistics and e-business models can support this process (Modrak, Soltysova, & Poklemba, 2019). In particular, the technological basis of I4.0 is ensured by enabling technologies, cyber-physical systems (CPSs), real-time availability of all data, capacity to determine an optimized process at any time based on the information, integration of people, objects, and systems into the value chain (Rajnai and Kocsis 2018). Companies that succeed with smart factory implementation can increase value creation by lowering the costs of production, increasing quality and flexibility, and reducing the time to market. Enterprises are facing important challenges to respond to the changes implemented, both at an organizational and technological level. The development process involves the definition of strategic plans to the updating of equipment and products, the introduction of new technologies and the creation of new skills. However, being a company 4.0 means not only acquiring new technologies but activating a process of change that affects company management; means jointly pursuing objectives of flexibility, speed, productivity, quality, greater competitiveness of the products and knowing how to combine different technologies in order to integrate the factory system and the production chains involved in a connected system.

To overtake rising uncertainty and dissatisfaction in enterprises about the I4.0 concept, companies need a methodology that allows them to define their I4.0 digital and technological strategy and to identify the actions and technologies necessary for the implementation of I4.0 paradigm. Companies need to identify their strengths and weaknesses to understand what to do to improve their current situation. It is essential to assess the level of digital maturity and implementation of paradigm I4.0 in the company and to be able to define and plan improvement interventions and to build a framework to assess the industry 4.0 maturity of each manufacturer.

For the assessment process, maturity models are a useful way to evaluate the maturity levels of the organizations. Maturity can be defined as "the state of being complete,

perfect or ready" (Simpson and Weiner 1989), and this concept is not new in the industrial engineering and management field (Oleśków-Szłapka and Stachowiak 2019). Maturity models have been designed to assess the maturity of a selected domain based on a comprehensive set of criteria. These models have spread in several domains since the concept of measuring maturity was introduced with the Capability Maturity Model from the Software Engineering Institute. Some examples of existing management models are: Capability Maturity Model Integration, Enterprise Architecture Maturity Model, European Foundation for Quality Management Excellence Model, Process Maturity Model, Project Management Maturity Model (Lasrado, et al. 2015).

With the development of the I4.0 paradigm, these models began to focus on this aspect as well, developing different approaches to evaluate the digital maturity of companies and define strategies and roadmaps to guide companies in the implementation of this paradigm. Companies can use the results of their self-assessment as a starting point for the implementation of the various strategic measures. The assessment is a survey methodology useful for investigating, through the analysis of internal processes, the state of I4.0 maturity and its ability to implement enabling technologies and organizational innovations to modify and make efficient its business model. The models and methodologies developed allow entrepreneurs to: evaluate where they are in their transformation path in the I4.0 perspective; create objectives and action plans in the short, medium and long term; make investments for large-scale transformation projects.

Several digital maturity models have been published in recent years, but a precise analysis and classification of the models available to the companies, according to the different needs, dimensions, types of technologies to be implemented, is not yet available. For these reasons, this paper aims to summarize the body of existing scientific literature on this topic, to analyse the conceptual content of the field, to identify the patterns and research trends and evaluate the strengths and weaknesses of selected literature. In this study, a Systematic Literature Review (SLR) on models and approaches developed to assess the readiness and maturity level of the industry about the paradigm 4.0 was conducted to identify and select peer-reviewed papers, that are focused on this topic. Then, the Latent Dirichlet Allocation (LDA) model was used for topic analysis in order to address two research questions: 1) which are the methodologies mainly applied for I4.0 assessment and implementation, and 2) which are the research trends on this subject.

The paper is organized as follows. Section 2 presents the SLR research method and the topic model analysis conducted, Section 3 shows the main results, and Section 4 provides a discussion about the results and summarizes the main research opportunities and conclusions.

2. Research design

2.1 Systematic literature review

In this paper, a SRL, following a clearly defined, rigorous, and reliable approach that allows presenting objective and reproducible results, was conducted (Di Pasquale et al. 2017, 2018; Franciosi et al., 2018). The main purpose was to identify and select papers that presented methodologies and/or tools developed for defining I4.0 digital and technological maturity level, identifying their strengths and weaknesses, the actions and technologies necessary for the complete implementation of I4.0 paradigm. The literature search consisted of the following steps: 1) identification of the research databases; 2) definition of relevant keywords; 3) search of scientific articles in selected databases; 4) definition of criteria for paper selection; 5) selection of relevant papers; 6) snowball strategy searches; 7) analysis of selected papers and data extraction.

The systematic searches were conducted using two scientific databases (Scopus and Web of Science). Preliminary search terms were developed by the research team to reflect the core concepts of relevance. Two sets of specific keywords were defined: Set A identifying tools and methodologies for assessment and implementation of I4.0 paradigm (maturity, readiness, roadmap, digital transformation) and Set B concerning the fourth industrial revolution and enabling technologies (Industry 4.0, Industrie 4.0, Smart Manufacturing, Advanced Manufacturing Solution, Additive Manufacturing, Augmented Reality, Simulation, Horizontal/Vertical Integration, Industrial Internet, Cloud, Cybersecurity, Big Data, and Analytics). The final keywords list used to search consists of all possible combinations of keywords from all Groups A and B using the Boolean "AND" operator (e.g. maturity AND industry 4.0), with the "OR" operator used within each group. For a paper to be included in the sample of identified papers, it was required to have at least one combined term from the final keywords list in its title, abstract and keywords. As search restrictions, the review was limited to articles published in English from 2013 in peer-reviewed scientific journals or conferences, and with available full-text. The search took place in October 2019.

After the search of scientific articles in selected databases, the exclusion criteria for screening paper were defined as follows: assessment and implementation are a secondary aspect than the main purpose of the paper; I4.0 is not the main context and, articles are not related to the industrial world. The selection screening was divided into two different steps. The first selection step involved the reading of the title, abstract and keywords. The second step included the reading of the full text of the papers which were selected in the previous stage and a definitive assessment based on the exclusion criteria. Citations and references from qualifying articles were examined in a "snowball" approach to identify other papers that may not have been identified by the literature search. A data extraction spreadsheet was developed to extract, structure and store the information and to facilitate data analysis from eligible studies.

2.2 Content and topic analysis

The analysis of selected papers was structured in several stages. In the first phase the articles were analysed concerning the following characteristics: publishing type (Journal, Conference or others); year of publication;

company size; single company or supply chain; main goals and outcomes of the papers; type of applied method (assessment, implementation or both); enabling technologies covered by the paper; and, if present, applications of the model. If the papers concern maturity models with the structure of the capability maturity model, about them are specified: the areas/dimensions of analysis, and the maturity levels. Based on these analysis criteria, all the pertinent information presented in the papers were extracted and used to build summary tables to enable evidence synthesis and to evaluate the methods used to assess the level of I4.0 digitalization.

Furthermore, the Latent Dirichlet Allocation (LDA) was used for topic analysis. LDA is a generative probabilistic model for collections of discrete data developed by Blei, Ng, and Jordan (2003). It is a three-level hierarchical Bayesian model in which each document is considered as a random mixture of an underlying set of topics, and each topic is characterized by a probability distribution over words. In the context of text modelling, the topic probabilities provide an explicit representation of a paper. LDA is a "bag-of-words" model, meaning that the order of words in a document is neglected. The main outputs of the LDA model are the document-topic distribution and the topic-word distribution. It is a topic model that discovers underlying topics in a collection of documents and infers word probabilities in topics. For the aim of this study, LDA was applied using Matlab® (R2017b). In a first step, a text file, containing the words of all the selected papers through the SLR was created. This file was uploaded in Matlab® for subsequent analysis steps: preparation of text; creation of a "Bag of Words"; application of LDA through the fitLDA function; identification of topic; and representation of word cloud. This process allowed us to obtain the research topics as word clouds, which is a novelty visual representation of text data, typically used to depict keyword metadata on websites. Each word cloud was analysed, to provide a description of each topic, identifying the relationship between the different words that make up the cloud, depending on their size and colour.

3. Results

The total number of studies resulted from the database search was 2964 papers, which only remains 2784 after removing all the duplicates. After the first screening process, 373 articles were identified as relevant but only 55 papers were selected after the second screening. 12 more articles were identified from the snowball search resulting in a final set of 67 studies. In Table 1, all the papers that have been selected and analysed are listed, and the full list of references is reported in Appendix A. 43% of the selected papers (29 papers) are published in journals and a similar number (30 papers, 45%) are conference proceedings, 7 papers (about 11%) are reports and only 1 paper (about 2%) is a book chapter.

Figure 1 shows the number of papers published each year. The publication frequency distribution over the years underlines the recent and growing attention on the topic by researchers. In particular, 34 papers (51%) were published in 2018 and 2019. Most of the selected papers (45 papers, 67%) were developed for general industrial sectors. The remaining were proposed for specific sectors, particularly manufacturing (16 papers, 27%) and other sectors such as finance, defence or industrial service (4 papers, 6%). Regarding the company size, most of the selected papers do not specify the size of the company, only 9 paper (about 13%) is for small and medium enterprises (IDs 3, 6, 8, 11, 26, 31, 33, 34, 54). Five of these (IDs 6, 8, 31, 34, 54) proposed a maturity model for SMEs. For example, paper 34, proposes "a new Smart Manufacturing Maturity Model for small and medium-sized Enterprises (SM3E)" because according to the authors, the most popular maturity models in the literature do not sufficiently reflect the SME perspective and their unique requirements when it comes to adopting the I4.0 paradigm. All papers, except ID 9, assess the level of maturity 4.0 or implementation of enabling technologies within a single company.

3.1 Content analysis results

Table 1 shows the main results of the content analysis performed. Each paper is classified in terms of type of model proposed (assessment 4.0, implementation 4.0, or both), enabling technologies involving in the evaluation (single or multiple) and the type of application (theoretical model, tool, applied tool). Table 1 reports also the type of model developed or applied in the papers. Most of them (33 papers, 49%) proposed an assessment model for the I4.0 level. In particular, 6 papers were a review of the assessment models and one paper was a review on assessment and improvement models. Only 3 papers (5%) developed a model for the implementation of the I4.0 paradigm. The other 24 papers considered the combined problem of assessment and implementation. Content analysis showed that 15 papers (22%) dealt with one specific enabling technology whereas the others covered a range or all the enabling technologies. Then, 45 papers (67%) presented an applicable tool, but only 19 of these showed the results of the model's applications in a specific case study. Instead, 15 papers (22%) presented theoretical models, which subsequently can be transformed into applicable tools.

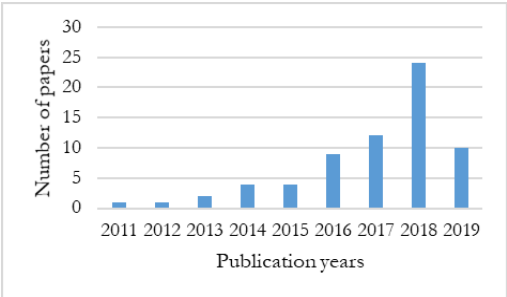

Figure 1: Number of papers published since 2011.

Crossing the extracted information, as reported in Table 2, there is a prevalence of models developed only for assessment (A), which have a very generalist nature and they are suitable for every type of company both in terms of size and sector. There are few models developed for specific targets such as SMEs or well-defined sectors, as highlighted above. Considering the models developed

Table 1. Main features of the selected papers.

ID	MODEL		ENABLING TECHNOLOGIES		APPLICATION		
	ASSESSMENT	IMPLEMENTATION	SINGLE	MULTI	MODEL	TOOL	APPLIED TOOL
1	✓ Maturity model	✓ Recommended activities		✓			✓
2	✓ Review			✓	✓		
3	✓ Review			✓	✓		
4	✓			✓			✓
5	✓ Maturity model	✓ Improvement plans		✓			✓
6	✓ Maturity model	✓ Roadmap		✓			✓
7	✓			✓	✓		
8	✓ Maturity model			✓			✓
9	✓ Maturity model	✓ Roadmap		✓		✓	
10	✓ Maturity model	✓ Roadmap		✓	✓		
11	✓ Review	✓ Review		✓	✓		
12	✓ Maturity model	✓ Gap analysis and roadmap		✓		✓	
13	✓ Review			✓	✓		
14		✓ Roadmap		✓			✓
15	✓ Maturity model			✓			✓
16	✓ Maturity model			✓			✓
17	✓ Maturity model		✓ VR and AR				✓
18	✓ Maturity model			✓		✓	
19	✓ Maturity model			✓	✓		
20	✓ Maturity model	✓ Roadmap		✓			✓
21	✓ Maturity model	✓ Roadmap		✓			✓
22	✓ Maturity model			✓	✓		
23	✓ Review			✓	✓		
24	✓ Maturity model	✓ Roadmap		✓		✓	
25	✓ Maturity model			✓			✓
26	✓ Review			✓	✓		
27	✓ Maturity model	✓ Improvement plans		✓		✓	
28	✓			✓			✓
29	✓ Maturity model	✓ Roadmap		✓			✓
30	✓ Maturity model			✓		✓	
31	✓ Maturity model			✓			✓
32		✓ Roadmap		✓	✓		
33	✓			✓		✓	
34	✓ Maturity model			✓	✓		
35	✓ Maturity model			✓		✓	
36	✓ Maturity model	✓ Roadmap		✓		✓	
37	✓ Maturity model	✓ Recommended activities		✓		✓	
38	✓ Maturity model			✓		✓	
39	✓ Maturity model		✓ Cloud			✓	
40	✓ Review		✓ Cybersecurity		✓		
41	✓ Maturity model			✓	✓		
42	✓ Maturity model	✓ Recommended activities	✓Cloud			✓	
43	✓ Maturity model			✓	✓		
44	✓ Maturity model			✓		✓	
45	✓ Maturity model	✓ Recommended activities	✓IT system				✓
46	✓ Maturity model	✓ Recommended activities	✓ Cybersecurity		✓		
47	✓ Maturity model			✓			✓
48	✓ Maturity model	✓ Gap analysis and roadmap		✓		✓	
49	✓ Maturity model	✓ Improvement plans		✓		✓	
50	✓ Maturity model	✓ Roadmap		✓			✓
51	✓ Maturity model			✓		✓	
52	✓ Maturity model	✓ Recommended activities		✓		✓	
53		✓ Roadmap		✓	✓		
54	✓ Maturity model	✓ Roadmap		✓		✓	
55	✓			✓	✓		
56	✓ Maturity model			✓		✓	
57	✓ Maturity model		✓ Cloud			✓	

ID	MODEL		ENABLING TECHNOLOGIES		APPLICATION		
	ASSESSMENT	IMPLEMENTATION	SINGLE	MULTI	MODEL	TOOL	APPLIED TOOL
58	✓		✓ Cloud		✓		
59	✓ Maturity model	✓ Improvement plans		✓			✓
60	✓	✓ Recommended activities	✓ Cloud			✓	
61	✓ Maturity model		✓ Cybersecurity			✓	
62	✓ Maturity model		✓ IT system			✓	
63	✓ Maturity model		✓ Cloud				✓
64	✓ Maturity model	✓ Improvement plans	✓ Cybersecurity			✓	
65	✓ Maturity model		✓ Simulation		✓		
66	✓ Maturity model		✓Cloud			✓	
67	✓ Maturity model			✓	✓		

only for the implementation (I) of the I4.0 paradigm, the number of models developed drops dramatically. Whereas the papers that developed an assessment model (33 papers that proposed only an assessment method and 24 papers that considered the combined problem), they were classified in maturity models (50 papers, 75% of all the selected papers) or other models (7 papers, 10% of all the selected papers). Many different maturity models were proposed in literature but only 4 were presented in more than one paper. In particular, DREAMY (Digital REadiness Assessment MaturitY model); SIMMI 4.0, Acatech Industrie 4.0 Maturity Index, IMPULS - Industrie 4.0-Readiness resulted as the most used approaches.

Focusing on the papers which provide models also for the implementation and evolution of the Industry 4.0 level, four main types were identified:

a) strategic roadmap, that is a schedule that supporting a company to communicate respective objectives and take concrete courses of action. 13 papers (19%) introduced a roadmap for the I4.0 improvement;
b) recommended activities that are offered, to move from one level to the next, after identifying maturity levels;
c) improvements plans/actions, in which the evaluation result is used to develop an improvement plan/ action;
d) gap analysis and roadmap, that, before realizing a roadmap for the development of the identified capabilities, highlights the gap between the current situation and the expected one.

3.2 Topic analysis results

LDA Matlab functions were applied in this study to identify the main topics covered by the papers.

Table 2: Number of papers for each category analysed.

		A	I	A/I	TOTAL
Any Company Size	Theoretical instrument	10	2	2	14
	Tool	12		12	24
	Applied Tool	7	1	8	16
	Review	4			4
SMEs	Theoretical instrument	1			1
	Tool	1		1	2
	Applied Tool	2		1	3
	Review	2		1	3
	TOTAL	**39**	**3**	**25**	**67**

A= assessment, I= implementation, A/I= assessment and implementation

The text of the 67 papers was extracted and organized in a file text for Matlab. A bagOfWords, which is a sparse vector of occurrences of the dictionary of local characteristics of the image, was obtained with 227 words. Considering the speed of resolution and the error percentage of LDA algorithm used, the number of topics, which best represented the dataset, was chosen equal to nine. The topics-words distribution is presented as word clouds (Figure 2). Considering that the size of each word within the cloud is proportional to its probability and importance; the word clouds were analyzed and exploded to highlight the different concepts that constitute the topic and how each of them fits into the Assessment and Implementation methodologies. The combined analysis of the paper's contents and topic contents allowed us to identifies the key argument for each topic, as reported in Table 3.

Table 3: Key concepts on assessment and implementation of I4.0 paradigm.

TOPICS	DESCRIPTION
1 Cyber-security	Several models for assessment and implementation were specifically developed for cybersecurity, one of the enabling technologies of Industry 4.0.
2 Data	The processing, analysis, and use of data is a key element for the real-time and integrated management of I4.0 production systems, and it is one of the key aspects for assessing and implementing the I4.0 paradigm.
3 Maturity levels of Industry 4.0	This topic highlights the need for companies to identify their digital I4.0 maturity level through the application of different models. Besides, it emerges as many of the models analyzed in this work address SMEs.
4 Maturity model	Maturity models are the most used for the evaluation and improvement of the current state of the organization. They follow a methodology of analysis by areas or dimensions and allow a classification of the companies based on the maturity level.
5 Digital Transfor-mation Process	The digital transformation underpins the I4.0 paradigm, and for this reason, it represents one of the main topics that cover many papers. It is based on the combination of traditional processes

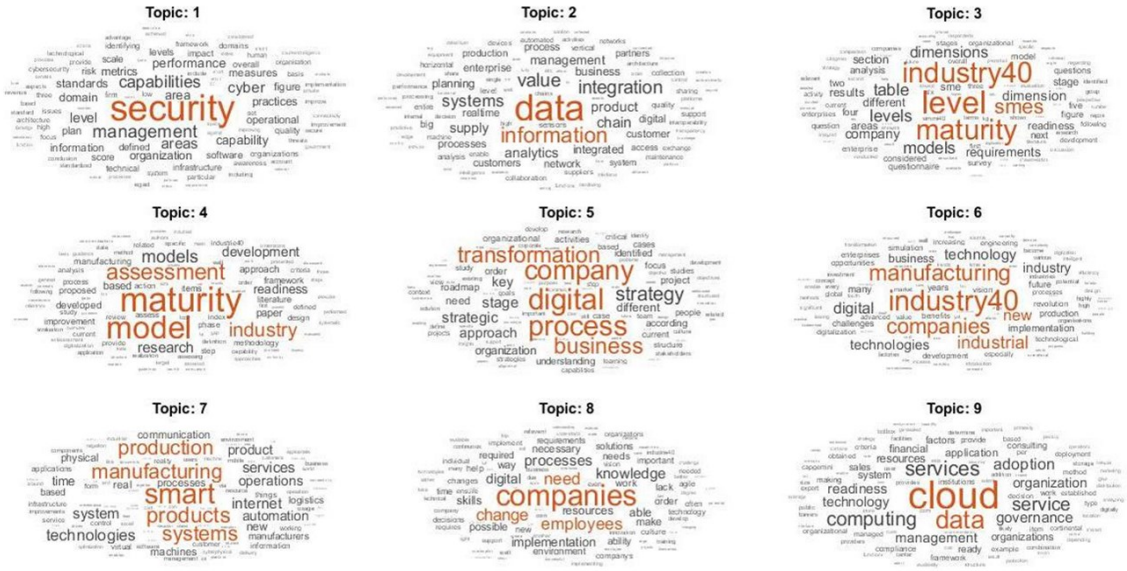

Figure 2: Identified Topics through LDA approach.

TOPICS	DESCRIPTION
	enhanced with new digital technologies and it is one of the main aspects analyzed to evaluate the I4.0 maturity level. It allows reorganizing the entire business process and strategy, favoring significant improvements in industry performance.
6 Industry 4.0 Paradigm	This topic concerns the general concept of Industry 4.0, as a transformation process that involves industrial companies through the development and implementation of new digital and advanced technologies.
7 Smart	"Smart" is another key aspect for assessing and implementing the Industry 4.0 paradigm, which indeed involves smart production processes, smart systems, smart products, smart services, smart operations, smart technologies and machines, smart operators.
8 New needs of companies	It focuses on the identification of needs, lacks, and opportunities for the companies. The gaps to overwhelm concern resources, skills, technologies, knowledge, processes, abilities. This step follows the implementation of an assessment process: the results of this phase make it possible to do a series of considerations to identify the changes to be made, depending on the level reached.
9 Cloud	This topic concerns one of the enabling technologies of Industry 4.0, which is Cloud. This is justified both by the fact that it is one of the main and most important enabling technologies of industry 4.0 and by the fact that many articles deal with this technology, offering models that focus on assessing the company's maturity level related to the use of such technology.

4. Discussion and conclusions

The SLR was conducted to review the body of scientific literature on assessment and implementation of industry 4.0 paradigm, 67 articles were selected and analysed to identify the current state of the art and the main research trends addressed so far. The interest in this subject is increasing in recent years, parallel to the growth and spread of the industry 4.0 paradigm. When the concept of smart factories, enabling technologies, CPSs have emerged and formalized both at the academic and industrial levels, the need for tools capable of supporting companies in this transformation has also grown. However, a clear and univocal definition of the I4.0 concept in literature is not yet present, and this uncertainty is influencing the development of the models for assessing and implementing the I4.0 paradigm.

The combined analysis of papers' contents and topics through the LDA method has allowed us to identify the three research trends on the subject, several literature gaps, and research opportunities. The three research trends are: 1) Digital and smart transformation (topics 5, 6, 7 and 8), highlighting two aspects that characterize industry 4.0; 2) Assessment models (topics 3 and 4), a trend that concerns the development of methods, with a particular focus on the maturity models, representing the main models developed to achieve this goal; 3) Enabling technologies (topics 1, 2 and 9), representing some enabling technologies that were evident from the analysis of the topics. Only two technologies (cybersecurity and cloud) were predominant in the analysis of the topics, and ad-hoc models were developed for them.

The identified trends present an overview of this scientific subject. However, the results highlighted several gaps. First, many of the key aspects of I4.0 are not evident in the literature because the problem of digitalization is always emphasized, and because not all technologies are investigated. Indeed, topic 5 highlights the need for manufacturing companies to evolve concerning the

improvement of digital processes, which however are not the true cornerstone of I4.0. This represents one of the first identified gaps. The models are still many connected to the models for digitalization, and it is also evident from the lack of in-depth analysis of the cyber-physical systems and enabling technologies. In particular, ad-hoc models have been developed concerning technologies only for some of them, while others are still little investigated and studied in depth. Considering the research trend focused on maturity models and the number of assessment tools proposed in the literature, few papers presented industrial and practical applications and the assessment procedure seems to be not consolidated. Indeed, several models were proposed but few are consolidated for assessment in real practice, and there are no recognized standards yet. Furthermore, the situation is quite confusing about areas and dimensions of the analysis because their terms are not used in a unique way, as well as sub-areas and sub-dimensions and domains, and about maturity levels, that are defined using different and heterogeneous scales, which can be numeric (when identified by an increasing number), descriptive (when identified by a descriptor), or both. Moreover, the identified topics are strongly linked to the assessment phase rather than to the implementation one, underlining an aspect already highlighted by the analysis of the topics. Few papers focused on models or tools for the implementation of the I4.0 paradigm, which is not a well-defined process yet, as well as the researchers did not investigate how companies are addressing the implementation of new technologies and production processes in I4.0 perspective. The recommended actions or the proposed strategic maps are often generic and not focused on different sectors, company dimensions, and strategic objectives of the company. Finally, some aspects are scarcely analysed, such as the role of human resources and the necessary skills in the new configuration of the company, which instead are an important issue of I4.0. Enterprises expect more productivity and opportunities for optimized performance by increasing the use and integration of innovative technologies. But – it's not only about intelligent algorithms and autonomous systems, but also about employees' autonomy. The evaluation and/or integration of human resources assessment was not deeply investigated in the current literature.

The identified gaps highlight the different open research questions and future research opportunities: 1) the development of consolidated models for assessment and implementation with greater integration of CPSs and enabling technologies; 2) the need of a benchmark and comparative analysis among different methods to identify their strength and weakness and field of applications and to provide a Decision Support System to choose the more suitable method for each company; 3) major focus on human resources necessary for the implementation of I4.0 paradigm; and finally 4) the development of decision-making models to choose the strategic and technological roadmap to achieve the business I4.0 goals.

The research trends identified in this paper allowed us to outline which methods and tools are currently being developed to support companies for defining their I4.0 digital and technological strategy and the actions and technologies necessary for the complete transformation I4.0. This paper, therefore, contributes to transfer the knowledge about assessment and implementation of I4.0 paradigm, providing practitioners and researchers with a comprehensive and helpful overview of this topic and several research opportunities for future studies.

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APPENDIX A. List of selected papers.

Appendix A can be accessed at:
https://drive.google.com/drive/folders/1d4G98msfvgSLIk0umya4NWzCVQFr8zAB?usp=sharing