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A deeper exploration of sustainable manufacturing practices: A Literature Review

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Abstract

The environmental, social and economic challenges facing the industrial have become key driers for the adoption of sustainable manufacturing practices (SMPs). These practices serve as a strategic tool to achieve a balance between industrial growth and the preservation of natural resources. while the literature generally agrees on the significance of SMPs, definition and classification of these practices vary due to differences in academic background and industrial contexts. This research aims to bridge the knowledge gap by identifying and categorizing the most commonly adopted sustainable manufacturing practices. The descriptive-analytical approach was employed through a comprehensive review of relevant literature and previous studies to present a broad understander of sustainable manufacturing practices from both theoretical and practical perspectives. The importance of this study lies in its contribution to harmonizing the understanding of these practices and emphasizing the most prominent among them, thereby facilitating their adopting across various in industrial contexts. Moreover, the study highlighting the key factors motivating their implementation. The findings reveal a significant variation in how SMPs are defined; however, the most frequently identified practices include sustainable end-of-life of products, sustainable manufacturing processes, sustainable product development and design, and sustainable supply chains.

Research Type: Review Article

Keywords: Sustainable Manufacturing, Sustainable end-of-life Products, Sustainable Manufacturing Process, Sustainable Products Development and Design, Sustainable Supply Chain.

1. Introduction

The industrial sector has undergone profound transformations throughout history, particularly during and after the First and Second World Wars. These transformations have created numerous environmental, economic, and social challenges, largely due to increased awareness of the adverse impacts of conventional industrial models. In response, the concept of "sustainable manufacturing practices" has emerged as a comprehensive framework. It aims to integrating processes and systems capable of delivering high-quality products and services while minimizing the use of energy and materials, enhancing safer for employees, customers, and surrounding communities, and reducing environmental and social impacts across the product lifecycle (Machado et al., 2020).

With the growing importance of sustainable manufacturing practices, a review of existing literature reveals notable inconsistencies in how these practices are defined and classified. Studies such as Habidin et al. (2020), Gutterman (2023), and López et al. (2024), Geissdoerfer *et a*l.,(2017), and Sartal *et al.*,(2023) offer diverse perspectives regarding the description, scope, and implementation of such practices. This research aims to review critically and analyze previous studies on sustainable manufacturing, with goal of identifying the key divers behind their adoption. identifying the most prominent factors motivating the implementation of these practices. These factors have been classified into two main groups: **internal factors**, the most important of which are (top management support, employee engagement, and technological capabilities), and **external factors**, including (environmental systems support and supplier relationship management).

The primary objective of this research is to address the knowledge gap by examining the variation in conceptualization and classification of sustainable manufacturing practices. closing this gap is important is essential for both industrial practitioners and future researchers. To achieve this, the researcher adopted a critical analytical approach to review the existing literature. The analysis revealed a significant diversity in the definitions and interpretation of

sustainable manufacturing practices, which can be attributed in part to practical and applied contexts. Moreover, the indicate that the most common and widely adopted practices include sustainable end-of-life, sustainable manufacturing processes, sustainable product design and development, and sustainable supply chains.

Bridging the knowledge gap in this area is essential to achieving a unified understanding and enhancing the practical implementation of sustainable manufacturing. Future research is recommended to conduct comparative field studies across various industrial settings to assess the effectiveness and impact of these practices on environmental, economic, and social performance.

2. Research Problem

The research problem lies in the absence of an integrated conceptual framework that clearly defines the forms and domains of sustainable manufacturing practice (SMP). The absence resulted in a Signiant discrepancy within the existing literature concerning the description and definition practices. Such inconsistency reflects a persistent and knowledge gab in this field, charactered by the lack of comprehensive and unified understanding or model that research and practitioners can rely on when studying or implementing sustainable manufacturing in industrial contexts. A knowledge gap is defined as unexplored or insufficiently understood areas within a particular research field. In the context of sustainable manufacturing practices, identifying a knowledge gap is crucial because it forms the basis for guiding researcher efforts, outlines future trends, and identifies the most important relevant topics. The research contributes to addressing the Identified knowledge gap by critically reviewing recent literature and analyzing the inconsistencies fond in the treatment of sustainable manufacturing practices. The analysis was conducted to pinpoint key gaps, unanswered question, and untested hypotheses. Based on the foregoing, the following research question can by formulated:

- What are the classifications of sustainable manufacturing practices adopted in industrial organizations?
- What are the factors that influence the effectiveness of adopting sustainable manufacturing practices in industrial organizations?

- What are the research gaps in studies related to sustainable manufacturing?

3. Research Objectives

Based on the research questions and the identified research gap in the sustainable manufacturing literature, the current research primarily aims to provide an integrated and comprehensive theoretical framework that defines sustainable manufacturing practices. This research explores the concept of sustainable manufacturing and examines the differences in academic perspectives through analyzing relevant literature. The research also aims to:

- Identify the main and most common practices within the framework of sustainable manufacturing, as presented in previous studies.
- Bridging the knowledge gap by exploring the variation in concepts and classifications used to describe sustainable manufacturing practices.
- Reviewing the most prominent factors motivating the implementation of these practices in industrial organizations.

4. Research Significance

The Significance of this research stems from the core problem it addresses and it focus on a critical topic that aligns with the strategic direction of industrial organizations in general. In the face of mounting environmental and economic challenges, sustainable manufacturing practices have emerged as cornerstone for achieving sustainable development and simultaneously enhancing both. environmental and economic performance. The importance of the research lies in its contribution to bridging the existing knowledge gap in the academic literature, it enriches contemporary literature by proposing a novel integrated, and comprehensive conceptual framework that underscores the strategic value of sustainable manufacturing practices. This framework serves not only to guide industrial organizations bout also provides a valuable reference for future researchers in the field.

5. Literature Review

Chowdhury & Yasmin (2018) describe sustainable manufacturing practices as a series of organizations initiatives adopted globally to strengthen competitive advantage, improve

customer relations, and raise product quality. These efforts encompass specific such as sustainable resource, green production, and effective waste management aimed at minimizing environmental pollution through the application of the circular economy principle, known as (14R). On the other hand, other scholars, such as Abdul-Rashid et al. (2017) Ibrahim et al. (2019), have employed the term dimensions rather than practices referring to components like sustainable product design (SPD), sustainable production processes (SPM), and sustainable supply chain (SSC). This distinction is justifying by the direct relevance of these to critical sectors such as oil and gas, as well as the ongoing challenge of achieving a balance between the three aspects of sustainability: economic, environmental, and social. In a different context, Ibrahim et al, (2020) conceptualized sustainable manufacturing practices as a management process involving to planning, implementing, and monitoring of activities to recover materials, components, or end-of-life product. This recovery strategies-such as reuse, remanufacturing, and recycling-are employed with the aim of recovering value and reducing energy and resource consumption.

Similarly, Siddique (2020) emphasized that practices constitute a strategic response to mounting environmental pressures, aiming to reduce waste, lower energy usage, and enhance the overall efficiency of production operations, thereby addressing the critical demand for effective environmental management and resource conservation. This includes implementing strategies such as Lean Manufacturing (LM) which focuses on reducing waste through continuous improvement (CI) and process improvement (IP), and adopting energy-efficient technologies that reduce the energy intensity of production systems. Kair (2024) argues that sustainable manufacturing practices constitute a strategic managerial endeavor designed to maximum value by integrating of environmental, economic, and social dimensions within manufacturing systems, while upholding the principle of " no harm to the environment." He also suggests that this integration can be achieved by adopting implementation models such as green manufacturing (GM), lean manufacturing (LM), and the circular economy model (EC).

A number of scholars emphasize that agrees that sustainable manufacturing should be understood as a set of integrated practices that extend beyond the product itself and core manufacturing processes to encompass the entire supply chain. As noted by Fatoki, (2019) Nazir & Doni. (2024), sustainable manufacturing practices develop on three levels: the system,

the process, and the product, as shown in Figure (1). At the **system** level, sustainable manufacturing focuses on the entire supply chain. At the **process** level, sustainable manufacturing takes into account activities such as process planning that help reduce toxic waste, occupational hazards, and worker safety. At the **product** level, sustainable manufacturing is no longer limited to the traditional three-dimensional concept (reduce, recycle, and remanufacture) to promote sustainable technologies. It focuses on a ten-dimensional concept: Reduce, Recycle, Repair, Reuse, Reproduce, Redesign, Remanufacture, Refurbish, Reject, and Recover.

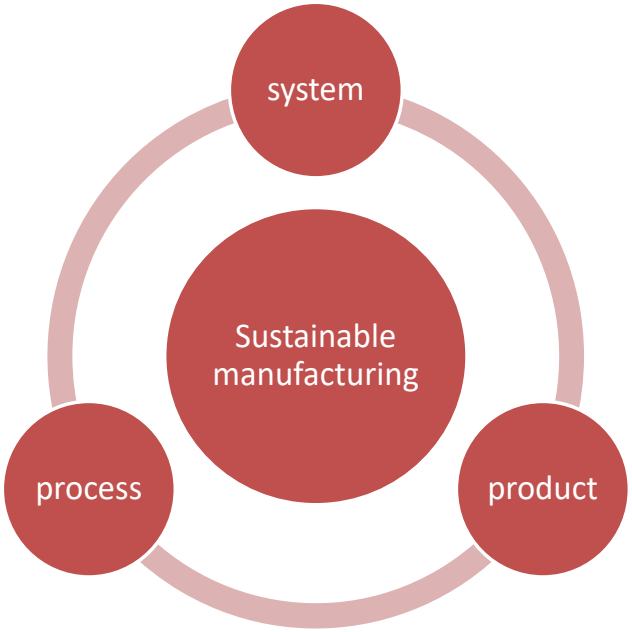

Figure (1) levels for sustainable manufacturing.

Sources: Baral, B., Kharel, B., Dawadi, A., Timsina, S., & Joshi, R. (2024). Sustainable Manufacturing Practices in the Hydropower Industry: A review. In IOP Conference Series: Earth and Environmental Science (Vol. 1385, No. 1, p. 012017). P3

A review of studies on sustainable manufacturing practices reveals a discrepancy among researchers in defining these practices and defining their frameworks, indicating a knowledge gap that needs to be addressed. Based on this, the sixth section of this study will address efforts

to bridge this gap by presenting an integrated analytical framework for sustainable manufacturing practices.

5.1 Definition of sustainable manufacturing

Since the late twentieth century, the world has witnessed fundamental transformations in the understanding of the relationship between the environment and development. One of its results was Sustainable Development (SD), which was defined by the World Commission on Environment and Development in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their needs." This concept gained international recognition the Earth Summit held in Rio de Janeiro in 1992, where it was established as global framework grounded in the integration of three dimensions economic, environmental, and social (Ozili, 2022, 261).

In response to these transformations, the industrial sector didn't remain unaffected isolated from these transformations, rather, it become a focal point of global concern due to the significant environment pressures it exerts ranging from intensive natural resource consumption to greenhouse gas emissions, and industrial waste generation , the concept of sustainable manufacturing emerged as a scientific application and natural extension of the concept of sustainable development within production systems, whereby production processes are reconsidered to align with economic, environmental, and social considerations (Zhang & Haapala, 2015, 28).

Zhong (2021:1) emphasizer that sustainable manufacturing embodies industrial activities designed for minimize environment harm, particularly, emissions, waste, pollution, and consumption of natural resources (less resource-intensive). These industries include recycling, reuse, remanufacturing, disassembly, and attracting environmentally conscious investments.

(Paulraj et al.,2022:5), (Yeo & ong.2024,3) define sustainable manufacturing as the process of producing goods with minimal environmental impacts, achieved through two important principles:

- Understanding the product's life cycle and its impact on the environment at each stage of the life cycle.

- Making the necessary decisions to reduce environmental impacts to the lowest possible level during product design and manufacturing.

To complete the review of sustainable manufacturing, Table (1) presents a summary of researcher's definition and perspective on the concept of sustainable manufacturing, according to what was available to the researcher.

Table (1) definition of sustainable manufacturing

Theory	Definition
(Bhatt et al.2020)	A set of practices for developing products by integrating social, economic, and environmental values into industrial activities.
(Barletta et al.,2021)	Some of the transformative practices in operations and business are used to produce products in a way that brings prosperity to society, conserves the planet's resources, ensures profitability for organizations, and contributes to the well-being of stakeholders—employees, customers, and society at large.
(Huang&Zaheer.2021)	Create products that use processes that reduce negative environmental impacts, conserve energy and natural resources, are safe for workers, communities and customers, and are economically sound.
(Ali et al.,2021)	The ability of organizations to intelligently use natural resources to achieve economic, social, and environmental benefits, ultimately improving the quality of life and preserving the environment.
(Ghelani.2022)	A set of practices aimed at meeting the growing need for environmentally responsible manufacturing without sacrificing quality or profitability.
(Gutterman.2023)	Producing goods and services using processes and systems that

	are non-polluting, conserve energy and natural resources, are economically viable, safe and healthy for workers and customer communities, and are socially and creatively rewarding for all employees.
(Babu et al., 2024)	A comprehensive approach to the production of goods that takes into account the economic, environmental, and social impacts of industrial processes.

Source: Developed by the researcher.

In line with the above, the researcher views sustainable manufacturing as an applied practice aimed at designing and producing high-quality, functionally efficient products. This is intended to reduce the negative impacts resulting from industrial processes, through the efficient use of energy free of toxic substances and natural resources. This can include operational practices that ensure occupational safety and take into account social and environmental aspects, thus contributing to achieving economic benefits and profitability for organizations.

5.2 Reasons for adopting sustainable manufacturing practices

Sustainable manufacturing has attracted significant attention from researchers and practitioners in recent years, due to the added value it provides at the environmental, economic, and social levels. The existing literature reveals that sustainable manufacturing has been discussed from various perspectives, with some pointing to the benefits of sustainable manufacturing as factors that motivate organizations to adopt it.

According (Ghodrati *et al*., 2016,2) (Kishawy *et al*., 2018,4) the adopting of sustainable manufacturing contributes to achieving many gains that make it more desirable than traditional manufacturing, in addition to improving industrial processes, as follows:

1. Select environmentally friendly materials and reduce the environmental impact throughout the product lifecycle by conducting a comprehensive product design evaluation.
2. Simplicity of design facilitates product maintenance and efficient recycling, extending product lifespan and reducing waste.

3. Adopting the concept of design for disassembly, which enables products to be easily analyzed, disassembled, reused, and recycled.
4. Reducing the amount of products sent to landfills by implementing effective systems for collecting and storing industrial waste.
5. Implementing safe practices for disposing of waste containing hazardous materials in accordance with international environmental standards, thus reducing health and environmental risks.
6. Achieving tangible economic savings by improving resource efficiency levels through promoting the principles of the circular economy.

(Xie & Han.2020:3) (Machado *et al*.,2020:1464) (Maldonado *et al*.,2024:3)see that sustainable manufacturing has a set of benefits in many areas, by adopting green production technologies and equipment. The manufacturers couldn't only reduce their environmental footprint, but also gain a competitive advantage in the market, as follows:

A. **Economic Benefits:** Sustainable manufacturing could lead to economic benefits for manufacturers, by adopting green production technologies and equipment, manufacturers can optimize resource utilization, reduce emissions, and conserve energy. This could lead to cost savings, increased efficiency, and increased profits.
B. **Environmental Advancements:** sustainable manufacturing approaches significantly to reducing environmental pollution and minimize adverse ecological effects. By adopting advanced environmentally responsible production method, such as automated manufacturing technology and efficient equipment, manufacturers can reduce wastewater, decrease overall energy usage, and reduce carbon dioxide emissions. This contributes to a cleaner, more sustainable environment.
C. **Regulatory Compliance**: Sustainable manufacturing ensures compliance with environmental regulations and standards. By implementing environmentally friendly practices, organizations can minimize the risk of incurring fines or facing legal consequences associated with pollution and environmental harm. This helps maintain a positive reputation and build trust with customers and stakeholders.
D. **Enhancing Brand Image:** As Consumers are becoming increasingly aware of environmental issues and prefer to support companies that prioritize sustainability. By demonstrating a

commitment to eco-friendly practices, manufacturers can attract environmentally conscious customers and differentiate themselves in the marketplace.

E. **Long-term sustainability:** Sustainable manufacturing promotes long-term sustainability by conserving natural resources and reducing waste. Through the adoption of closed-loop supply chains and designing products for recyclability, manufacturers can significantly reduce reliance on raw materials and extend the life of products. These practices support the of the principle of the circular economy and reduces overall environmental impact.

Based on the preceding discussion regarding the reasons for adopting sustainable manufacturing, the researcher argues that this approach has transcended being merely a strategic choice driven by competitive or regulatory considerations. Instead, it has become a necessity dictated by the pressing environmental and economic challenges. Sustainable manufacturing today serves as a core pathway for achieving operational efficiencies, enhancing regulatory compliance, and building trust with stakeholders. Such as, its adoption constitutes a critical factor in the sustainability and development of industrial enterprises.

5.3 Critical success factors sustainable manufacturing practices

Research trends in this field consider that success factors can be divided into two groups: internal and external.

- **Internal factors**

The internal success factors for SM implementation were focused on top management support, employee engagement, and technological capabilities. Each of these factors is described below:

1. **Top management support:** Leadership and commitment from top management are widely recognized as key a motivating factor in implementing sustainable manufacturing. Senior management hold a central responsibility in shaping strategic decisions and actions to aimed at environmental preservation and improve organizational performance. This includes the adopt clear policies and framework that foster a culture of sustainability within the organization, as well as allocating of adequate financial and human resources necessary for effective implementation (Aboelmaged.2018,210). Moreover, they are expected to invest in capacity

building efforts through training programs to elevate managerial and worker competence. Top management support is involvement should go beyond symbolic gestures, encompassing the establishment of concrete environmental goals and ensuring alignment sustainability targets and the organization strategy and operational plan. which is essential to achieving the success of implementing sustainable manufacturing (Moktadir *et al*., 2018:168)

2. **Employee engagement:** Employee engagement is a pivotal element in the success of SM implementation, as it reflects employees' awareness of the importance of environmental protection and shared responsibility (Yusoff *et al.,* 2016). To foster this engagement, senior management should empower employees by involving them in decision-making process, particularly those related to environmental practices and operational improvement. When employees are granted autonomy and are actively involved, their commitment to improving product quality and optimizing manufacturing processes. Implementing SM requires a true partnership between senior management and employees, built on trust, empowerment, and ongoing collaboration toward shared environmental and economic goals. (Ceptureanu *et al.*, 2018)
3. **Technological capabilities**: Technology applications are a critical factor in SM implementation. The effectiveness of this application depends on the availability of technological infrastructure, processes, and capabilities that contribute to the implementation of innovative tools and practices. Technological capabilities facilitate the movement of materials in the production line, improve energy transfer efficiency, and control waste, making operations more sustainable. This technology also reduces energy consumption and operational costs, which in turn impacts productivity levels. An organization's possession of an adequate technology infrastructure is a prerequisite for enabling production processes to achieve the highest levels of environmental and economic efficiency. (Ceptureanu *et al.*,2018)

- **External factors**

The internal success factors for SM implementation were focused on supporting ecosystems and managing supplier relationships. Each of these factors is described below:

1. **Environmental regulations:** play a crucial role in driving organizations toward adopted of environmental initiatives. Abdul-Rashid *et al.,* (2017) They serve as key mechanism for controlling the environmental impacts resulting by organizational operations. Industrial

organizations are required to comply with regulatory framework such as ISO 14000 and ISO 14001. These regulations enhance the implementation of SM in industrial organizations by providing these standards and requirements related to environmental compliance. Therefore, there is an urgent need for environmental compliance to enhance organizations' ability to implement SM. (Maruthi & Rashmi.2015:3352)

2. **Supplier Relationship Management**: Roni *et al*. (2014) emphasized that external forces such as customers, competitors, and suppliers significantly influence the adoption of SMP. Among these, suppliers play a particularly critical role. Implementing environmental management principles throughout the Supply China necessitates close collaboration with suppliers particularly during the product design phase. Robust partnerships and continuous engagement with suppliers on environmentally focused projects could accelerate the adoption of green initiatives within organization. Also, suppliers contribute to the advancement of sustainable manufacturing through green supple chain practices and sustainable procurement, thereby reinforcing the organization environment preference.

6. Sustainable Manufacturing Practices Classifications

While there is relative agreement in global studies on the importance of implementing sustainable manufacturing practices (SMP) as a tool for achieving sustainable development goals, studies have shown variation in the naming and description of these practices. This variation reflects the diversity of academic backgrounds and methodologies used (administrative, engineering, environmental), as well as the diversity of industrial environments addressed in the literature. Table (2) illustrates researchers' views on sustainable manufacturing practices (SMP).

Table (2) Sustainable Manufacturing Practices Classification

Theory / Practice	Sustainable end of life products	Sustainable manufacturing processes	sustainable resources	Design and development of sustainable products	Sustainable supply chain	Environmental Management
(Esfahbodi.2016)	✓	✓		✓	✓	
(Abdul-Rashid et al.2017)	✓	✓		✓	✓	
(Chowdhury & Yasmin.2018)	✓	✓	✓			
(Ibrahim et al.2019)	✓	✓		✓	✓	
(Pande et al.2019)	✓	✓		✓	✓	
(Qureshi et al.2020)		✓				✓
(Habidin et al.2020)		✓			✓	✓
(Gutterman.2023)				✓	✓	
(Orji.2024)		✓				
(Lee & Kasakova.2024)			✓	✓	✓	
(Baral et al.2024)	✓	✓	✓			✓
(López et al.2024)						✓
Total	**6**	**9**	**3**	**6**	**7**	**4**

Source: Developed by the researcher.

In continuation of the previous literature that revealed the discrepancy in the naming and description of sustainable manufacturing practices and the different terms such as strategies, processes, dimensions, and initiatives, the researcher believes that the term "practices" is the most accurate and comprehensive for the context of the study. This is because it clearly expresses a set of executive procedures and activities adopted by industrial organizations to improve their environmental, economic, and social performance in a practical and applied manner.

Based on the views presented by researchers in this field, there was agreement among the opinions regarding the SMP used, which are (**sustainable end of life of products, sustainable processes, sustainable product design and development, sustainable supply chain**), which the researcher will address.

6.1 Sustainable manufacturing processes

Shaikh (2024)In general, manufacturing processes have a significant impact on the environment because they consume a large amount of energy and generate unwanted solid, liquid, and gaseous waste. Therefore, manufacturing processes must be designed and operated in a way that minimizes waste and by-products, eliminates hazardous and toxic materials, conserves materials and energy, and reduces physical hazards. Many initiatives have been developed to reduce the impact of manufacturing processes on the environment (Santhanamarisamy.2022,1047). Also, the green energy sources are any energy source available in natural sources such as sunlight, wind, and water. They often come from renewable sources (Ibrahim *et al*.,2020,16). There is a difference between green and renewable energy. Green energy does not leave pollution, and fossil fuels are not considered a green energy source. Examples of green energy include (solar energy, wind energy, hydropower, biomass, biogas, green hydrogen) (Das.2022,5-16)

6.2 Sustainable supply chain

(Björklund & Forslund.2018,209) The sustainability of organizations and supply chains has become a topical issue. This is a result of the general view that organizations are responsible for their functions and the entire supply chain, which impacts the environment, society, and the economy. In the face of change, organizations are under pressure from internal and external

stakeholders. (Gutterman.2023) Previous studies have found that sustainable supply chain management practices have a positive impact on company performance, including financial performance. This is evidence that sustainable practices such as sustainable warehousing, sustainable packaging, reverse logistics, and environmentally friendly purchasing contribute to improved organization performance (Abbasi & Nilsson.2016:279)

6.3 Design and development of sustainable products

(Abdul-Rashid *et al*.,2017:5) The increasing importance of environmental issues forces product designers to take into account certain environmental standards in the design process. These considerations fall under the broader concept of sustainable product development and design. Meaning they are all within environmental standards, they differ in their focus and application during implementation, as follows: (Paulraj *et al*.,.2022:2)

- **Design for the environment (DFE):** To minimize environmental impact throughout their lifecycle, some companies implement a Quality Function Deployment (QFD) approach. This method enables the integration of environmental standards alongside customer requirements during the design phase. QFD helps balance quality requirements, environmental performance, and production costs early in the product development process, thereby promoting more sustainable and efficient design decisions**.**
- **Design for deconstruction (DFD):** Considering the ease and complexity of disassembling products, we offer a method for rating disassembly ease using a spreadsheet-like chart and a catalog of task difficulty ratings. Ratings are determined based on work measurement analyses of standard disassembly tasks.
- **Designed for recycling (DFR):** This approach Focuses on design features that support cost-effective recycling and materials classification within product. through the development of mathematical models that assess the feasibility of bulk recycling by determining the cumulative net profit, thus enabling designers to make informed decisions about the recyclability and economic of a product at the design phase.

6.4 Sustainable end of life products

(Ibrahim et al.2020:61) Dealing with end-of-life products is an increasingly important environmental, economic, and social challenge for organizations and stakeholders. Due to the

damage, they cause if left untreated, sustainable end-of-life products refer to environmentally friendly operating practices that aim to recover materials or components at the end of a product's life. This approach is based on the principles and strategies of the circular economy (R0-13), which are detailed in Table (3) explaining the underlying principles of each strategy.

Table (3) The basic principles of each strategy in circular economy

Strategy	Principle	Description
Improving production and consumption methods	R0(Refuse)	Refusing to approve packaging, bags, or containers when they constitute waste; accepting or approving certain production processes; choosing to purchase limited quantities of products or reduce their use.
	R1(Rethink)	A new, design-driven technology known as “eco-efficiency” reduces material flow and eliminates raw materials; promoting more efficient use of products for longer periods of time.
	R2(Re-educate)	Training and educating customers to change their consumption behavior
	R3(Redesign)	Designing and manufacturing products with a new purpose and a "long-lasting" design through waste-free industrial processes
	R4(Reduce)	Reducing the amount of waste produced; reducing energy consumption in production processes; reducing the use of unnecessary packaging materials, and avoiding single-use items.
Top circular bikes	R5(Reuse)	Use items and products as much as possible.
	R6(Repair)	Extend product life by replacing broken or damaged parts.

	R7(Refurbish)	It corresponds to the process that products undergo when they are upgraded, i.e., larger frame parts and components must be replaced in order to extend the product's life cycle.
	R8(Remanufacturing)	Product repair, starting with inspection, then disassembling, cleaning and repairing the product, through industrial processes in a controlled atmosphere.
	R9(Repurpose)	Using discontinued or obsolete parts or components and providing them with a new purpose or function, allowing this discarded equipment to return to a new life cycle.
Optimal use of resources	R10(Recycle)	Recycling products by disassembling components and separating parts.
	R11(Recover)	Recovery of materials after burial.
	R12(Remine)	Recovering materials before they are buried.
	R13(Return)	Disposing of products or components in an environmentally friendly manner, which may include proper treatment, handling, or even containment.

Source: Costa, B., Rodrigues, S., & Santos, N. (2024, March). The Implementation of the Circular Economy R-Principles and Strategies: The Portuguese Hotel Industry Perspective. In *7th International Conference on Tourism Research: ICTR 2024*. Academic Conferences and publishing limited. p61-62.

Well, the sustainable end-of-life practices fall under the general term “product recovery management,” which aims to preserve the value of a product after use. The focus should be on recovering end-of-use products as soon as possible, as the product design phase is the most

influential phase in product recovery planning (Costa et al.2024:58) (Chowdhury & Yasmin.2018:3).

7. Conclusions

The current study developed a comprehensive conceptual framework for sustainable manufacturing by reviewing the most prominent concepts addressed in previous studies, and the benefits achieved by adopting sustainable manufacturing, which included improving the brand, enhancing competitive capabilities, and reducing the amount of resource consumption that is reflected in production costs. The current study also revealed the most common practices in sustainable manufacturing, including sustainable end-of-life, sustainable manufacturing processes, sustainable product design and development, and a sustainable supply chain. These practices can therefore serve as a benchmark for organizations to assess their readiness and ability to implement them in line with the concept of sustainable development, achieving a balance between economic, social, and environmental dimensions.

To achieve the study's objectives of identifying the factors motivating the implementation of sustainable manufacturing practices, previous studies revealed a range of internal and external factors. Internally, the role of senior management, employee engagement, and technological capabilities emerged as key determinants of an organization's readiness to adopt the practices. Externally, the importance of considering environmental regulations, legislation, and systems, as well as the role and influence of stakeholders in these practices, is evident.

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