REST Publisher; ISSN No: 2583-4800(Online)

Journal on Advances in Mechanical Engineering

journal homepage: https://restpublisher.com/journals/jame/

Fracture Behaviour of Glass Fibre-Reinforced Polymer Composites using TOPSIS Method

Mythili Senthil *, Arunambigai Ramesh, M. Ramachandran , Chandrasekar Raja

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India

ARTICLE INFO

Article history:
Received: 3 March 2026
Accepted: 22 March 2026
Available online: 28 March 2026

Keywords:
Carbon Fiber-Reinforced Polymer Composites
Natural Fiber-Reinforced Polymer Composites
Aramid Fiber-Reinforced Polymer Composites
Basalt Fiber-Reinforced Polymer Composites

ABSTRACT

Glass Fiber Reinforced Polymer (GFRP) composites have emerged as indispensable materials across countless industries due to their superior mechanical performance, lightweight nature, corrosion resistance, and versatility. This study provides a comprehensive review of GFRPs, covering their composition, manufacturing methods, material properties, recent technological advancements, and key challenges. The composite structure of GFRPs relies on polymer matrices such as epoxy, polyethylene, and vinyl ester resins. These are combined with glass fiber reinforcements in the form of rovings, mats, or woven fabrics. Various manufacturing techniques—including hand lay-up, filament winding, pultrusion, and compression molding—are evaluated based on their cost, complexity, and suitability for specific applications. GFRPs are renowned for their excellent strength-to-weight ratio, corrosion resistance, and dimensional stability. Factors such as fiber orientation, volume fraction, and matrix selection all significantly influence the ultimate performance of the composite. While emerging innovations—such as nanostructured reinforcements, hybrid fiber systems, and advanced processing methods—continue to enhance GFRP capabilities, issues regarding recyclability and fiber-matrix adhesion remain persistent challenges.

1. INTRODUCTION

Glass fiber-reinforced polymer composites (GFRPs) have emerged as a significant material category across diverse industrial sectors, owing to their remarkable mechanical properties, lightweight construction, corrosion resistance, and adaptable design features. This introduction aims to furnish a comprehensive overview of GFRPs, delving into their composition, manufacturing processes, properties, recent advancements, challenges, and wide-ranging applications. Through a thorough examination of pertinent literature, this paper seeks to deepen comprehension regarding the potentials and constraints of GFRPs in contemporary engineering and manufacturing [1]. Glass fibers, commonly found in roving, mat, or fabric forms, confer strength and rigidity to the composite due to their elevated tensile strength and modulus. Various manufacturing techniques are employed in GFRP component production, including hand lay-up, spray-up, filament winding, pultrusion, and compression molding. Each method offers distinct advantages in terms of cost-effectiveness, complexity, and suitability for specific applications. GFRPs boast a blend of properties that render them highly appealing for numerous applications [2]. These properties include a high strength-to-weight ratio, exceptional corrosion resistance, dimensional stability, and low

*Corresponding author: mythilisenthil631@gmail.com

DOI: https://doi.org/10.46632/jame/5/1/2

thermal conductivity. Innovations such as nanostructured reinforcements, hybrid fiber systems, and advanced manufacturing techniques have led to enhancements in strength, durability, and process ability. Despite their myriad advantages, GFRPs confront several challenges that impede widespread adoption [3]. These challenges include concerns regarding recyclability, environmental impact, long-term sustainability, and issues associated with the bonding between fiber and matrix phases. Addressing these challenges is imperative to unlocking the full potential of GFRPs across various industries. GFRPs find applications across a spectrum of fields, encompassing and renewable energy. In aerospace, GFRP composites are utilized in manufacturing aircraft components such as fuselages, wings, and interior panels [4]. In the automotive sector, GFRPs are employed for producing lightweight body panels, chassis components, and structural reinforcements, thereby contributing to enhanced fuel efficiency and emissions reduction. In the marine domain, GFRP composites offer excellent corrosion resistance and durability, rendering them ideal for boat hulls, decks, and structural elements. Furthermore, GFRPs are increasingly leveraged in renewable energy applications such as wind turbine blades and solar panels, where their lightweight construction and corrosion resistance augment performance and longevity [5]. Composite materials, formed by combining two or more components, offer unique properties unattainable by individual fibers or matrices. Fiber-reinforced composites, a longstanding choice in engineering, especially feature Composites made primarily of glass fiber-reinforced polymeric (GFRP) are used in production. Organics matrices including polyester, vinylester, phenolic material, and epoxy resins are commonly used in these materials; resins made of polyester can be further classified as morpho or isophthalic. The mechanical performance of polymers reinforced with fibers is primarily affected by variables such as cohesive strength, stability chemically, fiber strength and modulus, and the interfacial bonding that allows stress transfer between the fibers and matrix. The desired characteristics and integration of GFRP composites can be achieved by tailoring the combinations and alignments of the fibers. often resulting in properties comparable to steel but with greater stiffness and significantly lower specific gravity [6]. Various forms of glass fibers, including long-length reinforcements, woven mats, individual chopped fibers, and chopped mats, are employed to enhance mechanical and tribological properties. The final properties of the composite are heavily influenced by the arrangement of fibers within the matrix during mixing or lamination processes. The costliness of polymers has traditionally limited their widespread commercial use; however, the incorporation of fillers has led to improved properties of both the composite materials and the final products, ultimately reducing production costs. These composite materials find extensive applications across various industries, particularly in marine and plumbing sectors, where they offer exceptional environmental resistance and damage tolerance, particularly against impact loading [7]. Polymeric composites, in particular, see widespread use in aerospace applications, serving in components like rudders, elevators, fuselages, landing gears, gear doors, and fasteners due to their lightweight nature and high fatigue resistance. A new age has been brought about by the development of carbon, fiberglass, and high-modulus organic composites that are reinforced with fibers. characterized by lightweight, durable structural materials. Employing coupling agents in both the matrix and reinforcement, as well as chemical modifications to alter surface characteristics, has proven to be highly effective in achieving strong bonds between components [8]. Extensive Determining the cellular makeup of the transitional zone across the reinforcement and matrix, which is essential for guaranteeing chemical and mechanical stability, has been the focus of research. A significant factor influencing the durability of composites made from fibers is the degree of adhesive at the matrix-fiber surface junction. Therefore, maintaining robust interfacial adhesion is essential for ensuring the long-term performance and reliability of these composite materials [9]. A hybrid fiber-reinforced polymer (FRP) amalgamates various reinforcing grids and phases, ranging from single-team grids or reinforcements to multiple-team grids and phases. These hybrid compounds, comprising both natural and synthetic fibers, offer enhanced flexibility compared to single-fiber composites. They encompass a wide array of reinforcements, including natural fibers such as coir, jute, sisal, banana, bamboo, and abaca. The hybridization effects, particularly in combination with polyester resins, have been scrutinized for their role in augmenting the mechanical properties of these compounds [10]. This plays a significant role in potentially substituting or reducing the use of conventional materials in industries like construction, aviation, and transportation, where they find applications in sleeper berth packing, interiors, doors, windows, bus seats, and backs. While numerous studies have explored the studies concentrating particularly on natural hybrid fiber-reinforced polymers, the mechanical characteristics of natural fiber-reinforced composites are lacking. As such, this paper offers a summary that is particularly focused on sisal-glass fiber reinforced composites [11]. A composite material composed of particle-filled glass fibers, also known as Aggregates from minerals are added to glass fiber-reinforced polymeric composites (PC) to create particle-filled PC. into fused glasses, creating a fiber structure bonded with adhesive. They are both cost-effective and durable, owing to the combination of particles within the polymer matrix, which is optimized for size in composite formulation [12]. In the realm of fracture mechanics, studies have investigated the behavior of Particle-filled polymer composites, grout, and cement-based concrete to understand the response to multiple cracks. Various approaches, including Elastic Longitudinal Fracture Elastic-plastic fracture anatomy and mechanisms were once used to characterize critical parameters such as the critical pressure, intensity factors (KIC), and different specimen types. Techniques such as R-curve analysis, conformity approach, critical split orifice opening movement, and J-integral parameters have been utilized in this endeavour [13]. This particular study focuses on examining the Moderate I use single edge pitched columns engaged in three-point bending to study the fracture history and crack surfaces breaks of glass-fiber-reinforced polymeric composites. The ramifications of polyester resin and the way in which the polymer matrix containing glass fibers are analyzed in detail to understand their composition and performance characteristics. Fiber Reinforced Polymers (FRP) are versatile materials known for their diverse compositions and anisotropic nature, which means they exhibit different properties in different directions and do not undergo plastic deformation. These materials find extensive use in modern uses, especially in sectors like rocketry, aviation, and automobile manufacture, marine engineering, and sports equipment production [14]. Carbon Fiber Reinforced Polymer (CFRP) are two prominent types of composite materials within the FRP category. These materials combine fibers with polymer matrices, offering exceptional strength-to-weight ratios and specific properties like high fatigue resistance, hardness, heat resistance, and corrosion resistance. This versatility makes them highly desirable for various engineering applications [15]. In recent research, a literature review was conducted to explore the mechanical properties and associated methodologies of CFRP and GFRP composites. Carbon fiber-reinforced composites, CFRP, in particular, has gained prominence in the aviation industry due to its superior strength properties, leading to its increasing use in aircraft components such as doors, clips, small parts, wing components, and main body structures. These applications benefit from CFRP's lightweight nature, high strength, and resistance to fatigue. Similarly, GFRP compounds are also preferred in aerospace applications for their advantageous properties [16].

2. MATERIAL AND METHOD

Carbon Fiber-Reinforced Polymer Composites (CFRP): are an advanced material utilized in engineering and manufacturing. Constructed with carbon fibers integrated into a polymer matrix, CFRP possesses an outstanding strength-to-weight ratio, rendering it suitable for diverse applications. Across aerospace and automotive sectors, CFRP is progressively substituting conventional materials such as aluminum and steel, owing to its lightweight composition and superior mechanical attributes. These composite materials demonstrate remarkable stiffness, resistance to corrosion, and endurance against fatigue, making them indispensable for structures necessitating strength and durability while minimizing weight.

Natural Fiber-Reinforced Polymer Composites: NFRP composites incorporate natural fibers like bamboo, jute, or flax within a polymer matrix, offering benefits such as renewability, biodegradability, and minimal environmental impact. These lightweight materials are cost-effective and find utility across various sectors from automotive to construction. Aramid Fiber-Reinforced Polymer Composites: AFRP composites blend aramid fibers akin to Kevlar with a polymer matrix, boasting remarkable strength, stiffness, and resistance to wear and impact. Consequently, they are prevalent in applications necessitating robustness such as ballistic armor, aerospace components, and sporting goods.

Basalt Fiber-Reinforced Polymer Composites: BFRP composites employ basalt fibers sourced from volcanic rock, embedded within a polymer matrix. With attributes resembling glass fibers yet possessing superior tensile strength and resistance to heat and chemicals, BFRP composites excel in industries like infrastructure, marine, and automobile because of their resilience to oxidation and longevity.

Hybrid Composites: Hybrid composites merge different fiber types like carbon, glass, aramid, or natural fibers within a polymer matrix, enabling tailored performance characteristics for specific applications by leveraging the unique properties of each fiber. They are widely deployed across industries from aerospace to renewable energy for enhanced functionality.

Bio-based Composites: Bio-based composites utilize renewable resources such as cellulose, lignin, or starch reinforcing fibers combined with a biopolymer matrix. These materials offer environmental benefits including reduced carbon emissions and biodegradability, making them appealing alternatives to traditional composites. Bio-based composites are increasingly adopted in packaging, automotive interiors, and construction materials as sustainable options.

Mechanical Properties: The mechanical characteristics of a substance encompass its reaction to external forces, encompassing attributes such as robustness, rigidity, toughness, and malleability. These traits dictate the material's behavior under diverse stress scenarios, serving as pivotal factors in engineering design and material choice.

Durability and Environmental Resistance: Durability denotes a material's capacity to withstand degradation, wear, and harm over time, while environmental resilience encompasses its ability to endure various environmental stressors like moisture, chemicals, temperature fluctuations, and UV exposure. Materials exhibiting robust durability and environmental resistance are indispensable for applications subjected to adverse conditions, ensuring prolonged service life and dependability.

Manufacturability and Processing Characteristics: Manufacturability and processing features pertain to the ease with which a material can be transformed into a final product using manufacturing methods such as casting, machining, molding, or additive manufacturing. Considerations such as ease of handling, compatibility with manufacturing processes, and feasibility of achieving desired shapes and sizes influence material selection for specific applications.

Cost and Economic Considerations: Cost and economic factors encompass the overall expenses associated with acquiring, processing, and utilizing a product, encompassing initial material expenses, manufacturing outlays, maintenance costs, and life cycle expenditures. Striking a balance between performance requisites and budgetary constraints is crucial in optimizing the economic viability of material selection for a given application. Additionally, factors like raw material availability, market demand, and regulatory adherence may impact the economic feasibility of employing a particular product.

3. TOPSIS METHOD

TOPSIS, which stands for Technique for Order of Preference by Similarity to Ideal Solution, is a popular approach in multi-criterion decision-making (MCDM). It aids in ranking and selecting alternatives by comparing their similarities to an ideal solution. multiple criteria. This paper provides a comprehensive analysis of TOPSIS methodology, covering its principles, applications, and extensions. Through a detailed review of relevant literature, this study aims to deepen understanding of the theoretical foundations, computational procedures, and practical implementations of TOPSIS [17]. Additionally, recent advancements and emerging trends in TOPSIS research are discussed, along with potential future directions for its development and application in various domains. The concept of resemblance to ideal the solution. This is which ranks possibilities relative to how near and how far one is from the ideal result that is not desirable, forms the basis of TOPSIS. This section covers the conceptual underpinnings of TOPSIS, as well as the definition of ideal and environmental sciences. This section provides an overview of the TOPSIS methodology, outlining its basic principles, computational steps, and key features [18]. The foundation of TOPSIS is the idea of similarity to ideal solution, in which options are ranked according to how close they are to the perfect solution and how far they are from the undesirable ideal result. The theoretical underpinnings of TOPSIS are covered in this portion, along with the meaning of perfect and negative ideal solutions, determination of weights for criteria, and calculation of similarity measures. The computational procedure of TOPSIS involves several steps, including normalization of criteria values, determination of weighted normalizing judgment matrix, a calculation for each alternative's position in relation to the optimum solution, and the computation of positive and negative optimal options [19]. This section provides a detailed explanation of each step in the TOPSIS algorithm, along with illustrative examples. TOPSIS has been applied in various real-world decision-making problems, including supplier selection, project management, investment decision, and environmental impact assessment. This section reviews the applications of TOPSIS in different domains, highlighting its strengths, limitations, and practical considerations. Over the years, several extensions and variants of TOPSIS have been proposed to address specific challenges or incorporate additional features [20]. This section discusses some of the notable extensions of TOPSIS, such as fuzzy TOPSIS, interval-valued TOPSIS, and hesitant fuzzy TOPSIS, along with their theoretical underpinnings and practical implications. Recent advancements in TOPSIS research have focused on enhancing its computational efficiency, robustness, and applicability to complex decision-making problems. This section provides an overview of some of the latest developments in TOPSIS methodology, including hybrid approaches, metaheuristic optimization, and integration with other decision-making methods [21]. Despite its widespread use, TOPSIS still faces certain challenges and limitations, such as sensitivity to criteria weights, vulnerability to outliers, and difficulties in handling uncertainty. This section discusses potential future directions for TOPSIS research, including the development of more robust algorithms, incorporation of advanced uncertainty modelling techniques, and integration with emerging technologies such as artificial intelligence and machine learning [22]. TOPSIS is a powerful and versatile method for multi-criteria decision-making, with a wide range of applications across different domains. By providing a comprehensive analysis of TOPSIS methodology, this paper aims to contribute to a deeper understanding of its principles, applications, and extensions, and stimulate further research in this important field of decision analysis [23]. The TOPSIS ranking method has been assessed for its enhanced clarity compared to weighted average methods. An approach commonly utilized is the comprehensive global method within TOPSIS, aiming to optimize solutions, reduce uncertainty, ascertain response weights, and address multiple factors concurrently [24]. This technique is a sophisticated yet straightforward ranking engine. It endeavours to identify alternatives with the most advantageous optimal solutions. Favourable outcomes elevate advantage criteria and reduce cost criteria, while unfavourable outcomes do the opposite. Utilizing attribute data comprehensively, TOPSIS employs fuzzy membership functions and a census paper. Distinguished by its effectiveness, stability amidst parameter variations, and handling of multiple responses, TOPSIS stands as a notable method [25]. The algorithmic development emphasizes five distance metrics for rankings, with a comparative analysis encompassing various metrics and regression analysis to understand secondary influences. Despite its seeming rationality, TOPSIS faces criticisms. Issues such as neglecting the relative importance of sections, overlooking complexity, and its adaptation for multiple target selection are raised. Nevertheless, TOPSIS proves useful for regulatory performance analysis, option evaluations, and real-world decision-making scenarios, with extensions like E-TOPSIS facilitating effective integration of external weights [26].

4. RESULTS AND DISCUSSIONS

TABLE 1. Comparison of Composite Materials Based on Key Properties

Material Type	Mechanical Properties	Durability and Environmental Resistance	Manufacturability and Processing	Cost and Economic Considerations
Carbon Fiber-Reinforced Polymer Composites	51.36	65.96	89.68	25.63
Natural Fiber-Reinforced Polymer Composites	75.89	89.96	85.74	27.30
Aramid Fiber-Reinforced Polymer Composites	63.52	75.63	99.69	23.10
Basalt Fiber-Reinforced Polymer Composites	75.63	69.56	68.65	29.63
Hybrid Composites	65.56	79.65	63.74	26.36
Bio-based Composites	63.54	85.45	96.54	25.96

Table 1 shows the Analysis of Glass Fibre-Reinforced Polymer Composites for Analysis using the TOPSIS Method. Carbon Fiber-Reinforced Polymer Composites (CFRP), Natural Fiber-Reinforced Polymer Composites, Aramid Fiber-Reinforced Polymer Composites, Basalt Fiber-Reinforced Polymer Composites, Hybrid Composites and Bio-based Composites. Mechanical Properties, Durability and Environmental Resistance, Manufacturability and Processing Characteristics and Cost and Economic Considerations. It is that seen Mechanical Properties in Natural Fiber-Reinforced Polymer Composites exhibit the highest value (75.89), while Carbon Fiber-Reinforced Polymer Composites have the lowest value (51.36). Durability and Environmental Resistance in Natural Fiber-Reinforced Polymer Composites show the highest value (89.96), whereas Carbon Fiber-Reinforced Polymer Composites demonstrate the lowest value (65.96). Manufacturability and Processing Characteristics in Aramid Fiber-Reinforced Polymer Composites have the highest value (99.69), while Hybrid Composites exhibit the lowest value (63.74). Cost and Economic Considerations in Basalt Fiber-Reinforced Polymer Composites have the highest value (29.63), while Aramid Fiber-Reinforced Polymer Composites demonstrate the lowest value (23.10).

Figure 1 shows the Analysis of Glass Fibre-Reinforced Polymer Composites for Analysis using the TOPSIS Method. Carbon Fiber-Reinforced Polymer Composites (CFRP), Natural Fiber-Reinforced Polymer Composites, Aramid Fiber-Reinforced

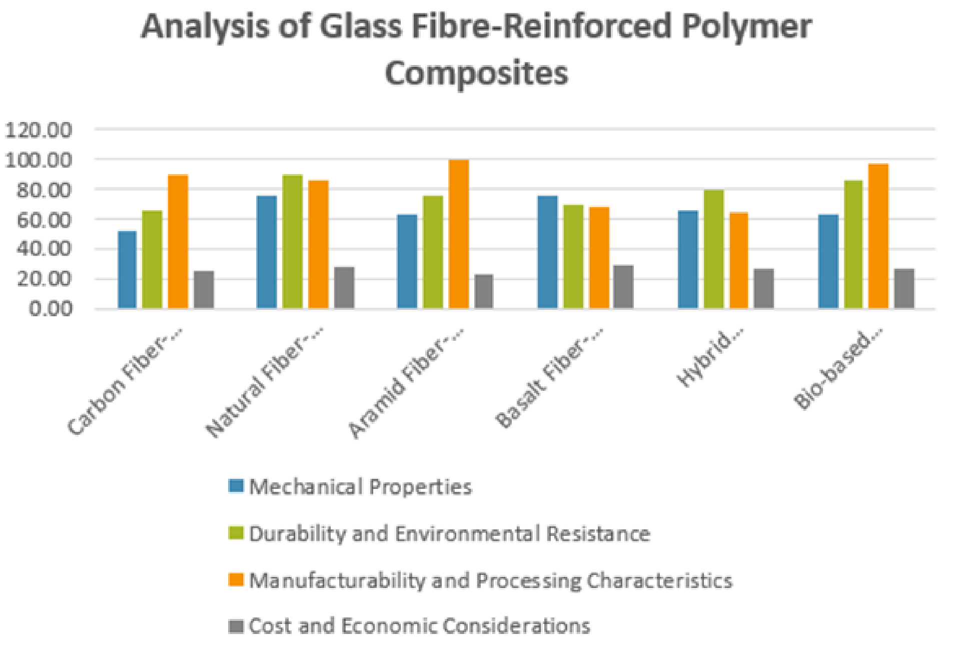

FIGURE 1. Analysis of Glass Fibre-Reinforced Polymer Composites

Polymer Composites, Basalt Fiber-Reinforced Polymer Composites, Hybrid Composites and Bio-based Composites. Mechanical Properties, Durability and Environmental Resistance, Manufacturability and Processing Characteristics and Cost and Economic Considerations. It is that seen Mechanical Properties in Natural Fiber-Reinforced Polymer Composites exhibit the highest value (75.89), while Carbon Fiber-Reinforced Polymer Composites have the lowest value (51.36). Durability and Environmental Resistance in Natural Fiber-Reinforced Polymer Composites show the highest value (89.96), whereas Carbon Fiber-Reinforced Polymer Composites demonstrate the lowest value (65.96). Manufacturability and Processing Characteristics in Aramid Fiber-Reinforced Polymer Composites have the highest value (99.69), while Hybrid Composites exhibit the lowest value (63.74). Cost and Economic Considerations in Basalt Fiber-Reinforced Polymer Composites have the highest value (29.63), while Aramid Fiber-Reinforced Polymer Composites demonstrate the lowest value (23.10).

TABLE 2. Normalized Data

Mechanical Properties	Durability and Environmental Resistance	Manufacturability and Processing Characteristics	Cost and Economic Considerations
0.3156	0.3446	0.4303	0.3963
0.4663	0.4699	0.4114	0.4221
0.3903	0.3951	0.4784	0.3572
0.4647	0.3634	0.3294	0.4582
0.4028	0.4161	0.3059	0.4076
0.3904	0.4464	0.4633	0.4014

Table 2 this normalized data provides a relative comparison of each type of fiber-reinforced polymer composite across the different criteria. Mechanical Properties: The highest value is 0.4663, corresponding to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.3156, associated with Carbon Fiber-Reinforced Polymer Composites. Durability and Environmental Resistance: The highest value is 0.4699, again attributed to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.3446, related to Carbon Fiber-Reinforced Polymer Composites. Manufacturability and Processing Characteristics: The highest value is 0.4784, which belongs to Aramid Fiber-Reinforced Polymer Composites. The lowest value is 0.3059, corresponding to Hybrid Composites. Cost and Economic Considerations: The highest value is 0.4582, attributed to Basalt Fiber-Reinforced Polymer Composites. The lowest value is 0.3572, associated with Aramid Fiber-Reinforced Polymer Composites. Normalized value is obtained by using the formula (1). Table 3 shows Weightages used for the analysis. We taken same weights for all the parameters for the analysis.

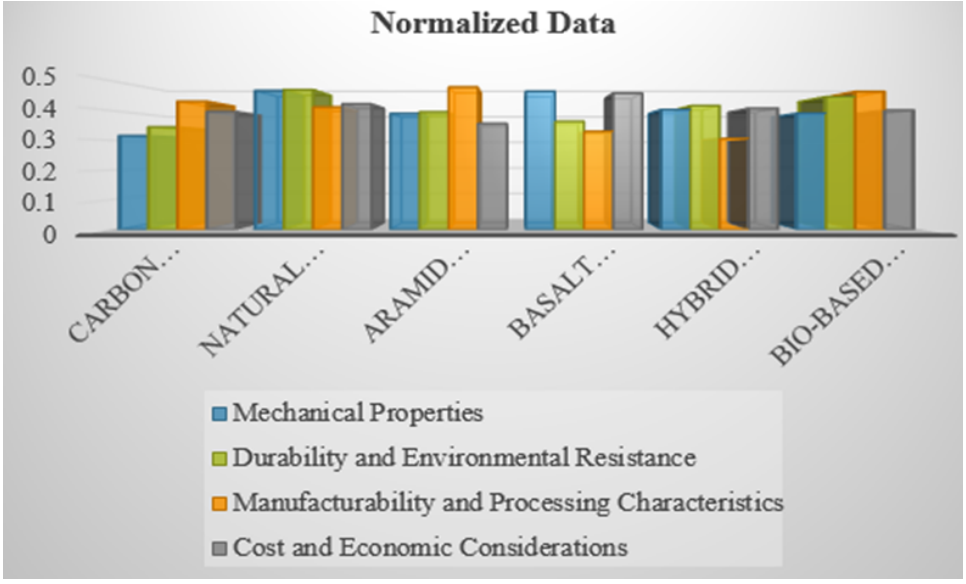

FIGURE 2. Normalized Data

Figure 2 This normalized data provides a relative comparison of each type of fiber-reinforced polymer composite across the different criteria. Mechanical Properties: The highest value is 0.4663, corresponding to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.3156, associated with Carbon Fiber-Reinforced Polymer Composites. Durability and Environmental Resistance: The highest value is 0.4699, again attributed to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.3446, related to Carbon Fiber-Reinforced Polymer Composites. Manufacturability and Processing Characteristics: The highest value is 0.4784, which belongs to Aramid Fiber-Reinforced Polymer Composites. The lowest value is 0.3059, corresponding to Hybrid Composites. Cost and Economic Considerations: The highest value is 0.4582, attributed to Basalt Fiber-Reinforced Polymer Composites. The lowest value is 0.3572, associated with Aramid Fiber-Reinforced Polymer Composites. Normalized value is obtained by using the formula (1).

TABLE 3. Weightages

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
0.25	0.25	0.25	0.25

$$X_{\text{wnormal}1} = X_{n1} \times w_1$$

Table 3 shows Weightages used for the analysis. We taken same weights for all the parameters for the analysis.

TABLE 4. Weighted Normalized Decision Matrix

Composite Material	C1	C2	C3	C4
Carbon Fiber-Reinforced Polymer Composites (CFRP)	0.0789	0.0861	0.1076	0.0991
Natural Fiber-Reinforced Polymer Composites	0.1166	0.1175	0.1029	0.1055
Aramid Fiber-Reinforced Polymer Composites	0.0976	0.0988	0.1196	0.0893
Basalt Fiber-Reinforced Polymer Composites	0.1162	0.0908	0.0824	0.1145
Hybrid Composites	0.1007	0.1040	0.0765	0.1019
Bio-based Composites	0.0976	0.1116	0.1158	0.1004

Table **??** This weighted normalized decision matrix provides a comprehensive evaluation of each type of fiber-reinforced polymer composite, considering the specified criteria with their respective weights. Mechanical Properties: The highest value is 0.1166, attributed to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.0789, associated with Carbon Fiber-Reinforced Polymer Composites. Durability and Environmental Resistance: The highest value is 0.1175, also for Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.0861, corresponding to Carbon Fiber-Reinforced Polymer Composites. Manufacturability and Processing Characteristics: The highest value is 0.1196, which belongs to Aramid Fiber-Reinforced Polymer Composites. The lowest value is 0.0765, related to Hybrid Composites. Cost and Economic Considerations: The highest value is 0.1145, attributed to Basalt Fiber-Reinforced Polymer Composites. The lowest value is 0.0893, associated with Aramid Fiber-Reinforced Polymer Composites. To figure out the weighted normalized decision matrix, we used the formula (2).

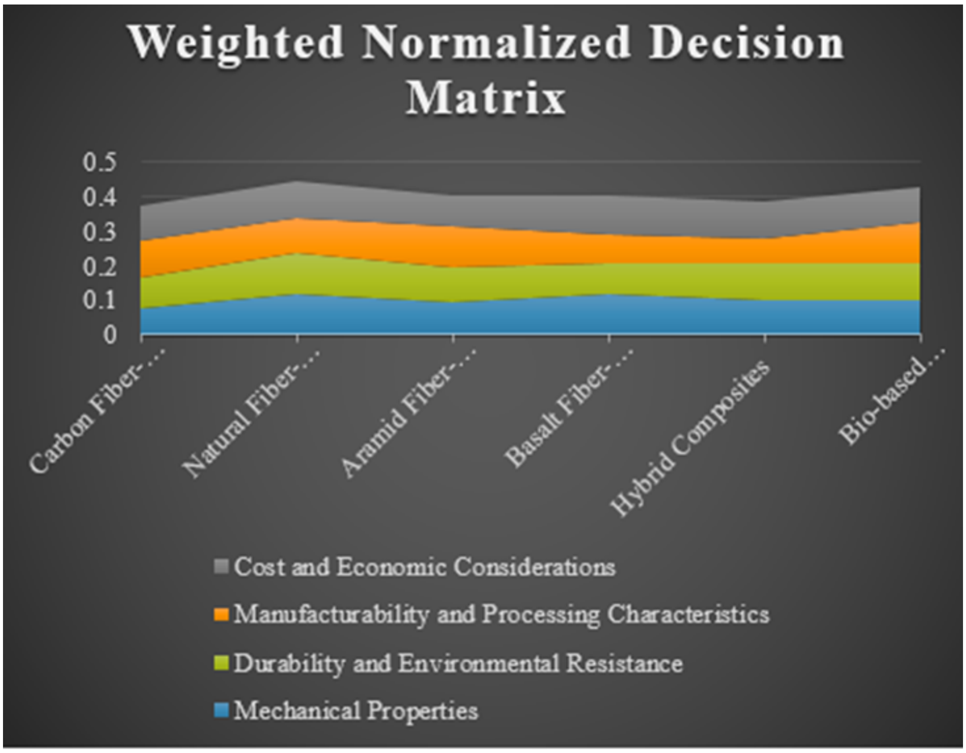

FIGURE 3. Weighted Normalized Decision Matrix

Figure 3 This weighted normalized decision matrix provides a comprehensive evaluation of each type of fiber-reinforced polymer composite, considering the specified criteria with their respective weights. Mechanical Properties: The highest value is 0.1166, attributed to Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.0789, associated with Carbon Fiber-Reinforced Polymer Composites. Durability and Environmental Resistance: The highest value is 0.1175, also for Natural Fiber-Reinforced Polymer Composites. The lowest value is 0.0861, corresponding to Carbon Fiber-Reinforced Polymer Composites. Manufacturability and Processing Characteristics: The highest value is 0.1196, which belongs to Aramid Fiber-Reinforced Polymer Composites. The lowest value is 0.0765, related to Hybrid Composites. Cost and Economic Considerations: The highest value is 0.1145, attributed to Basalt Fiber-Reinforced Polymer Composites. The lowest value is 0.0893, associated with Aramid Fiber-Reinforced Polymer Composites. To figure out the weighted normalized decision matrix, we used the formula (2).

Table 5 These matrices provide a comparative perspective on the positive and negative aspects of each type of fiber-reinforced polymer composite based on the specified criteria. Positive Matrix in The highest values in each row of the positive matrix are 0.1196, representing Aramid Fiber-Reinforced Polymer Composites. The lowest values in each row of the positive matrix are 0.0765, associated with Hybrid Composites. Negative Matrix in The highest values in each row of the negative matrix are 0.1196, also attributed to Aramid Fiber-Reinforced Polymer Composites. The lowest values in each row of the negative matrix are 0.0765, corresponding to Hybrid Composites.

TABLE 5. Positive Matrix and Negative Matrix

Positive Matrix				Negative Matrix			
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145
0.1166	0.1175	0.0765	0.0893	0.0789	0.0861	0.1196	0.1145

TABLE 6. Separation Measures, Closeness Coefficient, and Rank

Material	SI Plus	SI Negative	Ci	Rank
Carbon Fiber-Reinforced Polymer Composites (CFRP)	0.0589	0.0196	0.2496	6
Natural Fiber-Reinforced Polymer Composites	0.0310	0.0526	0.6291	2
Aramid Fiber-Reinforced Polymer Composites	0.0507	0.0338	0.4003	5
Basalt Fiber-Reinforced Polymer Composites	0.0372	0.0529	0.5873	3
Hybrid Composites	0.0243	0.0531	0.6856	1
Bio-based Composites	0.0454	0.0348	0.4339	4

Table 5 shows the final result of TOPSIS for Analysis of Glass Fibre-Reinforced Polymer Composites. Figure 3 shows the TOPSIS Analysis Result of Alternative Energy Exploitation. In Table 6, Si positive is calculated using the formula (3). From The ranking is based on the Ci values, where Hybrid Composites rank first with a Ci value of 0.6856, followed by Natural Fiber-Reinforced Polymer Composites, Basalt Fiber-Reinforced Polymer Composites, Aramid Fiber-Reinforced Polymer Composites, Bio-based Composites, and finally Carbon Fiber-Reinforced Polymer Composites with a Ci value of 0.2496, placing them last in ranking. For Si Plus (Si+), Hybrid Composites have the highest value of 0.0243, while Natural Fiber-Reinforced Polymer Composites have the lowest value of 0.0589. For Si Negative (Si-), Hybrid Composites have the highest value of 0.0531, while Carbon Fiber-Reinforced Polymer Composites have the lowest value of 0.0196. Ci represents the composite index, which is a combination of Si+ and Si-. Hybrid Composites have the lowest value of 0.6856, indicating the highest overall ranking, while Natural Fiber-Reinforced Polymer Composites have the highest value of 0.2496, indicating the lowest overall ranking. figure 3, Si Negative is calculated using the formula (4).

$$X_{si+1} = \sqrt{(X_{wn1} - X_{p1})^2 + (Y_{wn1} - Y_{p1})^2 + (Z_{wn1} - Z_{p1})^2} \tag{3}$$

$$X_{si-1} = \sqrt{(X_{wn1} - X_{n1})^2 + (Y_{wn1} - Y_{n1})^2 + (Z_{wn1} - Z_{n1})^2} \tag{4}$$

$$X_{ci1} = \frac{X_{si-1}}{X_{si+1} + X_{si-1}} \tag{5}$$

Figure **??** shows the final result of TOPSIS for Analysis of Glass Fibre-Reinforced Polymer Composites. Figure 3 shows the TOPSIS Analysis Result of Alternative Energy Exploitation. In Table 6, Si positive is calculated using the formula (3). From The ranking is based on the Ci values, where Hybrid Composites rank first with a Ci value of 0.6856, followed by Natural Fiber-Reinforced Polymer Composites, Basalt Fiber-Reinforced Polymer Composites, Aramid Fiber-Reinforced Polymer Composites, Bio-based Composites, and finally Carbon Fiber-Reinforced Polymer Composites with a Ci value of 0.2496, placing them last in ranking. For Si Plus (Si+), Hybrid Composites have the highest value of 0.0243, while Natural Fiber-Reinforced Polymer Composites have the lowest value of 0.0589. For Si Negative (Si-), Hybrid Composites

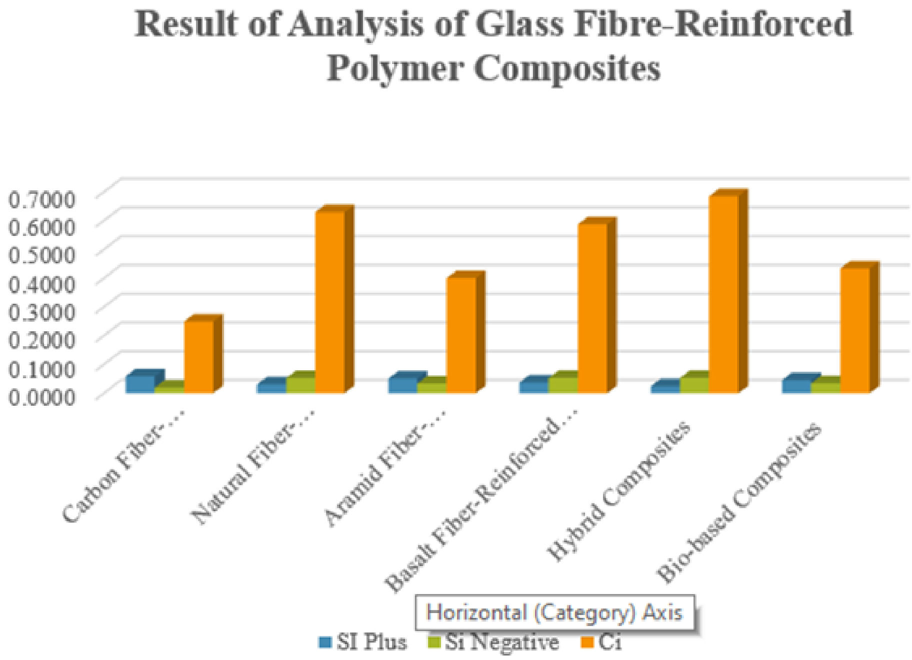

FIGURE 4. Result of Analysis of Glass Fibre-Reinforced Polymer Composites

have the highest value of 0.0531, while Carbon Fiber-Reinforced Polymer Composites have the lowest value of 0.0196. Ci represents the composite index, which is a combination of Si+ and Si-. Hybrid Composites have the lowest value of 0.6856, indicating the highest overall ranking, while Natural Fiber-Reinforced Polymer Composites have the highest value of 0.2496, indicating the lowest overall ranking. figure 3, Si Negative is calculated using the formula (4).

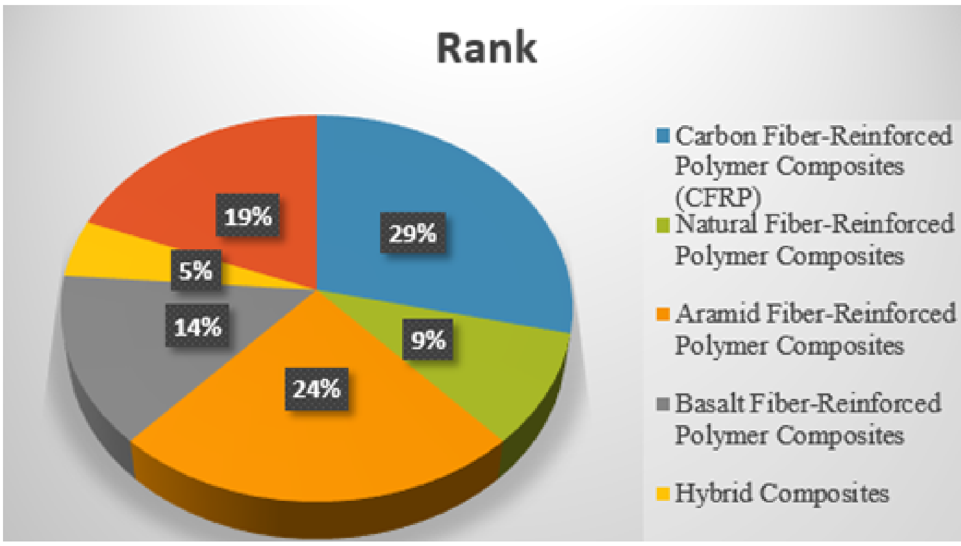

FIGURE 5. Rank

Figure 5 shows the final result of TOPSIS for Analysis of Glass Fibre-Reinforced Polymer Composites. Hybrid Composites have the highest rank (1). and Carbon Fiber-Reinforced Polymer Composites (CFRP) have the lowest rank (6).

5. CONCLUSION

Glass fiber-reinforced Polymer Composites (GFRPs) at their best mechanical properties, Lightweight design, corrosion resistance and In various industrial sectors have become important commodities. adaptability. This study offers a comprehensive analysis of GFRPs, examining their composition, manufacturing techniques, properties, recent advancements, challenges, and wide-ranging applications. This study attempts to increase comprehension of by a thorough analysis of pertinent literature. both the potentials and limitations of GFRPs in contemporary engineering and manufacturing. The composition of GFRPs is explored, highlighting the importance of a glass fiber-reinforced polymers matrix. Numerous polymer matrices, including polyethylene, the epoxy, or vinyl ester resin, are scrutinized for their bonding abilities and capacity to transmit loads. Glass fiber-reinforced polymer composites (GFRPs) have emerged as a significant material category across diverse industrial sectors, owing to their remarkable mechanical properties, lightweight construction, corrosion resistance, and adaptable design features. This introduction aims to furnish a comprehensive overview of GFRPs, delving into their composition, manufacturing processes, properties, recent advancements, challenges, and wide-ranging applications. Through a thorough examination of pertinent literature, this paper seeks to deepen comprehension regarding the potentials and constraints of GFRPs in contemporary engineering and manufacturing.. Nanostructured reinforcements, hybrid fiber systems, and advanced manufacturing techniques are explored for their contributions to enhancing strength, durability, and processability of GFRPs. Challenges facing GFRPs are identified and scrutinized, encompassing issues related to recyclability, environmental impact, long-term sustainability, and bonding between fiber and matrix phases. Strategies for overcoming these challenges are proposed, including material selection, process optimization, and development of recycling technologies. TOPSIS, which stands for Technique for Order of Preference by Similarity to Ideal Solution, is a popular approach in multi-criterion decision-making (MCDM). It aids in ranking and selecting alternatives by comparing their similarities to an ideal solution. multiple criteria. This paper provides a comprehensive analysis of TOPSIS methodology, covering its principles, applications, and extensions. Through a detailed review of relevant literature, this study aims to deepen understanding of the theoretical foundations, computational procedures, and practical implementations of TOPSIS Carbon Fiber-Reinforced Polymer Composites (CFRP), Natural Fiber-Reinforced Polymer Composites, Aramid Fiber-Reinforced Polymer Composites, Basalt Fiber-Reinforced Polymer Composites, Hybrid Composites and Bio-based Composites. Mechanical Properties, Durability and Environmental Resistance, Manufacturability and Processing Characteristics and Cost and Economic Considerations. the final result of TOPSIS for Analysis of Glass Fibre-Reinforced Polymer Composites. Hybrid Composites have the highest rank (1). and Carbon Fiber-Reinforced Polymer Composites (CFRP) have the lowest rank (6).

REFERENCES

[1]. Sathishkumar, T. P., S. Satheeshkumar, and Jesuarockiam Naveen. "Glass fiber-reinforced polymer composites–a review." Journal of reinforced plastics and composites 33, no. 13 (2014): 1258-1275.

[2]. DiBenedetto, Anthony T. "Tailoring of interfaces in glass fiber reinforced polymer composites: a review." Materials Science and Engineering: A 302, no. 1 (2001): 74-82.

[3]. Yalavarthi, Sreekanth, Satya Sukumar Makkapati, Haritha Murari, K. S. Balamurugan, and P. Rajendran. "Advanced Breast Cancer Diagnostics Through a Comparative Analysis of SVM, Random Forests, and Neural Networks in MRI Image Analysis." In 2024 Asian Conference on Communication and Networks (ASIANComNet), pp. 1-7. IEEE, 2024.

[4]. Manjula selvam, Vidhya Prasanth, M. Ramachandran, Ramya Sharama, "A Study on Economic Models of Animal Communication Methods" Journal on Innovations in Teaching and Learning, 3(2), June 2024, 13-19.

[5]. Rana, R. S., and Rajesh Purohit. "A Review on mechanical property of sisal glass fiber reinforced polymer composites." Materials Today: Proceedings 4, no. 2 (2017): 3466-3476.

[6]. Avci, A., H. Arikan, and A. Akdemir. "Fracture behavior of glass fiber reinforced polymer composite." Cement and Concrete Research 34, no. 3 (2004): 429-434.

[7]. Rajender Radharam, "Empirical Evaluation of Cloud Migration Performance Using Gradient Boosting Models", Journal of Business Intelligence and Data Analytics, 2(3), 2025, 1-8.

[8]. Karataş, Meltem Altin, and Hasan Gökkaya. "A review on machinability of carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) composite materials." Defence Technology 14, no. 4 (2018): 318-326.

[9]. Sanjay, M. R., and B. Yogesha. "Studies on natural/glass fiber reinforced polymer hybrid composites: An evolution." Materials today: proceedings 4, no. 2 (2017): 2739-2747.

[10]. Poonkodi Sathiyamoorthy, Vimala Saravanan, M. Ramachandran, Devipriya Mani, "REST Journal on Advances in Mechanical Engineering" REST Journal on Advances in Mechanical Engineering, 4(3), 2025, 13-25.

[11]. Palanikumar, K., L. Karunamoorthy, and R. Karthikeyan. "Assessment of factors influencing surface roughness on the machining of glass fiber-reinforced polymer composites." Materials & design 27, no. 10 (2006): 862-871.

[12]. Bilquis Ali and Prabha Patil Rajendra Kattunga, "Predictive Performance Modeling of Java-Based Microservices in Dynamic

Cloud Environments Using Machine Learning Focus: ML prediction and Java optimization", International Journal of Cloud Computing and Supply Chain Management, 1(4), 2025, 1-7.
[13]. Wu, H. F., D. W. Dwight, and N. T. Huff. "Effects of silane coupling agents on the interphase and performance of glass-fiber-reinforced polymer composites." Composites Science and Technology 57, no. 8 (1997): 975-983.
[14]. Azmi, A. I., R. J. T. Lin, and D. Bhattacharyya. "Tool wear prediction models during end milling of glass fibre-reinforced polymer composites." The International Journal of Advanced Manufacturing Technology 67 (2013): 701-718.
[15]. Rajender Radharam, "Effective Detection of Down Syndrome from Facial Expressions Using Deep Learning Predictive Models", International Journal of Research in Computer Applications and Information Technology, 8(5), 2025, 9-37.
[16]. Pender, K., and L. Yang. "Investigation of the potential for catalysed thermal recycling in glass fibre reinforced polymer composites by using metal oxides." Composites Part A: Applied Science and Manufacturing 100 (2017): 285-293.
[17]. Makkapati, Satya Sukumar, and N. Nagamalleswara Rao. "COVID-19 disease detection using attention based Bi-Directional capsule network model." Biomedical Signal Processing and Control 96 (2024): 106636.
[18]. Khan, MZ Shah, G. Simpson, and E. P. Gellert. "Resistance of glass-fibre reinforced polymer composites to increasing compressive strain rates and loading rates." Composites Part A: Applied Science and Manufacturing 31, no. 1 (2000): 57-67.
[19]. Soundarapandian, Divya. "Algorithmic Framework for Retail Media Optimization and Consumer Engagement Enhancement." Journal of Business Intelligence and Data Analytics 1, no. 3 (2024): 1-7.
[20]. Choudhury, I. A., and P. C. Chuan. "Experimental evaluation of laser cut quality of glass fibre reinforced plastic composite." Optics and Lasers in Engineering 51, no. 10 (2013): 1125-1132.
[21]. Madhu, S., and M. Balasubramanian. "Impact of nozzle design on surface roughness of abrasive jet machined glass fibre reinforced polymer composites." Silicon 10, no. 6 (2018): 2453-2462.
[22]. S Bakshi, S Sharma, R Khanna, "Shapley-value-based hybrid metaheuristic multi-objective optimization for energy efficiency in an energy-harvesting cognitive radio network", Mathematics, 11(7), 2023, 1656-1666.
[23]. Asokan, Pappu, Mohamed Osmani, and Andrew DF Price. "Assessing the recycling potential of glass fibre reinforced plastic waste in concrete and cement composites." Journal of Cleaner Production 17, no. 9 (2009): 821-829.
[24]. Nguong, C. W., S. N. B. Lee, and D. Sujan. "A review on natural fibre reinforced polymer composites." International Journal of Materials and Metallurgical Engineering 7, no. 1 (2013): 52-59.
[25]. Liu, Xiaojiang, Wei Shian Tey, Pengfei Tan, Kah Kit Leong, Jiayao Chen, Yujia Tian, Adrian Ong, Lihua Zhao, and Kun Zhou. "Effect of the fibre length on the mechanical anisotropy of glass fibre–reinforced polymer composites printed by Multi Jet Fusion." Virtual and Physical Prototyping 17, no. 3 (2022): 734-748.
[26]. Rajendra Kattunga, "Cross-Functional SAP EWM Integration with SD, MM, 3PL, Production, and Quality management", International Journal of Research and Analytical Reviews (IJRAR), 12(3), 932-927.
[27]. Zavadskas, Edmundas Kazimieras, Abbas Mardani, Zenonas Turskis, Ahmad Jusoh, and Khalil MD Nor. "Development of TOPSIS method to solve complicated decision-making problems—An overview on developments from 2000 to 2015." International Journal of Information Technology & Decision Making 15, no. 03 (2016): 645-682.
[28]. Naidu Paila, "Heuristic Planning to Agentic AI, Transforming Demand and Supply Planning in SAP IBP", Journal of Computer Science Applications and Information Technology, 9(2), 2024, 1-15
[29]. Behzadian, Majid, S. Khanmohammadi Otaghsara, Morteza Yazdani, and Joshua Ignatius. "A state-of the-art survey of TOPSIS applications." Expert Systems with applications 39, no. 17 (2012): 13051-13069.
[30]. Perikala, Karthik. "Architecting MCP-Based Platforms for Enterprise-Scale Agentic Generative AI." Journal of Business Intelligence and Data Analytics 2(3), 2025, 1-8.
[31]. Salih, Mahmood M., B. B. Zaidan, A. A. Zaidan, and Mohamed A. Ahmed. "Survey on fuzzy TOPSIS state-of-the-art between 2007 and 2017." Computers & Operations Research 104 (2019): 207-227.
[32]. Shukla, Atul, Pankaj Agarwal, R. S. Rana, and Rajesh Purohit. "Applications of TOPSIS algorithm on various manufacturing processes: a review." Materials Today: Proceedings 4, no. 4 (2017): 5320-5329.
[33]. A Bansal, S Sharma, R Khanna, "Compact meandered folded-dipole RFID tag antenna for dual band operation in UHF range" Wireless Personal Communications, 114(4), 2020, 3321-3336.
[34]. Opricovic, Serafim, and Gwo-Hshiung Tzeng. "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS." European journal of operational research 156, no. 2 (2004): 445-455.
[35]. Priya, K. Janaki, M. Ramachandran, Kurinjimalar Ramu, and Malarvizhi Mani. "Social Media Communication Using TOPSIS Method." Social Media Communication Using TOPSIS Method 1, no. 3 (2022): 27-35.
[36]. Paila, Naidu. "Artificial Intelligence for Accurate Service Level Assessment in Modern Inventory Management." Journal of Business Management and Entrepreneurship 3, no. 1 (2024): 1-10.
[37]. Jahanshahloo, Gholam Reza, F. Hosseinzadeh Lotfi, and Mohammad Izadikhah. "An algorithmic method to extend TOPSIS for decision-making problems with interval data." Applied mathematics and computation 175, no. 2 (2006): 1375-1384.
[38]. Soundarapandian, Divya. "Machine Learning Algorithms for Optimizing Search Personalization and Site Reliability in E-Commerce Platforms: A Comparative Analysis of Linear Regression, SVR, and AdaBoost." Journal of Artificial Intelligence and Machine Learning 3, no. 4 (2025), 1-7.
[39]. Kuo, Ting. "A modified TOPSIS with a different ranking index." European journal of operational research 260, no. 1 (2017): 152-160.
[40]. Perikala, Karthik. "Structured Language Interpretation Using Small Language Models for Real-Time Systems." Journal of Data

Science and Information Technology 2 (2), 2025, 1-6.
[41]. Shih, Hsu-Shih, Huan-Jyh Shyur, and E. Stanley Lee. "An extension of TOPSIS for group decision making." Mathematical and computer modelling 45, no. 7-8 (2007): 801-813.
[42]. Chen, Pengyu. "Effects of the entropy weight on TOPSIS." Expert Systems with Applications 168 (2021): 114186.