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Proposal Of Cleaner Production (P+L) Methodology For IFAM Construction Works

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Abstract:
The increase in consumption levels, the development model focused on economic growth, and the culture of consumption have caused imbalances in the environment, leading to the accelerated depletion of the planet's natural resources. This context results in a growing demand for technologies, methodologies, and processes that have less impact on the environment, are aligned with sustainable development, and can ensure that future generations have their share of the planet's natural resources. One of these methodologies is Cleaner Production (CP), which aims to counteract so-called end-of-pipe technologies, promoting a more proactive strategy of increasing efficiency and reducing process costs. Thus, considering the importance of public administration in promoting practices that enable environmental damage mitigation and the context of internalization and deficit of works at IFAM, this research aims to propose a methodology of Cleaner Production focused on IFAM's construction and building activities. Regarding the approach, this research can be characterized as qualitative. Regarding the purpose, it can be classified as exploratory and applied in nature. In terms of approach, this research can be classified as a case study. The first stage of the research consists of a literature review using a systematic literature review protocol, defining parameters such as research questions, keywords, and criteria for inclusion and exclusion of studies. The second stage consists of characterizing the works and processes related to engineering services, carried out through documentary research based on IFAM's archives related to the research theme; process modeling through interviews with coordinators who are part of the technical and administrative staff of the Infrastructure Directorate; and a questionnaire to assess employees' perception of concepts and ideas relevant to the application of Cleaner Production methodology at IFAM. The third stage includes evaluating the applicability of existing Cleaner Production methodology in the institutional context of IFAM. The fourth stage consists of evaluating the barriers and adjustments necessary for existing Cleaner Production methodologies to be applied at IFAM. The fifth stage is the proposal of a Cleaner Production methodology aligned with IFAM's reality. The results obtained in this research present an analysis of the applicability of Cleaner Production methodology at IFAM, as well as the modifications in the processes of basic project development, construction supervision, and contract measurement, necessary for the program to be applicable in the context of IFAM's construction and building activities. The research limitations are related to the scope of process modeling and the Cleaner Production manual employed for analysis.

Keywords: *Cleaner Production; IFAM; Public Administration; Construction; Public Works*

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I. Introduction

The increase in consumption levels and economic growth, both in developed and developing countries, disrupts the environment, resulting in an ecological deficit, where the rate at which natural resources are consumed exceeds the rate at which nature can replenish them (DINPANAH and LASHGARARA, 2008; ABBASI et al., 2021; ALVARADO et al., 2021).

In this context, the development model focused on economic growth, associated with the culture of consumer society, the desire to consume more and the personal satisfaction through consumption, may prevent future generations from having their share of the planet's natural wealth (Zanirato and Rotondaro, 2016; Oliveira et al., 2016). Thus, raising awareness among communities, through a continuous process of sensitizing individuals, makes it necessary to rethink how we produce and consume, so that society recognizes that the environment should not be treated as an inexhaustible source of resources (CHAVES and SILVA, 2008).

This leads to a growing demand for technologies and processes that have less impact on the environment, are aligned with sustainable development (Gunnarsdottir et al., 2021), and can ensure that future generations have their share of the planet's natural resources, especially non-renewable resources (WEST, 2020).

From this perspective, there has been a search for the adoption of environmental preservation measures in various branches of human activity, contributing to sustainable development through efficient resource and energy management, as well as the development of new intelligent technologies (GIANNETTI et al., 2020).

Among these branches of activity capable of environmental improvements, the construction industry stands out. It is an important sector among productive activities, distinguished from others by its own characteristics and representing a considerable contribution to economic development. It is one of the pillars of the Brazilian economy, generating a significant number of jobs directly, with 7.57% of the workforce (IBGE, 2019), and contributing to the composition of the Gross Domestic Product (GDP) of the country (Paz et al., 2014). It is a sector typically focused on cost, production, and time, and its processes and activities are generally managed to establish a unit cost per production, while also complying with environmental and safety regulations (CARMICHAEL et al., 2019).

However, it is also a sector marked by the abundance of losses, both in materials and labor, related to inefficiencies in some of its processes (Souza et al., 2004), representing approximately 10% to 30% of the waste received in landfills (Begum et al., 2006), besides being recognized as a sector with high environmental impact, as its processes produce a worrying volume of waste (Duan, Wang, and Huang, 2015). Activities in the construction industry require a high quantity of materials. As an illustration, in China alone, approximately 300 million linear meters of concrete pipes were consumed in 2017 (CUI et al., 2020).

Furthermore, the production of materials and inputs for construction requires high amounts of energy and generates a massive amount of greenhouse gases. Thus, the energy used and the CO_2 emissions in the manufacturing processes of construction materials have received more attention recently (Mohammadhosseini, Alyousef, and Tahir, 2021), with the construction industry accounting for 36% of energy use and 39% of CO_2 emissions related to processes and energy (GLOBALABC, 2019). Therefore, the construction sector presents vast potential for improvements, and actions promoting sustainability in this industry are of strategic importance, especially in projects financed by national governments (WANG et al., 2019).

In general, due to the inherent characteristics of private organizations, namely the pursuit of profit margin expansion, competitiveness among others, these tend to develop and implement EMS (Environmental Management Systems, such as ISO 14000) more rapidly (Bezerra et al., 2015). These construction-specialized companies perceive a great potential for maximizing their profits by reducing losses (Karpinski et al., 2009), encouraging the use of methodologies that increase production efficiency in the private environment, reducing economic losses related to misused materials or labor. One of these methodologies is Cleaner Production (CP), originated from the United Nations Environment Program (UNEP) conference held in 1989, aiming to counteract the so-called end-of-pipe technologies, promoting a more proactive strategy of increasing efficiency and reducing process costs (VIEIRA and AMARAL, 2017; MATOS et al., 2018).

On the other hand, regarding public administration, there is a temporal gap in the adoption of improvement and resource optimization measures and processes between the public sector and the private sector (Bezerra et al., 2015). This does not mean that public administration does not value efficiency or seek socio-environmental responsibility. Since the mid-1990s, efforts have been made to reform the State, building a model of public management that can make it more open to the needs of Brazilian citizens, more oriented towards public interests in general, and more efficient in coordinating between the economy and public services (Paula, 2005). In addition, initiatives of the public sector such as the Environmental Agenda in Public Administration (A3P), created by the Ministry of the Environment, aim to implement socio-environmental responsibility in the administrative and operational activities of public administration (MMA, 2016), being an important instrument to guide the application of sustainable principles, highlighting the importance of observing and experiencing socio-environmental practices within public organizations (Peixoto et al., 2018). However, the realm of research associating the Brazilian public sector with sustainability is still relatively limited, with a large portion of the research conducted by public higher education institutions, few specialists who publish systematically in the field, and few national authors with a relevant history of research (Rohrich and Takahashi, 2019; Marcuz Junior et al., 2020), hence there is a vast field to be explored.

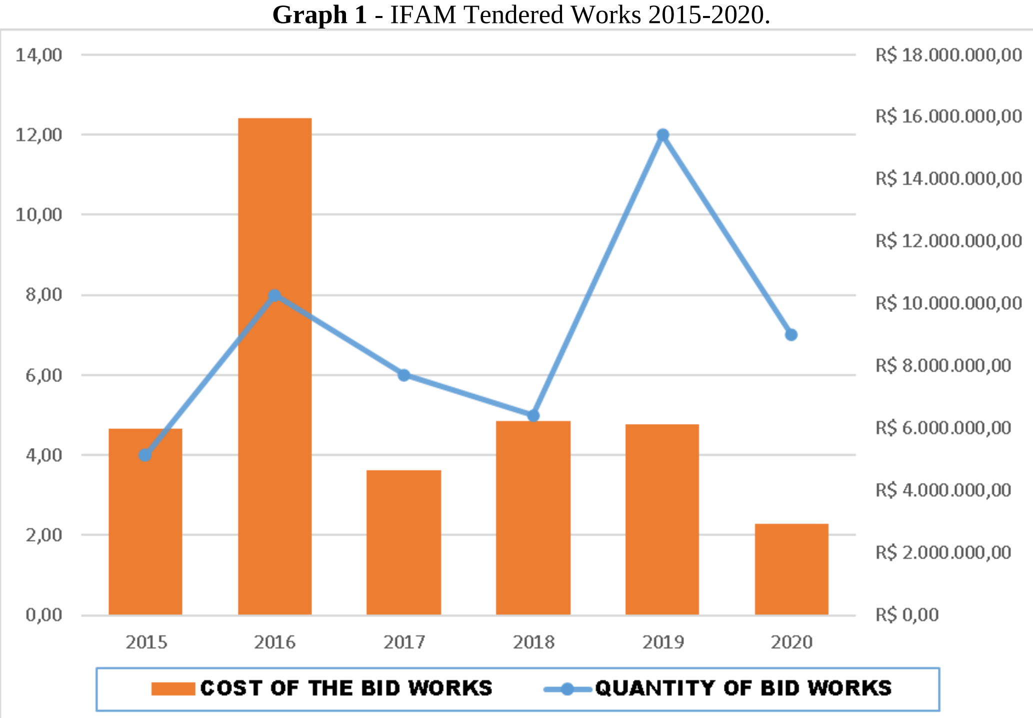
It is worth noting that, despite the importance of public works, the overall Brazilian context is still concerning, due to the use of inefficient construction methods, frequent rework, unnecessarily generated waste, material losses, and unnecessary task execution, which entail costs that do not necessarily add value (Rezende et al., 2012), as well as delays with social costs that inefficient delivery of necessary structures for the population can bring about.

The Public Sector, in addition to its primary role in legislation and oversight of environmental issues, also has the function, through its processes, of promoting practices that allow for the mitigation of environmental damage (Peixoto et al., 2018). Considering that public administration is the largest consumer of goods and services in the Brazilian market, accounting for about 10% to 15% of GDP, changes in consumption patterns and practices adopted by the public sector can contribute to environmental issues (Carvalho and Souza, 2013). Therefore, public administration plays a strategic role in reviewing production and consumption patterns and adopting new socio-environmental sustainability frameworks, through its regulatory capacities and inducer of new standards and practices (MMA, 2016).

In this context, the Federal Institute of Education, Science, and Technology of Amazonas (IFAM) is part of public administration. It is a century-old institution, whose history is intertwined with the history of professional and technological education in the northern region and in Brazil as a whole. The context of the origin of IFAM dates back to the golden age of rubber, when the School of Artisans of Amazonas was inaugurated on October 1, 1910 (Mello, 2010). The most recent stage in the evolution of this Institution occurred through Law No. 11,892, of December 29, 2008, which established the Federal Network of Professional, Scientific, and Technological Education, initially establishing that this Network would be composed of the following educational institutions: Federal Center for Technological Education of Amazonas (including the Manaus-Centro and Manaus-Distrito Industrial units) and Federal Agrotechnical Schools of Manaus and São Gabriel da Cachoeira (BRAZIL, 2008), resulting in a process of considerable expansion and internalization of professional and technological education (Leite, 2013), as well as a considerable expansion in the number of campuses.

This expansion naturally involved a context of public works, with a considerable increase in the quantity of engineering works interventions, whether in the construction of administrative buildings, classroom blocks, laboratories, sports courts, infrastructure works: urbanization, sewage and drainage network, capture and distribution of drinking water, etc., modifying spaces and somewhat altering environmental conditions in the context in which they are inserted. The following graph shows a sample of works tendered in the period from 2015 to 2020.

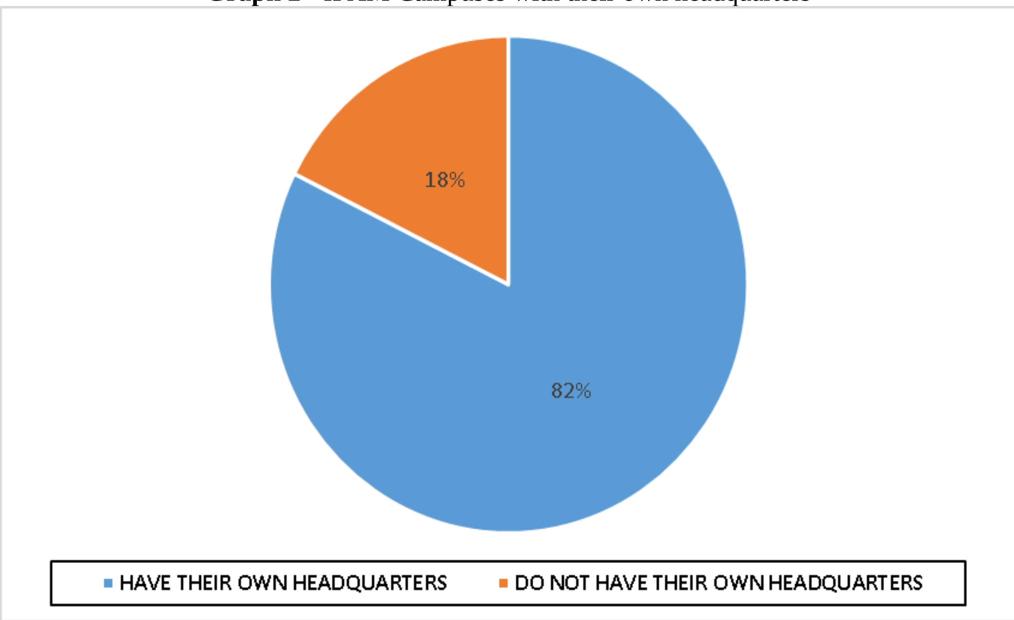
Graph 1 - IFAM Tendered Works 2015-2020.



Source: Own authorship (2022)

Analyzing the graph, it can be observed that, on average, around R$ 5.2 million are allocated for bidding on construction works, with the exception of the atypical year of 2016, which recorded approximately R$ 15.9 million. The annual average of tendered works is approximately 7. In 2019, there is a noticeable trend of increasing the number of tendered works (12), with average costs around R$ 6.0 million, suggesting the realization of more minor interventions, such as renovations and adjustments. From 2020 onwards, a steep decline is noted in both costs and the quantity of tendered works: R$ 2.9 million for 7 works. Although these data do not guarantee a future trend, it is plausible to infer, considering the economic impacts of Covid-19 (PORSSE ET AL., 2020; MONTEIRO ET AL., 2021), that this reduction in investments will persist in 2021 and possibly in the following years. In this context, methodologies such as cleaner production can be valuable, resulting in more efficient construction techniques and reducing costs associated with material and input wastage. Despite the expansion and internalization of IFAM, combined with national economic and political adversities, there still exists a significant deficit in educational infrastructure, especially in rural campuses. This is evidenced by the percentage of campuses without their own headquarters, as shown in the graph.

Graph 2 - IFAM Campuses with their own headquarters



Source: Own authorship (2022)

From the analysis of the graph, it is noted that approximately 82% of IFAM's campuses have their own headquarters, while approximately 18% operate in temporary facilities, mainly in rural areas, highlighting a pent-up demand for infrastructure and engineering works. Given this context, there arises the necessity to adopt more sustainable approaches for future expansions and interventions. Thus, it is proposed to develop a Cleaner Production (P+L) methodology for IFAM's constructions, aiming to minimize losses, increase efficiency in the use of materials, and reduce waste. To achieve this, surveys will be conducted on the state of the art of P+L in civil construction, characterization of IFAM's works, assessment of the applicability of existing methodologies, identification of barriers and necessary adjustments, culminating in the proposition of a methodology adapted to the institution's reality. It is expected that this will promote a more sustainable and efficient management of the works, contributing to a more suitable and resilient academic and social environment.

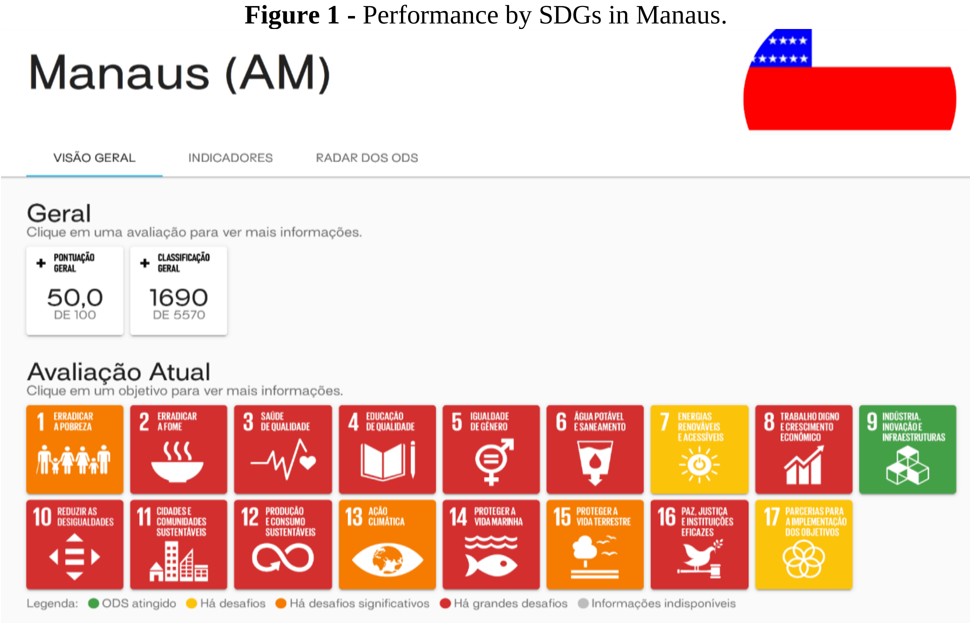
Scope of the Study

The study focuses on the reality of engineering works and services at IFAM, addressing different stages of these activities. Data will be collected through process modeling and questionnaires applied to permanent staff directly involved in construction activities. Due to the centralized organizational structure at the Rectorate, the respondents to the questionnaire are mainly located in Manaus. Furthermore, some technical staff in building construction at the Coari and Parintins campuses will also be included in the research, as their responsibilities are similar to those of higher-level positions. This approach reflects the context of IFAM's construction works comprehensively and accurately.

Research Relevance

Both public institutions and private companies have recognized their responsibilities in the face of contemporary ecological challenges, highlighting the need to rethink production and consumption models. In this context, it is essential to develop strategies to reduce the gap in the adoption of sustainable practices between the public and private sectors, considering the strategic role of public administration in this process. IFAM, as a prominent public institution in the Amazon region, has the mission of promoting education, science, and technology for the sustainable development of the Amazon, an area characterized by low levels of development. A relevant tool is the IDSC-BR (Sustainable Development Index of Cities - Brazil), which classifies Brazilian municipalities based on the indicators of the 17 Sustainable Development Goals. All municipalities in the state of Amazonas have a low or very low classification, with Manaus only achieving SDG No. 9. There are significant challenges to be faced in various other objectives, as detailed in Figure 1.

Figure 1 - Performance by SDGs in Manaus.



Source: Sustainable Cities Institute (2022)

In the context of IFAM, there is a pursuit for sustainability parameters, such as the adoption of the A3P seal (Agenda Ambiental na Administração Pública - Environmental Agenda in Public Administration), in addition to the presence of structures such as the Environmental Management Coordination and the Commission for Energy Efficiency and Renewable Energy. However, the guidelines to promote sustainability in construction projects lack specificity, requiring more detailed resolutions to allow comprehensive discussions among stakeholders. The introduction of a Cleaner Production methodology within IFAM's engineering projects and services is justified by the need to address sustainability through waste minimization. Therefore, it is essential for Cleaner Production concepts and methodologies to be studied and incorporated into IFAM's reality, as research in this area is still limited in the Brazilian public sector, with few publications and experts (ROHRICH & TAKAHASHI, 2019; MARCUZ JUNIOR et al., 2020).

Moreover, in the Brazilian context, Cleaner Production still does not have a high level of implementation nor the inclusion of stakeholders in decisions made for implementing environmental practices (Neto et al., 2015), representing a missed opportunity for organizations to minimize their costs through waste reduction, thereby reducing environmental impact and making the market more competitive. It also represents a missed opportunity for Brazilian universities to generate more innovation and recognize environmental education as a means of survival for future generations (NETO, SHIBAO, & FILHO, 2016).

Another point is that the specific context of public works differs significantly from the context of works carried out by private sector agents, which usually receive greater attention in available literature regarding Cleaner Production. Therefore, from a theoretical standpoint, this research may have its relevance justified by exploring the theme of Cleaner Production from the less explored perspective of public administration, more particularly in the context of public works.

Opportunity

The implementation of a cleaner production methodology in IFAM's construction works and buildings can represent a significant improvement in environmental management, reducing energy, materials, and input waste, as well as minimizing waste generation. Opportunities for improvement are identified at all three levels of cleaner production, from waste reduction at the source to external recycling, enabling the reuse of materials and the adoption of more sustainable practices throughout the construction processes.

The current context of expansion and decentralization of IFAM makes the adoption of this approach even more opportune, given the demand for educational infrastructure in new advanced campuses and municipalities in the interior. The application of cleaner production not only makes the works more efficient and sustainable but also reinforces IFAM's strategic role in promoting environmentally responsible practices, acting as an inducer of positive changes in the Amazon region.

Feasibility

The feasibility of implementing a cleaner production methodology in IFAM's construction works is evident, considering its wide applicability in various industries such as agriculture, civil construction, and manufacturing. Although not yet widely adopted in Brazil, cleaner production demonstrates potential for reducing material consumption, losses, and costs, as well as promoting improvements in work efficiency. In the context of public works, this approach can result in a more rational and effective use of public resources, contributing to the sustainability and efficiency of projects. However, it is crucial that the implementation be carefully planned, considering the specificities of public works and ensuring compliance with legal and public management principles, such as legality and legitimacy. Thus, provided that effectively planned, the application of cleaner production can be feasible and beneficial in the context of IFAM's construction works.

Cleaner Production - Origin and Applicability

The sustainability issue, global competition, and pressures for legal adjustments in social and environmental matters lead the productive sectors of society to seriously consider ways to manage the impacts and waste arising from their activities and to seek solutions beyond common sense, which merely aim at maximizing the financial returns of their investors (NETO et al., 2015). Among the transformations observed in recent history, it is possible to highlight the United Nations Conference held in 1992 in Rio de Janeiro as a milestone, with one of its most important outcomes being the creation of the Global Agenda 21, of which 179 countries were signatories (SILVA E BARROS, 2003), leading to the establishment of a variety of programs promoting the use of cleaner technologies and techniques in developing countries, considering pollution prevention concepts (LUKEN and NAVRATIL, 2004).

Initially, in the mid-1970s, environmental concerns included laws, regulations, and guidelines that were mostly conceived as command and control strategies, using pollution control and an "end-of-pipe" reduction approach, which only aims to treat waste without considering the reasons for its generation (KHALILI et al., 2015). Thus, despite these concerns, end-of-pipe systems do not efficiently reduce the use of natural resources, much less the waste related to this use, since the purpose of the end-of-pipe approach is limited to reducing emissions of these wastes at the end of the process, continuing to degrade the soil and the environment (GOMES, LIMA and FRANCO, 2016).

This end-of-pipe vision does not satisfactorily meet the ideas of sustainable development (BARNABY, 1987). More than just waste disposal is required; there is concern about the source of the problem, waste production in production processes, making end-of-pipe options the last resort after all alternatives have been exhausted: technology change, process alteration, product modification, work organization systems, and internal recycling (MEDEIROS et al., 2007). Moreover, merely meeting environmental legal requirements through legal environmental strategies is no longer understood as the only alternative to improving environmental performance, besides being costly and financially burdensome for organizations.

Progress in relation to this mindset is represented by the adoption of Cleaner Production processes, also known as CP. This methodology was proposed by the United Nations Environment Programme (UNEP) as an alternative way to approach resource conservation and environmental management (Pereira and Sant'Anna, 2012), starting from the simple idea of producing while generating less waste, evolving to include resource efficiency in production in general (FONGANG et al., 2015), playing a fundamental role as a possible strategy for promoting Sustainable Industrial Development (SILVA and BARROS, 2003).

The concept of cleaner production emerged as a way to meet the needs for disseminating information related to sustainable development among enterprises, governmental bodies, and the academic community, so that the impacts related to industrial activities on ecosystems could be understood and mitigated (NETO et al., 2016), characterizing a set of measures to make production processes more rational, properly planned from their design (SILVA, 2003).

Thus, the understanding that led to the creation of the concept of cleaner production started from the assumption that end-of-pipe prevention methods, which focus on treating pollutants after they are generated, have high costs and reduced efficiency, while cleaner production seeks a preventive strategy that concerns emissions of pollutants from the source, reducing costs associated with treating these pollutants and increasing process efficiency (MATOS et al., 2018).

Therefore, cleaner production opposes end-of-pipe options: while CP, through appropriate methodologies, reduces material consumption and pollution directly at the source, end-of-pipe technologies curb emissions by implementing measures after the waste has already been generated, which makes cleaner production technologies often seen as superior to end-of-pipe measures, whether for environmental or economic reasons (FRONDEL, HORBACH and RENNINGS, 2007).

Figure 2, shown below, condenses the mindset behind the end-of-pipe approach and cleaner production. While the first column presents a reactive, closed, and linear mentality, thinking about waste treatment afterwards, characterizing end-of-pipe technology, the second column presents a proactive position, questioning the origin of waste and emissions, planning integratively at various levels.

Figure 2 - Differences between cleaner production and end-of-pipe technologies.

End of Tube Technology	**Cleaner Production**
1. How can existing waste and emissions be treated?	1. Where do waste and emissions come from?
2. Want reaction	2. Intend reaction
3. Waste, effluents and emissions are limited via filters and treatment units 1. end-of-pipe solutions 2. repair technology 3. waste storage	3. Prevention of the generation of waste, effluents and emissions at source, avoiding potentially toxic processes and materials
4. Environmental protection introduced after products and processes have been developed	4. Environmental protection is an integral part of product design and process engineering
5. Environmental problems are resolved from a technological point of view	5. Environmental protection is everyone's task, as it is an innovation developed in the company and thus reduces the consumption of materials and energy
6. Complexity of processes and risks are increased	6. Risks and transparency are increased
7. Environmental protection focused on compliance with legal requirements is the result of a production paradigm that dates back to a time when environmental problems were not yet known	7. It is an approach that creates production techniques and technologies for sustainable development.

Source: CNTL (2003)

The necessary changes for the implementation of cleaner production are challenging, with a complex learning curve, prompting UNEP to suggest cleaner production centers and research institutes, along with industry associations, to make this process more efficient (KHALILI et al., 2015). Thus, the dissemination of Cleaner Production Techniques promoted by the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP) was carried out through the Centers, especially for developing countries (including Brazil) called the National Center for Clean Technologies, the NCCT (ARAÚJO, 2002).

The first National Cleaner Production Centers (NCPC acronym, National Cleaner Production Center) were established in the mid-1990s, with their activities expanded to 37 countries, including: Czech Republic (1994); Bolivia, Brazil, China, India, Mexico, Slovakia, Tanzania, and Zimbabwe (1995); Tunisia (1996); Croatia, Hungary, and Nicaragua (1997); Colombia, Costa Rica, and Vietnam (1998); El Salvador and Guatemala (1999); Ethiopia, Honduras, Kenya, Morocco, and Mozambique (2000); Cuba, Macedonia, Korea, Russia, Sri Lanka, and Uganda (2001); Lebanon, Peru, and South Africa (2002); Cambodia, Egypt, and Laos (2004); Uzbekistan and Armenia (2005) (BERKEL, 2010).

In general, Cleaner Production Centers in developing countries, such as Brazil, mainly deal with assessments of cleaner production through projects involving collaboration with organizations and employee training, while in developed countries, such as the United States and Canada, the Centers research new methods aligned with environmental protection trends, considering public opinion, financial return, and the impact of production processes on local and global scales (PETEK and GLAVIÇ, 1999).

Among the basic services offered by Cleaner Production Centers, it is possible to highlight: awareness-raising and dissemination of general information on cleaner production through short-duration seminars; training of professionals in on-site cleaner production assessment methodologies; technical assistance in cleaner production assessment; consultancy on financing sources for cleaner production technologies; dissemination of information necessary for assessments in factories; and policy consultancy (LUKEN and NAVRATIL, 2004).

During the last decades, perspectives related to cleaner production have changed considerably in scope, content, and sectors applying this approach, mainly due to the need for new methods that encompass advances in sustainable development, with a shift in focus, previously associated with pollution and waste reduction during production, now related to design changes for more sustainable products, sustainable tourism, quality of life, and smart cities (HENS et al., 2018).

Among these changes, it is also possible to mention the transition of the scope of cleaner production program themes, which underwent a renewal in 2009, expanding to cover the three dimensions of sustainability: improvement in the efficiency of natural resource utilization (water, energy, and materials), including cost reduction; reduction in the volume of waste and emissions generated; improvement in the well-being of employees, consumers, and society; as well as seeking integrated action among Cleaner Production Centers (LUKEN et al., 2015).

Regarding expectations for the implementation of cleaner production programs through Cleaner Production Centers, it is noted that most were met, although some objectives were not effectively achieved. Two expectations were exceeded: the centers operated in countries that together account for more than 80% of the Manufacturing Value Added (MVA) of developing economies, and the centers provided the four basic services (information dissemination, training, technical assistance, and policy advice); five expectations were met: revenues were sufficient to provide key cleaner production services, the implementation of cleaner production measures generated significant financial gains, in addition to allowing a significant reduction in pollutant emissions and waste, the Centers became experts in the countries where they were established, as well as becoming financially sustainable; three expectations were partially met: the institutions that received the Centers were mostly industry-related, some centers managed to decentralize the main cleaner production services to governments and research institutions, and some companies were transformed with the assistance of the centers into more sustainable organizations; some expectations were not met: providing cleaner production services failed to make industrial sectors entirely sustainable and implementing cleaner production alongside pollution control technologies did not result in quantifiable improvements in environmental quality (LUKEN et al., 2015).

For investments in cleaner production on a global scale, recommendations are made, including: the need for national governments to signal the necessary changes for the effective adoption of cleaner production; the need for the industry to accept the challenge of creating a continuous demand for cleaner production measures that will stimulate continuous evolution; the need for the integration of cleaner production concepts into educational programs; and the need for financial services sectors to identify cleaner production as an innovation opportunity in investments (HUHTALA, 2002).

Regarding policies related to cleaner production, these are usually divided into three categories: regulation policies: with continuous monitoring of information and data related to pollutant emissions, so that it is possible to monitor and regulate the generation and release of contaminants; incentive policies: through incentives and subsidies, a change in behavior of the producing agents is possible, accelerating the pace of environmental changes; and guidance policies: with the government assuming guidance and facilitation roles for companies interested in adopting measures to promote cleaner production (PENG and LIU, 2016).

Regarding the evolution of cleaner production and trends for the future, it is possible to emphasize that, with the advancement of sustainable development proposals and sustainability in industries, the initial scope of cleaner production has been expanded, becoming a strategy that also includes product, process, and service assessments, adding all dimensions of sustainable development holistically (MATOS et al., 2018).

Thus, there is a willingness to increase the importance of cleaner production not only in production sectors (agriculture, industry, aquaculture, etc.), but also in service sectors, such as tourism, healthcare, and administration, which will consequently increase attention to cleaner consumption in these sectors: the consumption of products in hospitals, for example, is responsible for more than 40% of CO_2 emissions, with significant possibilities for reductions in these emissions through deeper environmental management (HENS et al., 2018).

Cleaner production in Brazil

The clean production was initially introduced in Brazil through the establishment of the National Center for Clean Technologies (CNTL) in 1995 (Neto et al., 2016). This center was established in partnership with the Federation of Industries of the State of Rio Grande do Sul, along with the Regional Department of Rio Grande do Sul of SENAI-RS, aiming to coordinate actions for promoting clean production in Brazil through training, consulting, technological information dissemination, as well as events across various states of Brazil, resulting in effective actions related to clean production (PEREIRA and SANT'ANNA, 2012).

Subsequently, in 1997, under the Brazilian Business Council for Sustainable Development (CEBDS), guided by CNTL and in partnership with six other organizations (National SEBRAE, Banco do Nordeste, FINEP, UNDP, CNI, and UNEP), the Brazilian Cleaner Production Network (Rede Brasileira de P+L) was established, with hubs in all states of Brazil. Its objectives included: minimizing or reducing environmental impacts; dissemination of clean production techniques; strengthening integrated actions related to environmental quality, safety, and occupational health; promoting research and transfer of cleaner technologies; and consolidating a database with experiences from network members (PEREIRA and SANT'ANNA, 2012; PEREIRA, 2014).

The actions of the Brazilian clean production network can be divided into three phases: the first phase involved an investment of approximately R$ 3.3 million, with R$ 2.8 million invested in implementing clean production measures, resulting in an annual reduction of R$ 18 million in expenses related to raw materials, auxiliary materials, water, electricity, and rework; the second phase began with an agreement between National SEBRAE and CEBDS, also focusing on serving small and micro-enterprises through case studies totaling approximately R$ 2.4 million in investments and improvement opportunities, generating annual benefits of R$ 5.6 million, in addition to environmental benefits, including an annual reduction of 167 tons of raw materials, 111 thousand m^3 of water, and 350 thousand kW of electricity; and the third phase, initiated in 2007 as the Brazilian Eco-efficiency Network, included actions to evaluate the existing network, develop new products, establish new hubs, support existing ones, and internalize local units, with an investment of about R$ 1.6 million in training 236 professionals in 17 states, who, together with facilitators and consultants, developed strategies for direct cost reduction related to waste and risks (SEBRAE/CEBDS, 2010).

Various public agencies and private entities played diverse and prominent roles in implementing clean production in the Brazilian scenario. Among the organizations highlighted are: MMA (Ministry of the Environment, Water Resources, and Legal Amazon), which coordinates programs such as Agenda 21, Environmental Agenda in Public Administration (A3P), Sustainable Production and Consumption, among other campaigns that encourage responsible practices; MDIC (Ministry of Development, Industry, and Foreign Trade), which coordinates activities related to productive sectors and the environment; CNI (National Confederation of Industries, the highest entity of Brazilian industries, which includes the Permanent Thematic Council on the Environment, formulating actions to increase the competitiveness of industries aligned with environmental preservation; CNTL (National Center for Clean Technologies), aiming to stimulate sustainable development aligned with greater efficiency in economic processes, which also decisively contributed to the establishment of several clean production hubs throughout Brazil (PEREIRA and SANT'ANNA, 2012).

Despite the joint efforts of agencies within the public administration and organizations representing private sector companies, the implementation of clean production has not yet achieved the expected success in Brazil. For clean production to be effectively established in Brazil, organizations need to understand its importance and internalize the principles of clean production in their strategic planning, fostering an institutional environment that allows cooperation and information exchange, also considering the action of external agents such as government, other organizations, universities, and consumers, acting as sources of encouragement and support for clean production (VIEIRA and AMARAL, 2017).

Another aspect that makes the practice of clean production challenging in developing countries is the financial issue. Developing countries, including those in Latin America, tend to have underdeveloped banking sectors and capital markets, lacking the legal basis for creating an environment conducive to investments (CICCOZZI, CHECKENYA, and RODRIGUES, 2002). Transition economies also tend to rely more on the exploitation of natural resources for their economic growth (SHI et al., 2021), making resource management even more important for these countries.

Some developing countries have had the opportunity to receive sponsorships offered by developed countries, which was not the case for Brazil, which did not receive sponsorship from other countries, and the process of implementing clean production was carried out by SENAI – RS (SILVA, 2003).

The channels responsible for financing clean production tend to prioritize technical assistance and consulting. In India, a country that has undergone rapid and disordered industrial growth, employing inefficient and obsolete technologies, while in Brazil there are difficulties in accessing financial resources, especially for micro and small enterprises (PEREIRA, 2014).

Methodologies that promote the more efficient use of resources, such as clean production, can play a crucial role in fostering sustainable development in Latin America, since economic instruments such as pollution taxes, fees, subsidies, and loans are perceived by companies, especially micro and small ones, as having less financial return and generally being less attractive than other types of investments (ASHTON et al., 2018).

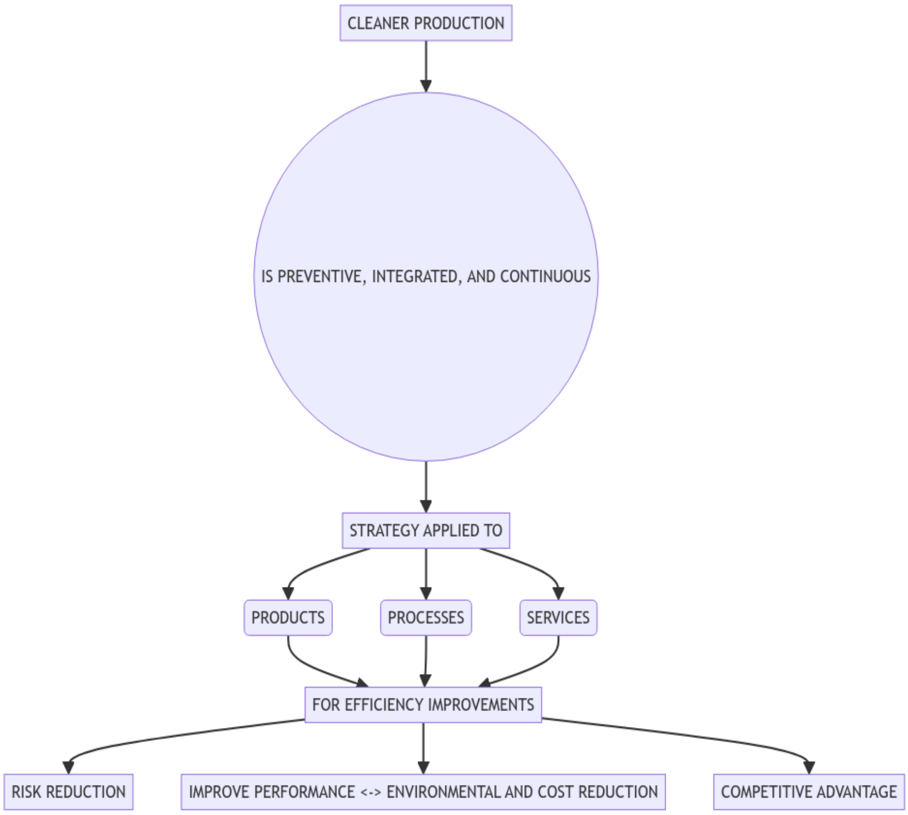
Despite considerable achievements in advancing clean production practices in Brazil, some gaps are still observed in the national scenario, such as the low number of research studies linking clean production with themes of renewable energy and environmental responsibility, which are overlooked compared to research focused on energy reduction measures, water, and waste management. Improvements in communication between government agencies, companies, universities, and society in general are necessary to facilitate the sharing of experiences (NETO et al., 2016).

Brazil also does not have any specific policy for clean production, even though ministries and private sector organizations seek integration. There is a lack of institutional measures aimed at managing companies, with a mismatch between governmental actions and the demands and needs of society, and organizations adopting measures based on their own motivations and interests, or to comply with legal command and control provisions, such as those related to environmental licensing, for example (PEREIRA and SANT'ANNA, 2012).

Concept and characteristics of cleaner production

The UNEP defines cleaner production as the continuous application of integrated environmental prevention strategies from processes, products, and services, to reduce risks to humans and the environment, including concepts such as eco-efficiency, pollution prevention, and green productivity, to protect the environment, consumers, and workers, improving industry efficiency, profitability, and competitiveness, as depicted in Figure 3 (UNEP, 2006).

Figure 3 - Definition of Cleaner Production.



Source: Adapted from UNIDO (2012)

Corazza (2020) asserts that cleaner production is based on the strategy known as PDCA (Plan, Do, Check, Act), which stands for "Planejar, Fazer, Checar e Agir" in Portuguese. This strategy advocates that the end of one cycle corresponds to the beginning of another cycle, continually seeking improvement in processes.

According to Milan et al. (2010), cleaner production is an approach method consisting of integrated economic, technological, and environmental strategies applied to processes and products. Its purpose is to increase efficiency in the use of raw materials and basic inputs by reducing waste, minimizing or recycling (internally or externally), and even avoiding waste generation, thus enabling economic and social benefits for the agent.

As stated in the Implementation Manual of Cleaner Production Programs, cleaner production involves the integrated application of technical, economic, and environmental methods to processes and products, aiming at improving the efficiency of raw material, water, and energy use. This is achieved through waste generation avoidance, minimization or recycling of emissions and waste, resulting in environmental, occupational health, and economic benefits (CNTL, 2003).

In Severo et al.'s (2015) understanding, the concept of cleaner production refers to actions that enable a particular organization to be qualified as an efficient consumer of raw materials and energy during production processes, aiming for productivity improvements and consequently, an increase in the company's competitiveness and organizational performance.

According to Yin et al. (2020), cleaner production can be understood as a preventive environmental strategy that aims to decrease waste and emissions to maximize product output.

Sark and Sena (2017) argue that cleaner production is not merely a change in the physical components of a given organization (raw materials, processes, and products), but also involves changes in the corporate culture of the company, as well as transformations in the attitudes of individuals with significant roles in adopting cleaner technologies and practices.

A broader view of cleaner production in the literature reveals that the presented concepts share some common characteristics: cleaner production focuses on the analysis of processes, products, and services, aiming for the most efficient use of resources possible, allowing for waste reduction at the sources generated by companies by decreasing or eliminating pollution and minimizing risks to people and the environment. Additionally, specialized authors often define cleaner production in terms of environmental strategy, a set of methods, a set of tools, product and process design, actions with uncommon objectives, production activities, mainly related to manufacturing processes (BORGES, 2020).

For production processes, cleaner production (CP) results in the conservation of raw materials and energy, substitution of toxic or hazardous materials with less harmful ones, reduction in the quantity of all emissions and waste; for products, cleaner production means reducing environmental impacts throughout the product life cycle; and for services, cleaner production implies considering environmental aspects in service design and delivery (UNEP/UNIDO, 2012).

The implementation of cleaner production can contribute to organizations gaining a better understanding of their production processes, since this implementation requires constant monitoring of their activities and the development of eco-efficient production systems (Silva et al., 2020). Factors such as worsening industrial pollution, resource scarcity, globalization, and market pressure can make the implementation of cleaner production more relevant (BERKEL, 2010).

In addition to these benefits, other improvements that the application of cleaner production-related concepts can provide include: reduction of costs related to energy and material waste, gains in operational efficiency, improvement in the quality of generated products, reuse of part of the generated waste, potential improvements in quality of life and safety in the work environment, enhancement of the organization's image, compliance with environmental regulations, reduction of costs related to end-of-pipe treatment of generated waste, new and better market opportunities, improvements in productivity, technology, and achieving better cost-effectiveness (UNIDO, 2001; HAMED and MAHGARY, 2004).

As noted by Catapan et al. (2010), regarding production processes, cleaner production adopts procedures to: a) conserve raw materials and energy, eliminating toxic ones and reducing both toxicity and the quantity of all emissions and waste; b) reduce negative impacts throughout the product life cycle, from raw material extraction to final disposal, through appropriate product design; c) incorporate environmental concerns into the design and provision of services. In other words, cleaner production subverts the traditional order represented by end-of-pipe technologies: while the latter prioritizes reaction, considering the treatment of existing waste and emissions and consequently their additional costs, representing the production paradigm in which environmental problems were not yet known, the former aims for proactive action, questioning where waste and emissions come from, helping to reduce costs related to waste, ultimately being an approach that creates production techniques and technologies for sustainable development (CNTL, 2003).

The various changes proposed by cleaner production may face barriers and resistance, both internal and external (Vieira and Amaral. 2016). Barriers are related to political and market factors, financial and economic factors, technical and informational barriers, as well as managerial and organizational barriers (GHISELLINI, JI, and LIU, 2018).

According to Mello (2002), these barriers can be classified as: a) organizational barriers, including lack of employee involvement, decision-making power concentrated in management, priority focus on production, turnover of technical staff, and lack of recognition of initiatives; b) systemic barriers, linked to inadequate or inefficient management, lack of records and controls, and planning; c) attitude barriers, including resistance to change, lack of leadership and safety, fear of failure; d) economic barriers, related to the predominance of low prices and relative abundance of resources and materials, lack of interest in investing in CP projects, exclusion of environmental costs from the economic calculation of waste reduction measures, inadequate investment planning, and prevalence of tax incentives related to production; e) technical barriers, with a lack of infrastructure, scarce or even unavailable technical workforce, limited access to technical information; f) governmental barriers, such as policies adopted for natural resource management, emphasis on end-of-pipe technologies to meet environmental regulations, lack of incentives for waste reduction efforts; g) other barriers, such as lack of institutional support, lack of public pressure, prevention of investment in operational improvements, etc.

Given the challenge of reconciling environmental protection with economic development, considering also issues related to social, ethical, and political aspects, integrated into three simultaneous and balanced dimensions: economic, environmental, and social, in the so-called triple bottom line (Elkington, 1997), cleaner production is recognized as the best path to achieving sustainable development (Zhang, 2000). Furthermore, cleaner production is feasible in a variety of industries and productive activities, although several difficulties are observed in reaching certain sectors (MATOS et al., 2018).

Cleaner production also considers the environmental variable at various levels of the organization, characterized by actions applied within the organization, mainly by actions related to the production process, with the main objective of making these processes more efficient by using its inputs to generate more products and less waste (ARAUJO, 2002).

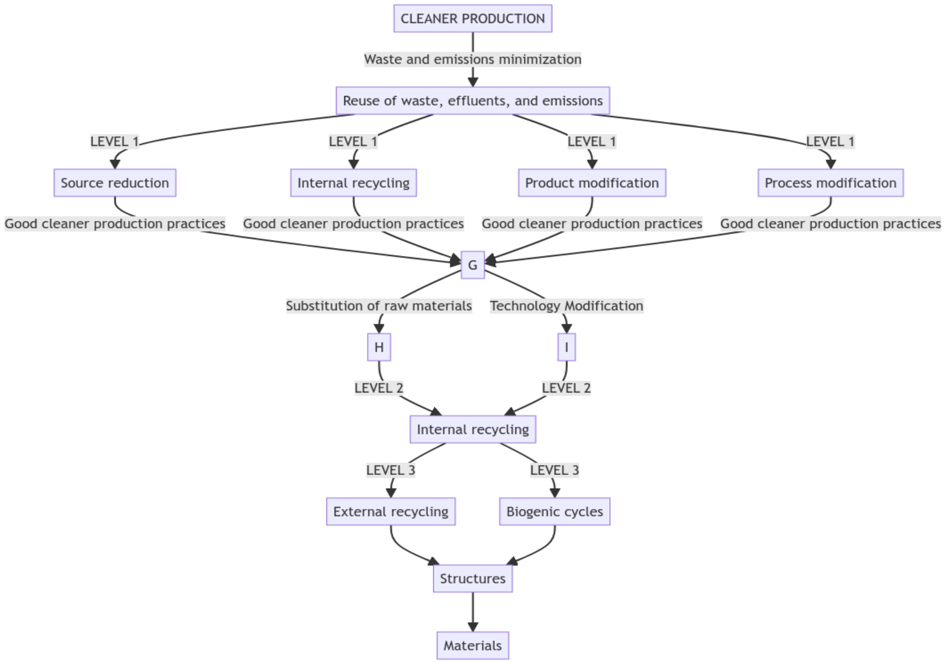
It can be affirmed that cleaner production is an economic action because any waste from the production system must necessarily come from raw materials or inputs, purchased and paid for as such, used in the production process. In addition to the social aspect of cleaner production, which, together with environmental and economic themes, also considers that a reduction in waste generation in a given production process can also solve problems related to the health and occupational safety of employees (MATTOSINHO, 2005).

Another important characteristic of cleaner production is the approach regarding priority levels. In traditional approaches, it is customary for waste disposal to be the first item considered and waste generation the last, while in the cleaner production approach, this cycle is reversed: the initial priority is to avoid generation, so that disposal is only used as a last resort, since waste not generated does not need to be segregated, transported, stored, or disposed of, thus resulting in a considerable reduction in the associated costs of these steps that will not be carried out, characterizing this solution as more complex but proposed to be definitive (CNTL SENAI-RS, 2007).

Thus, for a given waste generation problem to be analyzed from the perspective of cleaner production, some questions must be asked to search for solutions, in order of priority: 1. How to avoid generating waste? 2. How to reduce its generation? 3. How to recycle internally? 4. How to recycle externally? (CEBDS, 2003).

Based on this priority order, it is possible to develop a flowchart, which can be used as a reference for analyzing opportunities for each situation in which waste is produced: the focus should be on level 1, and if feasibility is not verified, the focus shifts to level 2, and if this also proves unfeasible, level 3 should be examined (CEBDS, 2003). Figure 4 below presents the three different levels of application of cleaner production strategies.

Figure 4 - Flowchart for generating cleaner production options.



Source: CNTL (2003)

Level 1 encompasses source reduction, and from the perspective of waste, emissions, and effluents, and considering application strategies, the cleaner production approach can occur through two forms: through product modifications or process modifications.

Product modifications are the most complex and difficult to achieve, as they involve changes to consumer-preferred products, including: complete product substitution, increased longevity, material substitution, product design modification, use of recyclable and recycled materials, replacement of critical components, reduction in the number of components, enabling product returns, substitution of product items, and alterations in product dimensions to generate better raw material utilization (CNTL, 2003).

Process modifications can assist in significant waste, emissions, and effluent reduction, including measures such as: housekeeping, characterized by a more careful use of raw materials and processes, also including organizational changes and measures that are economically more viable and easily implementable, being ideal for application at the beginning of the cleaner production program, conducting an analysis of operational practices and practical housekeeping solutions; good cleaner production practices, including changes in product dosage and concentration, maximization of capacity utilization in production processes, reorganization of maintenance intervals and machinery cleaning, elimination of losses related to evaporation and leaks, improvements in the logistics of purchasing, storing, and distributing raw materials, preparation of operational best practice manuals, training and capacity building of personnel involved in the cleaner production program, layout changes and minor adjustments, increased logistics related to waste, improvements in information systems, standardization of operations and procedures, and replacement of raw materials and process aids (CNTL SENAI-RS, 2007).

The replacement of raw materials may include the substitution of toxicologically important materials, which may somehow jeopardize the safety and health of workers, requiring the use of personal protective equipment (PPE), including: substitution of organic solvents with aqueous agents, alteration of petrochemical products by biochemical ones, selection of raw materials with lower impurity levels, choice of raw materials less likely to generate undesirable products, change of suppliers, use of waste as raw materials in other processes, packaging modification, use of biodegradable raw materials, reduction in the number of components to decrease process complexity, use of heavy metal-free substances, use of raw materials with a known life cycle (CNTL, 2003).

Technological modifications range from simple reconstructions to complex changes in time expenditure in operations, in the way energy is consumed, or in the use of raw materials, requiring these measures to be analyzed jointly with housekeeping and raw material selection measures, including: substitution of thermochemical processes by mechanical ones, use of countercurrent flows, technologies that perform waste and effluent segregation, modification of process values, utilization of residual heat, ultimately complete replacement of certain technology (CNTL SENAI-RS, 2007).

Level 2 of cleaner production options corresponds to internal recycling, referring to processes aimed at recovering materials, raw materials, and inputs, carried out within the industrial plant, reused in the company's own production process, as examples: the reuse of products or raw materials for the same purpose, recovery of solvents that have already been used, use of raw materials or other products that have already been used for a different purpose, use of varnish residues for painting parts of a product that will not be visible, additional use of certain material for a purpose inferior to its previous use, utilization of paper waste for filling purposes (CNTL, 2003).

Finally, after exhausting all possible solutions presented in the previous levels, measures should be determined for the continuation of waste, emissions, and effluent recycling internally or externally to the organization, which may occur as external recycling or as reintroduction into the biogenic cycle, such as composting, paper recovery, scraps, glasses, in the organization's own production processes, being more economically advantageous to seek to close the loop within the company itself, opting for the external option only if there is no technical and economic feasibility (CNTL SENAI-RS, 2007).

Cleaner production manuals and related methodologies

There is a variety of publications available aimed at assisting companies interested in implementing a cleaner production methodology in their production processes, providing a range of theoretical knowledge, a structure of concepts, procedures, and tools. Notable among the national and international organizations involved in disseminating cleaner production practices are the United States Environmental Protection Agency (US EPA), the Environmental Company of the State of São Paulo (CETESB), the National Service for Industrial Learning (Senai), and the aforementioned UNEP, UNIDO, and CEBDS (GUARDIA, 2016).

Among the early publications on cleaner production, the UNEP's guide called Cleaner Production – A training resource package stands out. It is aimed at instructors and teachers, aiming to provide support material and ideas, including case studies and scenario situations that can be used as a basis for interactive training and decision-making simulations, through teamwork for problem-solving (UNEP, 1996).

The phases discussed for the implementation of cleaner production include pre-assessment, material balance, and synthesis, with the planning level presenting methods for assessing environmental impacts, risk assessment and management, total quality management, environmental audits, among others; and tools for products and processes including environmental labeling, product life cycle analysis, waste audits, among other instruments (GUARDIA, 2016).

Another prominent material related to cleaner production is the Guidance Manual on How to Establish and Operate Cleaner Production Centres, developed by UNIDO/UNEP. The establishment of a new Cleaner Production Centre or the maintenance of an existing one requires a range of costly and burdensome information, which requires the guidance manual to provide a comprehensive overview of all the planning necessary for the creation of a new National Center or maintenance of an existing center, providing the necessary guidelines for the satisfactory operation of these organizations (UNEP/UNIDO, 2012).

The manual is divided into six chapters, including: understanding cleaner production; evolution of cleaner production centers; how to establish a cleaner production center (basic services); how to provide services from a cleaner production center (strategic services) and how to monitor and evaluate the progress of a cleaner production center, presenting cleaner production as a process that goes beyond manufacturing and involves products in their life cycle context more comprehensively, through the implementation of more suitable product designs (GUARDIA, 2016).

Among the phases presented for the implementation of cleaner production according to this manual, it is possible to highlight: planning and organization, obtaining top management commitment, employee involvement, planning for cleaner production team, identification of barriers and solutions for cleaner production, decision on the focus of cleaner production, pre-assessment, compilation and preparation of basic information, conducting a walkthrough, preparing the eco-map, preparing preliminary material for mass and energy balance, preparing detailed mass and energy balance, conducting root cause diagnosis, generating options, evaluating options, feasibility analysis, conducting economic and environmental analyses, selecting viable options, implementation and continuity, preparation of cleaner production action plan, and maintaining cleaner production (UNEP/UNIDO, 2004).

The dissemination of Cleaner Production Techniques promoted by the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Program (UNEP) was carried out through the Centers, especially for developing countries (including Brazil) called National Clean Technologies Centers, the NCTC (Araújo, 2002). The NCTC provides, through the manual Implementation of Cleaner Production Programs, a flowchart with the stages for the implementation of CP in a given activity, regardless of its nature and whether the company is small, medium, or large.

The methodology consists of five stages: the first includes planning and organization, including obtaining managerial commitment, characterizing barriers to implementation, seeking solutions, establishing the scope of the cleaner production program, and forming the eco-team; the second stage includes detailed analysis of the flowchart, environmental diagnosis of processes, and selection of the focus of evaluation, allowing for a better assessment of waste generation during the process, quantification of input raw materials, and selection of the focus of work; the third stage outlines the material balance and establishes indicators, identifies the reasons for waste generation, and selects cleaner production options; the fourth stage consists of an analysis from technical, economic, and environmental perspectives, including the selection of options that are viable from these perspectives; and the fifth stage brings together the implementation and monitoring plan, aiming for the continuity of the program (CNTL, 2003).

The guide Cleaner Production in Buildings, a project carried out jointly between CNTL, SENAI, UNIDO, and UNEP, follows the guidelines of the 2003 CNTL manual, but from the perspective of the construction industry, with its main objective being to present to organizations and professionals in the construction industry some measures already implemented by companies, proposing the cleaner production plan as a way to reduce environmental impacts and economic waste in the construction industry (CNTL SENAI-RS, 2007).

Another methodology available for guidance on the implementation of Cleaner Production is the guide elaborated by the Brazilian Business Council for Sustainable Development, following the same approach as UNIDO/UNEP, conceived through the creation of nuclei in various states, acting interlinked in the provision of specialized services in Cleaner Production (CEBDS, 2003).

This guide was created based on the UNEP Guidance Material for UNIDO, as guidance for entrepreneurs in using a cleaner production method, with the main objective of reducing waste generation and achieving economic benefits (GUARDIA, 2016).

In general, the methods and structures proposed by the different available guides do not differ substantially from each other (Simião, 2011). It is worth noting that it is up to each institution wishing to implement a Cleaner Production program to analyze the ways that best suit their specific case and seek the best way to implement their program.

Cleaner production also has relationships with other sustainability concepts. Although conceived for different reasons, cleaner production and Lean Thinking are concepts that complement each other satisfactorily (Belayutham, González, Yiu, 2016). There is also evidence of compatibility and synergy between cleaner production and Lean Manufacturing (RAMOS et al., 2018).

Similarly, Green Building can also contribute to cleaner production, through the reduction of environmental damage, protection of natural resources (energy, water, and soil), reduction and recycling of construction waste, reducing carbon emissions, and maintaining a healthier construction environment (OFEK and PORTNOV, 2020).

It is also verified that there are opportunities for the use of cleaner production in conjunction with Industrial Symbiosis, allowing a reduction in waste generation and commercialization with partner companies, with the sale and exchange of waste with partner companies, which reuse or recycle them in their processes, with a reduction in environmental liabilities and a projected economy of around 95% compared to the estimated expense without the application of these strategies together (HERZER, ROBINSON, and NUNES, 2017).

Similarly, cleaner productions in conjunction with Lean Production can be used as complementary tools, as both bring together systemic elements to the objectives of waste reduction, contributing to the sustainability of organizations, bringing benefits that involve increased productivity, improvements in quality, optimization of environmental resources, energy, and inputs (VAZ et al., 2010).

Likewise, cleaner production can be an important factor in improving sustainability performance in industries, together with Circular Economy and Industry 4.0, and allowing organizations adopting these strategies in developing economies to achieve greater advantages in global competitiveness (GUPTA, KUMAR, and WASAN, 2021).

Regarding practical applications, it is possible to observe a wide range of studies that use cleaner production concepts, such as in the surfboard manufacturing industry (Barcelos, Magnano, and Leripio, 2018), in the construction industry of prefabricated buildings (Wu et al., 2019), and in the reduction of SO_2 and CO_2 emissions in China, through industrial restructuring measures and improvements in environmentally compatible production technologies (LIU and WANG, 2017).

In the Brazilian context, cleaner production still does not have a high level of implementation or the inclusion of stakeholders in the decisions made to implement environmental practices (Neto et al., 2015), representing a missed opportunity for organizations, which would minimize their costs by reducing waste, reducing environmental impact, and making the market competitive, and for Brazilian universities, which would generate more innovation and recognition of environmental education as a means of survival for future generations (NETO, SHIBAO, and FILHO, 2016).

Cleaner Production in Civil Construction and Public Administration

The construction industry is one of the main human activities. It represents a prominent element in the Brazilian economy, with significant participation in the composition of the Gross Domestic Product (GDP) of Brazil. This economic importance is directly proportional to the impacts that the activity causes on the environment: the construction industry consumes about 40 to 75% of the natural resources extracted from the planet, not considering water and energy (CBCS, 2009), and 48.5% of electricity consumption in Brazil (CBCS, 2014).

Another aspect that stands out, albeit negatively, in this sector is waste, both in terms of materials and labor. These losses are related to frequent rework and the execution of unnecessary or incorrectly performed tasks, resulting in costs that do not necessarily add value (Rezende et al., 2012). In addition to these aspects, it is worth noting the social relevance of this industry, with 7.57% of total employment in Brazil in 2017, representing no less than 7,692,147 people (IBGE, 2019). In this sense, actions promoting sustainability in the construction industry have strategic importance. As Araújo (2009) explains, "intervention in the construction industry is essential, allowing us to conclude that, to achieve sustainable development, it is necessary to practice more sustainable construction" (ARAÚJO, 2009, p.2-3).

The waste generated from the processes of the construction industry, broadly speaking, originates from leftovers or inherent wastage in the construction process (Mattosinho and Pionório, 2009). Most of the waste consists of inert materials, that is, materials that do not undergo transformations in their composition and remain unchanged for a long time (ABNT, 2004), which makes them potentially reusable for other purposes. Examples of the most commonly observed waste in conventional construction works, renovations, repairs, and demolitions are bricks, ceramic coatings, general concrete, soils from excavation, rocks, metals, resins, glues, paints, woods and plywood, ceilings, mortar, gypsum, asphalt pavement, glass, plastics, pipes, electrical wiring, etc. (CONAMA, 2002). Among the reasons contributing to the generation of waste and debris, Carneiro et al. (2001) highlight: a) insufficient definition and detailing in architectural, structural, formwork, installation projects, among others; b) inferior quality of materials and construction components available in the market; c) unskilled labor; d) absence of operational procedures and execution control and inspection mechanisms.

Efforts to reduce or mitigate these characteristics of the construction industry have been aimed at finding different applications for the waste resulting from this activity. However, these efforts assume that the waste has already been generated, which characterizes a reactive or end-of-pipe measure, not addressing the root cause of the problem but acting to mitigate its most pressing effects (MATTOSINHO and PIONÓRIO, 2009).

The implementation of Cleaner Production procedures in the construction industry can be a viable option due to its preventive action and the possibility of optimizing the use of materials and inputs, making the industry more sustainable and bringing environmental benefits to society as a whole. As Silva et al. (2017) point out, Cleaner Production can be implemented in any sector of activity, regardless of its size, based on a detailed technical, economic, and environmental analysis of the production process. There are several examples in the scientific literature of successful cases of Cleaner Production application: Santos and Gerber (2012) achieved a 75.94% reduction in waste from wood raw materials for forms through the diagnosis of a more advantageous process with less waste, Araújo (2002) found a 23.08% reduction in wood waste through the Cleaner Production Ecodesign tool, among several other examples.

Through simple measures, which do not always require deep technical knowledge but rather a more critical look at production processes, or with simple changes in the technology employed in these processes, it is possible to eliminate most of the generated waste (Silva et al., 2013), making these processes more efficient.

On the other hand, the Public Power has the function, through its processes, to promote practices that allow the mitigation of environmental damages (Peixoto et al., 2018), considering that the public administration is the largest consumer of goods and services in the Brazilian market, accounting for about 10% to 15% of the Gross Domestic Product (GDP), a fact that contributes to changes in consumption patterns and practices adopted by the Brazilian public sector (Carvalho and Souza, 2013). Therefore, public administration plays a strategic role in reviewing production and consumption patterns and adopting new socio-environmental sustainability benchmarks, through its regulatory capacities and the induction of new standards and practices (MMA, 2016).

In this context, the Ministry of the Environment created a project called the Environmental Agenda in Public Administration (A3P), aimed at implementing socio-environmental responsibility in the administrative and operational activities of public administration, with the objectives of: a) raising awareness among public managers about environmental issues; b) promoting savings of natural resources and reduction of institutional expenses; c) reducing the negative socio-environmental impact caused by the execution of administrative and operational activities; d) contributing to the review of production and consumption patterns and the adoption of new benchmarks, within the public administration; and e) contributing to improving the quality of life (MMA, 2016). According to Peixoto et al. (2018), the A3P program has proven to be an important guiding instrument for the implementation of sustainable actions, highlighting the relevance of observing and experiencing socio-environmental practices within public organizations.

Among the axes that guide the adoption of sustainable practices of the A3P, it is possible to verify a synergy between its principles and the principles of Cleaner Production. Therefore, even though public administration has structural differences from the private sector, where Cleaner Production concepts are more commonly employed, it is perfectly possible and desirable for these concepts to be appropriated by public managers, in light of the references of legislation and the principles of the Environmental Agenda in Public Administration, conducting the necessary analyzes, adaptations, and modifications of what can be employed in the important sector of public works.

Waste Management and Cleaner Production

In Brazil, there are several legal, normative, and public policy instruments regulating the management of solid waste. Among the normative instruments, it is possible to highlight the Brazilian Standard ABNT NBR 10004:2004, which sets parameters for the classification of waste based on the identification of the process or activity that originated them, as well as defining the concept of solid waste as waste in a solid or semi-solid state, resulting from industrial, domestic, hospital, commercial, agricultural, and sweeping activities (ABNT, 2004).

Among public policy instruments, it is possible to highlight the National Solid Waste Policy (PNRS), enacted by Law No. 13,305, of August 2, 2010. The PNRS was presented in this scenario as a public policy with a proposed significant effect, due to its potential for integration into the various dimensions of sustainable development, with objectives related to issues such as public health, environmental quality, integrated management, socio-productive inclusion, and shared responsibility (Cavalheiro, Gazolla, and Marini, 2019). Thus, the innovative nature of the PNRS is supported by solid waste management plans developed at the national, state, and municipal levels, social control, reverse logistics, incentives for the creation of recyclable material cooperatives with waste pickers included in selective collection programs, shared responsibility, fiscal incentives for recycling industries, carbon inventories, as well as planning, a systemic waste management approach, respect for local and regional diversities, and waste hierarchy, prioritizing waste reduction, reuse, and recycling, ultimately leading to treatment and final disposal (SANTOS AND ELK, 2021).

Despite this innovative nature, Brazilian municipalities still face difficulties in complying with the PNRS, particularly regarding the requirement to end open dumps with environmentally appropriate waste management, with few municipalities able to comply with what the PNRS demands, confirming the inefficiency that urban centers present in dealing with environmental issues, especially those related to solid waste management (BARROS AND SOUZA, 2017). Thus, success for more efficient waste management requires municipal public managers to be committed to the social inclusion of waste pickers, through their effective inclusion in selective collection programs, as well as recognizing both social and environmental dimensions as means for sustainable development over time (BONJARDIM, PEREIRA, and GUARDABASSIO, 2018).

The ideas of solid waste management and cleaner production discussed here naturally intertwine, as both seek sustainable strategies to address waste in general. Among these interconnections, it is possible to highlight two points of synergy between these two concepts: the contribution of cleaner production to making waste management more efficient and the hierarchy of waste management priorities existing in both the PNRS and literature related to cleaner production.

The application of cleaner production methodologies allows for the reduction of energy and material waste, consequently leading to a quantitative reduction in the volume of waste generated in production processes, resulting in reduced operational costs related to waste management, such as segregation, collection, packaging, storage, treatment, and final disposal, making management more financially and operationally optimized, as well as allowing for increases in productivity and energy efficiency (Santos, Queiroz, and Neto, 2018). A practical example illustrating this situation is the execution process of wooden structures for roofing, in which inefficiency bottlenecks were detected, leading to a greater amount of wood waste than necessary. Opportunities for the application of cleaner production methodology were identified, resulting in approximately a 23% reduction in the amount of waste generated, leading to a decrease in costs related to the packaging, storage, treatment, and final disposal of these wastes, as well as improving the productivity of the structure execution process (ARAÚJO, 2002).

Waste management based on cleaner production concepts should follow a preference hierarchy to identify the origin of waste and thus assess possible ways to reduce the problem at the source: waste and emissions minimization is sought through source reduction and internal recycling, or if not possible, the reuse of waste, effluents, and emissions through external recycling or biogenic cycles (Santos and Silva, 2017). Similarly, the PNRS also presents a hierarchy scale and priorities for the management and handling of solid waste, including in four blocks the so-called traditional end-of-pipe practices (reuse, recycling, treatment, and final disposal), and in two initial blocks, preventive criteria, including waste generation avoidance and reduction in production waste (MIGLIANO, 2013). Thus, it is possible to see that the hierarchy of cleaner production presents similarities with the priorities set forth in the PNRS, denoting a synergy between these two sets of ideas.

II. Methodology

Regarding its purposes, this research is classified as exploratory, as it is conducted in an area where there is still little accumulated and systematized knowledge (VERGARA, 2004). As seen previously, scientific research associating the public sector with sustainability is still relatively limited, with few national authors having a relevant research background, including a quantitative reduction in the number of publications related to the theme in the CAPES portal (ROHRICH and TAKAHASHI, 2019; MARCUZ JUNIOR et al., 2020). Furthermore, considering the practical objective described here, the development of a cleaner production methodology compatible with the reality of IFAM's civil construction works and allowing greater efficiency in construction processes, the research can also be classified concerning its purpose as applied research, which aims to acquire knowledge for application in a specific situation (GIL, 2017), typically with modest scope, seeking to understand the reality experienced by people in society and its consequences (ROBSON and MCCARTAN, 2016).

This research can be characterized, in terms of approach, as qualitative research, that is, interpretive research, involving an academic investigation approach based on philosophical conceptions, research strategies, data collection methods, and interpretation that differ from quantitative research methods, which often distinguish themselves by their structures: in terms of the use of words (qualitative research) rather than numbers (quantitative research), according to Creswell (2010). Qualitative research allows analyzing, therefore, from the surveys carried out, which cleaner production methodology is most suitable for the IFAM context.

The chosen method for application in the research is the case study, which involves a deep analysis of an individual or multiple cases (TEDDLIE and TASHAKKORI, 2009), where the case is the situation, individual, group, organization, or whatever the object of interest of the researcher (ROBSON and MCCARTAN, 2016), defined as an empirical investigation that investigates a specific contemporary phenomenon within its reality context, especially when the boundaries between the phenomenon and the context are not clearly delineated, with the planning logic incorporating specific views into data collection and analysis (YIN, 2001).

Thus, from the study of a proposed case, the elaboration of a cleaner production methodology in a civil construction work of IFAM will be possible to evaluate not only this specific case, applied in a concrete situation but also to analyze what this case represents and how it would be possible to apply the observed principles of cleaner production in other cases of the same nature.

Research Structure

To conduct the state-of-the-art survey of cleaner production (intermediate objective n.º 1), a literature search was conducted. This is an important step for the research to be relevant, as the researcher needs to be aware of the gaps, consensus, and controversies in the topic they wish to study, as well as to position their research problem in a path yet unexplored by other researchers (BRIZOLA & FANTIN, 2016; SANTOS SILVA, DE OLIVEIRA, 2023). This can only be achieved when the researcher has effectively examined what has already been produced in terms of science on the studied subject.

In general, literature reviews are elaborated to justify why the conducted research is interesting, important, and fills the gaps in the respective field of knowledge, despite presenting some inherent problems in their format: the choice of publications to be included in the review involves a certain degree of cherry-picking, that is, the handpicking of publications that corroborate the researcher's point of view, at the expense of research that may somehow challenge this point of view; the space allocated for reviews is usually limited, which does not allow for a deep, balanced, and detailed description of the topic; publications rarely discuss the process through which the review was conducted, without transparently specifying the structure of the literature review execution (BRINER & DENYER, 2012; HIEBL, 2021).

To address these problems, a systematic literature review protocol was proposed, which is a research methodology that, unlike an ad hoc selection of literature, follows rigorous pre-determined specific protocols, seeking to understand and make logical sense of a large documentary corpus, verifying what works or doesn't work in a given context (GALVÃO & RICARTE, 2020; KITCHENHAM et al., 2009). In this protocol, research questions, keywords, and criteria for inclusion and exclusion of scientific research, as well as data extraction, were defined.

To carry out the characterization of works and processes related to engineering services (intermediate objective n.º 2), documentary research, process modeling, and questionnaire application were proposed. Documentary research draws on various sources of documents, presenting similarities with bibliographic research, due to the fact that both modalities use existing data, with the main difference being the nature of the sources (GIL, 2017). Process modeling is carried out for internal knowledge of certain processes, related to the methodologies adopted by an organization, making it possible to obtain a systemic view and a diagnosis of how the adopted processes are interconnected (RODRIGUES & SOUZA, 2015). The questionnaire consists of a series of questions presented to a specific respondent, in writing (VERGARA, 2004), being considered an important element of research, as it provides real subsidies from a certain universe or sample to be analyzed (OLIVEIRA, 2011).

Documentary research was conducted based on IFAM's archives that were relevant to the research topic, such as: master plan of campus works, databases of existing projects, solid waste management plans, technical notes, descriptive memoranda, technical reports, opinions, work orders, among other documents. From this documentary research, it was possible to define the basic characteristics of IFAM's buildings that are relevant to the research, such as the types of waste generated, construction processes employed, inefficiency bottlenecks, how waste is stored, who is responsible for final disposal, among other characteristics.

The information gathering necessary for process modeling was done through interviews with the coordinators who make up the technical and administrative staff of the Infrastructure Directorate (DINFRA) of IFAM. This technique is the most used, being considered adequate for recording what people know, besides enabling the collection of data related to various organizational aspects (OLIVEIRA, 2021).

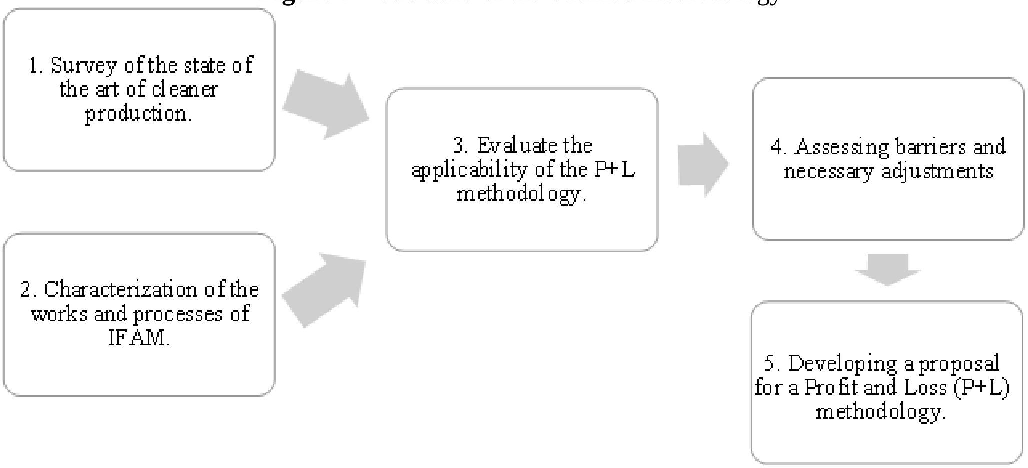
The questionnaire consists of a list of questions arranged into six main categories: the first one is the characterization of the respondent, which includes general information about the employees who are the target of the questionnaire, their participation in the organization, and their knowledge about cleaner production; the second one is the characterization of the organization, which includes general organizational aspects of IFAM; the third one deals with more general questions about cleaner production; the fourth category contains questions that relate cleaner production to the development of public works projects; the fifth category presents questions that relate cleaner production to construction inspection; the sixth category presents possible barriers and difficulties for the implementation of cleaner production for the specific case of public works. The questionnaire was developed based on the results of the systematic literature review and includes open-ended questions, closed-ended questions, multiple-choice questions, and scaled responses on a Likert scale from 0 to 5, with "Completely Disagree" assigned to number 1 and "Completely Agree" to number 5, while number 0 corresponds to the response "Don't Know".

Based on the state-of-the-art survey of cleaner production and the characterization of IFAM's works and processes of engineering services, the applicability of an existing cleaner production methodology, the Cleaner Production in Buildings of CNTL SENAI RS, in the institutional context of IFAM (intermediate objective n.º 3) was evaluated. This evaluation is necessary because, as seen above, the public administration presents some characteristics that distinguish it from private sector organizations, and a good part of the research related to cleaner production is carried out in corporate contexts.

Due to the various changes that the implementation of a cleaner production program can bring to a certain organization, it is natural that barriers and resistances arise that hinder the achievement of the program (MELLO, 2002). Therefore, considering the institutional reality of IFAM, the barriers that the application of a cleaner production methodology could entail (intermediate objective n.º 4) were verified. Adjustments points in cleaner production methodologies were also verified, especially in relation to the legal limitations that IFAM is subject to as a federal agency.

Therefore, considering the barriers and specificities of the case study, a cleaner production methodology aligned with the reality of IFAM will be proposed (intermediate objective n.º 5). Figure 7 below shows the structure of the methodology.

Figure 7 - Structure of the outlined methodology



Source: Own authorship (2022)

The objectives number 1 and 2 together allow for a broader understanding, both of the topic to be researched (cleaner production) and of the research object (the construction works of IFAM), being the objectives that will underpin the remainder of the research. As shown in the image above, both objectives can be carried out simultaneously, since they are, a priori, independent processes and present distinct methodologies. For the subsequent objectives number 3 to 5, a sequential approach is observed, as each objective requires the information gathered and accumulated from the previous objectives.

Planning and Conducting the Systematic Literature Review

The methodology for planning and conducting the systematic literature review adopted in this research was based on the systematic literature review processes proposed by Kitchenham et al. (2004) and Santos and Barreto (2015). Succinctly, these processes consist of three different phases: planning the review, conducting the review, and analyzing the results. Initially, the guidelines of these processes are intended for researchers in the software engineering field. However, it can be verified that these are general guidelines that have satisfactory applicability in other areas of knowledge. Next, the guidelines that compose this process will be explored, contextualized for the research developed.

The initial question, which will prompt the entire research, can be defined as follows: what is the need for conducting a systematic review? Researchers often adopt this type of review when it is necessary to employ objective and consistent criteria to prevent the information leading to the research question's solution from being confusing and yielding inconsistent results (GOMES E CAMINHA, 2014). For this research, the current relevance of sustainability-related topics was verified, which motivated the undertaking of a systematic review in this direction. From this relevance, the researcher's academic interests and competencies, a central axis was chosen to underpin the systematic review questions, and themes adjacent to this axis were selected to condition and shape the research results to the reality that one wishes to analyze. Thus, the chosen theme is related to cleaner production, with cleaner production as the central theme, understood in the context of public administration, from the standpoint of the construction industry. Therefore, one of the intermediate objectives of the research is to conduct a systematic review based on this theme.

Consequently, the questions that the systematic review answered are defined. These questions are directly related to the chosen theme and seek to investigate how these different themes interrelate. The initial question assumes that this review is the researcher's first contact with the subject, necessitating introductory general knowledge that demonstrates the evolution of cleaner production research, familiarizing the researcher and providing the necessary tools for the review's development. Thus, the first question can be formulated as follows: "What is the state of the art of cleaner production?" Subsequent questions relate cleaner production to the defined adjacent themes, construction and public administration. Finally, a question is formulated to investigate the relationship between cleaner production and the triple bottom line concept. Table 1 below presents the questions of the systematic review succinctly.

Table 1 - Research questions.

N.º	Question	*String*
1	What is the state of the art in cleaner production?	1
2	How does cleaner production relate to civil construction?	2,3,4
3	Which methodologies of cleaner production are currently being applied in the construction industry?	2,3,4
4	How does cleaner production relate to public administration?	5,6,7
5	What is the relationship between cleaner production and *Triple Bottom Line*?	8

Source: own authorship (2021)

For the scope of this research, the CAPES journals portal was defined as the basis due to guaranteed access for students of the Graduate Program in Management and Strategy at the Federal Rural University of Rio de Janeiro. It is worth noting that the procedure for conducting research in this database is similar to procedures carried out in other databases. Therefore, the methodology presented here can be reproduced in other scientific databases with few adaptations.

The keywords were defined based on the themes of the research questions, aiming to avoid the use of generic or overly specific terms to prevent difficulty or negative influence on the results. As it is a national research database, the keywords were defined in Portuguese. For research in English-language databases, additional searches would be necessary to find the translation and synonyms of the keywords in Portuguese. Table 2 below shows the eight keywords defined.

Table 2 - Keywords.

N.º	Keywords
1	Cleaner Production
2	Construction
3	Construction Sector
4	Construction Industry
5	Public service
6	Public sector
7	Public administration
8	*Triple Bottom Line*

Source: own authorship (2022)

The inclusion and exclusion criteria for articles in the systematic review were observed based on the research questions, as advocated by Kitchenham et al. (2004). In general, the criteria for including articles aim to restrict the language of the researched articles (to the scope defined in this review) and to optimize the article selection process, including only those articles that have at least some of the keywords and address the research questions. Table 3 below demonstrates the criteria for article inclusion.

Table 3 - Criteria for inclusion.

N.º	Criterion
CI1	Works must be written in English or Portuguese
CI2	Works must contain keywords in the abstract and/or title and/or keywords
CI3	Work must relate cleaner production with construction (*strings* 2,3 and 4)
CI4	Papers must address the research questions
CI5	Works published in the last 10 years (*string* 1)

Source: own authorship (2022)

Similarly, the article exclusion criteria also aim to optimize the research procedure by removing articles that are not relevant to the review. Articles are excluded if they do not meet the inclusion criteria, if they are duplicates, or if they are not available for reading. Given that this is a master's level academic work, the decision was made to also exclude undergraduate thesis papers or monographs. Table 4 below presents the criteria for article exclusion.

Table 4 - Criteria for exclusion.

N.º	Criterion
CE1	Works that do not meet the requirements will not be selected.no criteria inclusion
CE2	Works with a language other than those required will not be selected
CE3	Duplicate articles will not be selected
CE4	Works without content availability for reading and data analysis will not be selected
CE5	Course completion works or monographs will be excluded

Source: own authorship (2022)

Finally, based on the combination of keywords and their synonyms, aided by boolean operators, search strings are defined, which are the terms that will be used in the CAPES journals portal database for conducting the research itself. For this systematic review, we chose to use only the AND operator to combine keywords, not using the OR operator. This choice was made so that the data from the found results could be presented in a more didactic way, individually separating each result into eight different strings.

Once the review protocol is defined, the actual searches are conducted. The defined strings are entered into the advanced search field on the CAPES journals portal, configuring the parameters as defined in the protocol. For each of the eight strings, formed by the combination of keywords, there is a quantity of article returns. It is worth noting that this is an iterative process, and the search strings are subject to changes depending on the articles returned in the research database. It is common to find that a particular keyword does not have broad application in the writing of scientific texts, so it is preferable to replace it with a synonym that results in a more satisfactory number of articles found.

The selection of articles was done by applying two filters. The first consisted of reading the title, abstract, keywords, and abstracts of the articles, applying the inclusion and exclusion criteria. If the analyzed article fit into at least one exclusion criterion, it would be excluded from the review results. On the other hand, if the inclusion criteria were met, it would be included in the review results. The second filter is a more detailed analysis, since a reading of only the titles and abstracts is not sufficient to evaluate whether the analyzed study is indeed relevant to the systematic review and adequately addresses the research questions. A reading of the article is carried out, not necessarily the entire article. The full-screening technique was applied, which consists of "skimming" through the article to make the selection more efficient (Jaques et al., 2020).

From these results, an assessment of the qualities of the selected articles is carried out, i.e., how well these studies address the research questions. A scale of 1 to 5 was assigned, with 1 being the lower limit, assigned to works that do not address the research questions at all, and 5 being the upper limit, which fully addresses the questions. Table 5 below presents the eight search strings searched in the CAPES journals database, showing the research result, the works effectively selected, and the inclusion and exclusion criteria applied through the filters.

Table 5 - Results

N.º	String	Result	Selected	Criteria
1	"cleaner production"	152	21	CI1, CI2, CI4
2	"cleaner production" AND "civil construction"	18	5	CI1, CI2, CI3, CI4
3	"cleaner production" AND "construction sector"	5	0	CE3
4	"cleaner production" AND "construction industry"	2	0	CE3
5	"cleaner production" AND "public service"	3	0	CE1
6	"cleaner production" AND "public sector"	8	0	CE1
7	"cleaner production" AND "public administration"	14	2	CI1, CI2, CI4
8	"cleaner production" AND "*Triple Bottom Line*"	12	2	CI1, CI2, CI4, CE3

Source: own authorship (2022)

Process Modeling

The data for mapping and modeling the processes were obtained through interviews with employees of the Department of Infrastructure (DINFRA) of the IFAM's rectory. Initially, the relevant internal processes of IFAM for this research were identified based on documentary research of existing flowcharts. Given that cleaner production manuals often focus on implementing measures during the execution of the work, processes related to this phase were selected for mapping.

Due to the peculiarities of IFAM as a federal autarchy, where the execution of works is carried out indirectly, the processes related to execution are more about supervision and control, as required by current legislation. Thus, the chosen processes for analysis were Inspection and Measurements.

The Inspection process was selected due to its role in controlling the execution of the work, monitoring aspects such as quality, compliance with the contract, and schedule, all relevant to cleaner production. The Measurement process was chosen because it is an effective means of execution control, in addition to having financial implications that can encourage the implementation of cleaner production measures.

In addition to interviews, the Inspection and Measurement processes were mapped based on existing literature on the inspection of public works, considering IFAM's peculiarities, such as the use of outsourced inspection companies due to regional logistical challenges.

Cleaner production manuals also highlight opportunities during the planning phase of works, especially regarding engineering projects. This was another perspective considered in this research, considering the aspects of planning and project development.

Furthermore, considering the specific characteristics of public service (legality, legitimacy, etc.), it is exceptionally unlikely that the application of a cleaner production methodology impromptu and without planning will have any positive effects on waste reduction in works, besides being perfectly possible, provided that the work planning is developed concurrently with the application of cleaner production concepts (CORREIA and CONCEIÇÃO, 2021).

Thus, in this research, the planning and project development stage were incorporated, considering the peculiarity of IFAM, where all planning and projects are encapsulated in a macro process called Basic Project. Depending on the project's complexity, its development is carried out by IFAM's internal technical staff or by an outsourced company. This phase covers all the necessary stages and procedures for the development of an engineering services project, involving the campus requesting the project, the Vice-Rectorate for Planning and Administration, the Infrastructure Directorate, and the Federal Attorney's Office.

The interviews were conducted following a script with open questions, adapted from a questionnaire developed by the National Council of the Public Prosecutor's Office (2016), as described in the Process Management Methodology. This questionnaire aims to understand how processes start, what the flow of activities is, and how they are completed. It is assumed that the user, represented by the Vice-Rector of the PROPLAD, issues a Service Order to start the inspection of a certain work (in the Inspection and Measurement processes). In the case of the Basic Project elaboration process, the user making the request can be considered the director of a certain campus.

The interviews can be classified as semi-structured, since they present a script with open questions, aiming to study a phenomenon with a specific population (IFAM employees performing functions related to works), with flexibility in the sequence of how questions are presented to the interviewee, with the interviewer being able to ask complementary questions to understand more clearly the phenomenon being studied (MANZINI, 2012). The questionnaire used to conduct the semi-structured interviews can be found in Appendix A.

For the semi-structured interviews, the employees directly involved in the processes addressed in this research were identified. It was found that in the Inspection and Measurement processes, the Coordinator of Inspection of Works and Engineering Services plays a central role, while in the Basic Project process, it is the Coordinator of Planning and Engineering Projects who is involved. The interviews were conducted individually by the researcher at the institution, with the participation of these employees at previously scheduled times. It is important to emphasize that the processes were modeled in their current state (AS IS), since the focus of the research is to understand how a cleaner production approach can be applied to these processes, not proposing improvements. Additionally, internal processes of other departments and coordinations besides DINFRA were mapped in a simplified manner, as they are outside the defined scope for this study.

The BPMN (Business Process Management Notation) notation was used for process flow representation, which is a notation adopted as a standard and widely accepted for modeling business processes (MARQUES, 2018). The tool chosen for process modeling was the Bizagi Modeler® software, as it is a tool available for free, which uses the chosen BPMN notation, making the modeling and publication process of the studied processes simpler and more agile (CNMP, 2016). Thus, based on the results of the interviews, the Inspection, Measurement, and Basic Project processes were modeled.

Cleaner production methodology adopted

To achieve the objectives of the present research, the guides and manuals for the application of cleaner production methodologies available in specialized literature were analyzed. These manuals have the primary purpose of providing assistance to users in implementing cleaner production by supplying theoretical, structural, conceptual, procedural, and tool-related knowledge (GUARDIA, 2016). Therefore, manuals and guides on cleaner production were researched, both those developed by national and international organizations. Among the analyzed material, manuals aimed at a more generic use were identified, covering the application of cleaner production across various industries, as well as more specific guides tailored to specific production sectors, such as "Cleaner Production in Dairy Processing," aimed at organizations in the dairy industry.

Thus, for the purposes of this research, which deals with construction works, the manual "Cleaner Production in Buildings," by CNTL SENAI-RS, was selected. This is the most commonly adopted manual in studies related to cleaner production (BORGES, 2016; SILVA et al., 2017), as it presents several specific characteristics of the construction industry.

The manual "Cleaner Production in Buildings" follows a structure similar to the guide "Implementation of Cleaner Production Programs," dividing into five stages: technical visit for pre-awareness, Planning and Organization, Pre-assessment, Assessment, Feasibility Study, and Implementation. For this research, six stages were considered, with the technical visit being the first, numbered sequentially from it.

Regarding content, the manual addresses specific aspects of the construction industry, making it the ideal choice for this study. It contextualizes the construction industry in Brazil, including relevant legislation, and presents a synthesis of construction processes, inputs, and associated waste. A table displays cleaner production opportunities, and case studies, illustrate implemented measures and their economic and environmental impacts. These characteristics demonstrate the suitability of the manual for achieving the objectives of this research.

III. IFAM Characterization

This section aims to discuss the results obtained through process mapping and the application of questionnaires.

Fiscal Inspection Process

The fiscal inspection process commences with the issuance of the Service Order by the Chancellor, appointing the inspection committee, typically composed of three members, with substitutes available in case of the titular members' unavailability. Following preliminary meetings between the committee and the executing company of the project, weekly visits to the construction site are conducted, enabling the monitoring of activities and the recording of occurrences.

The travel for inspection to the IFAM's inland units involves extensive distances, often undertaken through river trips, resulting in costs associated with tickets and per diems. To mitigate this situation, local employees are appointed to the committee, although they may not always possess the necessary technical knowledge, leading to the hiring of third-party companies for technical inspection.

During the visit, the project schedule is analyzed, and if necessary, contractual changes or deadline extensions are made. Non-compliances are recorded, and the company is notified for corrections, which may result in sanctions if they fail to comply with the inspection's determinations.

Upon correction of non-compliances, the entries are recorded in the construction diary. If it is the last week of the month, the measurement process begins; otherwise, the process restarts until the last week of the month. This step is essential to ensure compliance with the schedule and the quality of the project.

Measurement Process

The measurement process, which involves formal procedures for remunerating the services performed by the contracted company, begins after the weekly inspection visit conducted in the last week of the month. Within DINFRA, this process can be divided into two parts, represented in the two lanes of the consolidated mapping: the contract inspector, responsible for monitoring and ensuring contract compliance, and the executing company, responsible for executing the contracted services.

After initiation, the process of measuring completed services commences. The initial check determines the measurement number, distinguishing between the first measurement, with its specific checklist, and subsequent measurements. If the measurement is the last one, the process of provisional acceptance of the work is initiated before further proceedings.

Next, a detailed analysis of the services and documentation is conducted to verify if they have been completed as specified in the basic project and contract. If there are discrepancies, the process is returned to the executing company for corrections. After the inspector reviews the corrections, the process advances only when all discrepancies have been rectified.

Upon approval, the approved measurement spreadsheet is issued, containing the measured services and corresponding values. The executing company issues the invoice based on these values and organizes the documentation for the final approval by the contract inspector. From that point on, the process is concluded from the inspector's perspective, continuing in other departments not addressed in this research.

Basic Design Process

The basic design is a set of essential elements to characterize an engineering work or service. The process of developing this project involves several stages, from preliminary analyses to the elaboration of executive projects, aiming to specify the object satisfactorily. Four distinct elements participate in this process, represented in different lanes in the mapping: the Director's Office, responsible for receiving local demands from the campus; PROPLAD, which performs analyzes and checks in the process; DINFRA, responsible for technical studies and elaboration of executive projects; and the Federal Attorney's Office, which provides legal consultancy to IFAM.

The process begins with local demands brought by the academic community to the Director's Office, which formalizes these demands through the Demand Formalization Document. The management then issues a planning ordinance, appointing the team responsible for planning the hiring, composed of qualified staff for the necessary tasks, including technical and legal knowledge (BRAZIL, 2017).

After the planning committee is appointed, the process is sent to PROPLAD, where internal analyses are carried out, whose focus is beyond the scope of this research, determining whether the basic design process is approved for its continuation or not. If the project development is not approved, the process ends. If the process is approved, a memorandum is then issued containing the service order authorizing the start of the elaboration of the executive projects and the documentation necessary for the basic project to be tendered.

With the project accepted and the service order issued, the process returns to the director's office at the local campus, where the planning and supervision committee prepares the situational report of the work, describing important information about the physical space where the work will be carried out, such as the conditions of the existing infrastructure (water supply, sewage collection, etc.), presence of large tree vegetation, and if the project is a renovation or completion of work, the physical conditions of the services already executed, among other information relevant to subsequent stages.

The process is forwarded to DINFRA after the elaboration of the situational report. The first activity carried out in this department is the preliminary technical study, which can be defined as the initial stage of contracting planning, characterizing the public interest involved together with its best solution, basing the preliminary project, the terms of reference, or the basic project (Brazil, 2022) including information regarding the need and requirements of the contracting, description of the solution, estimation of quantities and value of the contracting, among other important data. Thus, the preliminary technical study presents in its conclusion the declaration and justification of viability, analyzing whether the project realization is feasible or not. If the project is feasible, the process moves forward to the next stage. If the continuation of the process is not viable, an analysis of changes in the project is carried out. This analysis aims to verify if it is possible to make changes so that the project becomes technically viable, and if these changes can be made in such a way that the project does not become completely characterized, that is, does not undergo changes of such a nature that the object does not change unexpectedly and prevents the original needs of the users from being fully met. Thus, if these changes are possible, modifications are made to the project to make it technically viable, and the Preliminary Technical Study of the altered project is carried out again, to formally attest to the viability of the project. If it is not possible to make changes to make the project technically viable without characterizing it, the process ends.

Consequently, with the technical viability of the project formally attested, the risk map of the project is elaborated, which can be defined as a document prepared to identify the main risks that are part of the contracting procedures, in addition to control, prevention, and mitigation actions of impacts (Brazil, 2017). Thus, these characteristics are consolidated into a document that assigns scores referring to the impact and probability for the risks for the different phases and factors that threaten the achievement of the project.

From this point on, with the risk map defined, the process returns to the director's office, so that the local campus administration can provide the definitive title of the area where the work project will be implemented, containing information such as the limits and confrontations of the terrain, descriptive memorial, perimeter data, situation and location plans, among other information, guaranteeing the legal possession of the lot where the construction will be carried out. If the area where the project will be implemented does not have a definitive title, the local campus administration must work together with the municipal administration to provide this documentation. Thus, the process only proceeds when the land situation is duly regularized.

From obtaining the regularization title of the project implementation area, the process returns to DINFRA for the elaboration of the basic project or terms of reference, elaborated from the preliminary studies and risk management, defined as documents containing sufficient technical elements to allow cost evaluation by the administration, with sufficient and necessary technical elements, with an appropriate level to characterize the service that will be contracted, guiding future execution and contractual supervision (Brazil, 2017), including declaration of the object, contracting rationale, contracting requirements, among other relevant information.

The elaboration of the executive architectural project begins based on all the documentation generated so far, covering planning, specification, and detailed description of all elements of the construction, from floor plans, sections, and elevations to structural systems, equipment, and layout. Once the executive architectural project is completed, the elaboration of complementary projects begins, which provide essential information for the realization of the project, addressing aspects such as topography, earthworks, hydraulic, electrical installations, and fire prevention, among others, usually not included in the scope of the architectural project.

With the completion of the stage of elaboration of all executive projects, the process is sent again to the director's office for approval by the competent municipal authorities, aiming to obtain the necessary environmental license. If the projects are approved, the process continues its course. However, if the local regulatory agency identifies the need for changes for approval, the process returns to DINFRA for analysis and implementation of the required changes. If such changes can be made without characterizing the project and meet the needs of the users, the projects are reviewed and resent to the director's office for new approval by the competent municipal authorities, repeating the process until obtaining the environmental license for the projects elaborated by DINFRA.

After obtaining approval and environmental license, the process returns to DINFRA to elaborate complementary documents, which characterize the elements of the project. These documents include the budget, which predicts the costs of services, labor, and materials necessary for the execution of the work; the calculation memory, which details the calculations to determine the quantities of the budgetary worksheet; the technical note, which explains the bidding modality of the project; and the descriptive memorial, which specifies the materials, construction technologies, and adopted sizing parameters. Subsequently, Technical Responsibility Annotations (ART) are issued for engineers or Technical Responsibility Records (RRT) for architects, proving and linking the technical responsibility of the professionals involved in the elaboration of the projects.

Subsequently, with the executive projects completed, the process is forwarded to PROPLAD for document analysis and procedural certification, guaranteeing the conformity of the documentation with the current legislation. The parameters for determining the bidding modality are also verified. If it is possible to waive the bidding, the process is finalized and forwarded to the responsible coordination. Otherwise, it is forwarded for legal analysis at the Federal Attorney's Office.

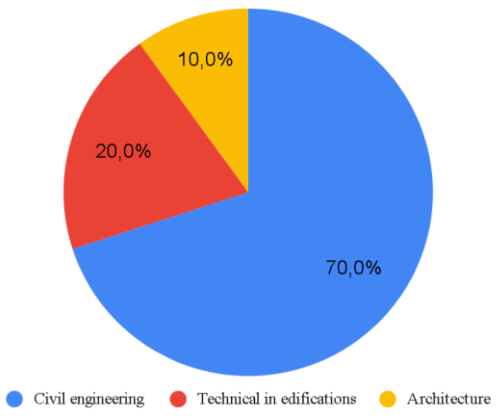
At the Federal Attorney's Office, a thorough analysis of the basic project documentation is carried out in light of current legislation. If the legal analysis confirms that the documentation is in accordance with the law, the process is closed. However, if legal inconsistencies are identified, the process is returned to DINFRA for corrections, from the stage of elaboration of the basic project or terms of reference to subsequent stages.

Result Quiz Application

The results obtained through the questionnaire on cleaner production, applied to the IFAM (Federal Institute of Education, Science and Technology of Amazonas) servers, are presented via graphs to facilitate understanding, following the discussed structure: characterization of the respondent, characterization of the organization, general aspects of production, cleaner production in projects, cleaner production in inspection, and barriers to cleaner production.

Regarding the characterization of the respondents, it is observed that the majority (80%) have higher education in areas related to construction technology, such as civil engineering and architecture, while a smaller portion (20%) have technical training in building construction. Additionally, some respondents have postgraduate education (2) and stricto sensu (1), in areas also related to performing activities linked to construction, such as construction management, technology, and quality in civil construction, and asphalt paving. These data suggest that the servers have an academic level conducive to the application of the cleaner production methodology. Although the application of this methodology does not necessarily require complex interventions that demand advanced academic knowledge, having a body of specialized servers can be a positive differential for the implementation of cleaner production in the institution.

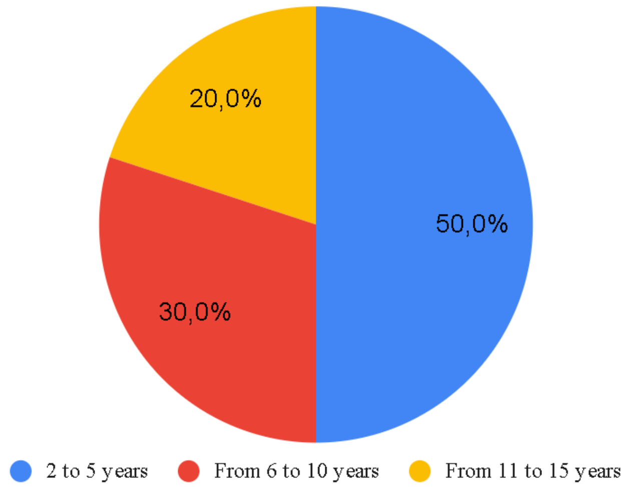
Graph 3 - Question 1.1: academic background.



Source: Own authorship (2022)

In relation to the tenure of the respondents, it was observed that no employee has served for less than 2 years in the institution, while 50% have been working for 2 to 5 years, 30% for 6 to 10 years, and 20% of the respondents have been working for 11 to 15 years at IFAM. These results indicate that at least 50% are permanent employees with stability, while the remaining 50% are also on track to obtain stability. The results also suggest that employees tend to possess a thorough understanding of the institution's construction and building processes, as they have been performing their duties for a considerable amount of time. This characteristic proves significant for the scope of cleaner production, as its application requires a deep knowledge of the production processes employed, enabling the detection of inefficiencies and opportunities for improvement. Therefore, regarding the tenure of the employees, the organizational environment also appears suitable for a cleaner production methodology.

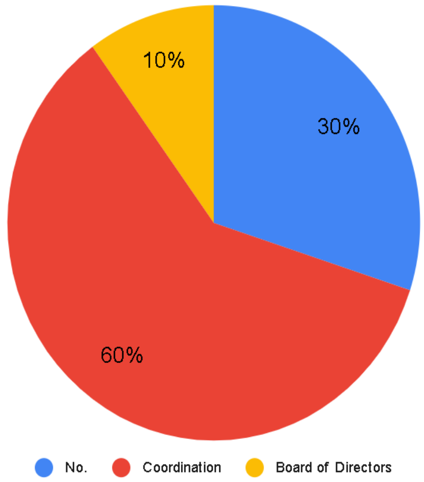
Graph 4 - Question 1.2: time of operation.



Source: Own authorship (2022)

Regarding the performance of leadership positions or functions by the respondents, it was found that the majority (70%) have already held some managerial position: 60% have held coordination positions, while 10% of the employees have held director positions, with 30% of the employees never having held any managerial-level position. From the perspective of a cleaner production methodology, these data demonstrate an organizational environment suitable for its implementation, since managerial commitment is of paramount importance for raising awareness among top management, thus ensuring the success of the program's application. Therefore, a high percentage of employees with technical knowledge who, even with turnover in leadership positions, perform coordination functions, may indicate an increased likelihood of successful implementation of cleaner production.

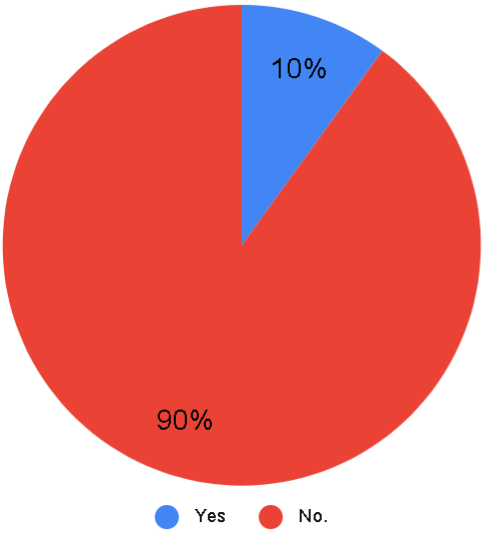
Graph 5 - Question 1.3: performance of management positions



Source: Own authorship (2022)

Regarding the participation of employees in training courses related to cleaner production, it was found that the vast majority of employees (90%) have never undergone any training related to this topic, while only 10% have participated in training related to it. Among those who participated, it was a course on cleaner production in the industry, offered by SENAI/SESI, which was not directly related to the construction theme. These data show that most respondents still lack prior knowledge of what cleaner production is and how it works, indicating the need to impart this knowledge to IFAM employees for the implementation of cleaner production to be feasible within the institution.

Graph 6 - Question 1.4: participation training cleaner production



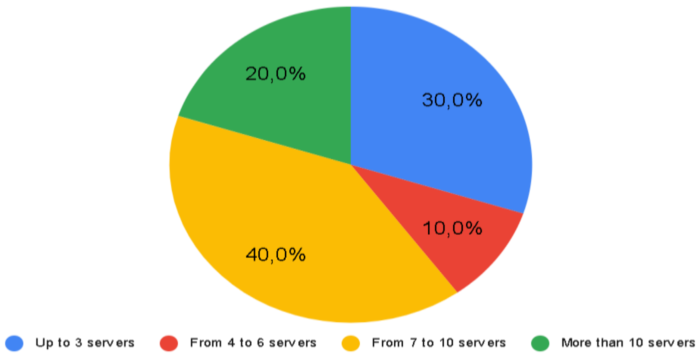
Source: Own authorship (2022)

Organizational Characterization

Regarding the quantity of servers operating within departments, it was observed that 30% have up to 3 servers, 10% have from 4 to 6 servers, while 40% have 7 to 10 servers, and departments with more than 10 servers represent 20% of the sample. These data suggest a numerical diversity in the composition of the departments related to construction and works at IFAM. Departments with fewer servers exclusively meet the demands of construction and works at the campus to which the department is linked. Departments with a relatively larger number of servers cater to a greater number of IFAM campuses in the interior of the state, which do not have a specific department dealing with construction and works.

Regarding cleaner production, it can be noted that in campuses with smaller departments, the application of the methodology can be more dynamic, as the physical proximity between the construction site and the campus makes the supervision of processes and the application of cleaner production methodology more practical. On the other hand, in departments with a relatively high number of servers, dealing with works in municipalities far from the capital and requiring long commutes to reach, the application of cleaner production may encounter some challenges.

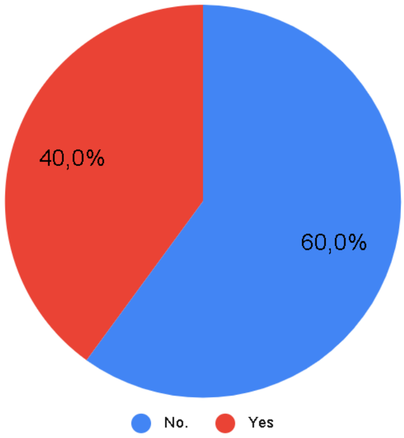
Graph 7 - Question 2.1: number of employees in departments.



Source: Own authorship (2022)

Regarding the goals related to environmental management in construction projects, it was found that 60% of the respondents claimed to be unaware of objectives in this regard, while 40% of the employees stated that IFAM has such goals. Respondents mentioned some examples of objectives related to this theme, highlighting goals such as reducing energy consumption, minimizing the production of materials that will result in waste, as well as collecting and selecting construction waste for reuse in future projects. It is possible to emphasize that these goals are related to cleaner production since they aim at the more efficient use of inputs such as energy and water, the reduction at the source of waste generation (level 1 of cleaner production application), and external recycling (level 2). Therefore, IFAM has already been taking some measures related to cleaner production punctually, demonstrating a concern with waste management and a more efficient use of inputs, thus showing an existing sensitivity necessary for the application of a cleaner production methodology.

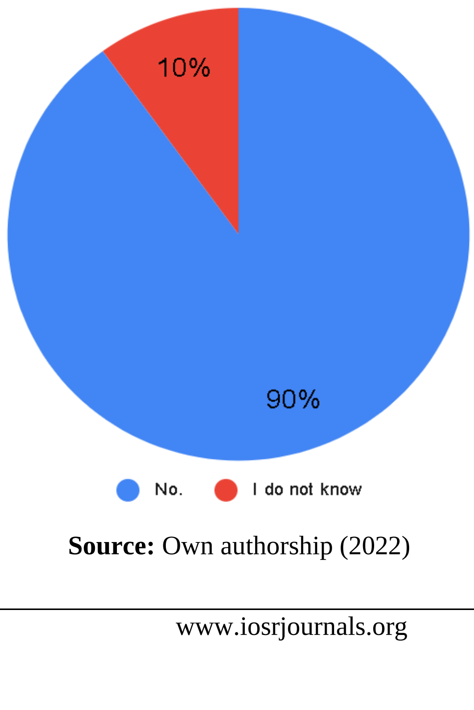
Graph 8 - Question 2.2: goals related to environmental management in works at IFAM.



Source: Own authorship (2022)

When it comes to any specific responsible party (department, coordinator, etc.) dealing with environmental management in construction projects, it was found that 90% of the respondents stated that such a department does not exist, while 10% claimed to be unaware of the existence of a specific responsible party. It is worth noting that among the responses provided, there is occasional mention of the senior management's intention to establish a specific department dedicated to this purpose. However, planning and deliberation among the managers on the deliberative council of IFAM are still necessary regarding this matter. Therefore, this intention also indicates a sensitivity to issues related to environmental management, thus reflecting a mindset within the institution that favors cleaner production.

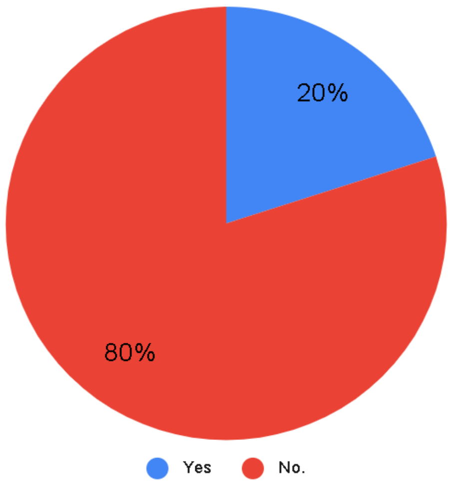
Graph 9 - Question 2.3: responsible for environmental management in works at IFAM.



Source: Own authorship (2022)

Regarding the existence of a manual with environmental management practices in IFAM construction works, it was verified that 80% of the participants claimed not to be aware of this document, while 20% stated that the organization does possess such a manual. Despite the affirmative responses regarding the existence of the manual, respondents also mentioned that it is outdated, indicating the need for updates. Additionally, the use of complementary manuals, such as the Sustainable Procurement Guide from the CGU, is mentioned. Thus, the IFAM manual, if it indeed exists, is outdated, with the possibility of adding and updating information to incorporate concepts of cleaner production.

Graph 10 - Question 2.4: environmental management manual at IFAM.

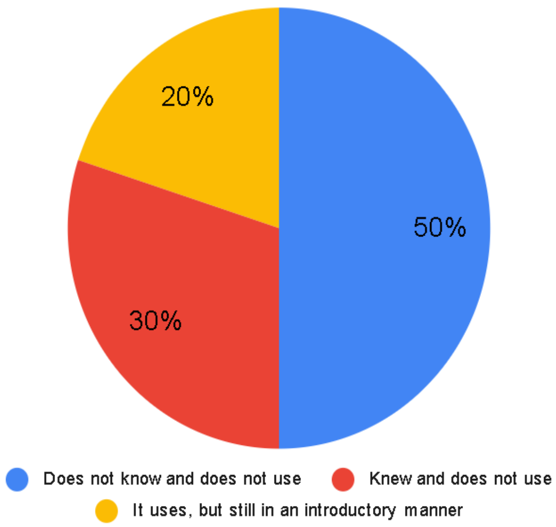


Source: Own authorship (2022)

General aspects of cleaner production

Regarding the general aspects of cleaner production, it was found that 50% of respondents do not have any previous knowledge about cleaner production and do not use it in their work processes; while 30% claim to know the concept but do not use it; and 20% of the employees declare to have knowledge of the methodology's concept, but still use it in an introductory and not fully integrated manner. These responses are directly related to the lack of training, capacity-building, and courses focusing on cleaner production, so that the methodology can be consolidated in the work processes of the employees. Furthermore, it is possible to note that some employees already have knowledge related to the methodology, even though it is not applied systematically, which may be associated with the adoption of some cleaner production practices already implemented sporadically at IFAM.

Graph 11 - Question 3.1: knowledge, production cleaner.



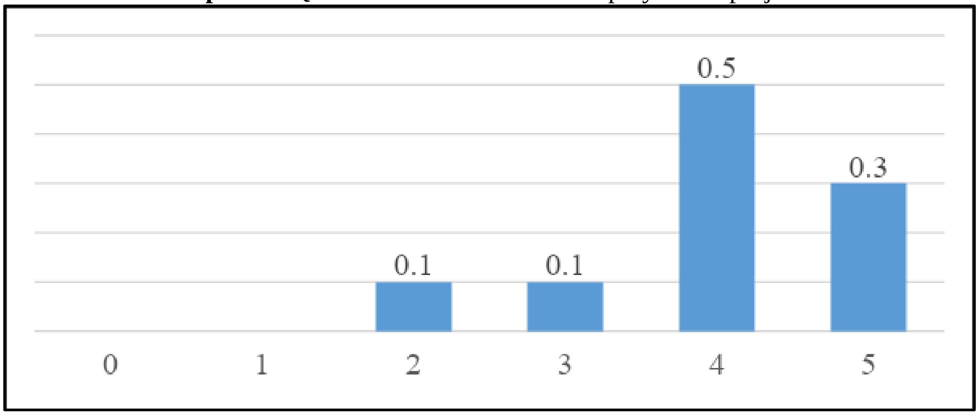
Source: Own authorship (2022)

The following question in the section on general aspects of cleaner production deals with the concepts of cleaner production presented by the respondents who answered the questionnaire. The concepts described in the respondents' own words relate cleaner production to various conceptions, such as sustainability, waste management, resource optimization, rational use of raw materials and energy, environmental degradation, among other ideas, which are generally directly related to the definitions found in the literature discussed earlier. Therefore, the concept of cleaner production among IFAM servers is generally aligned with the concept presented in the literature.

Cleaner production projects

Regarding the project stage, it was found that the majority of respondents present positive responses regarding the influence of servers in the conception of building projects, with 50% of the responses according to the statement and 30% in full agreement. This finding represents a favorable organizational environment for cleaner production, since the project and planning stage presents an important part of the opportunities for applying this methodology. Therefore, if servers with technical knowledge have autonomy and sufficient influence at this stage, changes can be made to projects aiming at improvements related to cleaner production.

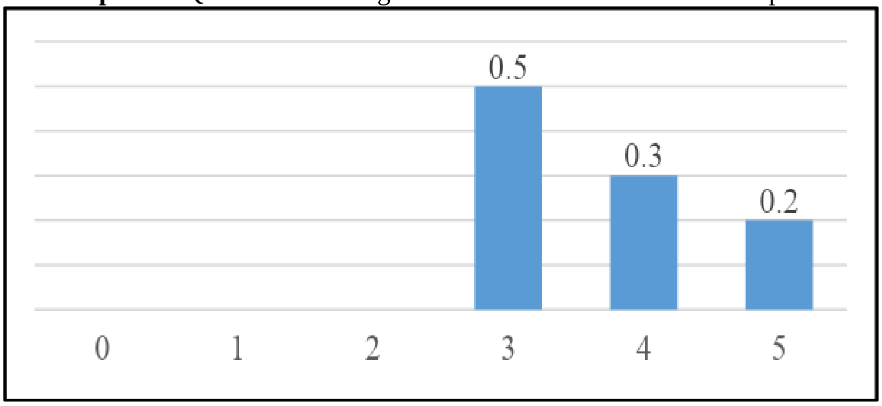
Graph 12 - Question 4.1: influence of employees on projects.



Source: Own authorship (2022)

In relation to the concern of designers regarding the environmental management aspects of construction projects during the project development stage, it was found that 50% of the respondents neither agree nor disagree with the statement, while 30% agree and 20% strongly agree. The data gathered from this assertion allow us to infer that perceptions regarding environmental management in the project development stage remain divided, which could be mitigated through the implementation of training and capacity-building activities that demonstrate the importance of cleaner production concepts and environmental management, aiming to sensitize the staff involved in this stage. Despite this difference in positions, it is observed that 50% of the participants hold a positive perception regarding the designers' concern for environmental aspects, indicating signs of awareness within the organizational environment of IFAM, thus being conducive to the implementation of cleaner production methodologies.

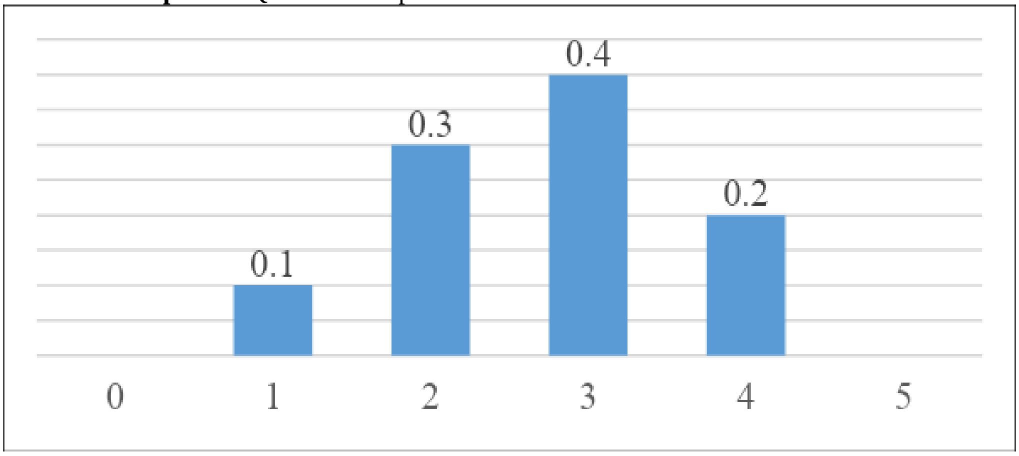
Graph 13 - Question 4.2: designer concerns with environmental aspects.



Source: Own authorship (2022)

Regarding the preference of designers for specifying renewable and/or sustainable materials in the project development stage, it was observed that 40% of respondents neither agree nor disagree, while 10% totally disagree, 30% disagree, and 20% agree. These data indicate that a considerable portion of the respondents still tend to show a preference for potentially unsustainable materials, aligned with end-of-pipe technologies, which aim to solve environmental problems solely from a technological standpoint, a perspective diametrically opposed to the concepts of cleaner production, which envisage the substitution of harmful materials as product modifications. Therefore, adjustments are needed regarding the preference for materials specified by designers so that the stages of cleaner production methodology can be effectively applied.

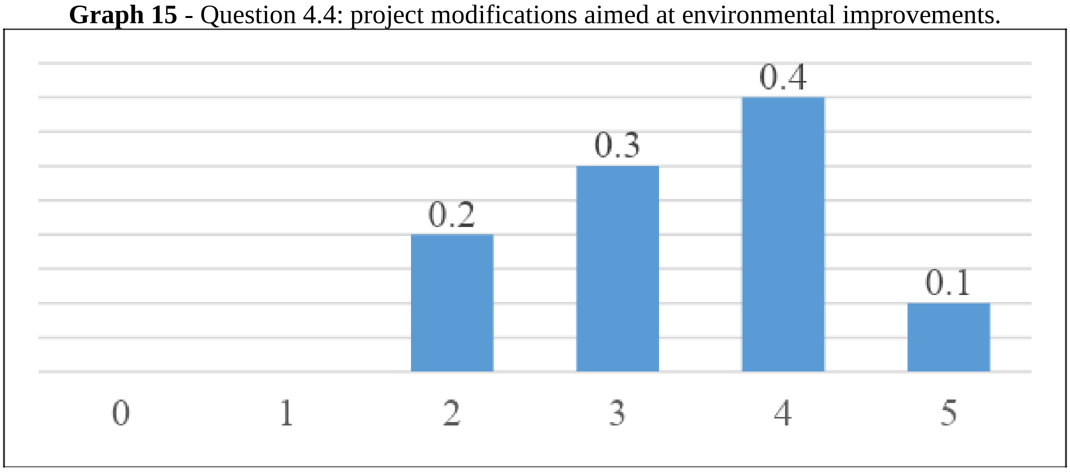
Graph 14 - Question 4.3: preference for renewable/sustainable materials.



Source: Own authorship (2022)

Regarding the implementation of modifications in building projects aimed at environmental improvements and adaptations, it was found that 30% of respondents neither agree nor disagree with the statement, 20% disagree, 40% claim to agree, and 10% are in full agreement. These results indicate that a portion of the staff (50%) exhibits a positive attitude towards changes in the project, which is an important stage of cleaner production: waste and emissions minimization includes, at level 1 of application, source reduction through modifications in the product or processes, through good practices of cleaner production, substitution of raw materials, and technological modifications, all of which can be carried out in the elaboration and planning stage of the project. Thus, a mindset of greater openness to project modifications is necessary for the effective application of cleaner production.

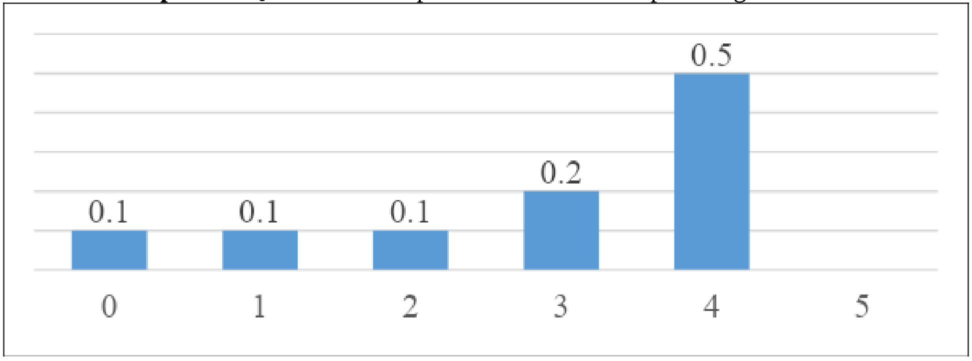
Graph 15 - Question 4.4: project modifications aimed at environmental improvements.



Source: Own authorship (2022)

Regarding the replacement of toxic and/or polluting materials in the project development stage, it is possible to observe that 20% of the respondents neither agree nor disagree with the statement, while 10% cannot respond, 10% strongly disagree, 10% disagree, and 50% agree. This is also a positive attitude concerning cleaner production, which needs to be further disseminated throughout the project development stage: while end-of-pipe technologies employ limited waste treatment and filtration measures, cleaner production promotes waste generation prevention, avoiding potentially toxic materials, thus being the preferable behavior.

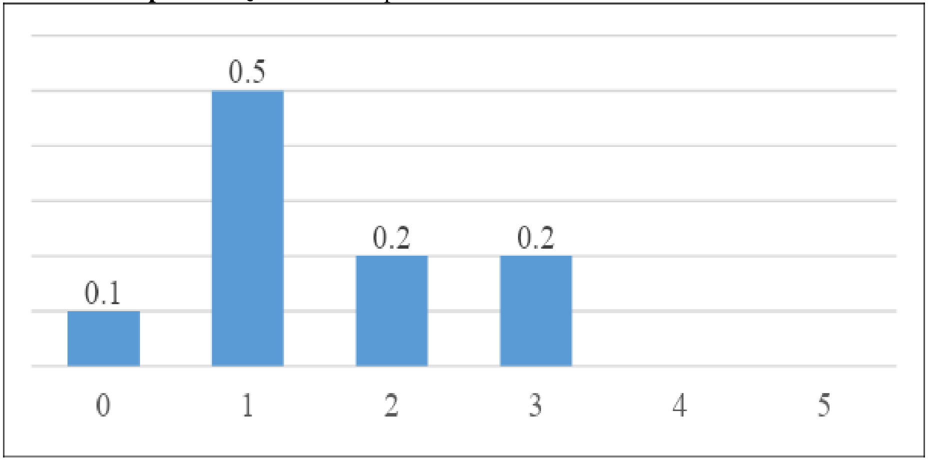
Graph 16 - Question 4.5: replacement of toxic or polluting materials.



Source: Own authorship (2022)

Regarding planning, during the project development stage, internal reuse or recycling of waste generated during the construction process, it was verified that 20% of respondents neither agree nor disagree, 10% do not know how to respond, 20% disagree, and 50% totally disagree. An analysis of the results reveals that there was no positive response, either partially or totally agreeing with the statement, allowing to infer that the internal reuse or recycling of waste generated during the construction process is not usually applied at IFAM. This shows an unfavorable scenario from the perspective of cleaner production, since internal recycling, referring to level 2 priority application, and external recycling, at level 3, are fundamental for the application of a cleaner production methodology, making it urgent to consider these levels of application in the planning and project development stage.

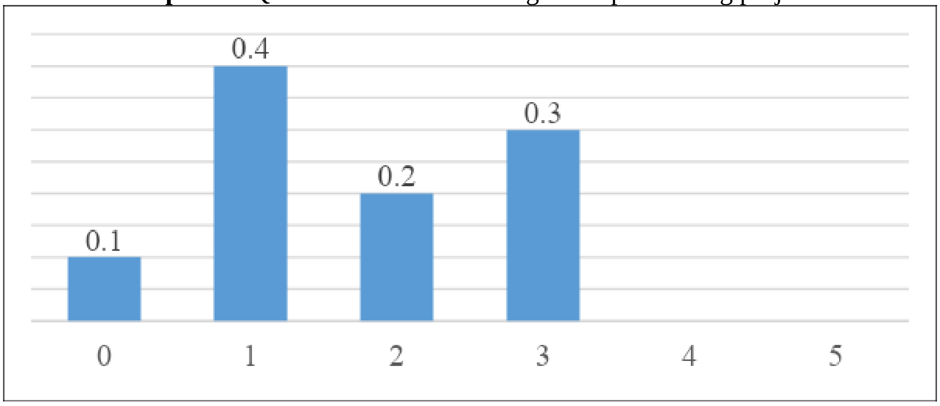
Graph 17 - Question 4.6: prediction of reuse of construction waste.



Source: Own authorship (2022)

Regarding the development of the Solid Waste Management Plan for construction projects during the project development stage, it was found that 30% of respondents neither agree nor disagree with the statement, while 10% are unsure, 20% disagree, and 40% strongly disagree. In this matter, it is also possible to observe that the majority of respondents have a perception that tends towards negativity, partially or totally disagreeing, leading to the deduction that the Management Plan for the projects is not usually developed during the project development stage. This is a mandatory document of paramount importance for the diagnosis and final disposition of construction waste, being equally important for cleaner production, especially in stage 2 of methodology application, which analyzes the process flowchart of production and foresees quantification of both inputs (raw materials, water, energy, etc.) and outputs (waste, effluents, emissions, etc.), serving as the basis for the elaboration of material balances, establishment of indicators in phase 3, and consequently, all subsequent stages of the methodology. Therefore, the elaboration of a Waste Management Plan is imperative for the implementation of a cleaner production methodology.

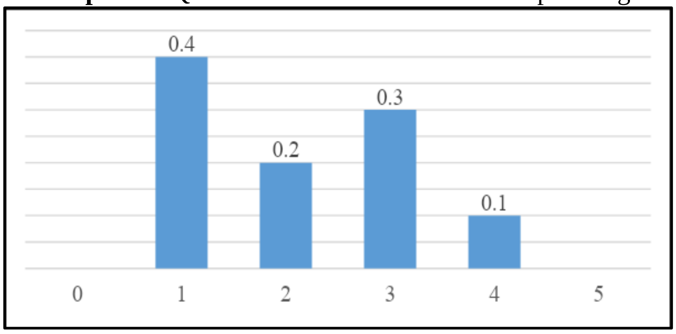
Graph 18 - Question 4.7: waste management plan during project.



Source: Own authorship (2022)

In relation to the planning of measures to minimize construction waste generation during the project development stage, it was found that 30% of respondents neither agree nor disagree with the statement, while 40% totally disagree, 20% disagree, and 10% agree with the assertion. The perception of the majority of respondents (60%) places waste minimization planning in the area of disagreement, either total or partial, while only 10% of respondents understand the statement as partially true. The analysis of these data leads to the belief that measures for waste generation minimization are not usually conceived at this stage of project development. From the perspective of cleaner production, waste minimization at the source is one of the priorities, taking precedence over other measures, and its consideration is necessary at this stage of project development.

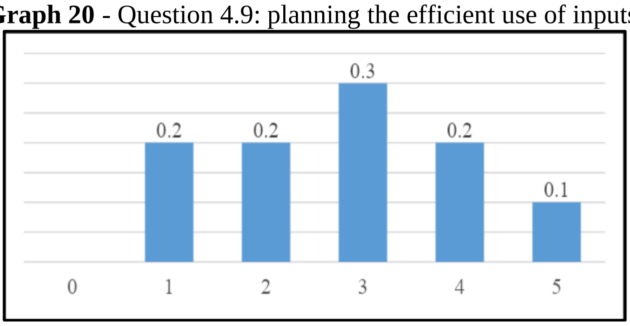
Graph 19 - Question 4.8: waste minimization planning.



Source: Own authorship (2022)

In terms of planning measures for the efficient use of inputs, such as drinking water and electricity, during the project development stage, it was found that 30% of the surveyed employees neither agree nor disagree with the assertion, while 20% completely disagree, 20% disagree, 20% agree, and 10% strongly agree. The distribution of collected responses indicates a lack of agreement or disagreement in the perception of the employees. One possible explanation for this discrepancy in perceptions is that measures for planning the efficient use of inputs during the project stage are implemented variably among different organizational contexts, such as different departments. Despite this possibility, the efficient use of inputs is crucial for the success of cleaner production, being one of its main objectives in the various stages of the methodology.

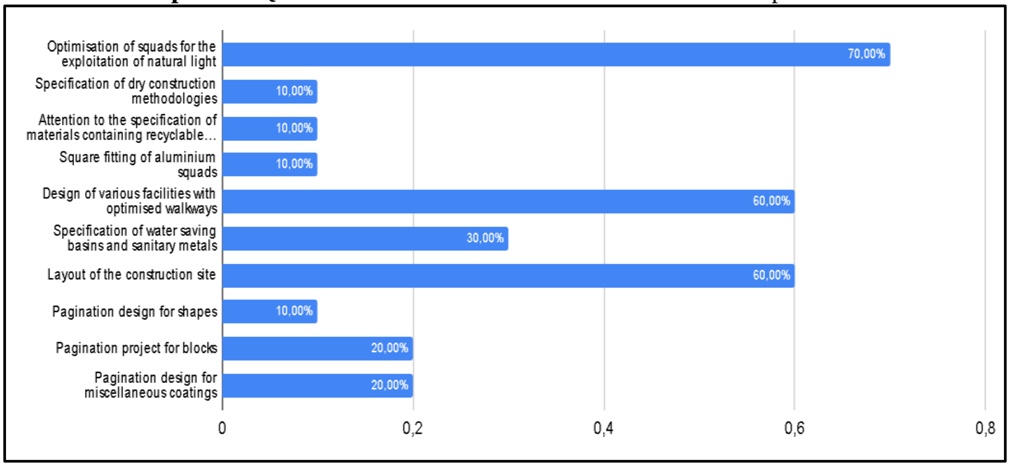
Graph 20 - Question 4.9: planning the efficient use of inputs.



Source: Own authorship (2022)

The issue that concludes the category on cleaner production and projects presents several options for measures of this methodology that can be adopted during the project stage, to verify which measures IFAM has already been spontaneously adopting, without systematically applying cleaner production. It was found that 70% of respondents indicated the optimization of frames for natural light utilization; 60% pointed out the development of installation projects with optimized routing and construction site layout; 30% noticed the specification of basins and sanitary fixtures that save water; 20% marked options for block layout and various coatings; 10% indicated the specification of dry construction methodologies, changes in material specification, realignment of aluminum frames, and layout design for molds. These results demonstrate the measures that already have reasonable application in the context of IFAM project development, with emphasis on the optimization of frame openings, which allows for the utilization of natural light and consequent reduction in electricity consumption; and construction site layout design, which promotes housekeeping and reduces losses related to poor storage and handling of inputs and materials. In addition to this aspect, these results also show measures that are not yet consistently used and have potential for application, such as coating layout design and specification of dry construction methodologies, so that improvements can be introduced, in addition to the implementation of a cleaner production methodology in the project development stage at IFAM.

Graph 21 - Question 4.10: Production measures cleaner adopted.

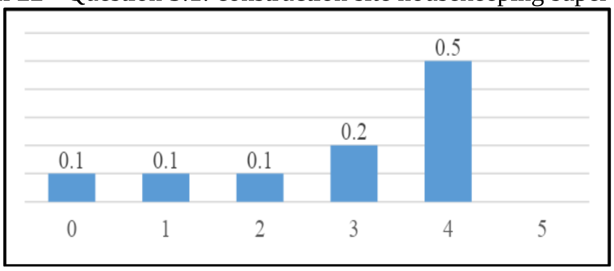


Source: Own authorship (2022)

Cleaner production inspection

Regarding cleaner production in the inspection stage, the first question presents an assertion about housekeeping inspection (related to cleanliness, organization, and safety) at construction sites. It was analyzed that 20% of respondents neither agree nor disagree with the assertion, while 10% do not know how to respond, 10% totally disagree, 10% disagree, and 50% agree with the assertion. The discrepancy in the presented results may be due to differences between the organizational scenarios of the engineering department in the central administration and the departments located in the campuses: while campus staff have daily access to the construction site facilities and can inspect housekeeping on a daily basis, staff stationed at the central administration rely on third-party observations, which are often not relayed in a timely manner, making it impossible to conduct more thorough inspections in this aspect. Nevertheless, site organization is an important item, which is usually considered both in the preparation of the contract and in the bidding process for the construction, and is also a significant part of the cleaner production methodology at level 1 application, which involves reducing emissions and waste at the source through process modification. Therefore, housekeeping inspection needs to be considered.

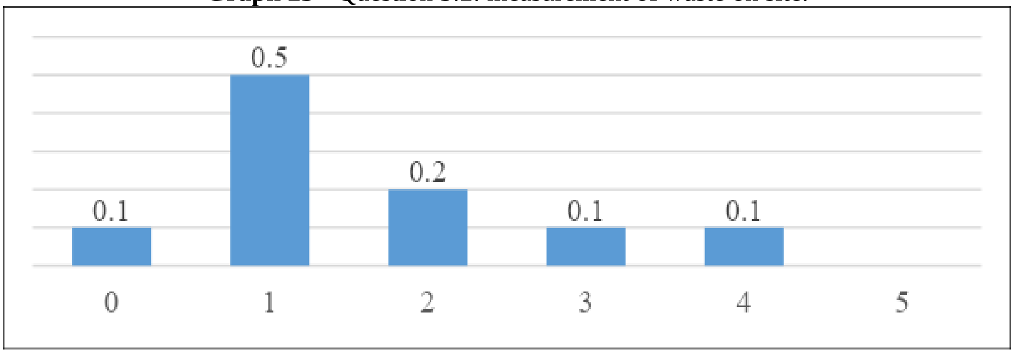
Graph 22 - Question 5.1: construction site housekeeping supervision.



Source: Own authorship (2022)

Regarding the measurement carried out by inspectors of the volumes of construction and demolition waste (CDW) generated during the construction process, it was found that 10% of respondents neither disagree nor agree with the statement, while 10% do not know how to respond, 50% totally disagree, 20% disagree, and 10% agree. An examination of the data shows that the majority of the inspectors (70%) chose responses that disagree, partially or completely, with the measurement of waste. This is because measuring construction waste generated during the process is not usually among the routine inspection activities, as the focus is more commonly on verifying the final destination of these wastes, rather than the volume they occupy. However, waste measurement and quantification are important steps in cleaner production, which is part of stage 3 of methodology application, where the material balance is elaborated, and indicators are established, enabling a quantitative analysis of inputs (raw materials, water, energy, and various inputs) and outputs (waste, effluents, among others). These data allow for the material balance to be surveyed, essential for analyzing the causes of waste generation. Therefore, this is an important step for cleaner production that needs to be integrated into construction inspection processes for the application of this methodology to be possible.

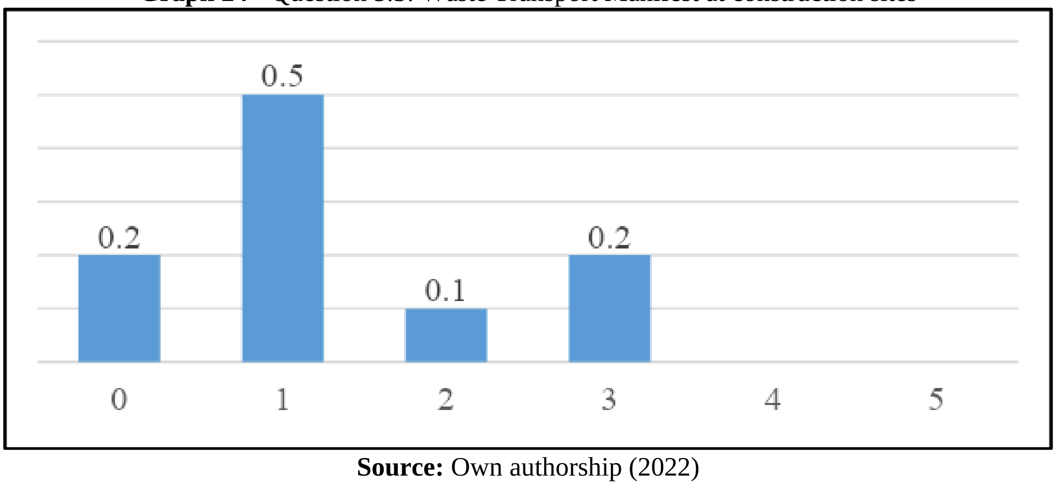
Graph 23 - Question 5.2: measurement of waste on site.



Source: Own authorship (2022)

Regarding the request, by the oversight, for the delivery of the Waste Transport Manifesto (MTR) from the monitored works, it was observed that 20% of the respondents neither agree nor disagree with the statement, while 20% do not know how to respond, 50% totally disagree, and 10% partially disagree with the assertion. The results presented show that the majority of respondents (60%) opted for total or partial disagreement with the statement, with no agreement response, which allows inferring that in some cases this documentation is not requested by the oversight to the companies executing the work. This is important documentation to prove that the generated and transported waste will receive environmentally adequate final disposal. Furthermore, from the perspective of cleaner production, proving the final destination of the waste is important for level 3 application of the methodology, which involves external recycling to the work being carried out or reintegration into the biogenic cycle. Thus, requesting this documentation is important for the application of the cleaner production methodology, making it necessary for oversight to request this documentation.

Graph 24 - Question 5.3: Waste Transport Manifest at construction sites

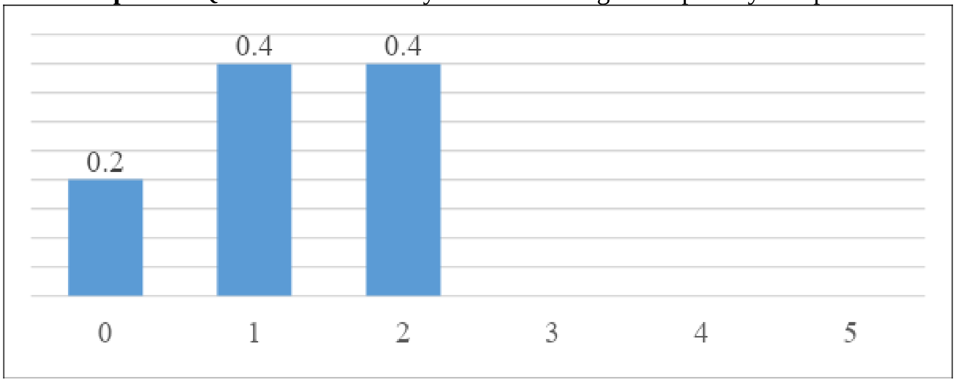


Source: Own authorship (2022)

Regarding the delivery of the Solid Waste Management Plan by the companies executing the works, it was observed that 20% of the respondents neither agree nor disagree with the statement, while 40% disagree and

40% totally disagree. These results indicate that the majority of participants (80%) have a perception of disagreement with the statement, either partial or total, suggesting that the companies executing the works do not usually deliver the Management Plan. As mentioned earlier in the question dealing with the elaboration of the Plan in the project stage, this document is of utmost importance for different phases of cleaner production application. Despite this importance, it was verified in the previous section that this document is not usually elaborated in the project elaboration phase, and it is also not usually delivered by the companies in the execution phase of the work. Thus, it is possible to observe a gap in the elaboration of the Management Plan, requiring, therefore, greater attention to this important aspect necessary for the application of a cleaner production methodology.

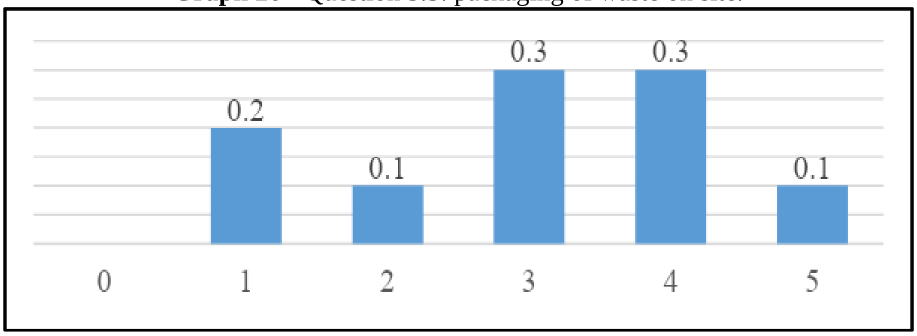
Graph 25 - Question 5.4: delivery of waste management plan by companies.



Source: Own authorship (2022)

Regarding the spaces in the construction sites intended for the storage of generated waste, it is possible to verify that 30% of the participants neither agree nor disagree with the statement, while 20% totally disagree, 10% disagree, 30% agree, and 10% totally agree. It can also be highlighted that the results show that a majority (60%) demonstrate some level of agreement with the statement, while a minority (30%) demonstrate an understanding of disagreement. The data presented show a multiplicity of perceptions, which can be explained by the diversity of types of construction works carried out at IFAM, ranging from small-scale works, such as minor renovations, to medium and high complexity works such as the construction of complexes and campuses. The analyzed information suggests that not all monitored works have adequate storage on the construction sites for the generated waste. From the perspective of cleaner production, proper storage is used to avoid waste related to the lack of organization of the construction site, as well as to allow for a more practical segregation process. Thus, this is an important aspect of the methodology that can be considered in the stage of construction site inspection.

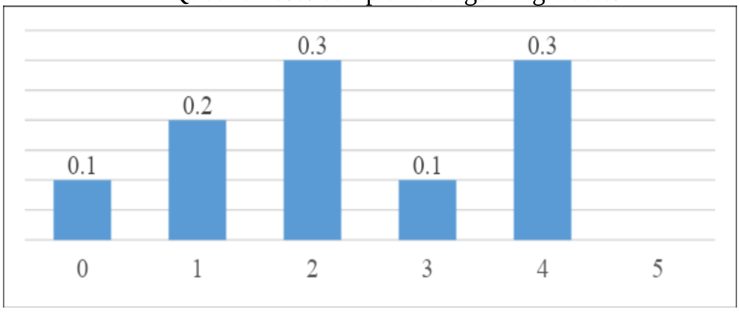
Graph 26 - Question 5.5: packaging of waste on site.



Source: Own authorship (2022)

Regarding complaints about the emission of waste or dust generated in construction works, by the academic community or neighboring residents, it was found that 10% of respondents neither agree nor disagree with the statement, while 10% do not know how to respond, 20% totally disagree, 30% disagree, and 40% agree. The lack of coincidence between the perspectives presented by the staff is probably due, among other factors, to the fact that some IFAM campuses have neighboring buildings, while others do not have this particularity. The percentage of agreement with the statement indicates that the waste generated in the works bothers the neighbors or the academic community, indicating inadequate containment of these wastes, stemming from inefficient waste management. Therefore, from the perspective of cleaner production, effective management of the waste from the productive processes of the works is fundamental for the success of applying this methodology, requiring its inclusion in the inspection stage.

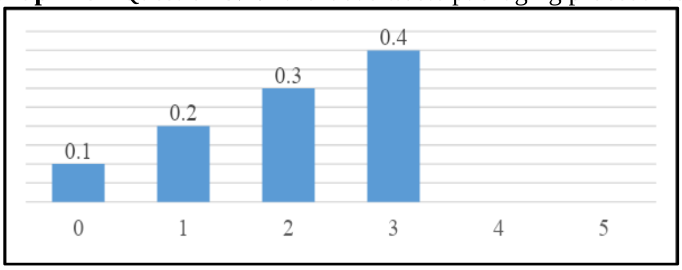
27 - Question 5.6: complaints regarding waste.



Source: Own authorship (2022)

Regarding special procedures for handling, packaging, and final disposal of construction waste classified as hazardous on inspected sites, respondents' understanding indicates that 40% neither disagree nor agree with the statement, 10% do not know how to answer, 20% totally disagree, and 30% disagree. The results show that a total of 50% of respondents disagree, either totally or partially, with the statement presented in the question, suggesting that in some cases, differentiated procedures for hazardous waste management are not employed, such as paints, solvents, oils, tiles, materials containing asbestos, or other harmful products. As for cleaner production, it has been mentioned that waste management, including proper handling, packaging, and final disposal, is essential for its full implementation. Additionally, products composed of hazardous raw materials represent one of the main sources of waste and emissions. Therefore, the adoption of differentiated procedures for hazardous waste proves to be a necessity for the implementation of cleaner production.

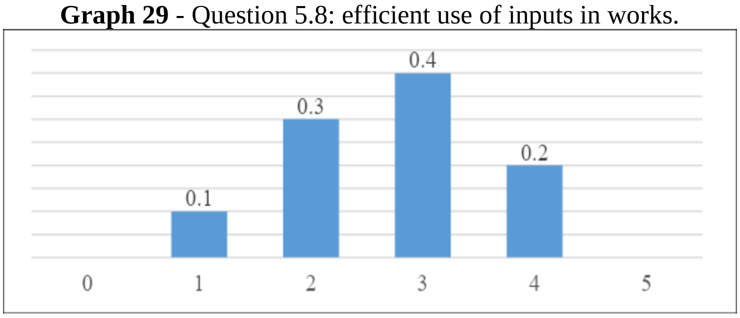
Graph 28 - Question 5.7: hazardous waste packaging procedures.



Source: Own authorship (2022)

Regarding the application of methods for efficient use of inputs such as water and electricity in the monitored works, the results indicate that 40% of the participants neither agree nor disagree with the statement, 10% completely disagree, 30% disagree, and 20% agree. As in similar issues analyzed previously, the distribution of results points to a diversity of perceptions, stemming from the diversity of organizational environments and types of monitored works. It is also noted that the efficient use of inputs in the works is not explicitly defined in the contract and bidding documents of the monitored work, so this efficient use mainly depends on a differentiated attitude of the company executing the work or on a personal initiative of the inspector. Thus, for a cleaner production approach, the adoption of efficient use of inputs results in preventing the generation of waste, effluents, and emissions, therefore it is necessary to promote this provision in the works monitoring stage.

Graph 29 - Question 5.8: efficient use of inputs in works.



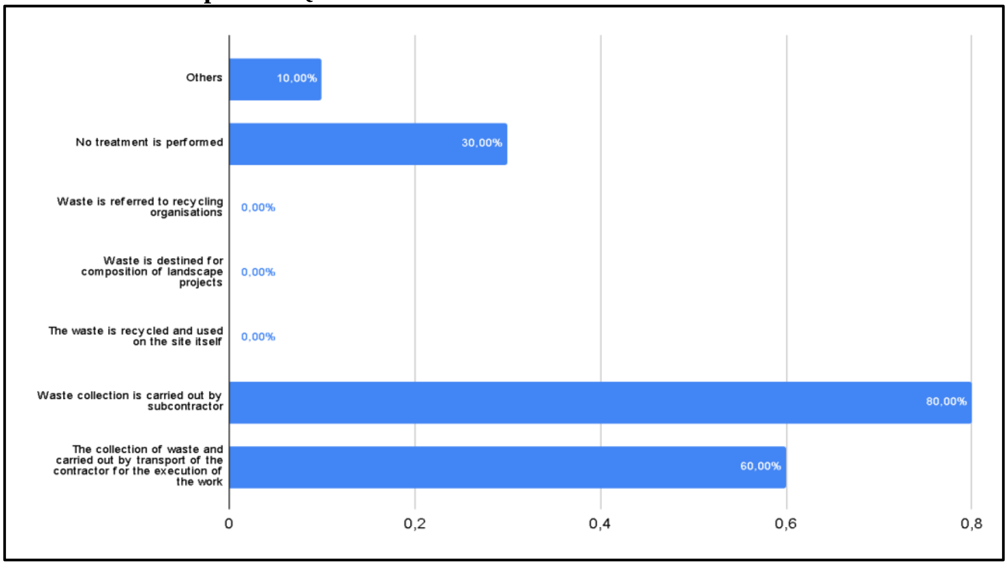
Source: Own authorship (2022)

In regard to preventive actions aimed at non-generation or minimization of waste generation in the inspected works, participants provided detailed responses describing these preventive actions. However, it was found that 80% of the responses indicated that preventive actions are not observed, while the remaining responses listed the reuse of demolition raw materials by the campus and the removal of debris from the worksite. These measures are more related to level 3 application of cleaner production, including external recycling and final disposal of waste, not directly addressing the question raised. Therefore, there were no positive responses to this question.

Finally, the ultimate question in the category relating cleaner production to the inspection stage presents a list of options representing ways of treating waste generated in the inspected works. The results show that no respondent selected the options stating that waste is recycled internally within the worksite, that waste is destined for landscaping projects, or that waste is sent to recycling organizations. Meanwhile, 80% of respondents selected the option that waste is collected by a subcontracted company, 60% responded that waste collection is carried out by a transport company, 30% chose the option that no treatment is performed on the waste, and 10% pointed out the option that some waste is used by the campus in other projects.

These data show that some possible options for waste treatment are discarded and not used. It is also possible to observe that level 3 cleaner production measures (external recycling) are already employed, and that the majority of waste transportation from the worksite is carried out by transport or subcontracted companies, without guaranteeing that the transported waste will receive adequate treatment, as previously verified by the absence of the Waste Transport Manifest (MTR). It is important to emphasize the considerable percentage of responses stating that no treatment is performed on the waste, which goes against an important characteristic of cleaner production, at the level 3 application, which deals with external recycling and reintegration of waste into the biogenic cycle, thus necessitating a reconsideration of the treatment solutions adopted.

Graph 30 – Question 5.10: waste treatment at construction sites.

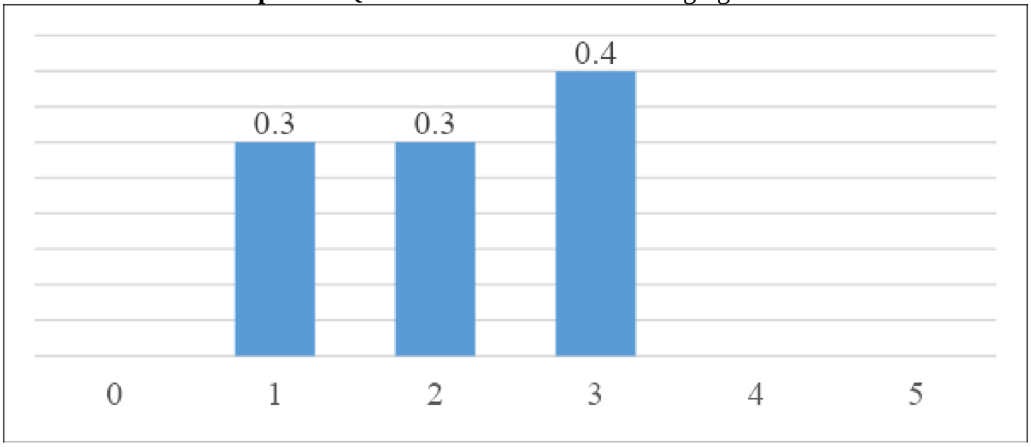


Source: Own authorship (2022

Cleaner Production Barriers

Regarding the barriers to the implementation of cleaner production, the first question presents a statement about resistance to change on the part of the employees for implementing the methodology. It was found that 40% of the respondents neither agree nor disagree with the statement, while 30% totally disagree and 30% partially disagree. These results indicate that the majority of participants (60%) perceive some degree of disagreement, either total or partial, showing that employees may exhibit an attitude of acceptance towards the proposed changes by a cleaner production methodology. These results are significant because the application of the methodology involves a series of changes and alterations that directly impact the daily activities of the employees, such as changes at level 1 of source reduction, which include modifications to products and processes, as well as a required commitment to monitoring processes and indicators, on-site measurement of generated waste, among other activities. Therefore, if employees demonstrate an attitude of openness to changes in the proportion indicated by these data, the implementation of cleaner production will have a higher probability of being successful.

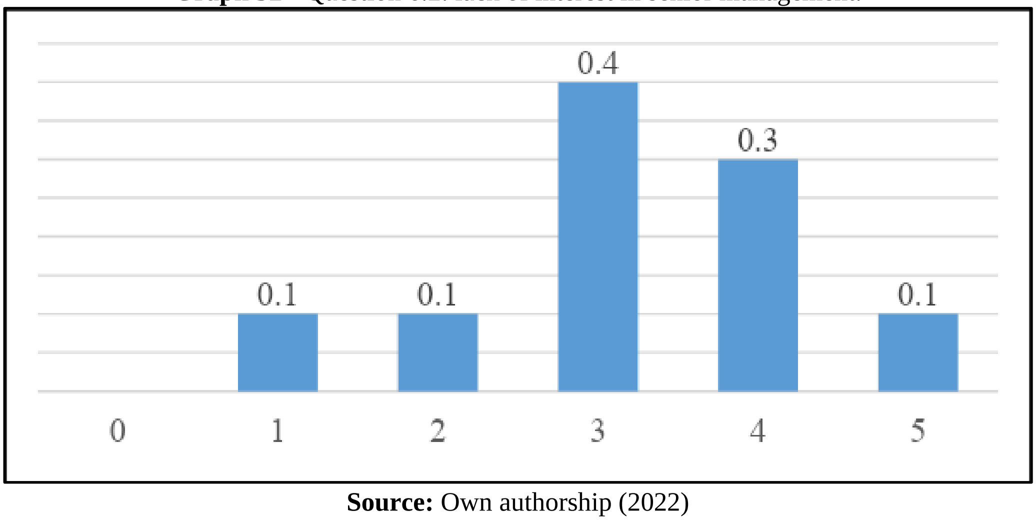
Graph 31 - Question 6.1: resistance to changing servers.



Source: Own authorship (2022)

Regarding the lack of interest from top management in implementing cleaner production, it was found that 40% of participants neither disagree nor agree with the statement, while 10% of respondents completely disagree, 10% disagree, 30% agree, and 10% completely agree. The data indicate a lack of compatibility between the perception of the employees, with 20% of respondents showing a stance of total or partial disagreement and 40% showing a perception of partial or total agreement, which can be explained, among other reasons, by the diversity of managers in the different departments analyzed in this research. From the perspective of cleaner production, the perception that agrees with the lack of interest from top management can make the application of the methodology more challenging, as this is identified as one of the most difficult stages of the methodology application, requiring significant managerial commitment from the organization, with the sensitization of this segment being fundamental for the success of the program. On the other hand, analyzing the smaller portion that disagrees with the aforementioned assertion, it is possible to highlight that the application of the methodology can be implemented more comprehensively in cases where the interest of top management in implementing cleaner production can be observed. Thus, from the perspective of top management's interest, the application of cleaner production may encounter institutional realities that can make its implementation more practical.

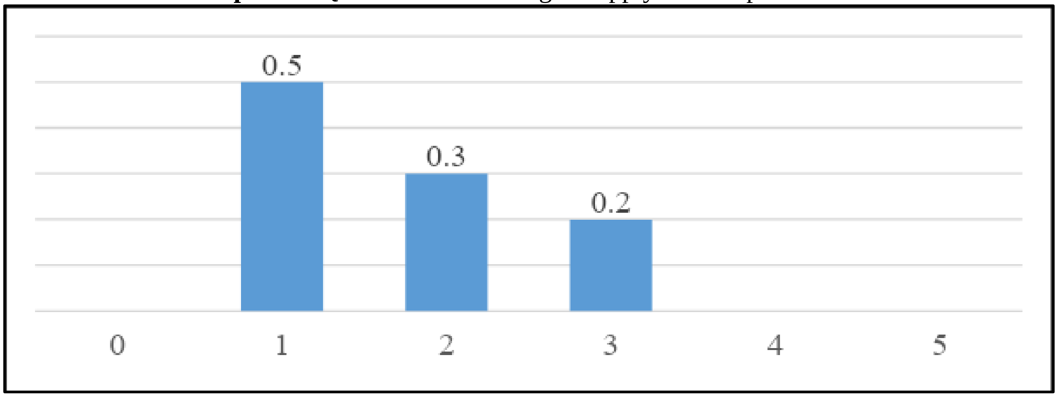
Graph 32 - Question 6.2: lack of interest in senior management.



Source: Own authorship (2022)

Regarding whether servers have training to apply a cleaner production methodology, it was observed that 20% of respondents neither agree nor disagree with the statement, while 50% completely disagree and 20% disagree. The data presented show that the vast majority of servers (80%) perceive disagreement with the statement, indicating that the level of knowledge among servers about cleaner production is still not sufficient for the application of the methodology. These results are aligned with other similar results presented in this research, such as participation in training related to cleaner production and the concept and level of utilization of cleaner production. Thus, in order for the lack of knowledge about cleaner production not to be a barrier to the introduction of this methodology, it is necessary for servers to obtain a better understanding of how the methodology works, what stages are developed, what agents are involved, among other characteristics, through contact with cleaner production manuals or participation in training sessions.

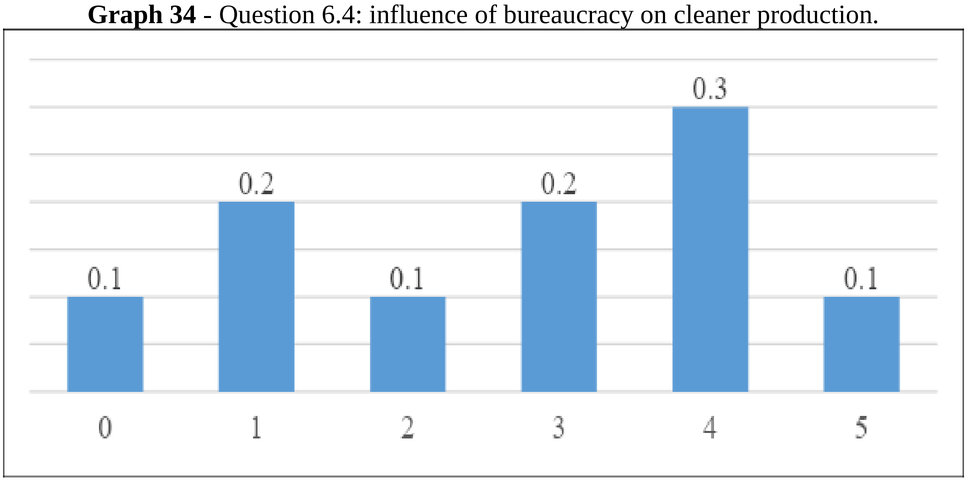
Graph 33 - Question 6.3: training for apply cleaner production.



Source: Own authorship (2022)

Regarding the difficulties related to the bureaucracy of public service for the implementation of cleaner production methodology, it was found that 20% of the respondents neither agree nor disagree with the statement, while 10% do not know how to respond, 20% totally disagree, 10% disagree, 30% agree, and 10% totally agree. The presented results demonstrate a disagreement in the perception of the civil servants, with 30% expressing total or partial agreement and 40% with a standpoint of total or partial disagreement. As previously verified in the section dealing with mapping, the processes have a defined sequence, which involves various departments in successive stages of relatively high numbers. Furthermore, the deadlines for process flow and the analyses conducted are usually lengthy due to the volume of activities that the civil servants need to perform. Therefore, there is bureaucracy associated with the processes, which can negatively influence the implementation of cleaner production to some extent. The divided perception of civil servants, with 30% expressing a standpoint of total or partial disagreement, and 40% of total or partial agreement, suggests that some respondents understand that procedural flow and analysis deadlines do not tend to hinder the cleaner production methodology, while others believe that these bureaucratic aspects can make the implementation of the methodology more difficult. Nevertheless, the procedural flow is a product of current legislation, so changes in the process format are unlikely, requiring the consideration of existing processes as a given that, a priori, cannot be changed. Therefore, based on the perception of participants' lack of consensus, it is not possible to indicate the influence of bureaucracy as a barrier to the application of cleaner production.

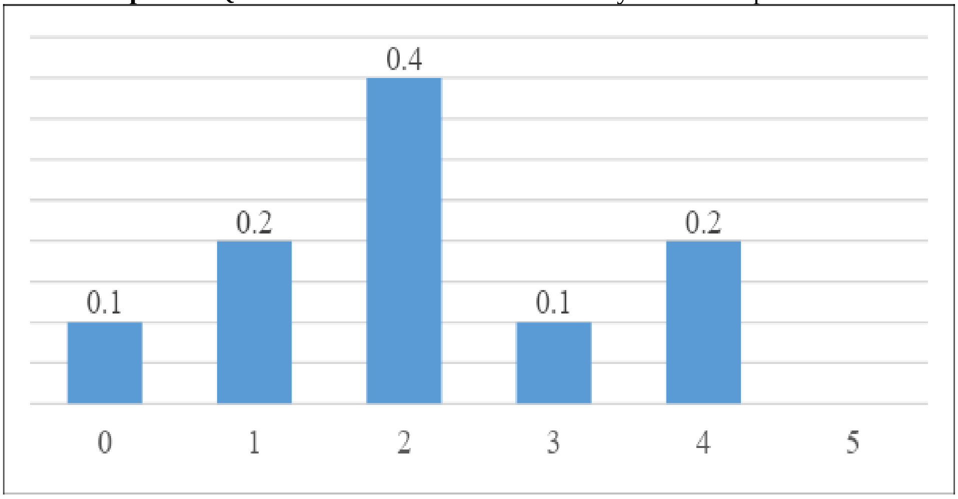
Graph 34 - Question 6.4: influence of bureaucracy on cleaner production.



Source: Own authorship (2022)

Finally, regarding the legal limitations inherent to public service that restrict the application of a cleaner production methodology, it was observed that 10% of the servers neither agree nor disagree with the statement, while 10% do not know how to respond, 20% totally disagree, 40% disagree, and 20% agree. The majority of participants (60%) exhibit a stance of total or partial disagreement, while 20% hold a perception of agreement. The implementation of cleaner production in activities carried out within the scope of public service is still a topic with limited development in the literature, thus there are few parameters to assert whether legal limits restrict the methodology or not, making this question an initial step in understanding the issue. Therefore, based on the perspective of the participating servers, legal limitations do not necessarily hinder the adoption of a cleaner production methodology within IFAM's projects.

Graph 35 - Question 6.4: influence of bureaucracy on cleaner production.



Source: Own authorship (2022)

IV. Discussion

The implementation of the cleaner production methodology at IFAM represents a significant step towards environmental sustainability and social responsibility. By adopting cleaner and more efficient practices in its operations, the institution will not only reduce its environmental footprint but also foster a culture of awareness and environmental care among its staff and students.

It is important to highlight that the transition to cleaner production may encounter challenges, especially considering the specific characteristics of a federal agency, as mentioned in the document. However, overcoming these barriers is essential to ensure a more sustainable future for IFAM and the community at large.

The approval of a specific resolution, based on extensive discussions and deliberations, is crucial to legitimize and guide the implementation of cleaner production within IFAM's engineering works and services. The active participation of senior management, advisors, and other stakeholders in this process is crucial for the success and effectiveness of this initiative.

Furthermore, the creation of a resolution model inspired by previous examples, such as Resolution No. 41, can serve as a guide to structure and formalize the guidelines for cleaner production at IFAM. Collaboration across different sectors and the adoption of good environmental practices will be essential to achieve the proposed sustainability goals.

In summary, the implementation of cleaner production at IFAM will not only contribute to reducing environmental impacts but also strengthen the institution's image as an agent of positive change in promoting sustainability. It is a necessary and rewarding challenge that reflects IFAM's commitment to a greener and more responsible future.

V. Final Considerations

Considering the growing demand for technologies and processes aligned with sustainable development, which minimize environmental impacts, it becomes imperative that organizations linked to the public sector recognize their fundamental responsibility in the face of the serious ecological challenges faced by contemporary societies. In this sense, it is essential that public administration promotes practices that allow for the mitigation of environmental damages and impacts.

The application of a cleaner production methodology emerges as an opportunity to enhance the environmental management of works and constructions. This methodology enables the reduction of inefficiencies associated with the waste of energy, materials, and inputs, as well as the minimization of waste generation in production processes.

The issue discussed in this research involves the adoption of a cleaner production methodology in the context of works at the Federal Institute of Education, Science, and Technology of Amazonas (IFAM), an institution of reference in the Amazon region, whose mission is to promote sustainable development in the

Amazon. The current stage of IFAM's interiorization makes it conducive to a focus on cleaner production, which has proven to be feasible in contexts similar to the one addressed in this research.

The results obtained allowed for the characterization of a part of IFAM's institutional reality related to works and engineering services, providing a deeper understanding of the organizational context of the institution and its relationship with cleaner production methodology, both in terms of processes, outlined by modeling, and in terms of staff perceptions, analyzed through questionnaires.

The first obstacle encountered was the lack of formal documentation or graphical representation of institutional processes, such as the elaboration of basic projects, supervision of works, and measurement of contracts. To overcome these gaps, the participation of IFAM's staff was fundamental, as they understood the need for changes and contributed both in interviews and in responses to questionnaires.

Mapping the processes related to works allowed for a more detailed understanding of each stage of the planning and execution of a work. The mapping highlighted the necessary procedures for the approval and elaboration of engineering projects, the procedures for supervising works, and the procedures for measuring contracts, providing a crucial basis for the analysis of cleaner production.

The questionnaire with the staff was essential to assess the existing conditions for the application of cleaner production, allowing for the evaluation of respondents' characteristics, relevant organizational aspects, and identification of possible barriers to the application of the methodology.

The proposal for a cleaner production methodology was elaborated considering the data collected from the characterization of IFAM. It was chosen to divide the stages of applying the methodology into six, discussing cleaner production measures present in the reference manual, their applicability in the context of IFAM, suggestions for modifications to make their application feasible, and how these modifications can be integrated into institutional processes.

As discussed, the application of the program in the context of IFAM's works requires substantial changes at different organizational levels, depending on the action, commitment, and awareness of a variety of staff. Despite the difficulties and challenges, these transformations are necessary, especially in the face of an increasingly critical environmental context.

It is expected that this research will demonstrate the need for changes in the context of works, highlighting that the application of a cleaner production methodology is viable in the context of IFAM, if a thorough analysis of its application is carried out.

The limitations of this research are related to the scope of the analyzed processes, which focused on the processes of the Infrastructure Directorate, and the analysis of a single cleaner production manual, suggesting the possibility of expanding the research to include other program manuals.

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