Circular and Sustainable productive processes: An approach to the practices adopted in the Industrial Pole of Manaus-AM

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Abstract. Considering the constant changes in a more competitive world, industries must find a new way of producing. The traditional form of production is called linear economy, which consists of extracting, transforming, producing, consuming, and discarding. One of the alternatives to the linear model is the Circular Economy (CE), which provides the economic system with an alternative flow model. CE is seen as a new form of sustainability and has gained popularity in the scarcity of resources, the circulation of materials, and the facilitation of the reuse and recycling paradigm. The research approach chosen was the "Survey", which makes it possible to obtain a quantitative description, opinions, trends, and activities of a population. In the present study, a survey was carried out through a questionnaire to map the practices of organization and management of sustainability and the perception of the Circular Economy of the companies that enjoy the tax incentives of the Industrial Pole of Manaus. The questionnaire was sent to 502 companies in the Industrial Pole of Manaus, with a response rate of around 32%. Based on the answers collected in the questionnaire, we can say that the biggest barrier to overcome for CE to be fostered is the economic one. The statement by companies that there is a lack of qualified labor to carry out sustainability projects, as well as labor to understand and comply with environmental legislation, also corroborates the economic barrier. In this context, the importance of adopting sustainable practices is highlighted, as well as the perception of companies about the circular economy, which can be built from effective public policies that encourage companies to remodel their production processes.

Keywords: Circular Economy, Sustainability, Circular and Sustainable Production Process.

1 Introduction

Due to constant changes in a more competitive world, industries must find a new way of producing. New skills are required, such as dynamism, proactivity, and the ability to make decisions. The traditional form of production is called linear economy, which consists of extracting, transforming, producing, consuming, and discarding [1, 2]. This model is beginning to be threatened by a series of factors. Among them, we can list the increase in the world population, which went from 3.3 billion people in 1965 to 7.79 billion in 2020, which will consequently lead to an increase in the consumer class. According to the Organization for Cooperation and Development (OECD), there is a forecast that this class, with disposable income, will increase from 1.8 billion in 2010 to almost 5 billion in 2030 [3]. The linear production flow caused serious environmental damage that led to irrational waste and scarcity of resources such as land, materials, energy, and water [4]. With this, the challenge of expanding supply to meet future demand is unprecedented, as the linear economy is threatened because of increased demand, increased use of natural resources, and the use of finite spaces in the capacity to assimilate information. pollution generated by this economy [5]. In this context, the search for new ways to promote sustainability, through private business models, led industries to abandon the classic production method to meet new market demands [6, 7]. One of the philosophies to meet this challenge is the Circular Economy (CE), which provides the economic system with an alternative flow model.

Although linearity is dominant in current capitalism, the idea of material cycles has existed since the beginning of industrialization. The idea has also been practiced with the argument of reducing negative environmental impacts and stimulating new business opportunities [1, 8]. CE is seen as a new form of sustainability and has gained popularity in the scarcity of resources, the circulation of materials, and the facilitation of the reuse and recycling paradigm. Consequently, due to the consumer lifestyle, the growth of manufacturing industries has made carbon emissions and waste generation increasingly present [9]. Some countries, concerned about the impact of the linear economy on the environment, have proposed specific laws that deal with the change from the traditional mode of production to a circular approach. Germany and Japan were pioneers in promoting CE in concrete policies [10], followed by China, in 2008 [8, 11]. The CE Initiation in Brazil is a recent activity. In 2017, an initial exploratory approach on the subject was published through the EMF CE100 program [12]. In this foundation study, it was proposed that the country has opportunities to explore three sectors: Agriculture and Biodiversity Assets, Buildings and Construction Sector, and Electronic Equipment. The initiatives in Brazil are of a “bottom-up” approach, where there is a private effort to implement CE [13]. Concerning Manaus, which has one of the largest industrial parks in Brazil, the responsibility of developing the pole is from the Manaus Free Trade Zone Superintendence, and it must have data to carry out public policies in several areas. As a way of supporting this responsibility, this article has the main objective of mapping the practices of organization and Sustainability Management and the perception of the Circular Economy of the companies of the Industrial Pole of Manaus, based on the elaboration of a questionnaire on a Web platform that was sent to all PIM companies.

2 Theoretical Background

2.1 Sustainability and Sustainable Development

The words sustainable, sustainability, and sustainable development, although used in the scientific literature, in the private sector, and in public policies, still do not have a consensus in terms of concept. In the literature, there is a vast diversity of concepts, predominantly related to sustainable development [14]. Despite the absence of consensus on the concepts, there is acceptance in relation to the search for a balance between the needs of human beings and the environment, and in understanding their complex interaction dynamics, to deepen and broaden their meaning [15]. Another aspect of consensus about the terms is that they represent something positive and good [16]. The discussions linked to the terms sustainable, sustainability, and sustainable development took place intending to achieve long-term human well-being through managing the human-environmental system [17, 18]. The driving forces behind the emergence of the idea of sustainability, according to [19], were essentially the crises of the energy system since antiquity. [20] add that this emergence is linked to improving environmental aspects with negative impacts, with positive effects on the economy and society. In this way, sustainability can be understood as a solution to the scarcity of natural resources linked to energy issues and resource use. It originated from the deterioration between global ecology and economic development. It encompasses sustainability and sustainable development and concerns the future of natural resources and human life [21].

The term sustainability was first used in the context of development in 1974 in a series of conferences on forest issues [22]. [23] point out that sustainable development, as a definition, has its roots in the publication of Silent Spring. Therefore, it is perceived that there is a dynamic tension between poverty and environmental concern, considering the continuation of human beings' lives within certain environmental restrictions [24]. Thus, sustainable development aims at economic growth without human environmental aggression. It proposes a change in the behavior of humanity materialized through strategies involving processes and practices [21].

2.2 Circular Economy

The CE concept is of great interest to academics and professionals because it is seen as an operationalization for companies to implement the much-discussed concept of sustainable development [25, 26]. [9] point out that “there are several possibilities for defining CE”, while [11] writes that “there is no commonly accepted definition of CE”. However, the concept is widely debated by different researchers, based on its importance and the necessary strategic actions to boost the model [9, 25, 26, 27, 28, 29]. To give greater transparency to this concept and resolve doubts, [30] distinguished between two types of fundamental principles: those that relate to the R frameworks, which means how to do CE, and the systems perspective, which shows where is CE being done. Based on the authors who carried out the CE literature reviews, the transition from a linear economy to a circular one is better understood with the

expansion of the structure from 4R to 9R, where the 9R is the beginning of the output of the linear and the 0R is the apex to get close to circularity [30].

The 9R framework looks at how to do CE, and the systems perspective is for knowing where CE is being implemented. [31] proposed the "ReSOLVE" framework (see Table 1), intending to define operational actions to put into practice the CE principles that are in the Framework and in the perspectives above [29, 31]. Some types of barriers to implementing CE are shown in Table 2 [32].

Table 1. ReSOLVE structure.

Analytical Category	Description
Regenerate	Shift to renewable energies and materials; reclaim, retain, and regenerate ecosystem health; return or recover biological resources to the biosphere.
Share	Share products between users; reuse/secondhand; extend product life (durability, upgradeability, maintenance).
Optimize	Increase product performance/efficiency; remove waste from production and the supply chain; leverage big data, automation, remote sensing, and driving.
Loops	Remanufacture products and components; recycle material; extract biochemicals from organic waste.
Virtualize	Dematerialize.
Exchange	Replace old materials with advanced non-renewable materials; apply new technologies; choose new products and services.

Source: Adapted from [31].

Table 2. Types of barriers to CE implementation.

Types of barriers	Description
Legislative	The inadequate and incomplete legislative framework that enhances the reuse/recycling of materials and the replacement of raw materials with secondary raw materials;
	Lack of coordination between environmental policies implemented at different levels: regional, provincial, and municipal;
	Lack of incentives to stimulate the consumption of recycled materials and products.
Economical	Low investment rate in research and development activities;
	The industrial structure is composed mainly of small family businesses.
Market	Competitiveness between the low price of virgin raw materials and the higher price of secondary raw materials derived from the recycling of waste materials.
Financial	Lack of availability of risk capital;
	Lack of adequate tools for investments in CE projects;
	Lack of access to credit to finance eco-innovation research.
Networking	Absence of platforms that allow the reuse of waste throughout various cycles and sectors.

Technological	Development of new advanced technologies for the reuse of waste materials and by-products.
Cultural	Lack of attention to waste prevention strategies (design, sustainable production, consumption, industrial and urban symbiosis) on the production and consumption side in the social and industrial debate.

Source: Adapted from [32].

3 Methodology

The research approach chosen was the survey, which makes it possible to obtain a quantitative description, opinions, trends, and activities of a population [33]. In the present study, a survey was carried out through a questionnaire elaborated on the google forms platform to map the practices of organization and management of sustainability and the perception of the Circular Economy of the companies that enjoy the tax incentives of the Industrial Pole of Manaus. The industrial hub has around 508 companies installed, where 157 companies responded to the questionnaire, resulting in a response rate of 31%.

Manaus Free Trade Zone is home to one of the main industrial parks in the country. Responsible for one of the largest GDPs in the Brazilian industry, PIM manufactures products that are part of the daily lives of all Brazilians, such as televisions, motorcycles, smartphones, air conditioners, notebooks, ballpoint pens, and shavers. About 95% of PIM's production is destined to supply the domestic market, with stages of industrialization regulated by Basic Production Processes. According to the [34], currently, there are 508 beneficiary industries in the PIM from different industrial sectors. The division by sectors, their proportion in relation to the total population, and sampling by sectors are shown in Table 3.

Table 3. Population and sample to be reached and the number of responses received.

Sector	Industry Population	Sector/Ratio	Sample by Sector	Answers
Beverage	11	2,17%	3	3
Toys/Leathers/Similar	8	1,57%	2	2
Several	20	3,94%	6	6
Two wheels	23	4,53%	7	8
Editorial and Graphic	6	1,18%	2	2
Electronics	102	20,08%	31	31
Packing	54	10,63%	16	16
Energy/Fuel	6	1,18%	2	2
Lighters/Pen/Timber sector	8	1,57%	2	2
Cleaning Supplies and Candles	14	2,76%	4	4
Mechanic	29	5,71%	9	9
Metallurgical	40	7,87%	12	14
Non-Metallic Mineral/Watch	8	1,57%	2	2

Furniture		19	3,74%	6	6
Paper and Cardboard		27	5,31%	8	8
Food products		48	9,45%	14	16
Chemical		15	2,95%	5	5
Recycling		10	1,97%	3	3
Textile		21	4,13%	6	6
Total	**508**		**100,00%**	**153**	**157**

Source: Authors (2022).

The structure of the questionnaire followed the ReSOLVE structure, where each analytical category has questions to see if the PIM companies have the capacity to reach which "R" of the 9R Framework. The walkthrough was based on [31] publication, which provides a detailed methodology for exploring and prioritizing CE opportunities; checking if CE actions already exist in the PIM; identifying the barriers that limit these opportunities; and mapping and prioritizing policy interventions to overcome these barriers. Section 2 searches for general company information. Section 3 aims to map the sustainability practices in the company's production process in Manaus. Finally, section 4 deals with perceptions of the Circular Economy.

4 Results and Discussion

4.1 Result of the general information of the companies

Section 2 of the questionnaire sent to the PIM companies aimed to obtain data from those who filled out the questionnaire and from the companies, such as: What is the position of the person who was filling it out; if you had expertise in any area of sustainability; how many years you worked at the company; As far as the company is concerned, this section sought to understand and map the company's main activity sector; how many employees it had; if the company has a department dedicated to the area of sustainability or similar; If the environmental management is seen as a strategic factor in the company and if the CE concept was known by the company's senior management. The most common position of those who filled out the questionnaire was engineer (33 people), accounting for 21.02% of the total, followed by 8 attorneys/representatives, which corresponds to 11.46%% and the third most declared was manager, with a participation of 10.83%; 16 supervisors answered the questionnaire (10.19%), followed by 14 assistants (8.92%) and 13 partners/owners. (8.28%). Three positions had the same number of declarants, which were technicians, analysts, and administrators, with 8 people declaring each position corresponding to 5.10% each. The remaining percentage was distributed among directors, chemists, pharmacists, and positions that appeared only once.

Regarding specialization, about 61.1% of the people who answered the questionnaire stated that they do not have specialization in any area of sustainability, environmental management, green economy, or similar, which corresponds to 96 out of 157 responses. The other 61 responses claimed to have expertise in one of these areas. That is, most

people who answered the questionnaire do not have specialization in any area of sustainability or similar. The most common specialization in the PIM was in the area of sustainability with 11 answers (7%), followed by the area of environmental engineering with 8 answers (5.1%), and by the areas of environmental analysis, environmental management (in any area) and environment, with 6 responses each (3.8% each). The questionnaire sought to investigate whether the company had in its organizational structure any department, sector, or section dedicated to matters of sustainability, environmental management, waste, CE, or similar, where 53.5% responded that they had no sector and 46.5% responded that had these sectors.

Finally, in this section, we investigated whether environmental management is seen as a strategic factor within the company and whether the CE concept is known by the company's top management. Regarding the company's perception of environmental management, the answers were: About 73.2% of the people who answered have the perception that they agree/completely agree that environmental management is seen as a strategic factor within the company. Specifically, to the CE theme. CE's perception is that 59.8% agree/completely agree that the concept is known by the company's top management. Such answers corroborate that the fact of those companies does not have a specific sector for the environmental area is the economic barrier.

4.2 Results of questions based on the ReSOLVE Framework

Section 3 of the questionnaire sent to PIM companies aimed to obtain data based on the "ReSOLVE" framework, to map the current stage of sustainability initiatives of PIM companies in early 2022. First, it was intended to know if there was waste management in the company. This question is related to the "R" (Regenerate) and the "O" (Optimize). Regarding the 157 industries that responded to the questionnaire, 104 stated that they practiced waste management in their own company (66.2%), and 53 answered that they did not (33.8%). Then, the respondents were asked to identify the most common types of waste that were controlled by the companies, obtaining a total of 114 responses, with the most common types of waste that the companies treated were: plastic (54 responses), metals (43 responses), rubber (20 responses), paper (19 responses), cardboard (15 responses) and wood (11 responses). In addition, of the 53 companies that responded negatively to the previous question, 20 reported that they outsourced waste management.

Regarding the use of renewable energy sources, a question based on the "R" (Regenerate) of the "ReSOLVE" structure, 40 companies answered that they used renewable energy. Among these, 29 declared that they used solar energy in their plant in Manaus. After the questions about waste management and the use of renewable energy sources, it was asked whether there is use/reuse of second-hand inputs in the production process (such as recycled, recovered products). This question was based on the "S" (Share) of the structure, in which 72 companies stated that they used/reused second-hand inputs in their production process. Of these 72, 47 were made of plastic, 22 of paper, 15 of cardboard, 12 of metal, 11 of rubber, and 5 of wood.

Next, it was investigated whether the industries had the intention of increasing the useful life cycle of the product manufactured in Manaus through repair and maintenance activities, based on "O" (optimize). The answers obtained were that 66

companies intend to increase the life cycle of the product through repair and maintenance activities. In addition to these activities, the companies gave us answers that they used extended warranties (17) and R&D (11), and product exchange (8).

Continuing with the questionnaire, it was asked whether the organization could reduce waste in its production process by adopting practices such as automation, big data, remote sensing, and the like. Based on the "O" (optimize) of the methodology, 42 companies responded that they manage to reduce waste in their production process by adopting the practices highlighted above. Regarding the interest in investing in R&D of sustainability, of the 157 responding companies, 67 are interested in this type of investment. This data shows that there may be a technological barrier to implementing CE in PIM companies. Regarding the possibility of being able to recover/recycle products, components, and/or residual resources through collection and segregation, based on the L (loop) of the "ReSOLVE" structure, the answers obtained were that 70 companies stated that they can recover/recycle products, components and/or residual resources through collection and segregation and 63 companies (40.01%) understand that the recovery/recycling of products, components and/or residual resources generate new business opportunities. According to [32], the technological barrier can hinder the search for advanced technologies for reusing waste materials and by-products.

Still, in this context, only 26.8% of the industries have the technology to recover the waste generated. Thus, demonstrating that PIM companies do not have the technology to increase the reuse of waste materials and by-products. Regarding the possibility of companies being able to extract biochemical products from organic waste, only 16.7% (26 companies) stated that they could carry out this extraction. This question was based on the "R" (regenerate) and the "L" (loop) of the model. The penultimate question in this section sought to verify whether the industries installed in the PIM can virtualize some production processes, based on the "V" (virtualize) of the "ReSOLVE" structure, where about 40 companies reported that they could virtualize production processes. These processes include employee entry, line control and maintenance, input selection, factory virtualization, product design, line review, new product development, R&D, and meetings. Such facts highlight the technological barrier that PIM industries face to developing CE.

The last question in this section I seek to identify was whether the company has already replaced traditional processes/technologies (those that pollute the environment) with green processes/technologies. This question is based on the E (Exchange - substitute), and the answers obtained showed that 44 industries stated that they managed to replace traditional processes/technologies with green processes/technologies. In this context, 20 companies declared using the Internet of Things – IoT in their factory; 10 stated that they use 3D Printing – I3D; 8 use Big Data; 7 inserted the term automation, and 4 declared to perform machine learning, corroborating with the technological barriers already detected in the previous questions.

4.3 Result of the perception of companies about the Circular Economy

The last section of the questionnaire aimed to assess the company's perception of the Circular Economy. In this sense, it was investigated whether the company had/has any specific policy for the adoption and implementation of CE pillars, where about 29.3%

(46 industries) responded that they had CE policies and 70.7% (111 industries) responded that they did not have CE policies. The last question in this section sought to identify the main obstacles companies face in carrying out sustainability and circular economy actions in Manaus. Figure 1 presents the result identified by the 111 companies that answered this question.

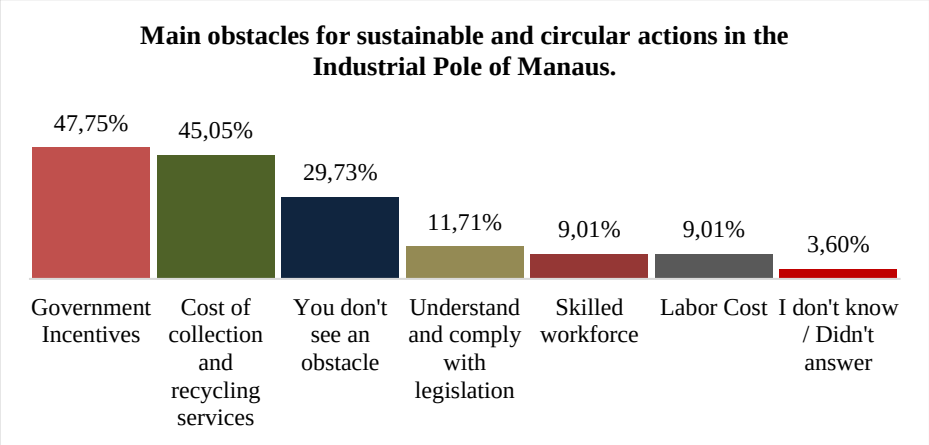

Fig. 1. Main obstacles to improving sustainability & CE actions.

Part of these obstacles have already been raised by [35], where they detected that the main difficulties of the PIM company consisted of: Hiring qualified and specialized employees; the High cost of waste collection and treatment; Does not have a final waste disposal unit; Technical knowledge of the area; Cost or lack of capital for the acquisition of machinery and equipment; and understanding of the legislation. The fact that both the current research and the research by [35] identify the understanding of environmental legislation as a barrier, as well as the hiring of qualified and specialized jobs, demonstrates that there may be a correlation between the lack of specialized professionals in the environmental area and the fulfillment of the legislation, a statement corroborated by the number of professionals who answered this questionnaire. In addition, it should be noted that the biggest difference between the two studies was the companies' perception of the high cost of collecting and treating waste, an issue that was rarely declared as a barrier in the current study.

The questionnaire detected CE initiatives, based on the “ReSOLVE” structure, as shown in Table 3.

Table 3. Structure ReSOLVE (PIM).

Analytical Category	Activity	% Of companies that practice
Regenerate	Waste Management	66,20%
	Renewable energy source	25,50%

	Extraction of biochemicals from organic waste	16,70%
Share	Use/reuse of second-hand inputs	45,90%
	Waste Management	66,20%
Optimize	To increase the useful life cycle	42,00%
	Decrease waste with the use of technology	26,80%
Loops	Recover/recycle waste products, components, and/or resources	44,60%
	Extraction of biochemicals from organic waste	16,70%
Virtualize	Virtualization of production processes	25,50%
Exchange	Replacement of traditional technologies with green technologies	28,80%

5 Conclusion

Based on the answers collected in the questionnaire, we can say that the biggest barrier to overcome for CE to be promoted is the economic one. Although 73.2% of the people who answered the questionnaire had the perception that they agree/completely agree that environmental management is seen as a strategic factor within companies and that 59.8% agree/completely agree that the concept is known from the company's top management, industries bar their capital structure and size to implement CE projects.

The statement by companies that there is a lack of qualified labor (50 responses) to carry out sustainability projects, as well as manpower to understand and comply with environmental legislation (33 responses), also corroborates to the economic barrier. In addition to the economic barrier, we also highlight the technological barrier, since 73.2% of the answers showed that there is no use of new technologies such as big data, remote sensing, and others; 74.5% are unable to virtualize any production process, and 72% have not replaced traditional processes/technologies (those that pollute the environment) with green processes/technologies.

Thus, more than half of the PIM companies are not included in the 9R (Recycle), as they do not have the ability to share or carry out the loop. What can be said is that the degree of circularity of the PIM is of useful application of materials which, according to Framework 9R, is the initial degree of circularity. This survey can be applied by Suframa in PIM companies to drive the search for improvements in the region's Sustainability indicators, thus reaching the public interest and the Environmental Protection Laws. Furthermore, it will enable transparency to the market, academia, and society. It is also expected a greater synergy of Suframa with other government entities for improvement actions in companies seeking the adoption of measures for productive processes based on the concepts of clean, cleaner, sustainable, and circular production in the Industrial Pole studied.

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