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Innovative Strategies for Sustainable Rattan Waste Utilization: A Circular Design Approach in Cirebon's Ratan Industries

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Abstract

Indonesia is one of the world's largest rattan producers. Cirebon is the central hub of the rattan furniture industry, contributing significantly to the local economy through craft production and exports. However, this industry generates a significant amount of waste, including rattan cuttings, shavings, and sawdust, most of which has not been optimally utilized despite the high potential of rattan waste. This study aims to analyze the types, characteristics, and potential value of rattan industry waste in Cirebon, using a qualitative descriptive method supported by field observations, in-depth interviews with stakeholders, and literature review. The research applied a SWOT analysis approach which describes strengths, weaknesses, opportunities, and threats to identify potentials to turn waste into resources, reduce environmental impacts, and create added value for local communities then the circular design approach was implemented to develop sustainable design concepts for rattan waste-based products as creative problem-solving can become an effective way to support this. This research shows that waste is a valuable resource that can be reintegrated as another useful product. This research provides fundamental insights that efficient waste classification can optimize material recycling and encourage product design innovation for sustainable product development in the industry. It supports the transition of the Cirebon rattan industry towards a more sustainable future. Further research is needed to examine adaptive manufacturing processes and the marketability of products made from rattan waste, to improve the implementation of circular design strategies in this sector.

Keywords: *Rattan Industry, Rattan Waste, Waste Characterization, Circular Design, Product Design.*

Introduction

Rattan is one of Indonesia's primary non-timber forest products that produces an estimated 660,000 tons of rattan annually, with major regions including Kalimantan, Sumatra, Sulawesi and Papua [1] [2]. Rattan is predominantly utilized as a raw material in the manufacturing of furniture and various handicrafts, and it has the potential to be utilized for processing into domestic trade and export materials [2]. Rattan holds an essential economic value in manufacturing handicrafts and furniture because it has pretty sturdy characteristics and can be processed easily [3]. The rattan-based industry in Indonesia has developed to the point where it can encourage development in the socio-economic sector domestically and internationally [3][4]. The rattan processing into usable products is widely practiced on the island of Java, particularly in West Java. Cirebon is one of the areas renowned for its locally crafted rattan products. With a high concentration of small and medium enterprises (SMES) engaged in rattan processing, Cirebon has gained increasing recognition in domestic and international markets. The production of diverse, high-quality, and innovative rattan products has played an essential role in the growth of the rattan industry in this region.

Rattan is also one of the natural fibers that is widely used for their high strength-to-weight ratio, non-toxicity, low density compared to glass fibers, high specific modulus, excellent flexibility, ease of

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processing, non-abrasiveness, and non-irritating to skin [5]. Rattan products are increasingly popular due to consumer preference for more environmentally friendly materials, in addition to their flexibility, lightweight and sturdy nature, making rattan an ideal material for handicraft products [6]. However, the production of rattan-based products generates a considerable amount of solid waste [7]. Rattan waste occurs at various stages of the production process and can be classified into different types based on its source and physical characteristics [8]. This rattan waste comes from the cutting, bending, weaving, and sanding processes. Rattan waste is also sorted during the pre-production process, where the rattan is sorted so that the imperfect parts of the rattan, such as cracks, bends, and diameters that do not meet industry standards, will be cut and discarded. And from observations made in these industries, it was found that rattan waste, which in many cases is still not effectively being utilized, may be disposed of by burning or dumping into landfills, and only a few are reused; this is the case in both large industries and small and medium-sized industries.

An effective waste management system is crucial for conserving non-renewable resources and minimizing environmental pollution [9]. A SWOT analysis stands for strengths, weaknesses, opportunities, and threats that helps generate a strategic planning framework used in evaluating an organization, a plan, a project or a business activity of alternatives and formulating effective plans to achieve specific goals [10]. In this research, SWOT analysis is applied to assess the potential of various types of rattan waste by understanding the types and properties of its components to make more suitable strategies to utilize it in new products. Circular design is an approach that emphasizes the creation of products and services with consideration to their impact throughout the whole life cycle [11]. Its main objectives are to reduce waste, maximize resource use, and promote a more sustainable economic system [12][13]. The application of circular design to rattan waste has led to a rethinking of how waste materials can be transformed into new functional products, which not only reduce negative impacts on the environment but also have economic and social impacts on society.

This study aims to identify and classify the waste produced by the rattan industry, especially in the Cirebon area. There is a limited amount of research specifically focused on identifying and classifying rattan waste; most existing studies concentrate only on one or two types of rattan waste to utilize it as a new product. Therefore, this study seeks to address this gap by analyzing rattan waste's types and physical characteristics in Cirebon Regency and evaluating its potential for developing alternative raw materials for new, sustainable products.

In this context, rattan-based industries reduce waste, improve the efficiency of natural resource use, and serve as an example of sustainable waste management practices aligned with these principles. By repurposing rattan waste into alternative raw materials, opportunities arise for innovative product development, contributing to the progress of eco-design and supporting broader innovation.

Method

The methodology used in this study is a qualitative descriptive research approach, which aims to map the production process and analyze the types and characteristics of waste generated. The research was conducted in the main rattan production centers in Cirebon, West Java, which was chosen due to its significant role in the rattan-based manufacturing industry in Indonesia, to provide a comprehensive understanding of waste generation at various stages of production. The researchers systematically observed production workflows in selected rattan workshops and factories. Research conducted in March 2025 and observations focused on identifying points in the production chain that generated waste, such as the cutting, bending, sanding, weaving and tying stages. Field notes and detailed photographs were used to document the physical characteristics of the waste generated. This method allows direct verification of the type of waste and the procedures for handling it. In-depth interviews were conducted with key stakeholders, including factory owners, production supervisors, and skilled workers. The interviews were designed to elicit detailed descriptions of the types of rattan waste (e.g., dust, cut, woven and peel waste), to identify them, and to identify current waste handling practices.

The collected data was analyzed using triangulation data to systematically assess and classify qualitative data concerning research findings. This approach offers an overview of the particular context of rattan waste produced throughout each rattan industry production process. In addition, SWOT analysis was used as a strategic planning tool to evaluate rattan waste's strengths, weaknesses, opportunities, and threats. This method enabled an in-depth analysis of the characteristics of rattan waste and its potential for further use, particularly in developing new products. By examining the internal and external factors affecting rattan waste, the SWOT analysis provided valuable insights to inform decision-making processes for utilizing rattan waste as a resource for sustainable product development.

Result and Discussion

The production process of rattan product not only creates the main product, but also generated waste in the form of small cutting pieces of rattan, dust, peel and defective materials that discarded for several reasons, such as inconsistencies in size, color, or texture, or any damage such as cracks, breaks, or weak fibers that make them unsuitable for further processing or end use. In this study, various types of rattan waste were systematically identified and documented after conducting a series of direct observations at several rattan processing facilities in Cirebon Regency. These observations allowed for a more detailed understanding of the waste generation points at various stages of production, including stripping, cutting, shaping and finishing.

Fig. 1. Rattan cutting waste is in the production area (left), rattan weaving waste is in the production area (center), rattan wastes are in the disposal area (right)

Figure 1 shows the rattan waste at the production and industrial disposal sites. The various wastes generated in the rattan production industries will be scattered around the production site and collected in garbage sacks or containers before being taken to the outdoor waste disposal area. Rattan waste is identified in the industry and categorized into four types based on their physical characteristics: dust, cutting, weaving, and peel. Dust waste is micron-sized, powder-like particles generated during the sanding or grinding processes and is often considered difficult to reuse due to its small size. Cutting waste comprises cylindrical segments characterized by dense fibers. These components are typically rigid and solid, ensuring durability; however, exposure to steaming turns them more malleable, allowing reshaping. Weaving waste is cylindrical and composed of thick fibers. However, it is inherently more flexible than cutting waste. This flexibility allows effortless alteration, making it suitable for weaving designs or complex product structures. On the other hand, peel waste is flat and has a usual width of 3–5 mm, which is strong and elastic. The description of each rattan waste can be seen in Table 1.

Table 1. Descriptions of Rattan Waste Categories That Are Sorted in This Research

Items	Description
Dust waste	Waste is small particles, like a powder, in the micron size.
Cutting waste	Cylindrical form with a dense fiber. It is solid and firm, but if it is steamed, it will be flexible.
Weaving waste	Cylindrical form with dense fibers. More flexible and easy to shape, like weaving
Peel waste	It is a flat-shaped form of waste with a 3-5mm width, so it is strong and flexible.

Dust Waste

Rattan dust waste is produced during the grinding, cutting, and sanding processes using sandpaper in rattan production. These processes, which are essential for shaping and smoothing the surface of rattan, naturally produce fine particles from the outer layer of the rattan. This waste comes from the abrasion of rattan fibers during the process, which causes the formation of tiny fine particles and is primarily generated from Manau Rattan and Tohiti Rattan, two common types of rattan used in the furniture and handicraft industries in Cirebon as shown in figure 2.

Fig. 2. Pictures of Rattan Dust Waste

Physically, rattan dust waste is a collection of small particles with no defined or consistent shape. It is generally microscopic, making it light, easily dispersed in the air, and capable of spreading over a wide area in the production environment, as shown in Figure 2.

Table 2. Rattan Dust Waste Physical Characteristics

Category	Description
Shape	powdery, tiny particles
Size	Pieces in the micron scale, making it very small
Texture	Soft like a powder or flour
Color	Generally, it is of a light natural color, but it depends on the variety of rattan used.
Characteristic	Lightweight, dry composition

Table 2 shows that dust waste is powdery, usually light and dry, with a natural light color that can vary depending on the type of rattan used. Despite its seemingly insignificant form, dust waste holds potential in recycling and sustainable production practices. One of its main strengths is its ability to be easily processed and repurposed. It can be utilized as a material in producing particle boards, contributing to the creation of pressed wood products [1][14]. Additionally, it is often used to make biomass briquettes, a renewable energy source commonly used for heating and industrial fuel [15]. Bio-composites derived from biological resources would substantially improve industrial sustainability and clean manufacturing from ecological, economic, and environmental viewpoints, due to the synergy among raw materials' capacity, cost, and performance [16] [17]. This rattan processed waste can also be used as fiber in the concrete [18].

However, there are also substantial weaknesses related to waste dust. Its light, airborne nature harms health, particularly in enclosed work environments where the dust can be inhaled by workers, causing respiratory problems if proper safety measures are not taken with caution. Furthermore, the waste consistency lacks structural strength and cannot be used independently, which requires adhesives to be formed into usable products.

Cutting Waste

Cutting waste refers to the leftover pieces of rattan that are removed during trimming, shaping, or adjusting the length and curvature of the material because of the cutting and bending in rattan manufacturing. These processes are essential to shape and prepare the raw material for various furniture and craft applications. However, these processes also generate significant waste, which is known as cutting waste. The waste physically appears as cylindrical pieces with a fibrous structure, offering a dense and firm texture as shown in Figure 3 below.

Fig. 3. Pictures of Rattan Cutting Waste

The rattan cutting waste has the characteristic of the initial form of the rattan stem. The diameter of these waste pieces varies significantly, ranging from 10mm to 30mm, depending on the raw material used in the production. Commonly, the sizes fall within the following diameter categories: 18mm, 20mm, 22mm, 24mm, 28mm, and 30mm for the furniture products, but can be thinner for craft items. Based on its length, cutting waste is usually divided into three groups: short pieces ranging from 1 to 5 cm, medium-sized pieces ranging from 6 to 10 cm, and long pieces more than 10 cm. All of this is based on how a product's parts are designed. The other point about this cutting waste is that it feels solid and thick. The color depends on the type of rattan, but it is usually the natural color of the rattan. In addition, this waste is hard but can be bent if steamed first. The description of the physical characteristics of cutting rattan can be seen in Table 3.

Table 3. Rattan Cutting Waste Physical Characteristics

Category	Description
Shape	The cylindrical shape
Size	Diameter ranges: 18mm, 20mm, 22mm, 24mm, 28mm, 30mm
Length	Short (1–5 cm), Medium (6–10 cm), Long (>10 cm)
Texture	Firm, rigid, sometimes there is a rough part at the cut edges
Color	It is usually in natural rattan tones
Characteristic	Strong, many fibers, stiff, and rigid. Can be bent if steamed or heated.

One strength of this rattan cutting waste is that its texture, strength, density, and other characteristics are still unaltered, allowing it to be utilized in another product. To reduce waste in raw materials in furniture production, rattan artisans make many product design innovations [7]. Treating these waste pieces is not only done using the typical bending technique but can also be developed using carving techniques, different cutting techniques, and spinning techniques. Furthermore, the waste can be processed to create hollow forms utilizing a machine tool designed for shaping objects via rotational cutting. Considering the number of production techniques that can be applied to this rattan waste, the potential of the products is even more extensive. Cutting waste that has a short cut length is suitable for making souvenirs or children's toys [19]. Also, with different processing techniques, we can produce home decoration products, furniture, crafts, and even rattan sheets.

Moreover, it is abundant and easily accessible, which makes it an excellent resource. However, there is also some weakness as the waste pieces are not uniform in size, so it takes time to sort and optimize the waste. In addition, this type of waste treatment often requires specialized tools to execute the work.

Weaving Waste

Rattan weaving waste is the remaining material wasted during weaving and tying products used in manufacturing. This waste has a cylindrical shape with a small diameter because the initial material comes from rattan canes, which are shaved into smaller diameter canes. The diameter of this weaving waste ranges from 2 to 5 mm, depending on the design and needs of the product, as shown in Figure 4.

Fig. 4. Pictures of Rattan Weaving Waste

This rattan waste is generally classified into three categories: short (1-5 cm), medium (6-10 cm), and long (greater than 10 cm), since this is waste that occurs due to cuttings of pitrite rattan material used in the weaving process. This waste's length varies depending on the design used for the initial products. This type of waste is known for its fibrous and flexible characteristics, making it highly flexible and ideal for various crafting purposes.

Table 4. Rattan Weaving Waste Physical Characteristics

Category	Description
Shape	The cylindrical but thin
Size	Diameter ranges from 2 mm to 5 mm
Length	Short (1–5 cm), Medium (6–10 cm), Long (>10 cm)
Texture	Smooth and slightly fibrous on the surface
Color	Natural color of rattan or colored based on the design of the products
Characteristic	Light, flexible, and easy to bend or shape

Table 4 shows that this rattan waste is flexible and suitable for applications that demand fine detailing and intricate shaping, such as creating home décor elements, ornamental designs, and handcrafted accessories. The small dimensions also make the material easy to handle and manipulate, enabling craftsmen to achieve precision in their designs. Both functional and aesthetic value can be combined in the product development [20]. Many craftsmen have started to utilize this waste to make small decorative products and combine it with other materials such as leather, fabric or other fibers. Developing existing decorative products by exploring new shapes and colors to have a higher selling value compared to previous products [21].

However, despite its many strengths, weaving waste does come with a few challenges. The pieces are not always intact or neatly cut, and their irregular shapes or incomplete forms may not always be ideal for creating large woven products. Nevertheless, with proper planning and creativity, weaving waste remains valuable for craftsmen and manufacturers to reduce waste and use every part of the rattan material.

Peel Waste

Rattan peel is the rattan plant's outer skin or layer, which is peeled off the rattan stem during processing. Rattan peel is naturally strong and flexible, and has generally been used for binding or weaving furniture products and other handicrafts. And the production process produces many small pieces of weaving and binding results, which are then referred to as peel waste, as seen in Figure 5.

Fig. 5. Pictures of Rattan Weaving Waste

Rattan peel waste does not have a specific diameter, as it is flat in shape with highly flexible fibers that are useful for various handicraft and manufacturing purposes, as it can be easily shaped and processed according to requirements. In terms of length, rattan peel waste can vary significantly, with pieces generally divided into three categories: short, ranging from 1 to 5 cm; medium, ranging from 6 to 10 cm; and long, more than 10cm. This variation in length allows for diverse uses, ranging from small decorative items to large woven products, although length can affect the material's flexibility in different projects.

Table 5. Rattan Peel Waste Physical Characteristics

Category	Description
Shape	Flat
Size	width: 3–5 mm
Length	Short (1–5 cm), Medium (6–10 cm), Long (>10 cm)
Texture	Smooth surface
Color	Natural color of rattan or colored based on the design of products is usually brown, tan, or black.
Characteristic	Thin, elastic, flexible, and easy to weave or tie.

Table 5 shows this kind of waste has unique physical characteristics, notably a flat appearance, a width of 3 to 5 mm, and a remarkable combination of durability and flexibility. One of the key strengths of peel waste is its flat and flexible nature, making it ideal for weaving, binding, or creating artistic items. Peel waste has strength and flexibility, enabling it to develop valuable and beautiful items. This material can be used to make detailed decorations, baskets, or as a binding material for larger rattan projects [22]. Its durability also makes it resistant to wear and tear, making it suitable for items that require strength [23]. However, rattan peel waste also has some shortcomings. Some of the fibers from this waste may not be of good quality; they may be weaker or stiffer, making them less useful for some projects. Furthermore, many of these fiber pieces are short, making them unsuitable for larger or more complex patterns due to insufficient material to create larger products.

Based on an analysis of rattan waste found in the rattan industry in Cirebon, the internal factors of SWOT analysis, which include the strengths and weaknesses of rattan waste, help identify the strengths and limitations of utilizing each type of rattan waste generated in the industry.

Table 6. Rattan Waste SWOT Analysis – Internal Factor (S-W)

Type	Strengths	Weaknesses
Dust Waste	a. In small particle form b. Can be used without leaving any waste	a. Can be airborne b. Need to use adhesive to glue all the components
Cutting Waste	a. Still in the same form as the production material b. Available in a variety of sizes c. The physical characteristics are strong, stiff and hard d. Available in large quantities	a. A variety of sizes and lengths require time and effort to sort b. Requires specialized tools and equipment for processing c. Need skilled craftsmen to apply processing methods

Weaving Waste	a. Flexible b. Easy to shape through weaving c. Suitable for making a craftsmanship product d. Comes in different sizes and lengths	a. A variety of sizes and lengths require time and effort to sort. b. Need skilled craftsmen for production
Peel Waste	a. Flat shape and flexible b. Easy to shape through weaving, roping or twisting techniques c. Suitable for a craftsmanship product d. Comes in different sizes and lengths	a. Some fibers may be too stiff or weak b. The variety of sizes and lengths requires time and effort for sorting c. Need skilled craftsmen for production

Table 6 shows that internal factor analysis indicates that every type of rattan waste can be recycled due to the waste's diverse physical characteristics, which aligns well with circular design principles. However, challenges remain in sorting, material inconsistency, and reliance on skilled craftsmen. In addition, dust waste also poses health and safety issues due to its respirable nature and the need for binding agents for structural use.

External factors in SWOT analysis, including opportunities and threats related to rattan waste, provide valuable insight into broader market conditions and environmental factors that may impact the industry. Understanding these factors, can make informed decisions on how best to utilize rattan waste.

Table 7. Rattan Waste SWOT Analysis – External Factor (O-T)

Type	Opportunities	Threats
Dust Waste	a. Can utilized for products using a pressed technique b. Potential for research and innovation in bio-composites	a. Health risks for workers due to inhaling fine dust b. High competition from other agricultural waste sources, like rice husk
Cutting Waste	a. Suitable for producing a wide range of products b. Easily implements a variety of original ideas c. Convenient for a variety of production methods d. Has economic value due to the growing market demand for environmentally friendly products.	a. It can still contribute to environmental waste b. Competitive product with wood waste
Weaving Waste	a. Potential for developing products through design innovation b. Has economic value due to decorative woven product available in market c. Possibility to collaborate with other industries for cross-material product development	a. Many competitors in the market b. Without strong branding, the products may struggle
Peel Waste	a. Potential for product diversification b. Has economic value due to decorative woven product available in market c. Possibility of unique product development	a. Many competitors in the market b. If processed incorrectly, it can become brittle over time.

The analysis of external factors of rattan waste can be seen in Table 7. It shows that rattan waste in the Cirebon industry has great potential for recycling, driven by market demand for sustainable products and opportunities for innovation. However, the main threats include health risks, product competition in the market, considering the whole life cycle, and the need for proper processing and good branding.

The overall results of the rattan waste identification and SWOT analysis indicate that rattan waste in the rattan-based industry in Cirebon has significant potential for recycling and innovation. The potential for the development of environmentally friendly products, compatibility with circular design principles, and flexibility in product applications are all unique advantages of each form of waste. Nevertheless, there are still problems to be resolved, such as inconsistent materials, the need for trained workers, dust risks, and competition from other materials in the market. The process of designing a product involves several different stages to ensure the product functions in the best way for the user which is usually formed due to the process of inspiration, ideation, and integration [24]. By addressing these weaknesses and exploring opportunities for sustainable product development, the rattan industry in Cirebon can optimize the value of rattan waste, while contributing to economic growth and environmental sustainability.

Table 8. Rattan Waste Identification

Type	Description	Technique	Potential
Dust Waste	Particle form	Pressing technique, using adhesive to glue	Material for briquettes, particle boards, mushroom growing substrate, fiber for concrete, etc
Cutting Waste	Cylindrical form, strong, stiff and hard	Bending, cutting, shaving, hollowing, carving	Depend on the technique that be used, this waste can be material for furniture, toys, decorative product, etc
Weaving Waste	Cylindrical form, light, flexible.	Weaving technique, combining with leather, fabric, other fibers	Material for decorative product, accessories, bags, baskets, etc
Peel Waste	Flat-shape, thin, elastic, flexible	Weaving, roping, twisting	Material for weaving product, furniture, ropes, decorative product, etc.

Table 8 shows that each type of waste has different characteristics, making it potentially able to be developed into a new resource in the manufacturing process of products. This finding aligns with the circular design concept, which emphasizes waste as a source of renewed materials, benefiting the environment and economic and social aspects [2]. In addition, sustainable design should not be overlooked, as it should already be standard practice to process rattan waste into new products. This approach not only helps reduce the volume of industrial waste but also opens up new opportunities to create value-added products from previously considered useless materials. By sorting waste based on its physical characteristics, the recycling process can be carried out more effectively so that each type of waste can be utilized according to its potential. Thus, it will support environmental preservation while increasing the economic value of the waste.

Conclusion and Recommendations

The analysis of rattan waste within the Cirebon rattan industry revealed that these waste materials, when examined and analyzed through SWOT analysis are not simply by-products, but rather valuable resources that can be reintegrated into the production cycle. These findings highlight that effective waste classification enables targeted strategies for material recovery and product innovation, thereby reducing environmental impacts, promoting sustainable manufacturing, and providing economic

opportunities for local communities. However, despite the significant potential of rattan waste, several challenges remain, such as variations in waste size depending on the production process and product design, which pose substantial obstacles to product design development. Additionally, the need for another worker to process the waste can complicate scalability and lead to higher production costs. Furthermore, the dust waste poses potential health risks, such as respiratory issues, if not handled with caution.

By identifying the unique properties of each type of rattan waste, the industry can develop product innovations that transform rattan waste from a mere by-product into a valuable resource that contributes to sustainability. This research supports the idea that waste can serve as a renewable asset in line with the Sustainable Development Goals, despite the threat of competition from products made from other materials in the market, which could limit the market share for rattan-based products.

The current research solely classified the type of rattan waste through the SWOT analysis. Future research should expand this inquiry to examine the potential of waste for innovative design, incorporating an assessment of the product life cycle to provide a comprehensive understanding of long-term impacts on the environment. Additional research and development are essential to determine the appropriate use of waste materials as products to improve sustainability.

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