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General Systems Theory and Remanufacturing

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Abstract: The general systems theory emerged from the works of the Austrian biologist Ludwig von Bertalanffy, published between 1950 and 1968. This theory has as its main purpose, to analyze the nature of systems and the interrelationship between these systems and different spaces, as well as the interrelationship of its parts. It also analyzes the fundamental laws of systems. Remanufacture, in turn, is an industrial process that consists of the steps of dismantling the discarded or already used product, the remanufacturing process includes the steps of cleaning its parts, repairing, or replacing damaged parts. This article aims to analyze the prose academic productions of the last ten years. Bibliometric analysis was performed through the Web of Science platform.

Keywords: Bibliometric; Remanufacturing Theory of systems.

Teoría general de sistemas y remanufactura

Resumen: La teoría general de sistemas surgió a partir de los trabajos del biólogo austriaco Ludwig von Bertalanffy, publicados entre 1950 y 1968. Esta teoría tiene como objetivo principal analizar la naturaleza de los sistemas y la interrelación entre estos sistemas y diferentes espacios, como así como la interrelación de sus partes. También analiza las leyes fundamentales de los sistemas. La remanufactura, a su vez, es un proceso industrial que consiste en los pasos de desmantelar el producto desechado o ya usado, el proceso de remanufactura incluye los pasos de limpiar sus partes, reparar o reemplazar las partes dañadas. Este artículo tiene como objetivo analizar las producciones académicas en prosa de los últimos diez años. El análisis bibliométrico se realizó a través de la plataforma web of Science.

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Palabras llave: Bibliometría; Teoría de sistemas de remanufactura.

Introduction

The evolution of information and communication technologies drives the creation and improvement of equipment that both help solve problems and automate tasks, as well as facilitate communication and entertainment. On the other hand, electronic devices usually have a pre-defined useful life: after a certain period of use, generally determined by the manufacturer, these devices tend to stop working and become “electronic waste”. When poorly discarded, the equipment causes damage to the environment, ranging from the creation of dumps with hundreds of millions of devices, to the cause of diseases, due to toxic substances present in the devices (Ferreira e Ferreira, 2008).

The IT - Information Technology - industry was not seen as polluting, a scenario that has been changed due to the increasingly shorter life cycle of equipment, which contributes to the generation of large volumes of technological waste, which often, do not have a correct destination (Mattos; Mattos; Perales, 2008). A number of chemical substances are present in electronic equipment, such as mercury, cadmium, arsenic, copper, lead and aluminum, and can penetrate the soil, reach and contaminate groundwater, harming plants and animals (Mattos; Mattos; Perales, 2008).

Electrical and electronic equipment are replaced more or less frequently due to obsolescence, which is subdivided into three categories: (i) technical or functional obsolescence, which occurs when an equipment makes its predecessor useless, or when the new one proves to be more efficient or viable economically; (ii) perceptual obsolescence, which relates to issues of status or “belonging” related to the use of certain equipment; and (iii) planned obsolescence, promoted by reducing the useful life of certain equipment in order to promote replacement of the item and, consequently, new sales (Oliveira, 2014).

The drop in the useful life of equipment is a fact that has been registered throughout recent history. In the case of CPU's, it would have dropped from six to two years (Culver, 2005). For mobile phones, life would be less than two years (Widmer et. al, 2005), reaching three years in the case of smartphones (Ercan et. al, 2016). In the case of printers, it is assumed that the useful life of this type of equipment varies from two to eight years (Bousquin et. al, 2012), used both in domestic and corporate environments. It is therefore

necessary to seek ways to mitigate the consequences of high consumption, which, together with planned obsolescence and the intense pace of innovation, ends up turning a large part of electronic equipment into technological scrap in short periods of time (Rocha et. al, 2010).

The solution was boosted after the world wars and has led to an increasing accumulation of waste. For considering the abundant and always available natural resources, taking advantage of them without worrying about waste or destination. (Leitão, 2015). To avoid or reduce environmental damage, it is necessary to seek approaches focused on environmental and economic rationalization, with models aimed not only at the market, but also at the planet (Leitão, 2015).

Remanufacturing is the process of returning a used product to a condition similar to new, through inspection, disassembly, cleaning, reprocessing, assembly and testing (Hatcher; Ijomah; Windmill, 2013). The process comprises the recovery of the added value of a product, making it similar to when it was manufactured for the first time, reducing energy costs and costs involved in production (Gray & Charter, 2008). It is, therefore, an important procedure for remanufacturing, since it puts back into use products that would possibly be discarded, in the same conditions as a new product.

In this sense, the study aims to analyze the characteristics of publications related to Remanufacture and General Systems Theory in the Web of Science (WOS) database of ISI Web of Knowledge in the period from 2009 to 2018. The WOS consists of a multidisciplinary database that has about 9,000 indexed journals, indexing only the most cited in their respective areas.

Literature Review

Researchers such as Braungart, McDonough, Anastas and Zimmerman (2003), Fiskel (2009), Ellen MacArthur Foundation (2012) claim that the world economy has been based on a linear business model, that is, based on extracting, transforming, producing, use and discard (and sometimes recycle or incinerate - Leitão, 2015). Due to the possible scarcity of natural resources, this model is starting to be questioned by environmental organizations and governments. Future projections indicate a mismatch between current production and consumption levels and the availability of natural resources for future generations (United Nations Environment Program [UNEP], 2011a). To support the remanufacturing problem, a

previous reference on electronic waste will be presented, seeking to exemplify the problem that technology can bring to the present time.

E-waste

Also called electronic waste, technological waste, digital waste or e-waste, electronic waste consists of household appliances, equipment, and electronic components for domestic, industrial, commercial, or service sector use that are in disuse and subject to final disposal; This category includes computer components and peripherals, monitors and televisions, energy accumulators (batteries and batteries), and magnetized products (Brasil, 2010).

The concern with the disposal of these components stems from the polluting/toxic potential of many devices: among the substances present in electronic waste considered more problematic from an environmental and human health point of view are heavy metals, greenhouse gases - such as CFCs (chlorofluorocarbons) - halogenated substances, polychlorinated biphenyls, bromates and arsenic (Rodrigues, 2007). The Table 1 summarizes a series of potentially toxic substances that are present in electronic devices in general.

Table 1. Substances present in electronic devices.

Component	Devices
Mercury	Computers, Monitors and Plasma TV
Cadmium	Computers, tube monitors and laptop batteries.
Arsenic	Cellphones
Beryllium	Cellphones
Flame retardants	Used to prevent fires in various electronics
Lead	Computer, cell phone and television.
Barium	Fluorescent lamps and tubes
PVC	Used on wires to insulate currents

Source: Adapted Ferreira and Ferreira (2008, p. 1650)

According to Guedes, Oliveira and Lima (2010, p. 3) “most of these elements are wasted in insufficient collections, inappropriate recycling and also with the illegal export of garbage”. In this process, there are large emissions of hazardous substances that can affect society, as inadequate disposal can contaminate the soil, sewage, and groundwater, thus affecting both drinking water and irrigation water for plantations and, consequently, the foods grown on these soils.

In Brazil, there is a slow process for approving policies for the treatment of solid waste, although there are ongoing projects in the National Congress such as the one that treats electronic waste as reverse waste, making manufacturers responsible for handling it before final disposal (Silva, 2013, p. 33).

Remanufacture

Remanufacturing is a process of transforming used products into products with the same quality, functionality and guarantee as when new, consisting of processes to disassemble, clean, inspect, repair, replace and reassemble the components of a product to restore it to its initial condition (Matsumoto et. al, 2016).

For Hatcher, Ijomah and Windmill (2013), remanufacturing is the process of returning a used product to a condition similar to new, through inspection, disassembly, cleaning, reprocessing, assembly and testing. Remanufacturing comprises the recovery of the added value of a product, making it similar to when it was manufactured for the first time, reducing energy costs and costs involved in production (Gray & Charter, 2008). Remanufacturing brings economic, environmental, and social benefits, since it reduces production costs, reduces energy costs and waste disposal, and allows the generation of employment and sale of products at more affordable prices than new ones, which, in recent years, has attracted increasing global attention (Matsumoto et. al, 2016).

Research Method

The present study proposes, from bibliometric research, to analyze the proposed works on governance in the last 10 years. This type of research seeks, through the quantification of written documents, to identify trends and possible patterns in scientific production in a given area.

Quevedo-Silva et al. (2016) comment that bibliometrics is a commonly adopted practice in research in applied social sciences, the application of which helps to understand new themes and may contribute to identifying trends for future work. According to Marcelo and Hayashi (2013), its main characteristic is to generate indices of scientific knowledge production and its use is based on the investigation of the behavior of knowledge and literature as a component of communication processes.

Furthermore, this work is a descriptive approach, as it seeks to describe characteristics of a given phenomenon (Vergara, 2015), as well as to identify, obtain information and describe the characteristics of a given issue (Collis; Hussey, 2005). As a data collection plan, the base chosen for this was the Web of Science of the Institute for Scientific Information (ISI).

ISI was founded in 1960 by Eugene Garfield and later – in 1992 – was acquired by Thomson Reuters Corporation, this year in which it began to be known as Thomson-ISI (Gomes, 2010; Albagli, 2013). According to Pinto and Fausto (2012), the Web of Science is a worldwide reference in terms of scientific journals, Motke, Ravanello and Rodrigues (2016) corroborate that it is a multidisciplinary database that indexes only the most cited journals in their respective areas. Capes (2000) emphasizes that, via the Web of Science, tools are available for analyzing citations, references, the h index, which makes bibliometric analysis possible.

Soon after choosing the referred database, the keywords defined as search parameters were remanufacturing and general theory of systems, delimiting the following fields: (a) selection by topic; (b) articles only; and (c) published in the last 10 years (2011 to 2020). In all, 2212 publications were found.

Analysis and Discussion of Results

The research results show the main characteristics of scientific production related to the term remanufacturing. From the survey carried out in the Web of Science database, it is possible to identify in Table 2 the total number of articles published in the period of 2011-2020.

Table 2: Total number of articles published in the period of 2011-2020.

Year	Amount	%

2020	704	31,612
2019	535	23,978
2018	362	16,255
2017	251	11,271
2016	161	7,329
2015	85	3,917
2014	67	3,109
2013	34	1,657
2012	8	0,459
2011	6	0,369

Source: Authors (2021).

By analyzing Table 2, it is observed that between 2012 and 2013 publications in the area have increased considerably, from the difference in annual publication of two articles (considering the difference between 2011 and 2012) to 26 published articles. It can be said that from 2011 onwards, the publication of articles in remanufacturing has increased, addressing the general systems theory. Table 3 shows the growing production in the area studied, demonstrating the importance of the remanufacturing area for research on a global scale. The growing interest in research that contemplates remanufacturing is noticeable, demonstrating how much more is being discussed about the issue of the end of life of products in an attempt to reduce the consumption of natural resources, as well as the generation of waste, as well as seeking ways to use less energy. Table 3 shows the main areas researched related to remanufacturing.

Table 3: Total articles published by research area

Nº	Search area	Amount	%
1	*Environmental Sciences*	906	40,683
2	*Green Sustainable Science Technology*	752	33,767
3	*Engineering Enviromental*	681	30,579
4	*Engineering Manufacturing*	323	14,504
5	*Engineering Industrial*	320	14,369
6	*Operations Research Management*	297	13,336
7	Management	221	9,924
8	Environmental Studies	186	8,352
9	Business	142	6,376
10	Applications	102	4,580

Source: Authors (2021).

When analyzing Table 3, the data show that among the 10 areas that produce the most, the great area of knowledge in Engineering appears three times, totaling approximately 1324 articles, thus, it allows us to infer that they are the most interested in the subject. However, the largest area producing research is the area of environmental sciences, corroborating the remanufacturing objective of reducing the environmental impact caused by the generation of new products instead of reusing components in good condition. With 336%, green IT stands out, with 752 jobs. Next, Table 4 includes the main mode of documentation and dissemination of research.

Table 4: Type of documents.

Nº	Types of Documents	Amount	%
1	Article	1741	78,177
2	Proceedings Papers	248	11,136
3	Review	228	10,238
4	Early Acess	53	2,38
5	Editorial Material	53	2,38

Source: Authors (2021).

Among the different ways of disseminating scientific studies/research, table 4 presents the five most used. The article format is the most used by researchers, totaling around 1741 articles, dominating this aspect with 78.177%. In addition to the article 'Proceedings Papers' and 'Proceedings Papers' together totaling 21%, thus being the 3 biggest ways of disseminating the theme. Table 5 shows which institutions are most interested in the topic addressed.

Table 5: Educational Institutions

Nº	Educational Institutions	Amount	%
1	Tsinghua University	51	2,29
2	Indian Institute of Technology System	35	1,572
3	University of Southern Denmark	34	1,527
4	Chongqing University	32	1,437

5	Delft University of Technology	30	1,347
6	Scientifique	28	1,257
7	Chinese Academy of Sciences	28	1,257
8	Hong Kong Polytechnic University	27	1,212
9	Shanghai Jiao Tong University	27	1,212
10	Islamic Azad University	25	1,123

Source: Authors (2021).

As for the institutions that publish the most articles on the subject, Tsinghua University leads this item, where it is possible to see 51 published works, representing 2.29% of the potential, according to the WOS database. Then there are two other institutions with the difference of one production, the Indian Institute of Technology System and the University of Southern Denmark. Respectively they published 35 and 34 works respectively. Table 6 shows the 5 agencies with the highest funding and investment in remanufacturing research with a general systems theory bias.

Table 6: Financing Agencies

Nº	**Funding Agencies**	**Amount**	**%**
1	National Natural Science Foundation of China	349	15,671
2	Fundamental Research Funds for the Central Universities	73	3,28
3	European Union	52	2,335
4	China PostDoctoral Science Foundation	50	2,245

5	Engineering Physical Sciences Research	36	1,617

Source: Authors (2021).

The National Natural Science Foundation of China is the agency that invested the most in the productions, with a large difference to the second largest investor (Fundamental Research Funds for the Central Universities) of approximately 276 productions. It dominates this item with 349 productions (15.671%). The European Union also presents good investment, totaling 52 productions. The 5 authors with the highest rate of publications are represented in the table below (Table 7).

Table 7: Authors

Nº	Authors	Amount	%
1	LI, J.H.	32	1,437%
2	GOVINDAN, K.	29	1,302%
3	ZENG, X.L.	23	1,033%
4	WANG, Y.	21	0,943%
5	JIANG, Z.G.	15	0,674%

Source: Authors (2021).

Zed with 32 productions, three more surveys than the second largest producer (Govidan). Zeng and Wang are respectively the third and fourth largest producers in the last ten years. The ten journals with the greatest publication of research on remanufacturing with a focus on general systems theory will be described below (Table 8).

Table 8: Total articles published by source

*Nº.	source title	Amount	%
1	*Journal of Cleaner Production*	466	20,925
2	*Sustainability*	147	6,601
3	*Resources Conservation and Recycling*	81	3,637
4	*International Journal of Production Research*	73	3,278
5	*International Journal of Production Economics*	48	2,155
6	*Procedia CIRP*	40	1,796
7	*International Journal of Advanced Manufacturing Technology*	37	1,661
8	*Computers Industrial Engineering*	31	1,392
9	*Journal of Industrial Ecology*	28	1,257
10	*Waste Management*	27	1,212

*Note: Display of the first 10 records.
Source: Authors (2021).

It is noted in Table 8 the vast difference (319 productions) between the journal with the first position (466 productions) and the second place (147). But both have the same focus, productions related to sustainability and production. Most of the journals have as main objective to publish productions with solutions to reduce the use of raw materials from the environment but use unused or discarded products to create new products, reducing production with resources never used.

Table 9: Total articles published by country

*Nº.	Country	Amount	%
1	China	582	26,134
2	United States	341	15,312
3	England	216	9,699
4	India	160	7,1
5	Italy	119	5,344
6	Brazil	113	5,074
7	France	103	4,625
8	Australia	101	4,535
9	Canada	91	4,086
10	Sweden	90	4,041

*Note: Display of the first 10 records.
Source: Authors (2021).

Regarding publications by countries, Table 9 shows that China and the United States released the ranking, together they account for more than 40% of the works in the period analyzed. From this perspective, Zhang, Yang and Chen (2017) points out that remanufacturing is an emerging industry in China. Among other initiatives, it should be noted that this country is the second largest producer of waste electrical and electronic equipment in the world and that remanufacturing is the way generally adopted for the recovery of this type of waste (Liu et al., 2017). In the United States, according to Chairman (2012), remanufactured products represent a small but growing share of the production industry, whose investment has almost doubled from US$ 639 million in 2009 to US$ 1.2 billion in 2011. Brazil is already among the top 10 countries, reinforcing the growth of the theme in academic and business debates in the country.

Final Considerations

The analysis of publications on Remanufacturing and General Systems Theory in the Web of Science database between 2011 and 2020 revealed the presence of 2212 articles, the vast majority of which belong to the Engineering area. In addition to this area, in the combination carried out, it was identified that the themes Climate Change, Electronic Waste and can be considered hot topics, that is, they can be considered as exclusive topics with scope not only in their own research area.

The United States and China are the countries that dominate production, as they are countries with a high industrial production rate and a high rate of waste generation. Both invest in research to generate new products with their waste. Engineering journals are the ones that most seek productions aimed at remanufacturing, most of them focused on environmental impact analysis.

Therefore, during this work it was possible to verify the usefulness of the search tool of the Web of Science database for academic research, which can be considered an important tool to help researchers seeking information in their area of interest.

As a limitation of this study, the use of only one specific database stands out. Therefore, as a suggestion for future studies, it is recommended to increase the range of sources, such as the use of other databases that also include academic events, both national and international, in addition to other sources of scientific data. Hot topics will also be explored in future work.

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