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# Utilization of Recycled Materials in the Production of Green Polymer Composites Using COPRAS Method

\*Soniya Sriram, Chitra Periyasamy, M. Ramachandran, Sathishkumar Mani

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India.

\*Corresponding Author Email: [soniyasriram257@gmail.com](mailto:soniyasriram257@gmail.com)

**Abstract:** Because it can lessen the environmental effects of traditional manufacturing techniques, the use of recycled resources in the creation of green polymer composites has attracted a lot of interest recently. In order to create ecologically friendly composites, this study investigates the viability and effectiveness of adding recycled materials to polymer matrices, such as waste fibers, recovered fillers, and post-consumer plastics. The viability of several recycling techniques, such as chemical, mechanical, and hybrid procedures, is assessed in order to turn recycled materials into composite components. Extensive research is conducted on the impact of recycled material on the mechanical, thermal, and morphological properties of green polymer composites. The findings underscore the potential and problems associated with attaining targeted performance attributes while upholding environmental sustainability. Additionally, the impact of processing variables and the degree of compatibility between recycled fillers and polymer matrices on the attributes of composites are examined. Overall, this work opens the door for the development of environmentally friendly and sustainable materials for a range of applications by shedding light on the possibility of using recycled resources in the creation of green polymer composites. Green composites are a particular kind of bio composites that are an emerging field in polymer science. They consist of natural fibers reinforcing a bio-based polymer matrix. The composites, which are commonly called "green," have a variety of industrial uses. However, there are certain issues, such as decreased ductility and worse process ability. Many of these restrictions can be addressed with the use of adhesion boosters, additives, or chemical filler modification.

## 1. INTRODUCTION

A viable approach to addressing the environmental issues related to conventional manufacturing techniques is the use of recycled resources in the creation of green polymer composites. In the materials sector, sustainable solutions are desperately needed due to growing worries about resource depletion, climate change, and environmental contamination. Because of its great strength-to-weight ratio, low weight, and adaptability, polymer composites are now widely used in a wide range of industries, including consumer products, construction, automotive, and aerospace. However, the significant use of non-renewable materials, energy-intensive production methods, and the buildup of non-biodegradable waste have also led to rising concerns over the environmental impact of polymer composites, despite their widespread use. Given this, incorporating recycled materials into polymer composites offers a strong way to lessen these negative effects on the environment and improve the sustainability of composite manufacturing. A wide range of materials are considered recycled, including post-consumer plastics, waste fibers from paper, textiles, and natural sources, as well as repurposed fillers like rubber, wood, and glass. By providing a plentiful and reasonably priced resource pool that may be saved from landfills and incineration, these materials lessen the load on waste management systems and save priceless resources. Additionally, using recycled materials in polymer composites can greatly lessen the need for fossil fuels, virgin feedstocks, and energy-intensive processes, which will cut energy and greenhouse gas emissions throughout the course of the product's lifetime. Although the use of recycled materials in polymer composites has clear environmental benefits, there are a number of technical issues that must be resolved to guarantee the best possible performance and quality. These difficulties include maintaining mechanical and thermal

qualities, ensuring optimal dispersion and compatibility of recycled fillers within the polymer matrix, and resolving any problems with contamination, degradation, and material property variability. The quality and appropriateness of recycled materials for composite applications are also greatly influenced by the choice of suitable recycling techniques, such as chemical, mechanical, or hybrid approaches. This study attempts to give a thorough review of the use of recycled resources in the creation of green polymer composites in light of these factors.. By conducting a methodical analysis of extant literature and case studies, we want to investigate the possible advantages, obstacles, and prospects linked to the integration of recycled materials into polymer composites. Additionally, we will investigate how different filler types, processing settings, recycling techniques, and polymer matrices affect the characteristics and functionality of green polymer composites.



FIGURE 1. Polymers | Free Full-Text | A Review on Natural Fiber Reinforced Polymer

This study aims to facilitate the development of sustainable and eco-friendly composite materials for a variety of applications by clarifying the important variables and mechanisms involved in the utilization of recycled materials. This will help to accelerate the shift towards a circular economy and a more sustainable future. In the current economic climate, when oil prices are rising, using green composites is beneficial for the environment as well as the economy. All things considered, it can be said that while green composites may attain higher levels of stiffness and thermomechanical resistance, their ductility and tensile strength are notably decreased. Most of the time, the composites are referred to as "green" and have industrial uses. Green composites are environmentally benign and may be a good substitute for polymers derived from petroleum and polymer composites. The "green composites," which are made of biofiber and bio-composites' cations, would drive up demand for bioplastics by requiring a large-scale production of bioplastic from renewable resources and promoting biodegradability. Because they have less of an impact on the environment than polymer composites derived from petroleum, green composites are seen as an alternative. In order to make biodegradable green composites sustainable and ecologically benign, several researchers have suggested creating them from renewable resources such as natural fibers, agricultural feedstocks, and biopolymers. The various mechanical and thermal characteristics of amine-cured EFB/epoxy composites and EFB/epoxy-lignin green composites with varying lignin percentages (15%, 20%, 25%, and 30%) utilized as hardener. Adhesion between the fibers and the polymer matrix was discovered to have a significant impact on the mechanical characteristics of the epoxy composites. Due to their environmental friendliness, green composite materials have become more widely produced and used in a variety of industries in recent years. Additionally, a number of technological and materialistic factors need to be taken into account to enhance the production of contemporary green composites at a reasonable cost. Green composites offer enormous potential for growth as sustainable, lightweight materials, particularly if the use of natural plant fibers is done correctly. Green composites have a bright future ahead of them because to their promise of easy end-of-life usage and environmental friendliness. hitosan. They may now be utilized as reinforcing

material in biopolymers to create reasonably priced, environmentally friendly composites that are sustainable. Due to the poor compatibility of hydrophilic CG phases with hydrophobic polymers, their hydrophilicity is thought to be a fundamental obstacle to their compounding in polymer matrices, which limits their use as bio reinforcement. Recently, a lot of research has been done on enhancing CG's hydrophilicity for use in materials. Fly ash's composition varies according on the coal source, but it mostly consists of SiO<sub>2</sub> with smaller amounts of Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, MgO, and K<sub>2</sub>O. In order to remove fly ash from the environment and make it useful for a variety of technical applications, efforts are currently being undertaken to establish it as an appealing mineral filler in polymer matrix composites. In order to build completely green composites, fundamental and revolutionary research is needed given the growing sustainability of the composite industries. Sustainable composites may greatly benefit from the use of innovative green fibers like nan cellulose and lignin-based carbon fiber, as well as renewable resource-based bio plastics and sustainable polymers. Green composites are just as strong as those reinforced with synthetic fibers in terms of mechanical, thermal, and tribological properties as well as acoustic and electrical insulating qualities. However, because they are naturally biodegradable and renewable, they have definite environmental benefits. Therefore, it is established that waste textiles from a variety of sources, including spinning mills, factories that produce synthetic fibers, and waste clothing, may be utilized in a safe manner to strengthen structures when creating recycled green composites. In order to enhance comprehension of eco-composites, the qualities of the materials are examined in accordance with global norms and production specifications. Numerous eco-composites have been effectively created and certified for application in a wide variety of non-load bearing items. Because they come from renewable resources and are biodegradable, there is a lot of interest in creating environmentally friendly green composites or bio composites using plant-derived bio/natural fibers and crop-derived bio plastics.

## 2. COPRAS METHODS

This study examines several material selection criteria and their relative relevance in an effort to address the material selection difficulties utilizing the complex proportional assessment (COPRAS) and complex proportional assessment with grey number (COPRAS-G) approaches. The current work is to give the information measures for HFSs and build the Shapley COPRAS technique, which expresses the assessment value of the alternatives on attributes and criterion weights, or both, in the form of HFSs. One of the newest techniques for making decisions, COPRAS, was first presented by Zavadskas et al. (1994) and is incredibly successful at handling MCDM issues. (COPRAS) technique to address decision-making issues in deterministic settings. The answer is found using the COPRAS approach in relation to both the ideal and anti-ideal solutions. Therefore, the primary objective of the paper is to classify the European nations that were researched using the COPRAS approach and to evaluate six criteria that describe the building industry. a. For this reason, the Zavadskas and Kaklauskas (1996) Complex Proportional Assessment System (COPRAS) technique can be used. Most criteria used in real-world scenarios to evaluate alternatives deal with ambiguous features, and criteria values are never specified in precise numerical terms. We will provide a novel approach to material selection that combines the coefficient of variation technique with the COPRAS method. Using both qualitative and quantitative criteria, MCDM techniques address assessment and selection issues. These factors make the choice of a quality control manager an MCDM issue. This study aims to evaluate and choose quality control managers using the AHP and COPRAS-G techniques One of the most widely used multicriteria decision making (MCDM) techniques is COPRAS, or complex proportional assessment. It determines a solution by comparing it to the ideal and ideal-worst solutions. This allows for the assignment of the best alternative among a set of workable alternatives (Zavadskas and Kaklauskas, 1996). Numerous scholars use this method to address decision-making issues. The Zavadskas and Kaklauskas (COPRAS) approach might be utilized. The COPRAS approach was used to address a number of construction-related issues. The majority of the options being considered always deal with an ambiguous future, making it impossible to precisely articulate the criteria's values.

### Alternative:

- Alternative 1: Virgin Polymer Composite
- Alternative 2: 25% Recycled Content Polymer Composite
- Alternative 3: 50% Recycled Content Polymer Composite
- Alternative 4: 75% Recycled Content Polymer Composite
- Alternative 5: 100% Recycled Content Polymer Composite

### Evaluation:

### Benefit Criteria:

- **Mechanical Strength:** A higher value indicates stronger material, which is crucial for durability and performance.
- **Environmental Impact:** Lower values indicate reduced environmental impact through the utilization of recycled materials.

#### Non-benefit Criteria:

- **Production Cost:** Lower values indicate cost-effectiveness in production.
- **Availability of Raw Materials:** Higher values indicate better availability of raw materials,

With a mechanical strength score of 100, the Virgin Polymer Composite (Alternative 1) is a material composition free of recycled materials, which is crucial for delivering outstanding performance and longevity. Nevertheless, it also has the greatest environmental impact score due to the lack of recycled components, which increases resource consumption and trash creation throughout the manufacturing process. Although it preserves the best possible raw material availability and manufacturing cost efficiency, the environmental trade-off raises possible sustainability issues. On the other hand, by including recycled materials, the 25% Recycled Content Polymer Composite (Alternative 2) meets sustainability goals by exhibiting a markedly decreased environmental impact of 85 and a slightly reduced mechanical strength of 90. Although there is a minor rise in manufacturing costs and minimal effect on the availability of raw materials, the environmental advantages highlight its potential as a more environmentally friendly substitute. Higher mechanical strength values indicate better resistance to external pressures and longer service lives. Mechanical strength is a crucial factor in evaluating the performance and durability of polymer composites. Lower values indicate reduced resource consumption, emissions, and trash creation, hence improving sustainability and minimizing environmental deterioration. Environmental impact assesses the ecological footprint of manufacturing operations. Lower production cost values indicate cost-effectiveness and increased market competitiveness. Production cost is a measure of manufacturing's financial efficiency. The availability of raw materials is a measure of the stability and accessibility of input resources; higher values guarantee a dependable supply chain, reduce production interruptions, and support long-term viability and overall operational efficiency. Making well-informed decisions when choosing polymer composite alternatives that strike a balance between performance, sustainability, affordability, and supply chain resilience is made possible by considering these factors holistically.

### 3. ANALYSIS AND DISCUSSION

TABLE 1. Given evaluation parameter

Alternative	Mechanical Strength	Environmental Impact	Production Cost	Availability of Raw Materials
Virgin Polymer Composite	100.00	100.00	100.00	100.00
25% Recycled Content Polymer Composite	90.00	85.00	95.00	95.00
50% Recycled Content Polymer Composite	85.00	75.00	90.00	90.00
75% Recycled Content Polymer Composite	80.00	65.00	85.00	85.00
100% Recycled Content Polymer Composite	75.00	50.00	80.00	80.00

The assessment parameters for the several polymer composite alternatives are shown in Table 1. Each option is evaluated based on four major factors: production cost, raw material availability, mechanical strength, and environmental impact. With flawless results in every category—including exceptional mechanical strength, low environmental impact, economical manufacture, and plentiful raw material availability—Virgin Polymer Composite stands out from the competition. The trade-off between sustainability and performance is demonstrated by the progressive decrease in mechanical strength and increase in environmental advantages in successive alternatives as the percentage of recycled content rises. When it comes to mechanical strength, the options with more recycled content have lower environmental effect scores, which is in line with eco-friendly goals. The intricacies in striking a balance between economic and environmental considerations in the manufacture of polymer composites are further reflected in the minor rise in production costs and the slight decrease in raw material availability with more recycled content.

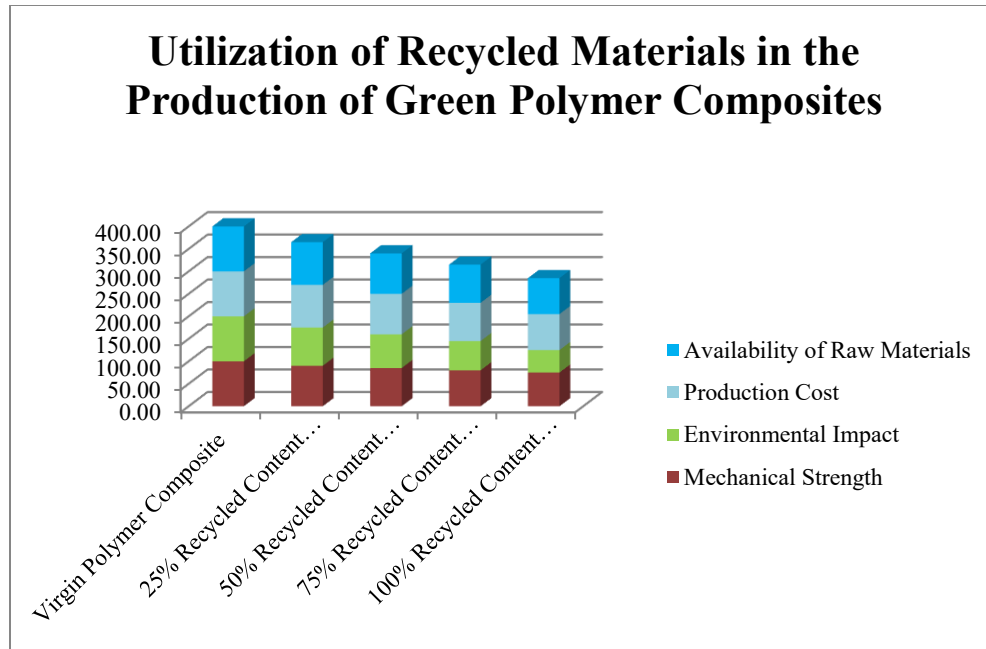


FIGURE 2. Data Set Graph

The assessment parameters for several polymer composite alternatives are shown in Figure 1. Each option is evaluated based on four major criteria: raw material availability, production cost, environmental impact, and mechanical strength. The intricacies in striking a balance between economic and environmental considerations in the manufacture of polymer composites are further reflected in the minor rise in production costs and the slight decrease in raw material availability with more recycled content.

TABLE 2. Normalized Data

Alternative	Mechanical Strength	Environmental Impact	Production Cost	Availability of Raw Materials
Virgin Polymer Composite	0.2326	0.2667	0.2222	0.2222
25% Recycled Content Polymer Composite	0.2093	0.2267	0.2111	0.2111
50% Recycled Content Polymer Composite	0.1977	0.2000	0.2000	0.2000
75% Recycled Content Polymer Composite	0.1860	0.1733	0.1889	0.1889
100% Recycled Content Polymer Composite	0.1744	0.1333	0.1778	0.1778

Table 2 presents the normalized data for the assessment parameters of the different polymer composite alternatives. It also emphasizes the relative performance of the alternatives with respect to raw material availability, production cost, mechanical strength, and environmental effect. The normalized values, which scale the original data to a common range between 0 and 1, making it easier to compare and comprehend how well one alternative performs in respect to the others. The Virgin Polymer Composite exhibits less dominance in normalized values, despite its initial high ratings, indicating a fairer comparison of the choices. As recycled content increases, the normalized values steadily decline, particularly in Mechanical Strength and Production Cost. The expected trade-off between performance and sustainability is shown in this pattern. This normalization assists decision-makers in selecting the optimal polymer composite solution within specified bounds and priorities by enabling them to impartially assess the relative benefits and downsides of each alternative.

TABLE 3. Weighted

Weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

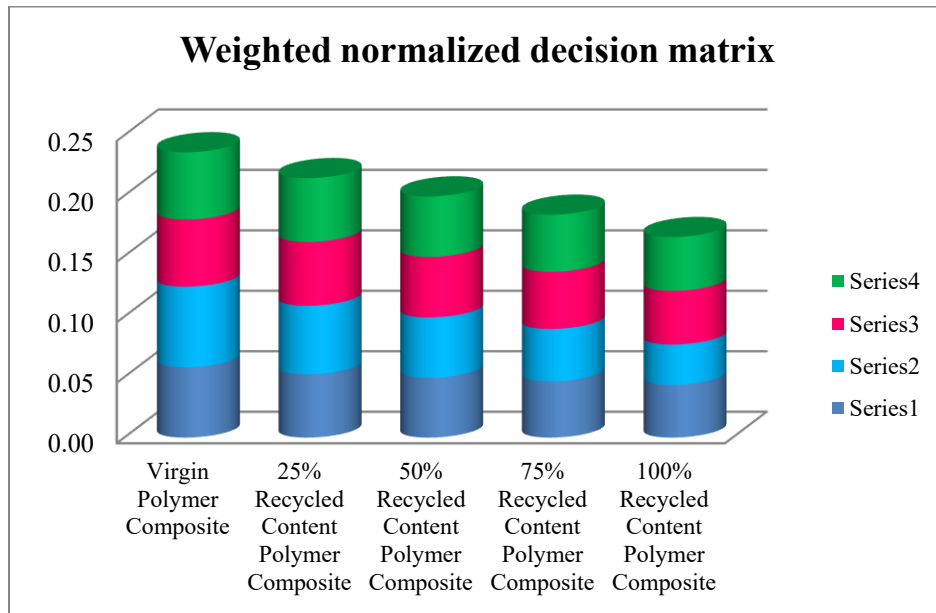
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

The weighted values assigned to each assessment parameter for the polymer composite alternatives are shown in Table 3, which indicates the order of relevance or priority for the following factors throughout the decision-making process: production cost, raw material availability, mechanical strength, and environmental impact. The table, which indicates a fair evaluation of all elements in assessing the alternatives, shows that each criterion has been allocated an equal weight of 0.25. By avoiding biases towards any one criterion, this uniform weighing technique guarantees fairness and openness in the evaluation process. Decision-makers may evaluate and rank the options based on how well they perform overall across the defined criteria by assigning uniform weights to all of them. This allows for informed decision-making that is in line with stakeholder expectations and organizational objectives.

**TABLE 4.** Weighted normalized decision matrix

Weighted normalized decision matrix			
0.06	0.07	0.06	0.06
0.05	0.06	0.05	0.05
0.05	0.05	0.05	0.05
0.05	0.04	0.05	0.05
0.04	0.03	0.04	0.04

The weighted normalized choice matrix, which takes into account each alternative's performance across assessment criteria as well as the relative value of each criterion, is shown in Table 4. Through the process of multiplying the normalized scores found in Table 2 by the appropriate weights found in Table 3, this matrix offers a thorough evaluation that takes into consideration the relative importance of each criterion as well as the actual performance of the alternatives. The weighted contributions of each option to reaching the intended goals are represented by the final values, which take into account variables including raw material availability, production costs, mechanical strength, and environmental impact. With the help of this integrated approach, decision-makers may rank options according to how well they perform overall in relation to the weighted criteria, enabling a more in foreannounced selection process that is in line with stakeholder and organizational goals.



**FIGURE 2.** Weighted normalized decision matrix

The weighted normalized choice matrix is shown in FIGURE 2, which includes the performance of each alternative together with the relative value of the assessment criteria. Through the process of multiplying the normalized scores found in Table 2 by the appropriate weights found in Table 3, this matrix offers a thorough evaluation that takes into consideration the relative importance of each criterion as well as the actual performance of the alternatives. The weighted contributions of each option to reaching the intended goals are represented by the final values, which take into account variables including raw material availability, production costs, mechanical strength, and environmental impact. With the help of this integrated approach, decision-makers may rank options according to how well they perform overall in relation to the weighted criteria, enabling a more informed and nuanced selection process that is in line with stakeholder and organizational goals.

**TABLE 5.** Bi, Ci

Bi	Ci
0.125	0.111
0.109	0.106
0.099	0.100
0.090	0.094
0.077	0.089

The values of Bi and Ci, which indicate the relative importance of the costs (Ci) and benefits (Bi) of each choice, are shown in Table 5. These numbers are essential for figuring out the Benefit-to-Cost Ratio (BCR), a critical decision-making tool that evaluates the efficacy and efficiency of different options. The advantages of each option are shown by the Bi values, while the costs are shown by the Ci values. Greater benefits from an alternative are indicated by a larger Bi value but a lower Ci value denotes lesser related expenses. Through a comparative analysis of these ratios across options, decision-makers may identify and give priority to those that exhibit a greater benefit-to-cost ratio. This analysis makes it possible for decision-makers to make more informed choices by pointing them in the direction of options that provide the best value proposition for meeting goals and cutting expenses.

**TABLE 6.** Min (Ci)/Ci, Qi, Ui

Min(Ci)/Ci	Qi	Ui
0.8000	0.214	100.0000
0.8421	0.203	94.8161
0.8889	0.199	92.7889
0.9412	0.195	91.0490
1.0000	0.189	88.0943

To evaluate the relative performance of alternatives according to their cost-effectiveness, Table 6 displays the findings of the computations for Qi, Ui, and Min (Ci)/Ci. The ratio of the least expensive option (Min (Ci)) to the cost of each alternative (Ci) is represented as Min (Ci)/Ci, showing how much more expensive each alternative is in comparison to the least expensive option. Greater cost-effectiveness is indicated by a number nearer 1, which implies that the alternative's cost is closer to the minimum. To facilitate comparisons between options, Qi is the normalized values of Min (Ci)/Ci. Better cost-effectiveness is shown by options with higher Qi values, which are closer to the minimal cost. The utility scores are represented by Ui, which are determined by scaling Qi values from 0 to 100. Higher scores indicate more cost-effective and useful options. These computations give decision-makers useful information about the trade-offs between alternatives' costs and performances, assisting them in choosing the least expensive option that nevertheless complies with organizational goals.

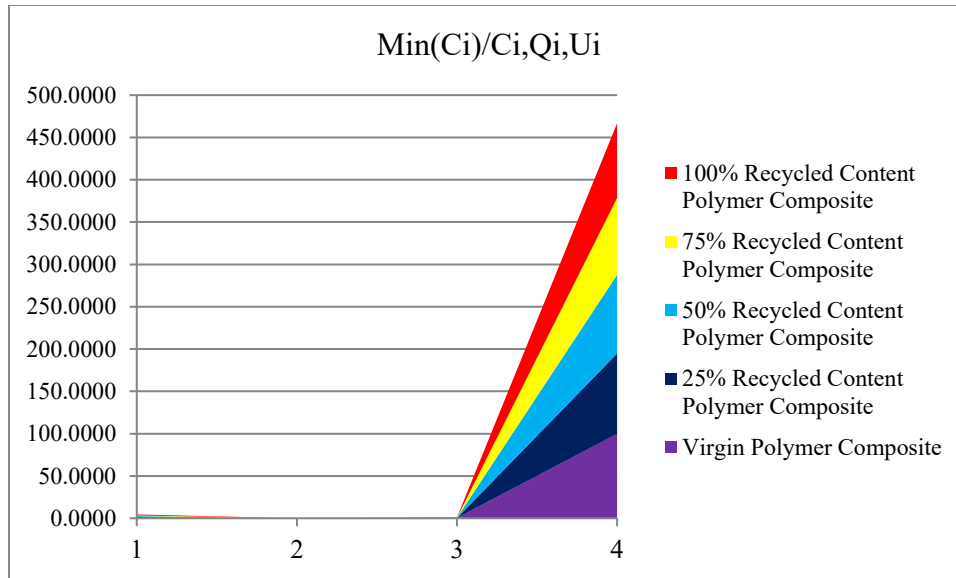


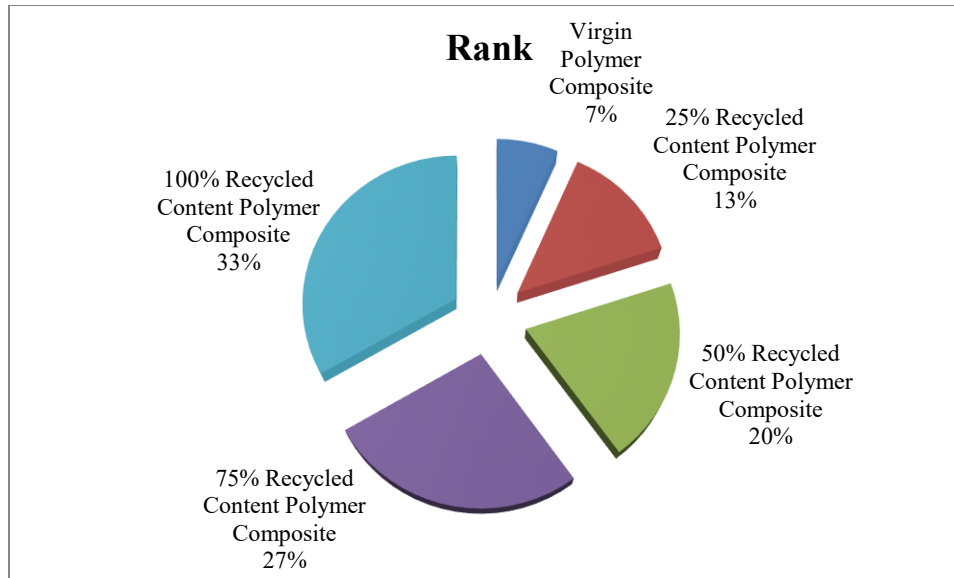
FIGURE 3. Min (Ci)/Ci, Qi, Ui

The results of the calculations for  $Q_i$ ,  $U_i$ , and  $\text{Min}(C_i)/C_i$  are shown in FIGURE 3. These calculations are crucial for evaluating the relative performance of alternatives in relation to their cost-effectiveness. The ratio of the least expensive option ( $\text{Min}(C_i)$ ) to the cost of each alternative ( $C_i$ ) is represented as  $\text{Min}(C_i)/C_i$ , showing how much more expensive each alternative is in comparison to the least expensive option. Greater cost-effectiveness is indicated by a number nearer 1, which implies that the alternative's cost is closer to the minimum. To facilitate comparisons between options,  $Q_i$  is the normalized values of  $\text{Min}(C_i)/C_i$ . Better cost-effectiveness is shown by options with higher  $Q_i$  values, which are closer to the minimal cost. The utility scores are represented by  $U_i$ , which are determined by scaling  $Q_i$  values from 0 to 100. Higher scores indicate more cost-effective and useful options. These computations give decision-makers useful information about the trade-offs between alternatives' costs and performances, assisting them in choosing the least expensive option that nevertheless complies with organizational goals.

TABLE 7 .Rank for Green Polymer Composites COPRAS Methods

Rank	
Virgin Polymer Composite	1
25% Recycled Content Polymer Composite	2
50% Recycled Content Polymer Composite	3
75% Recycled Content Polymer Composite	4
100% Recycled Content Polymer Composite	5

The ranks for green polymer composites utilizing the multi-criteria COPRAS (Complex Proportional Assessment) approach are shown in Table 7. The rankings are determined by evaluating each alternative's overall performance in relation to a number of factors, such as raw material availability, production costs, environmental impact, and mechanical strength. Virgin Polymer Composite comes in first place, demonstrating its better performance over the alternatives in all of these categories. The ranks of successive options gradually decline as the percentage of recycled content rises, indicating the compromises made between cost, environmental effect, and mechanical strength when using recycled materials. These rankings help decision-makers choose the best green polymer composite for certain needs or applications by giving them important information about the relative advantages and disadvantages of each option.



**FIGURE 4.** Rank for Green Polymer Composites Copra's Methods

The rankings for green polymer composites are shown in FIGURE 4 utilizing the multi-criteria COPRAS (Complex Proportional Assessment) approach of decision-making. The rankings are determined by evaluating each alternative's overall performance in relation to a number of factors, such as raw material availability, production costs, environmental impact, and mechanical strength. Virgin Polymer Composite comes in first place, demonstrating its better performance over the alternatives in all of these categories. The ranks of successive options gradually decline as the percentage of recycled content rises, indicating the compromises made between cost, environmental effect, and mechanical strength when using recycled materials. These rankings help decision-makers choose the best green polymer composite for certain needs or applications by giving them important information about the relative advantages and disadvantages of each option.

#### 4. CONCLUSION

Because of qualities like low density, relatively high strength, modulus, and stiffness, non-abrasive character, high filler loadings, biodegradability, and safe working conditions, plant fibers and their products are widely used. Plant fibers, on the other hand, are a yearly renewable raw resource that is virtually infinite in supply. For the first time, pulp and paper industry waste (PIW) was used in this study to create high-strength green composites. PIW, linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), and ultrahigh molecular weight polyethylene (UHMWPE) served as the foundation for the green composites. Reusing cleaner fractions has been made possible by advancements in recycling technology. One of the obstacles preventing open-loop recycling of resources into composites is the mixing and potential contamination of CDW ingredients. Because of the reinforcing, biobased composites made of PLA and cellulose fibers have better mechanical and thermal qualities. In order to do this, we need to discover how to enhance melt-blending procedures in order to produce better fiber dispersion with less fiber breakage. This is especially important since it affects the bonding between the wood fiber and plastic matrix, which is connected to more varied recycled materials.. This review study looks at a number of research that address the performance of PFRCs, the significance of the interface, the impact of different kinds of surface changes, and the kinds of matrices that are utilized for the composites. Green polymer composites, which are made from recycled materials, present a viable path to the materials industry's sustainability objectives. It is clear from evaluating several options with multicriteria decision-making techniques that adding recycled material may significantly lessen environmental impact while preserving reasonable levels of mechanical strength and cost-effectiveness. With a larger recycled content often correlated with lower mechanical strength and higher environmental advantages, the ranking options emphasize the trade-offs involved. To guarantee the supply chain's stability and economic sustainability, however, much thought must be given to the cost of manufacturing and the availability of raw materials. In the end, finding the best green polymer composite requires striking a balance between these variables in accordance with particular application needs and sustainability goals. This emphasizes how crucial it is to use comprehensive strategies

and make well-informed decisions in order to promote the use of recycled resources for the manufacture of more sustainably produced commodities.

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