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CIRCULAR ECONOMY MODELS IN THE INDUSTRY 4.0 ERA: A REVIEW OF THE LAST DECADE

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Abstract

The purpose of this document is to analyze and review the scientific literature relating to the circular economy model with an Industry 4.0 perspective (CE-I4.0) and its technologies implemented in the industry.

Advanced and digital production technologies can unlock the circularity of resources within organizations. A review of the academic literature on the connection between CE and Industry 4.0 helps to understand how the different Industry 4.0 technologies could support circular economy strategies, as a basis for the decision-making process of sustainable operations management. To this aim, different types of studies have been collected, dividing theoretical studies from technical-application case studies.

Keywords: I4.0; Smart Manufacturing; Circular Economy; Green Economy; Sustainability; Case Study.

1. Introduction

With reference to the definition given by the *Ellen MacArthur Foundation*, the Circular Economy (CE) is an economy designed to be self-regenerating, that is to say a planned economic system to reuse materials in successive production cycles, reducing waste to the minimum. Therefore, it is an economy in which someone's waste becomes the resource for someone else. In a business environment, for example, waste products can become useful to other companies in the supply chain. In some cases, they can even be reintegrated into the production cycle.

The CE, in this sense, offers a new perspective of production and consumption systems, focusing on restoring the value of the resources used. The adoption of the CE means proposing an approach to energy and materials that brings economic, environmental and social benefits [1] to organizations when they replace the linear economy, based to "take", "fabricate", "use" and "dispose", with the CE [2]. In other words, this new entrepreneurial mentality is able to help organizations and society move towards sustainable development [3]. Nevertheless, the full adoption of CE principles within organizations and supply chains encounters obstacles, identified above all with the lack of advanced technologies [4,5,6]. However, today the model development based on these new business models is also linked to the Industry 4.0 (I4.0)

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paradigm [7]. Thanks to ability increasing to interconnect and make productive resources cooperate, the fourth industrial revolution can increase competitiveness and efficiency, as well to promote the introduction of new business models [7,8,9]. In other words, I4.0 is able to change the industrial sector and the mechanisms to produce value, innovation, employment and well-being.

The overall aim of this study is to categorize the recent literature, examine the state-of-the-art CE models and highlight the key benefits of I4.0 technologies.

The remainder of this article is organized as follows. Section 2 describes the research methodology adopted for the literature review. Section 3 details the research activities to create the documents sample to review. Section 4 presents information about the sample analysed.

Nomenclature

CE	Circular Economy
I4.0	Industry 4.0
SLR	Sistematic Literature Review
KET	Key Enabling Tecnologies

2. Systematic Literature review

In this paragraph, the results of bibliometric research are disclosed and the process of sample construction is described.

Systematic Literature Review (SLR) is a well-known method that is widely used to identify, evaluate and interpret relevant parts of research for a specific issue, area or phenomena of interest [10]. The SLR aims to carry out a survey of researches with the same scopes, evaluating them critically in their methodology and bringing them together in a statistical analysis, meta-analysis, when this is possible. For the implementation of the SLR in this document, the methodology proposed was used.

2.1 Literature review planning protocol

The research criteria have to be clearly specified, with the purpose of correctly selecting the studies to be reviewed. Therefore, this paper considers the following planning protocol for the review.

Research questions

The purpose of formulating the questions is to define the objective of the survey, allowing to search for documents that have a specific topic. In particular, the research focuses on 4 questions:

- RQ#1: How much is the scientific community interested to know the potentialities that the I4.0 paradigm offers to the CE?
- RQ#2: What is the contribution that I4.0 or Key Enabling Tecnologies (KETs) provide to the CE?
- RQ#3: What are the I4.0-related practices that facilitate the transition of industry towards CE?
- RQ#4: How the I4.0 paradigm is employed in the CE model applications?

These questions help to identify the impact of I4.0 technologies on performance CE models.

Databases for literature searching

Bibliometric data was collected from three databases, i.e. Scopus, EBSCO and Google Scholar, using appropriate keywords to get the desired result, with a time horizon considered starting from 2010 to 2020.

Exclusion criteria

Documents not related to I4.0 and CE were excluded. The same applies to documents concerning subject areas not relevant to the industrial or engineering field.

Quality criterion

To have a high quality of review, the criterion chosen is based on articles that must deal the concept of I4.0 for CE, from applicative and theoretical points of view.

Data extraction fields

The objective of data extraction fields is to design data to accurately record the information obtained from research. In particular, data extraction fields concern to:

- D#1: State-of-the art on the connection between I4.0 and CE
- D#2: Descriptive or conceptual model with I4.0-CE approach
- D#3: Model in which I4.0 concept or technologies have been applied to CE

2.2 Execution

The execution phase is dedicated to the operational research and construction of the document sample. It is divided in two steps, each of which is useful for selecting the documents of interest and excluding ones that are not interesting for the purpose. First step, *"Material Collection"* is represented the primary search and is dedicated to documents collection. Second step, *"Material Selection"*, is dedicated to final sample construction At the end of this phase, the sample is classified and analyzed. With the classification, the sample is divided into three subsamples, to distinguish conceptual documents from application documents. Then, subsamples are analyzed with respect to keywords, years, countries, subject areas and authors. Figure 1 shows the research process flow.

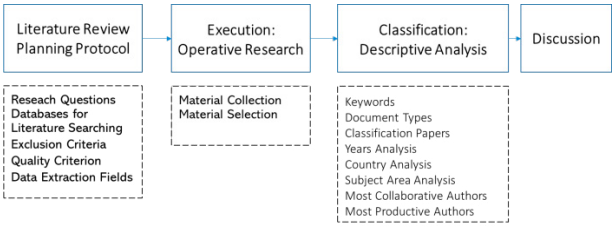


Figure 1: Research Process Flow

2.2.1 Material Collection

In this step, the databases have been consulted. Given the difference in how databases manage queries, different search methods have been used.

First of all, the keywords that could return a result consistent with the object of this study are thought. In particular, keywords chosen are:

- Industry 4.0
- Smart Manufacturing
- Circular Economy
- Green Economy
- Sustainability
- Case Study

Depending on the database, different search methods are used.

Google Scholar uses the same algorithm as Google for web search. Therefore, the advanced search was used, searching for articles starting with all the keywords, with 95 results.

Scopus and EBSCO queries are based on several keywords combinations. In Scopus, the search tips for documents are *"All fields"* in some cases and limited to the *"Article title, Abstract, Keywords"* in the others. In EBSCO, *"All fields"* is the only search tips used.

However, in both, Boolean operator *AND* is used to link keywords considered in every combination, as shown in Table 1.

The search methods, at this step, have returned a total of 1409 documents and they are distributed as follows:

- 1261 documents extracted from Scopus
- 55 documents extracted from EBSCO
- 93 documents extracted from Google Scholar

Not all of them are valid for the purposes of the study, therefore they have to be subject to a screening process.

2.2.2 Material Selection

Starting from the results obtained in the first step, the second step is dedicated to the selection of documents suitable for revision

Despite the keywords and search settings, the databases returned results that partially respected them. The most suitable solution was to read the abstracts of the documents and the keywords that the databases assign to them.

The criteria used are based on the attendance in the text of the CE models in I4.0 perspective with a sustainability point of view. In particular, the interest has been on documents that talk about how I4.0 key enabling technologies or the simple paradigm can activate CE paths. Therefore, documents that deal with I4.0 for recycling or remanufacturing processes, for processes that lengthen the useful life of an asset or service and, in general, processes that promote sustainability are accepted. In addition to conceptual and descriptive documents of applicable practices, the objective of the study also allowed to accept literature reviews and case studies.

Following these criteria, the total number has been reduced to 160:

- 107 documents selected from Scopus
- 48 documents selected from EBSCO
- 5 documents selected from Google Scholar.

These results are not the final ones yet, since the same document was returned from all the databases. Therefore, a final selection is necessary: the redundancies have been excluded and the documents destined to populate the sample have been included. Ultimately, the sample consists of 78 documents.

Table 1 summarizes the research process and the results obtained.

Table 1: Panel of the query and related results

Keywords and Results Time period: 2010 – 2020										
Source	Keywords						Research Type		Results	Selected
	I4.0	Smart Manufacturing	Circular Economy	Green Economy	Sustainability	Case Study	All Field	Article Title, Abstarct, Keywords		
Scopus	*		*		*		*		251	34
		*	*					*	20	9
		*	*		*			*	6	4
	*		*	*			*		200	24
		*	*			*	*		784	36
EBSCO	*		*	*	*		*		2	2
	*	*	*		*		*		1	1
	*	*	*				*		2	2
	*	*				*	*		3	3
	*		*				*		4	4
	*				*		*		43	36
Google Scholar	*	*	*	*	*	*	*		93	5
							Tot		1409	160
							Total without duplicates		--	78

3. Classification and Analysis

In this section the findings of the review are presented and discussed.

Firstly, an overview of the selected 78 studies is presented. Then the papers are classified in 3 subsamples according to the type of document. Finally, for each type of document the following characteristics are highlighted:

- Publication by years
- Country analysis
- Top most keywords analysis
- Research area analysis

- Most collaborative authors
- Affiliation analysis

3.1 Document types

The first classification concerns the type of documents. As it is shown in the Figure 2, most of the documents consist of articles: 53 documents, representing the 68% of the sample analyzed.

The remaining documents are 14 Conference Papers (18%), 6 Reviews (8%) and finally only one Book, one Short Survey, and one Note, which together account for 3%.

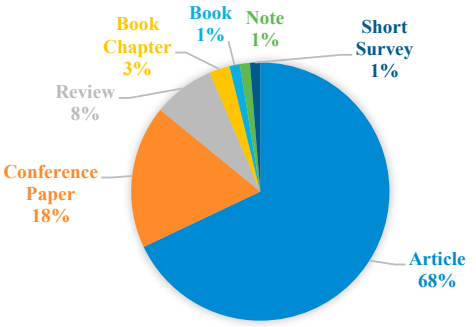


Figure 2: Document types

As shown in the Tables 2 and 3, less than half documents are in Open Access format while 4 documents are still in press.

Table 2: Access Type

Access Type	
Open Access	32
Others	46
Tot	78

Table 3: Publication stage

Publication Stage	
Final	74
Article in Press	4
Tot	78

3.2 Classification papers

The 78 documents were initially classified into the three following groups or subsamples:

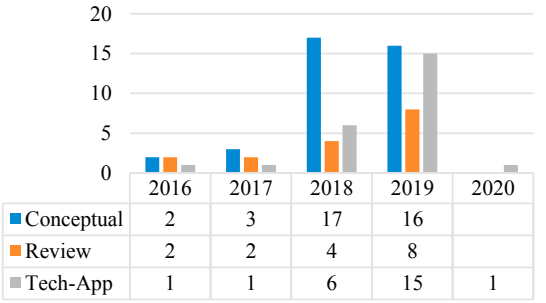
- Review papers (16), documents whose aim is to analyze and describe the existing literature. Technical-application papers (24), papers whose main focus is on the development, calibration or refinement (and possibly testing) of CE-I4.0 approach, or documents whose main focus is on the development, deployment and possibly testing of new proposed solutions.
- Conceptual papers (38), documents that do not either develop new models or apply existing system, but rather discuss some specific aspects or issues of approach CE-I4.0.
- In the following subparagraphs these different groups of papers are analyzed with respect to the years of publication, geographical origin of the study, keywords, subject area, most collaborative authors and most productive authors.

1.3 Publication by Years

The analysis of the sample compared to the years of publication shows that the research has been particularly intense in the last two years. 2018 and 2019 are the years with the highest number of researches on this topic, with 27 and 39 documents respectively (Figure 4).

The previous years reported low research results, emphasizing the fact that only recently the theme of industry 4.0 is being combined to the one of sustainability.

In last two years the groups composition is similar for Conceptual papers that are 17 and 16 respectively in 2018 and 2019. Review papers doubled in 2019 compared to 2018, while in 2019 Technical-application papers have increased more than double compared to 2018. These data underline a growing interest in case studies presenting innovative solutions in I4.0-CE. To emphasize the increasing importance of Tech-App paper is the fact that until September 2019 the only document planned for 2020 about CE-I4.0 belongs to this category.



	2016	2017	2018	2019	2020
Conceptual	2	3	17	16	
Review	2	2	4	8	
Tech-App	1	1	6	15	1

Figure 3: Subsamples Distribution by Years

1.4 Country analysis

Interesting considerations emerge from the geographical distribution of the studies reviewed.

The distribution by country was carried out for the whole sample and for the subsamples.

For the whole sample, Europe gives the greatest contribution to the research with 53 documents. The countries most interested on the topic are UK, Italy and Spain, respectively with 12, 10 and 9 papers, followed by Germany and Finland, with 5 and 3 publication. Other European Countries have only one publication. Other continents interested in publishing documents about CE-I4.0 are Asia, America and Africa, with respectively 17, 7 and 1 documents. The first Asian Country is India, with 7 publication, while for the American continent the first country is Brazil with 5 documents. In Africa there is only one Egyptian publication.

Figure 5 shows the distribution of the sample.

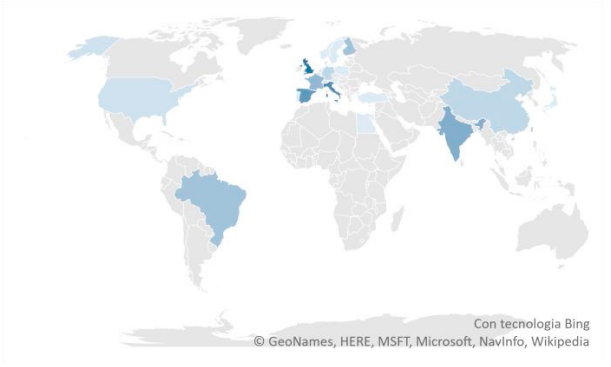


Figure 4: Country Distribution

For the subsamples, most of the documents are Conceptual: 26 in Europe, 9 in Asia, 2 in America and 1 in Africa, fot a total number of 38 documents. The majority of 24 Tech-App papers are in Europe (17), then there are Asia (4) and America (4). Regarding the 16 Review papers Europe is at the first place (10) followed by Asia (4) and America (3).

Figure 6 shows the distribution of the subsamples.

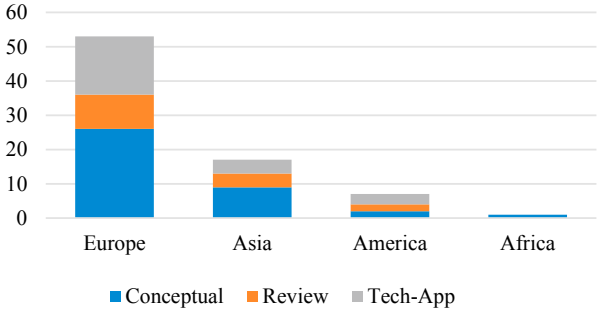


Figure 5: Subsample Distribution by Countries

1.5 Top most keywords analysis

The keywords analysis for the whole sample generated an original list of more than 30 different terms extracted from the documents.

The keywords cloud (Figure 6) describes how much the keyword is indexed. The most indexed words are those represented with the larger size, while the small size described a low frequency. Therefore, it can be noted that the most used term are precisely “I4.0” and “Circular Economy”, used 44 times; “Sustainable Development” and “Sustainability” are used respectively 26 and 24 times; “Manufacture” is used 15 times; “Supply Chains” and “Literature Review” are used 11 times. The remaining 11 keywords are used less then 10 times.

Figure 6: Keywords Cloud

To be more effective, the following analysis and figure show the first 20 keywords with a frequency of ≥ 4 and therefore it excludes some keywords that are difficult to group with others, as they relate to very specific topics.

In Figure 7 is reported the total frequency of each keywords considering the document type.

The first four keywords express generic concepts of the studied topic and therefore, they are available in all the documents type. As it was predictable, those words are most repeated in Conceptual paper, that are the largest number of documents. “Manufacture” and “Supply chains” are keywords for Technical-application and Conceptual papers: while the first word has a highest frequency in Technical-application papers, the second has a highest frequency in Conceptual ones. The last twelve words are mostly repeated in the type of document to which they are most related: “Literature Review” and “Internet of things” are keywords for Review papers; “Recycling”, “Additive Manufacturing”, “Big Data”, “Agri-food industry”, “Circular Business Model”, “Energy Use” and “Industrial Economics” are keywords for Technical-Application papers; “Sustainable Manufacturing”, “Big Data & Analytics” and “DEMATEL” are keywords for Conceptual papers.

This last keyword, with a frequency of 4, is an abbreviation for “decision making trial and evaluation laboratory” method. As it is possible to notice in the analysis, Technical-Application model analized the enabling technologies of I4.0 that activate the circular economy through case studies.

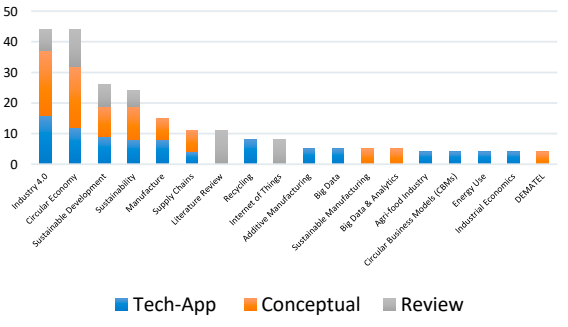


Figure 7: Subsample Keywords Distribution

1.6 Subject area

The 78 documents selected belong to 16 different subject areas, while the total number of subject areas collected from all the papers is 194: each paper can take into account more than one research area analysis.

Considering each type of document there are respectively 90, 43 and 61 area analysis for Conceptual, Review and Technical-Application papers.

The large number of areas in which this kind of research is involved underlines that nowadays i4.0 and circular economy are paradigms used in many fields.

As it is possible to see in the hystogram (Figure 9) the most significant areas, at the top of the ranking, are the first six: Engineering, Environmental Science, Energy, Business, Management and Accounting, Computer science and social science respectively with 43, 30, 24, 22, 20 and 17 publications: this areas together reach a total contribute of about 80% of the papers considered. The remaing 10 subject areas, that reach a total contribute of about 20%, have less then 10 publications each.

Eight subject areas have at last one paper for each type of document, with a majority for Conceptual documents. Five areas have at least one document for Conceptual and Technical-Application papers, two areas have only one Conceptual paper and one Review paper, and finally the last area has only one Technical-Application paper. Therefore, each area, except the last, has at least one Conceptual paper.

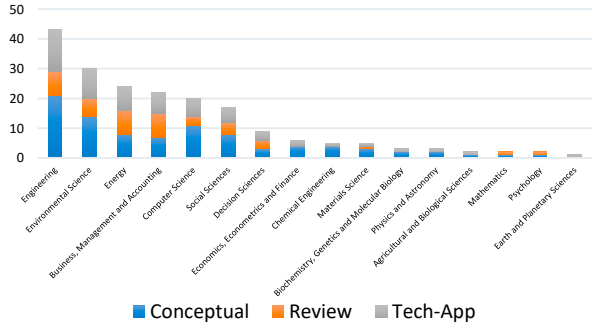


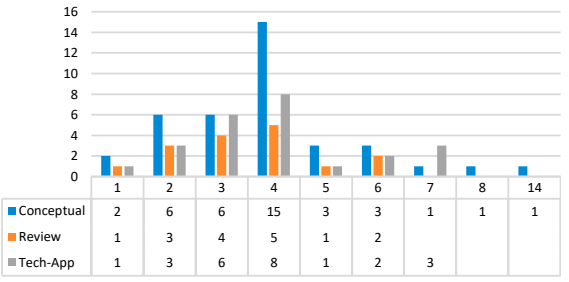
Figure 8: Subsamples Publication by Subject Area

1.7 Most collaborative authors

For the authors, the collaboration analysis is carried out. As it is possible to notice in Figure 10, the collaboration between 4 authors is the most popular among the 78 analyzed papers. For four authors collaborations there are 15 Conceptual, 5 Review and 8 Technical-Application papers, so this type of collaboration represent about the 36% of the total. In second position there are papers with 3 authors which reach about the 20% of the total, with 6 Conceptual, 4 Review and 6 Technical-Application papers. Further down the rankings there are collaboration between 2 authors which reach about the 15% of the total with 6 Conceptual, 3 Review and 3 Technical-Application papers. The other types of collaboration reach together less than 30% of the total.

From 1 to 6 collaboration authors there are all the document type, for collaboration between 7 authors there is only one Conceptual paper, and 3 Technical-Application papers, while for collaboration with 8 and 14 authors there is only one Conceptual paper.

Also, in this case, for every number of collaborations there is at least one Conceptual paper.



	1	2	3	4	5	6	7	8	14
Conceptual	2	6	6	15	3	3	1	1	1
Review	1	3	4	5	1	2			
Tech-App	1	3	6	8	1	2	3		

Figure 9: Subsample analysis by most collaborative authors

1.8 Most productive authors

In this subparagraph, the whole sample authors are analyzed with respect to the number of publications associated with them. The number of citations received is also analyzed, relative to the publications and the h-index is calculated. This index quantifies the prolificacy and the scientific impact of the authors taken into consideration.

From the analysis carried out, it can be observed that there are 160 authors. As it is shown in the histogram representing the first ten authors (Figure 11), the author with the highest number of publication (TP) is Moreno M., [11] from Cranfield University (UK), with 6 publication. in second and third position there are Charnley F. [12] and Jabbour C.J.C. [13] par with Tiwari A., [12] respectively with 5 and 3 publication. 22 authors have two publication, and the remaining 134 authors have only one publication.

In addition to the number of documents produced, it is interesting to analyze the number of citations of each authors. This indicator shows how influential each author is and therefore how much it contributes to future research. The author with the highest citation number is Jabbour C.J.C., [13] from Montpellier Business School (France), with 54 citations. Below there are Moreno M., [11] Charnley F., [12] Adrodegari F. par with Bressanelli G., [14] respectively with 35, 28 and 25 citations.

However, in order to be able to evaluate the effectiveness of each author, it is necessary to compare the number of citations with the number of documents produced. This indicator, called h-index, is *n* if there are at least *n* documents, among those published, that were cited at least *n* times each one. If this index is considered, the ranking is almost equal to that for number of publications. The top 2 authors are Moreno M. [11] in par with Charnley F., [12] with a h-index of 3, and Jabbour C.J.C. [13]

in par with Adrodegari F. and Bressanelli G., [14] with a h-index of 2. The remaining authors have an h-index of 1.

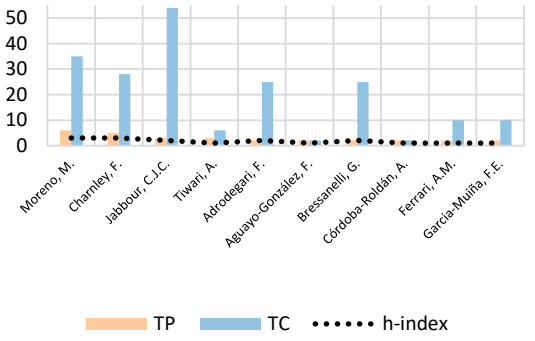


Figure 10: Most Productive Authors of Sample

2. Discussion

Interesting information emerged from the analysis carried out. The first observation concerns the number of documents: the analysis of the sample with respect to the publication years shows that the research has been particularly intense in the last two years. The low number of documents available for 2016 and 2017 shows how the joint topic is still very young and unripe, but the sudden growth in the last few years underline an attractive ever increasing attention. More specifically, it is possible to notice the growth of Technical-Application paper compared to the growth of Review and Conceptual ones. The more alive interest on the subject has lad the authors to deal with more technical and less theoretical documents. However, to emphasize the importance of theory, the most cited document is a Review published in 2016.

This paper by Matsumoto M. et al., [15] counts 55 citations, and is about the importance of remanufacturing in circular economy and the existing gap between the increasing attention to remanufacturing and the low exploitation of this technique. Although this paper is not very recent, the number of citations is greater especially in the last three years (16, 18, 17 respectively in 2016, 2017 and 2018), to underline the recent increasing interest on the rebuilding of a product.

The second most cited document is a Conceptual paper by Tseng M. et al., [16] with 41 citation. This document, published in 2018, deals the industrial symbiosis (IS) of industry 4.0, an innovative approach that brings together companies from different sectors to promote valorization of waste, improvement of resource efficiency and reduction of environmental impact.

The Technical-Application paper with more citations is a document by Niakan F. et al, [17] (22 citations) from the Lyon University. This paper published in 2016, deals with new bi-objective mathematical model of the Dynamic Cell Formation Problem (DCFP), to face the increasing importance of environmental and social issues. The first objective of this model is to minimize both production and labor costs while the total production waste (e.g., energy, chemical material, raw material, CO2 emissions, etc.) is minimized as second objective. The model constraint are the Social criteria.

Summarizing, from citations point of view the gap between top cited article, that is a conceptual one (55 TC) and first tech-app article with more citation (22 TC), put in evidence topic's state of art. Even if, it is clear the importance of technical and application model to enhance CE system in I4.0 perspective to consider the environmental and social issues, is still very difficult turn theoretical studies into practical purposes [18].

3. Conclusion

The objective of this study was to carry out a literature review to examine current state-of-the-art of Circular Economy with I4.0 perspective and highlight its benefits from the point of view of sustainability within the industry. In line with the purpose, several search queries were made on three scientific databases and led to the identification of a sample of 78 studies published from 2010 to the early 2020. These studies were classified into three subsamples: Review papers (16), Conceptual papers (38) and Technical-Application papers (24). The whole sample was analyzed through descriptive statistics about the document types. Next, subsamples were examined individually through publication by years, countries, subject areas and authors.

The documents classification allowed to identify the major topics explored and their diffusion level in the scientific community, thanks to the h-index referable to the single authors. The analysis shows how the CE and I4.0 are closely linked: CE develops using business models, technologies and skills related to industry 4.0. The technologies can positively support the CE in the ability to have more knowledge (measurement, traceability) and monitoring of processes and products.

From the overall set of analyses made, the following considerations emerge. First, interest towards the Circular Economy is increasing over time, as highlighted by the growing number of recent papers during last decade. In relation to the period considered, studies demonstrate that this research topic is still in its early stage of attention. In fact, the number of studies found is still limited and suggests that the potential of these research area has not yet been fully explored.

Looking the sectors, majority of the scope papers are focused on the general context of I4.0, remanufacturing industry, regenerating, life cycle management, supply chain, sustainability model. Most of the published papers look at evaluate the benefits that Circular Economy systems can generate in industrial operations, compared with traditional Linear Economy.

Overall, from a practical point of view, these results suggest that the choice to implement CE model ultimately, depends on the application field of the I4.0 system.

To sum up, from the discussion above it can be concluded that CE shows great application potential in many industrial operations. Moreover, it has been proven to be helpful also in different (less explored) areas. From a scientific perspective, as any review study this article does not present relevant new research results; rather, its contribution comes from

consolidating existing information from many recent studies that discussed CE solutions for the manufacturing industry.

In addition, this review provides the reader with a good overview of the state-of-the-art of CE model adoption in the manufacturing industry, highlighting well-established applications areas and promising application fields.

Definitively, we cannot have a circular economy without the 4th Industrial Revolution, and we cannot have a socially useful and sustainable 4th Industrial Revolution without advancing the circular economy.

References

[1] Geissdoerfer M., Savaget P., Bocken N.M.P., Hultink E.J., 2017. The circular economy – A new sustainability paradigm? Journal of Cleaner Production, 143, 757-768.

[2] Yang S., Raghavendra M.R.A., Kaminski J., Pepin H., 2018. Opportunities for industry 4.0 to support remanufacturing. Applied Sciences (Switzerland), 8(7).

[3] McDowall W., Geng Y., Huang B., Barteková E., Bleischwitz R., Türkeli S., Doménech T., 2017. Circular economy policies in China and Europe. Journal of Industrial Ecology, 21(3), 651–661.

[4] Bocken N.M.P., de Pauw I., Bakker C., van der Grinten, B., 2016. Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 33(5), 308-320.

[5] Cayzer S., Griffiths P., Beghetto V., 2017. Design of indicators for measuring product performance in the circular economy. International Journal of Sustainable Engineering, 10(4-5), 289–298.

[6] Elia V., Gnoni M.G., Tornese, F., 2017. Measuring circular economy strategies through index methods: A critical analysis. Journal of Cleaner Production, 142, 2741–2751.

[7] Despeisse M., Baumers M., Brown P., Charnley F., Ford S.J., Garmulewicz A., Rowley J., 2017. Unlocking value for a circular economy through 3D printing: A research agenda. Technological Forecasting and Social Change, 115, 75-84.

[8] Garmulewicz A., Holweg M., Veldhuis H., Yang A., 2018. Disruptive Technology as an Enabler of the Circular Economy: What Potential Does 3D Printing Hold? California Management Review, 60(3), 112–132.

[9] Lacy P., Rutqvist J., 2015. Waste to Wealth: Creating Advantage in a Circular Economy. Accenture Strategy, 293.

[10] Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, *33*(2004), 1-26.

[11] Moreno M., Court R., Wright M., Charnley F., 2019. Opportunities for redistributed manufacturing and digital intelligence as enablers of a circular economy. International Journal of Sustainable Engineering, 12(2), 77-94.

[12] Charnley F., Tiwari D., Hutabarat W., Moreno M., Okorie O., Tiwari A., 2019. Simulation to enable a data-driven circular economy. Sustainability (Switzerland), 11(12).

[13] Jabbour C.J.C., Jabbour A.B.L.D.S., Sarkis J., Filho M.G., 2019. Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda. Technological Forecasting and Social Change, 144, 546-552.

[14] Bressanelli G., Adrodegari F., Perona M., Saccani N., 2018. Exploring how usage-focused business models enable circular economy through digital technologies. Sustainability (Switzerland), 10(3).

[15] Matsumoto M., Yang S., Martinsen K., Kainuma Y. 2016. Trends and research challenges in remanufacturing. International Journal of Precision Engineering and Manufacturing - Green Technology, 3(1), 129-142.

[16] Zheng P., Wang Z., Chen C., Pheng Khoo L., 2019. A survey of smart product-service systems: Key aspects, challenges and future perspectives. Advanced Engineering Informatics, 42.

[17] Niakan F., Baboli A., Moyaux T., Botta-Genoulaz V., 2016. A bi-objective model in sustainable dynamic cell formation problem with skill-based worker assignment. Journal of Manufacturing Systems, 38, 46-62.

[18] De Felice, F., Petrillo, A., Zomparelli, F., 2019. Prospective design of smart manufacturing: An Italian pilot case study. Manufacturing Letters 15, 81-85.