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A literature review about uncertainty in remanufacturing under the perspective of Circular Economy

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Introdução
In this article, we identify the scientific production that addresses the uncertainties in remanufacturing from the perspective of the Circular Economy (CE). In the circular economy, remanufacturing is essential because it contributes to bringing environmental, social and economic benefits by extending the life cycle of products, whether at the end of their life or in use.
Problema de Pesquisa e Objetivo
The remanufacturing is the primary means of retaining the value of products in order to encourage a CE. However, as far as we are concerned, no academic research has reviewed the literature with a focus on remanufacturing uncertainties in the context of a CE. Therefore, the purpose of this review article is to answer the following research question: How is the scientific production of uncertainty in remanufacturing from Circular Economy perspective characterized?
Fundamentação Teórica
Milliken (1987) defines uncertainty as an individual's perceived inability to accurately predict something. This individual is subject to uncertainty because it is possible to observe that he does not have enough information to make reasoned decisions. In a study on selectionism and learning, Sommer & Loch (2004) discussed that companies that are innovating in dynamic environments face unforeseeable uncertainty.
Metodologia
A search was made in Web of Science (WoS) and Scopus databases. In both databases, the following search terms were used: “uncertain*” AND “circular economy” AND (“remanufact*” OR “refurbish*”). We identify the scientific production on uncertainties in circular economy and remanufacturing using bibliometric analysis. The metadata of the final sample was analyzed using the software Rstudio, Bibliometrix and VOSviewer.
Análise dos Resultados
We identified that market uncertainty is related to the acceptance of remanufactured products by the consumer and the uncertainty of the resources is present in closed-loop supply chains. In addition, the implementation of remanufacturing presents technical uncertainties, especially in the disassembly phase of products and organizational uncertainties, as remanufacturing requires a well-structured supply chain.
Conclusão
In this paper, we carry out a bibliometric analysis of the scientific production on uncertainties in remanufacturing in the context of circular economy. We also discuss the main uncertainties identified in the remanufacturing scenario: market the uncertainty and resource uncertainty. This research aims to contribute to theory in identifying uncertainties present in the remanufacturing scenario in the context of a circular economy. However, this research has limitations, one of which refers to the use of only two databases considering documents written solely in English.
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Palavras Chave
Circular economy, , End-of-life products, Closed-loop supply chains

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A LITERATURE REVIEW ABOUT UNCERTAINTY IN REMANUFACTURING UNDER THE PERSPECTIVE OF CIRCULAR ECONOMY

1. INTRODUCTION

The operating scenario of companies in the world is not only risky, it is a scenario of the VUCA world (volatile, uncertain, complex and ambiguous), where there is the challenge of managing deep uncertainties going far beyond risk management (Schoemaker et al., 2018). In this regard, companies face the challenge of responding quickly to this changing environment (Sommer & Loch, 2004). One of the current challenges is the transition from a linear economy to a Circular Economy (CE). Concerns about environmental issues are increasingly debated on the agendas of companies' policy and strategy makers (Geissdoerfer et al., 2017). In the industrial development debate, many professionals see CE as a driver to induce regenerative industrial transformations that will enable both sustainable production and consumption (Korhonen et al., 2018). "*The Circular Economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling*" (Geissdoerfer et al., 2017,p.759). The transition towards a circular economy contributes to Sustainable development goals (SDGs) to reach more sustainable standards both on production and consumption (Schöggl et al., 2020).

In the circular economy, remanufacturing is essential because it contributes to bringing environmental, social and economic benefits by extending the life cycle of products, whether at the end of their life or in use (Singhal et al., 2020). "*Remanufacturing, which may be defined as 'the transformation of used products (referred to as cores), consisting of components and parts, into products that satisfy exactly the same quality and other standards as new products*" (Goltsos et al., 2019, p. 7361).

A company's decision to invest in remanufacturing will not always be easy, as there are several economic factors at play. For example, there is a high degree of uncertainty in remanufacturing that involves demand behavior, consumer acceptance to pay for end-of-life products, the supply and conditions of those products that will be collected (Low & Ng, 2018). Goltsos et al. (2019) claim that remanufacturing networks are the backbone of circular economy models as they are associated with environmental, social and financial sustainability.

In the literature, the study of remanufacturing in the context of the circular economy was the focus of research by Hazen et al. (2017) addressing consumer perceptions regarding remanufactured products. The acceptance of remanufactured products has also been studied by Singhal et al. (2019). The study by Bag et al.(2019) investigated the role of remanufacturing capability on resilience in the circular supply chain.

The research by Sitcharangsie et al.(2019) analyzed decision-making in the main remanufacturing activities. The survey highlights that remanufacturing is the primary means of retaining the value of products in order to encourage a circular economy. However, as far as we are concerned, no academic research has reviewed the literature with a focus on remanufacturing uncertainties in the context of a circular economy. Therefore, the purpose of this review article is to answer the following research question: (1) *How is the scientific production of uncertainty in remanufacturing from Circular Economy perspective characterized?*

This research contributes to the academic understanding of uncertainties present in the transition to a circular economy in a context where there are few studies exploring taxonomies of uncertainty. To answer this question, a literature review will be carried out. The type of

literature review chosen was the 'systematic literature review' which can be explained as a research method and process used to identify and critically evaluate relevant research, as well as to collect and analyze data from these researches (Snyder, 2019, p.334).
This systematic review uses bibliometric methods to identify the most cited documents, the most relevant sources and other information about data collection. Due to the growth of the literature, bibliometric analysis methods ease the identification of the major documents that approach the focus subject. In addition, we used the typology Ricet al. (2008) to identify and classify technical, market, resource and organizational uncertainties. Furthermore, in the present article, we adopt Milliken's definition of uncertainty.
This article is structured into five sections besides the introduction. Section 2 addresses the concept and sources of uncertainty according to the literature. Section 3 covers the methodological procedure. Section 4 addresses the results of the bibliometric analysis, followed by section 5, which addresses the discussion. Section 6 provides the conclusion of the article with a presentation of the research contribution, limitations and opportunities for future research.

2. UNCERTAINTIES

Uncertainties are present in various scenarios as the management of radical innovation projects involving the development of a product. There are also uncertainties regarding technology, uncertainty about the availability of resources, behavior of suppliers, competitors and consumers or even uncertainty regarding the political panorama (Meijer et al., 2010). The literature has a range of academic studies that explore uncertainties as well as risks in different contexts. However, before starting a debate on uncertainty, it is necessary to differentiate uncertainty from risk (Gomes et al., 2019). Knight (1921), in his publication entitled “Risk, Uncertainty and Profit” discusses that risk and uncertainty are distinct. Risks have probabilities and results that are calculated and optimized. Conversely, in uncertainty, the basis for calculating the probabilities of results and also their impact is practically non-existent (Brady et al., 2012). Risk refers to events whereby it is possible to perform statistical modeling because it involves a distribution of known probabilities. In contrast, in the case of uncertainty it is impossible to assign a probability distribution for a given event (Gomes et al., 2019, 2021). In uncertainty, it is not possible to calculate the probable results of an action (Knight, 1921).
Townsend et al. (2018) argues that more research based on Knight's (1921) seminal work is needed to explore the existing conceptions of uncertainty. Since uncertainty creates several challenges for managers or entrepreneurs, often preventing them from understanding or foreseeing the consequences of decision-making. However, the debate about uncertainty in the organizational world is not recent. In his article “Three Types of Perceived Uncertainty About the Environment: State, Effect, and Response Uncertainty”, published in the Academy of Management Review, Milliken (1987) argued that uncertainty is a central concept in the organizational theory literature. Many high-level managers face uncertainties; with this, academics in the organizational area focus their attention on a variable that became known as environmental uncertainty. The term environmental together with uncertainty indicates that the source of uncertainty is the organization's external environment. Research that addresses environmental uncertainty recognizes the link between the appearance of new information about the environment and the individual's uncertainties and perceptions (Gomes et al., 2021).
Milliken (1987) defines uncertainty as an individual's perceived inability to accurately predict something. This individual is subject to uncertainty because it is possible to observe that he does not have enough information to make reasoned decisions.

In a study on selectionism and learning, Sommer & Loch (2004) discussed that companies that are innovating in dynamic environments face unforeseeable uncertainty. According to Sommer & Loch (2004), unforeseeable uncertainty is related to the inability to recognize the relevant influence variables and their functional relationships; therefore, in unforeseeable uncertainty, the planning of actions and events cannot be carried out in advance.

Researches that address uncertainty are diverse in the literature, for example, based on Milliken's concept of uncertainty (1987), Meijer et al. (2010) researched the influence of perceived uncertainties in the decisions and actions of entrepreneurs linked with biomass combustion projects in the Netherlands. In a previous paper, Meijer et al. (2007) discuss that uncertainty is a multidimensional construct and identify six different sources of uncertainty related to the development and implementation of emerging technologies. The sources of uncertainty identified in the survey were: (1) Technical uncertainty refers to the characteristics of the new technology, such as costs or performance; also regarding the relationship between the new technology and the technical infrastructure in which the technology is inserted, and about the feasibility of choosing alternative (future) technological options (Meijer et al., 2007, 2010); (2) Uncertainty of resources involves both the quantity and availability of resources (labor, raw material, financial) fundamental for innovation; this uncertainty also encompasses the issues of how to organize the innovation process (e.g. technology transfer) (Meijer et al., 2007, 2010); (3) Competitive uncertainty is related to competitors' behavior and its effects (Meijer et al., 2007, 2010); (4) Uncertainty of the supplier is related to the reliability of suppliers, whether they will meet the established deadlines, the quality and effects agreements (Meijer et al., 2007, 2010); (5) Consumer uncertainty refers to consumer desires in relation to a new technology, whether the new technology will be compatible with customer characteristics (Meijer et al., 2007, 2010); (6) political uncertainty is related to behavior, and governmental articulations besides involving the unpredictability of the conduct of a government regime (Meijer et al., 2007, 2010).

In their review article, Simangunsong et al.(2012) also studied uncertainty with a focus on the supply chain, identifying fourteen sources of uncertainty, such as supplier uncertainty, natural uncertainty (non-deterministic chaos), decision complexity uncertainty (emerges due to multiple dimensions in the decision-making process). The sources of uncertainty identified by Simangunsong et al.(2012) were categorized into three groups: (2) Uncertainties that are within the focal company (internal uncertainty); (2) Uncertainty of the internal supply chain (occurs within the sphere of control of the focal company or its partners); and (3) external uncertainties (they are outside the company's direct control areas) (Simangunsong et al., 2012).

In a study focused on radical innovation projects, Rice et al. (2008) found that companies deal with multidimensional uncertainties. The 'Learning Plan' framework was developed to identify and prioritize four uncertainties. Rice et al. (2008, p.55) classified the uncertainties into: (1) Technical Uncertainties: This uncertainty is related to technological aspects. For example: the reliability of manufacturing processes, performance, maintainability, among others; (2) Market Uncertainties: This uncertainty is related to customer needs, appropriateness of sales/distribution methods. It also involves understanding competitors' products; (3) Organizational Uncertainties: It is related to the organizational context of the company, such as politics and power; (4) Resource Uncertainties: It is related to financial resources (investments) but also with the competence to achieve certain opportunities.

In a study on uncertainty and ambiguity in solving technical problems, Schrader et al. (1993,p.77) define uncertainty as a "*characteristic of a situation where the problem solver considers the structure of the problem (including the set of relevant variables) as given, but is dissatisfied with his knowledge of the value of these variables*".

Briefly, uncertainty can be linked to three components: (1) the lack of information about environmental factors that are associated with a given situation that involves decision-making; (2) not knowing the effect of a specific decision in terms of how much the company would lose if the decision is wrong, and (3) inability to assign probabilities with any degree of confidence regarding how environmental factors will affect success or the failure of the decision unit to perform its function (Duncan, 1972; Schrader et al., 1993). Table 1 presents a brief summary of the types and description of the uncertainties.

Table 1. Summary of types and description of uncertainties

Author	Type of uncertainty addressed	Uncertainty Description
Knight (1921)	Knightian uncertainty	The uncertainty where it is impossible to assign a probability distribution for a given event (Gomes et al., 2021).
Milliken(1987)	Environmental uncertainty	Uncertainty will be defined as an individual's perceived inability to predict something accurately (Milliken, 1987. p. 136).
Sommer & Loch (2004)	Unforeseeable uncertainty	The inability to recognize the relevant influence variables and their functional relationships; thus, events and actions cannot be planned ahead of time (Sommer & Loch, 2004, p.1334)
Meijer et al. (2007)	Perceived uncertainty. Sources of perceived uncertainty are: Technical uncertainty, Resource uncertainty, Competitive uncertainty, Supplier uncertainty, Consumer uncertainty, Political uncertainty	Uses Frances Milliken's 1987 definition of uncertainty.
Simangunsong et al. (2012)	Supply-chain uncertainty (including risks)	*They use the definition of uncertainty related to the supply chain given by Vorst and Beulens (2002): "decision-making situations in the supply-chain in which the decision-maker does not know definitely what to decide as he [or she] is indistinct about the objectives; lacks information about (or understanding of) the supply-chain or its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply-chain behavior; or, lacks effective control actions (non-controllability)"* (Simangunsong et al., 2012, p.4494).
Rice et al. (2008)	Technical Uncertainties; Market Uncertainties; Organizational Uncertainties; Resource Uncertainties	

Schrader et al.(1993, p.75)	Addresses the difference between uncertainty and ambiguity	The paper supports the concept of uncertainty by approaching the definition of uncertainty by Galbraith (1973) "*Uncertainty is the difference between the information an organization has and the information it needs*" and Duncan (1972).

Source: Elaborated by the authors

3. MATERIALS AND METHODS

We identify the scientific production on uncertainties in circular economy remanufacturing using bibliometric analysis to answer the research question. Bibliometrics is adopted to map the structure and development of a particular field of research (Carvalho et al., 2013; Zupic & Čater, 2015), and this technique has been increasingly used due to the large number of scientific publications.

The Web of Science Core Collection (WoS) and Scopus databases were used for data collection, due to the quality and quantity of publications that are peer-reviewed (Carvalho et al., 2013; Homrich et al., 2018). Furthermore, because they have journals indexed with an Impact Factor (IF) in the Journal Citation Report (JCR) (Galvão et al., 2020).

For the bibliographical survey, this work follows the five steps proposed by Zupic & Čater (2015): (1) Research design: in this step the definition of the appropriate method to answer the research question occurs; (2) Compilation of bibliometric data: in this step the choice of databases, choice of filters applied to the databases, export and unification of bibliometric data occurred; (3) Analysis: in this step, the cleaning and organization of data and use of bibliometric software occurred; (4) Visualization: the visualization of bibliometric networks occurred, for example, keywords co-occurrence network; (5) Interpretation: the results were interpreted (described in section 4 of Results of bibliometric analysis). Subsection 3.1 below clarifies the procedures adopted in data collection.

3.1 Sampling procedures

In June 2021, a search was made in Web of Science (WoS) and Scopus databases. In both databases, the following search terms were used: "uncertain*" AND "circular economy" AND ("remanufact*" OR "refurbish*"). The word refurbished was inserted from database searches, as it is the process in which a professional company collects and restores used products and resells these products to new consumers (Van Weelden et al., 2016. p.743).

On the Web of Science database, the search was applied to "TOPIC" and the "document type" filter applied was: Article, Early Access, Review and Proceedings Paper. In the Scopus database, the search was applied to "Article title, Abstract, Keywords" and the filter "document type" was applied to search only Article, Review and Conference papers. In both databases, only documents written in English were selected. The searches resulted in 73 documents (38 WoS documents and 35 Scopus documents). Document metadata was exported in BibTeX format ('.bib').

After exporting the metadata of the documents from the databases, the statistical software R (https://cran.r-project.org/) and the Bibliometrix package (https://bibliometrix.org/index.html) (Aria & Cuccurullo, 2017) were used to unify the exported files from WoS and Scopus. Then 24 duplicate documents were excluded, leaving 49 documents in the sample.

The metadata of the final sample was analyzed using the Bibliometrix package and, using Biblioshiny, an application that provides a web interface for Bibliometrix, the main bibliometric information of the sample was visualized. In addition, the VOSviewer software (Van Eck &

Waltman, 2010) was used to generate bibliometric networks, as keyword co-occurrence networks.

4. BIBLIOMETRIC ANALYSIS RESULTS

4.1 Descriptive analysis of the final sample

Through the Bibliometrix package, we extracted the main information about the bibliometric data of the final sample. Table 2 presents the main statistics of the documents. The search results range from 2008 to 2021. There are 49 documents, 30 of which are articles, 12 are conference papers, 3 are reviews and 4 are proceedings papers. Figure 1 shows the annual distribution of publications; 3 documents were published in 2016 and 8 documents in 2021.

Table 2. Main information about the final sample data collection.

Description	Results
Main information about data	
Period	2008-2021
Annual percentage growth rate	41.42%
Sources	28
Documents	49
Average years from publication	2.2
Average citations per documents	14.9
Average citations per year per documents	3.77
Document types	
Article	30
conference paper	12
proceedings paper	4
review	3
Document contents	
Keywords Plus (ID)	374
Author's Keywords (DE)	171

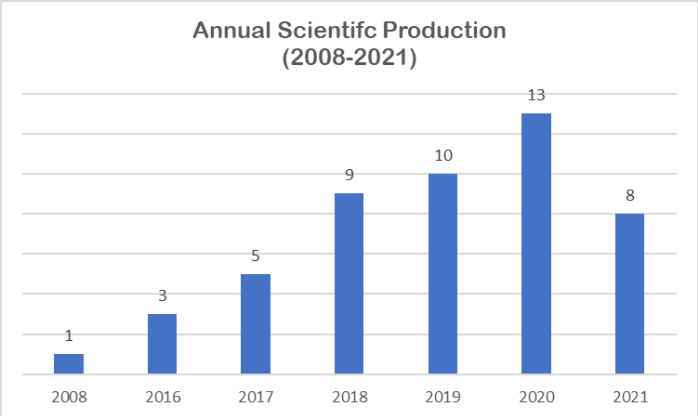

Figure 1. Number of publications over the years 2016 – 2021.

4.2 Sources

Table 3 presents the publication sources of the documents in the final sample. The Journal of Cleaner Production published 22.44% of the sample documents. This journal is transdisciplinary and publishes research involving the theme of circular economy. The

International Journal of Production Research published 3 sample documents; this journal researches in the field of manufacturing engineering.

Table 3. The 9 main journals that published the sample documents.

Sources	Number of publications
Journal of Cleaner Production	11
International Journal of Production Research	3
Procedia CIRP	3
Journal of Remanufacturing	3
Business Strategy and the Environment	2
Omega	2
Procedia Manufacturing	2
Sustainability	2
Resources Conservation and Recycling	2

4.3 Most cited documents

This subsection covers the 10 most cited documents (Table 4) from the final sample. The article by Linder & Williander (2017) published in the International Journal of Production Research is the most cited (229 citations). The second most cited article is by Van Weelden et al. (2016) with 103 citations, which was published in the Journal of Cleaner Production. The third most cited article (63 citations) is the review by Camacho-Otero et al. (2018), published in the Sustainability journal.

Table 4. The 10 most cited documents in the sample.

Authors	Title	Source	Type	Total citations	Average citation per year
(Linder & Williander, 2017)	Circular Business Model Innovation: Inherent Uncertainties	International Journal of Production Research	Article	229	45.80
(Van Weelden et al., 2016)	Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market	Journal of Cleaner Production	Article	103	17.17
(Camacho-Otero et al., 2018)	Consumption in the Circular Economy: A Literature Review	Sustainability	Review	64	16.00

(Van Loon & Van Wassenhove, 2018)	Assessing the economic and environmental impact of remanufacturing: a decision support tool for OEM suppliers	International Journal of Production Research	Article	36	9.00
(Atlason et al., 2017)	Product design in the circular economy: Users' perception of end-of-life scenarios for electrical and electronic appliances	Journal of Cleaner Production	Article	32	6.40
(Shi et al., 2019)	Barriers of a closed-loop cartridge remanufacturing supply chain for urban waste recovery governance in China	Journal of Cleaner Production	Article	21	7.00
(Low & Ng., 2020)	Uncertainty factors, methods, and solutions of closed-loop supply chain — A review for current situation and future prospects	Journal of Cleaner Production	Review	21	10.50
(Sitcharangsi, 2018)	Improving the Economic Performance of Remanufacturing Systems through Flexible Design Strategies: A Case Study Based on Remanufacturing Laptop Computers for the Cambodian Market	Business Strategy and the Environment	Article	20	5.00
(Buyle et al., 2019)	Sustainability assessment of circular building alternatives: Consequential LCA and LCC for internal wall assemblies as a case study in a Belgian context	Journal of Cleaner Production	Article	20	6.67
(Sitcharangsie et al., 2019)	Decision makings in key remanufacturing activities to optimize	Journal of Cleaner Production	Review	19	6.33

4.4 Most frequent keywords

The final sample contains 171 author keywords and also 374 Keywords Plus, which are words that frequently appear in the titles of an article references. Table 5 shows the most frequent author's keywords and the most frequent Keywords Plus. The VOSviewer software was used to generate a co-occurrence of the author's keywords in association with the plus keywords (Figure 2).

Table 5. The 10 most frequent author's keywords and Keyword Plus

Author's keywords	Frequency	Keywords Plus	Frequency
remanufacturing	28	circular economy	18
circular economy	23	uncertainty	10
uncertainty	5	remanufacturing	9
reuse	4	sustainable development	8
reverse logistics	4	life cycle	7
closed-loop supply chain	3	manufacture	7
inventory control	3	manufacturing	5
production planning and control	3	recycling	5
sustainable development	3	decision making	4

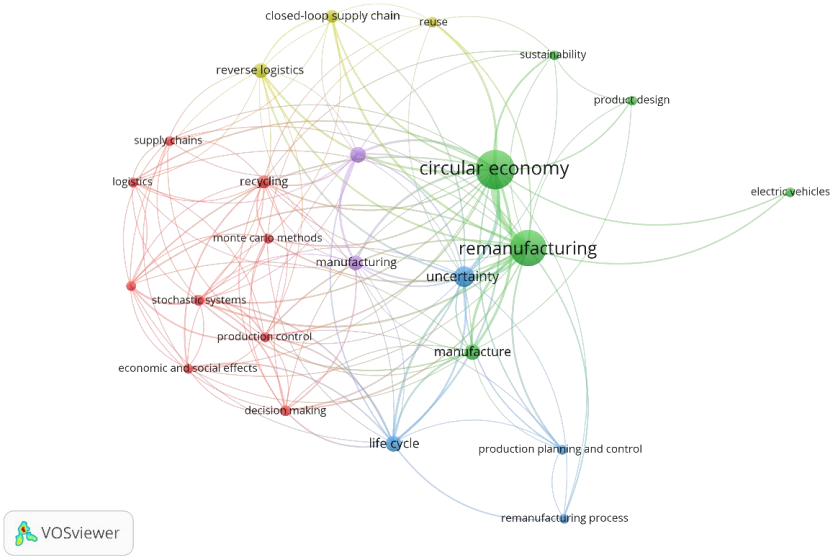

Figure 2. Authors keywords co-occurrence network diagram and keywords Plus. **Note:** The minimum number of occurrences of a keyword was equal to 3.

Note that in Figure 2 and Table 5 the keywords remanufacturing, circular economy, uncertainty and closed-loop supply chains appear more frequently. In addition, Figure 2 shows the clusters formed. The cluster in red color is related to methods for evaluating uncertainties, for example, Monte Carlo methods and stochastic programming. The yellow cluster addresses research involving closed-loop supply chain (CLSC) and reverse logistic. The green cluster encompasses

research involving circular economy, remanufacturing together with sustainability, while the blue cluster is related to studies that address life cycle analysis.

5. DISCUSSION

The article “Circular Business Model Innovation: Inherent Uncertainties”, which is the most cited in the final sample, carried out a single case study of longitudinal action research taking as its object of study a small Swedish bicycle manufacturer that is investing in the circularity model for remanufacturing electric bicycles (Linder & Williander, 2017). Linder & Williander (2017) discuss that circular business models based on remanufacturing and reuse can promise some benefits, such as cost savings and reduced environmental impact. However, there is currently no widespread adoption of the circular model with a focus on remanufacturing by companies.

According to Linder & Williander (2017), the Circular Business Model (CBM) in remanufacturing presents challenges and limitations: (1) restrictions on the type of customer likely to adhere to remanufactured products; (2) technological knowledge since remanufacturing requires high experience and knowledge of the product to be restored to its original state or in the best condition; (3) challenges regarding the return flow related to the lack of predictability, which causes difficulties in planning the capacity of the remanufacturing process; (4) restrictions regarding the type of product to be remanufactured as not all products will be suitable for remanufacturing (Linder & Williander, 2017). In addition, the CBM for remanufacturing may face a lack of supportive regulation with respect to tax laws and regulations.

Another challenge in circular business models for remanufacturing is the supply chain barriers regarding partners (retail or service), since the greater the recovery of the product, the greater is the need for collaboration from these partners (Linder & Williander, 2017).

Camacho-Otero et al. (2018) conducted a literature review on circular economy and specific circular solutions, focusing on issues of consumption and consumer acceptance. Several factors can contribute or hinder consumer acceptance of products and solutions in the context of circular economy. The consumer's lack of knowledge regarding remanufactured products may be a factor that hinders circularity solutions (Camacho-Otero et al., 2018) and this may indicate market uncertainty for organizations that are migrating to a circular model of business.

Small and medium companies try to advance in circular business models and solutions, but the lack of support from demand networks can impede the implementation of green innovations. For the authors, market uncertainty regarding consumer awareness can be an impediment to a transition towards a circular economy (Camacho-Otero et al., 2018).

Another study linked to market uncertainty is the research by Van Weelden et al.(2016) that studied the acceptance of refurbished cell phones in the Dutch market, through qualitative research using interviews with twenty consumers of new and refurbished phones. Consumers are uncertain about the quality of remanufactured products, and a solution to increase consumer understanding of these products and reduce uncertainty is to provide comprehensive and accessible information (Van Weelden et al., 2016). Informing consumers about the remanufactured product history (for example, the reason for disposal) allows for a more careful evaluation and can generate greater confidence in the purchase of the product. In addition, governments can encourage consumers to buy remanufactured products through subsidies (Zhou &Yuen, 2020).

Several companies establish strategies to become more sustainable (Atlason et al., 2017). These strategies are related to product design, manufacturing and also end-of-life product management. Often the end of a product useful life is uncertain. The work by Atlason et al.

(2017) through a survey of 146 Danish consumers investigated the perceptions of consumers in relation to three scenarios taking into account the proximity of the end-of-life (EoL) of the electronic product. The scenarios are: recycling, remanufacturing and reuse. The research identified that the reuse of these products is the most attractive scenario in the users' preference and that women are more prone to all three scenarios being more willing to pay for ecological electronic products. In this context, knowing the needs of customers and the acceptance of products that are declining in the useful life curve can help companies that intend to follow circular economy strategies in reducing market uncertainties. This is because remanufactured products have more complexities when compared to new products and consumers are not sure about the performance that the remanufactured product will present (Liao, 2018).

Shi et al. (2019) conducted a survey on barriers in the cartridge remanufacturing supply chain (collection of used cartridges, remanufacturing, sale and use of remanufactured cartridges). The research addresses that existing uncertainties regarding the supply of these products and the low demand, which hinders the development of remanufacturing. Therefore, a company that works with remanufacturing may suffer shortages of its raw material (the product to be remanufactured) culminating in resource uncertainty, and may also not have a forecast of demand against the purchasing behavior of consumers (market uncertainty). As a result, there may be a lack of products for remanufacture as the entry of these inputs depends on the use of consumers, the destination, the structural condition of the product. The sale of remanufactured products may also not occur (non-acceptance by consumers who prefer to buy new products).

In a literature review, Peng et al. (2020) addressed the Closed-Loop Supply Chain (CLSC) uncertainty factors, emphasizing that uncertainty is an inherent and practically unavoidable characteristic of CLSC and, furthermore, uncertainties hinder the transition to a circular economy. The study noted that most of the uncertainty factors that concern most scholars include the development of demands and customer/market behavior (market uncertainty). Peng et al. (2020) mentions that the study of uncertainty is not comprehensive and, in general, only a few factors are considered and their derivative relations are not systematically summarized or analyzed.

Another study on the closed-loop supply chain is by Goltsos et al. (2019), who studied the 'boomerang' effect and stated that the main uncertainties in remanufacturing are linked to the supply (time or when a return will occur, how many products will be returned). There are inefficiencies associated with remanufacturing operations, mainly due to uncertainties in material flows and conditions of the product to be remanufactured (Gaspari et al., 2017). Supply uncertainty is directly linked to resource uncertainty.

Dominguez et al. (2020) point to a lack of studies in the literature that address the variability of manufacturing processes. In a Closed-Loop Supply Chain (CLSC), the collection and restoration processes of used products present uncertainties linked to the quantity and quality of product returns (resource uncertainty), but also the dismantling operations that are expensive (technical uncertainty). This indicates that companies that want to act in remanufacturing need to invest in technology. When compared to manufacturing, remanufacturing differs in that it is characterized by high variability, high uncertainty and also high complexity (Kimita et al., 2021) which causes companies involved in remanufacturing organizational uncertainties because "*management of the planning and control of the remanufacturing process can differ greatly from management activities in new traditional manufacturing*" (Kimita et al., 2021, p.101001-3).

Liao et al. (2020) studied quality uncertainty in acquisition strategies for engine remanufacturing. The 3R system (Reuse, Remanufacture, Recycle) in a closed-loop supply chain (CLSC) is critical to decreasing reliance on raw materials and one solution is the remanufacturing of used products. However, uncertainties at CLSC increase the difficulty in

managing production. The operational conditions of the end-of-life (EoL) products to be remanufactured are uncertain (Liao et al., 2020). This uncertainty about the quality of those products represents an uncertainty related to resources. Seeing that uncertainty increases the complexity in planning remanufacturing operations, operational managers will have difficulty managing such resources (Tsiliyannis, 2020).

Reddy & Kumar (2021) state that companies that operate with a hybrid system (manufacturing-remanufacturing) may face uncertainties in demand and in a circular economy, customers not only need to return products, but also need to buy remanufactured products.

Low & Ng, (2018) argue that some studies have already highlighted the contributions of remanufacturing to sustainable development and also to the circular economy. However, a company's decision to adopt a remanufacturing strategy is fraught with uncertainty, especially when there is high capital involved. From a case study based on the remanufacture of laptops for the Cambodian market, the authors point out that market uncertainties should be considered in the company's decision to opt for remanufacturing.

The research of "Management of intellectual property uncertainty in a remanufacturing strategy for automotive energy storage systems" by Hartwell & Marco (2016) states that the lack of understanding of how to manage certain uncertainties related to intellectual property in remanufacture is a challenge for organizations that intend to introduce a circular economy with an emphasis on remanufacture. The research identified two intellectual property uncertainties that are specific to remanufacturing. The first is the lack of clear legally recognized definitions and the second is whether circular activities, regardless of how they are described, are covered by intellectual property rights. Conflicts about intellectual property represent organizational uncertainties, and the lack of a well-defined policy on remanufacturing can prevent companies from developing circular strategies.

6. CONCLUSION

In this paper, we carry out a bibliometric analysis of the scientific production on uncertainties in remanufacturing in the context of circular economy. Checking the growth of the annual scientific production, the main sources of publication, the most cited documents and the clusters were identified by the co-occurrence network of keywords. We also discuss the main uncertainties identified in the remanufacturing scenario: market the uncertainty and resource uncertainty. Market uncertainties (involve issues related to the market, for example, customer need and size of the consumer market) are related to consumer acceptance in the purchase of remanufactured products. Remanufacturing in the context of the circular economy not only involves the return of end-of-life products, but also involves returning those products to the market after the remanufacturing process. However, there is still resistance on the part of consumers to purchase remanufactured products regarding the quality of these products. This indicates that it is necessary to identify the barriers perceived by customers.

Resource uncertainty (uncertainty whether the organization will have the necessary resources to develop and/or commercialize) is the most prominent in the closed-loop supply chain (CLSC). The used product collection and restoration processes present uncertainties that are related to the quantity and quality of product returns. The lack of a forecast for the entrance of these products makes operational managers have greater difficulty in planning the production and sale of remanufactured products.

In addition to market and resource uncertainties, remanufacturing also presents technical uncertainties (underlying scientific knowledge, which may involve the technical specifications of a product, process reliability, among others). In remanufacturing, the disassembly process (depending on the product) is still expensive, which indicates that hybrid companies (working

in manufacturing and remanufacturing) or not, need to invest in technology if they want to adopt a circular economy. Technical knowledge of the remanufacturing process requires high experience and knowledge of the product to be restored either to its original state or to a better condition, since remanufacturing processes can have high variability and high complexity.

In the final sample, the research addressed the remanufacturing of electronic products, end-of-life batteries for vehicles, uncertainties in the closed-loop supply chain, circularity model for remanufacturing electric bicycles, consumer perceptions regarding remanufactured products. Future research may cover what barriers companies/entrepreneurs face when adopting the circular economy to implement remanufacturing. Additionally, future research may focus on organizational uncertainties, identifying how managers deal with the failures/difficulties inherent in remanufacturing projects in the circular economy.

This research aims to contribute to theory in identifying uncertainties present in the remanufacturing scenario in the context of a circular economy. However, this research has limitations, one of which refers to the use of only two databases considering documents written solely in English.

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