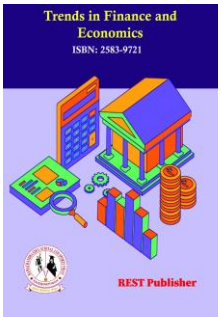
Trends in Finance and Economics

Vol: 2(3), September 2024

REST Publisher; ISSN: 2583-9721 (Online)

Website: https://restpublisher.com/journals/tfe/

DOI: https://doi.org/10.46632/tfe/2/3/1



Role of Green Building Materials in Reducing Environmental and Human Health Impacts Using VIKOR Method

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Abstract: *Green Building Materials (GBMs) are construction materials Green building materials (GBMs), sustainable building practices, resource conservation, energy efficiency, indoor air quality, environmental impact reduction, and renewable and recyclable materials. The drive to adopt GBMs is fueled by the need to reduce energy consumption, cut greenhouse gas emissions, and preserve natural resources. By incorporating renewable, recyclable, and non-toxic elements, GBMs are integral to sustainable building practices, ensuring a balance between development and environmental responsibility. Growing awareness of environmental challenges and the emphasis on sustainable development have made green building materials a central focus in contemporary construction. Environmental Impact Reduction: GBMs help decrease the environmental footprint of construction by cutting waste, cutting greenhouse gas emissions, and using less energy. These minerals are essential for maintaining ecosystems and halting climate change. Health & Well-Being: Research on GBMs makes it easier to create materials that improve indoor air quality and reduce exposure to dangerous pollutants, which benefits building occupants' comfort and health. Resource Conservation: This study promotes the use of recyclable and renewable materials, helping to preserve the planet's finite natural resources and encouraging the building sector to implement circular economy principles. Alternatives taken as Bamboo, Recycled Steel, Cork, Rammed Earth, Hempcrete, Straw Bale. Evaluation Parameters taken as Thermal Insulation (Benefit), Sustainability Score (Benefit), Cost per Square Meter (Non-Benefit), CO2 Emissions during Production (Non-Benefit). The results indicate that Recycled Steel achieved the highest rank, while Straw Bale had the lowest rank being attained. "The value of the dataset for Green Building Materials, according to the VIKOR, Recycled Steel achieves the highest ranking."*

Key words: *Green Building Materials (GBMs), Sustainable Construction, Environmental Impact Reduction, Resource Conservation, Renewable Materials, Recyclable Materials, Indoor Air Quality, Energy Efficiency.*

1. INTRODUCTION

From the outset, new development must be more cost-effective. This approach not only minimizes the negative impacts of construction and projects but also extends the lifespan of buildings. Elements with shorter lifespans should be designed for reuse or raw material recovery. Achieving this requires careful segmentation of the building's complexity into its components, ensuring that the integration of these parts is practical and clear. Effective exchange between integrated structures should aim for a purely supportive and sustainable arrangement. [1] While many materials can retain thermal energy, ceramic stands out for its ability to store energy for extended periods and release it only when necessary. Each module within the ceramic acts like a battery, with sufficient pressure to release energy. Beyond direct heat application, thermal energy can also be stored through electrical currents or light radiation. This material allows for the repeated absorption and release of thermal energy through multiple methods. [2]. There are indications that people's perspectives on sustainable development are evolving. Principles of "Green Building Design" are increasingly influencing design practices and shaping the architectural community. The American Green Building Council created a rating system as a guide for green and sustainable design, initially intended for the federal government. This The "Leadership in Energy and Environmental Design" (LEED) system is currently considered the norm. In its original or modified form, it has been adopted by many government agencies and plays a role in promoting energy efficiency. [3] The Green Building Council has recognized that polyvinyl chloride (PVC) building materials contain toxic levels of chlorine, and that dioxin emissions from PVC make it one of the worst materials for human health. The environmental effects and health concerns associated with using bio composites in place of conventional building materials (CBMs) can be reduced, therefore mitigating this problem. Prior studies have demonstrated that bio composites transform non-renewable materials, like petroleum-based composites, into renewable resources, particularly reducing indoor air pollutants such as VOC emissions. A bio composite known as GBM, made from biopolymer and natural fibers, is effective in lowering indoor air pollution and minimizing overall environmental and health impacts. [4] Fungal growth can harm both inorganic and green building materials, but it is most common in cellulose-rich, organic-based materials. Significant fungal growth was seen following natural exposure to indigenous fungus, particularly on cellulose-rich items like paper-free mineral ceiling tiles and drywall. In contrast, these materials offered little to no support for fungal development. Additionally, the time before fungal growth began was minimal, even though the materials were exposed only to high humidity rather than direct moisture immersion. [5] Green Building and Green Building Materials: This paper presents BMI as an important source of information for studies about the green shift. Few research discusses green building materials, even though many of the cited studies concentrate exclusively on green buildings. It is common for these studies to focus on the disposal, recycling, and reuse of building materials. Nevertheless, the use of evolutionary game theory to apply BMI to GBMI for the sustainable growth of cities is still relatively new. uncommon. [6] Customers and builders can choose eco-friendly items with the help of directories of green building materials and other resources. It is common for the standards used to choose environmentally friendly items to be arbitrary, thus a product may do very well in one area but terribly in another. Green products are one often utilized criterion. should have low emissions. [7] Green building practices lessen environmental impact and contribute to mitigating global warming. The concept of green buildings and smart living presents a significant opportunity to transform the lifestyle of the average Indian. As public awareness of the advantages of green buildings increases, developers will become more innovative in branding, marketing, and selling these structures. This shift will foster a favorable environment for the sector’s rapid growth. [8] The usefulness of bamboo as a green building material is very low in China, despite the country having a significant amount of naturally occurring bamboo. Bamboo is used far less frequently in building in China than in other nations, even though the country is home to an estimated 5.38 million hectares of bamboo forests. It has been observed that bamboo products are mostly utilized in China to make basic handcrafted goods like curtains, mats, and baskets. Just a small number of businesses are focused on producing and using bamboo. for construction purposes. [9] To be When asked to take part in the survey, participants must fulfill two requirements: They ought to have a lot of expertise working in Malaysia's construction industry and possess in-depth knowledge of green building materials. [10] The rising trend in green building development is driving growth in the green building materials industry and related services in India. Sustainable building involves various strategies throughout the design, construction, and operation of a project. Incorporating green building materials is a key aspect of these strategies, impacting both design and operational practices. [11] They stressed that the proposed approach to encouraging the use of affordable green building materials in mainstream housing should ensure that design professionals have easy access to comprehensive information about available options. This would help make the selection process more equitable and standardized during the design phase. [12] Do not arbitrarily break the entire structure; instead, separate individual bamboo fibers similar to wood. The resulting splinters follow the direction of the fibers, which minimizes their impact on critical areas. This process delays the energy transfer through diffusion. [13] Over the past decade, numerous There are now publications available on sustainable building materials. Scientists and organizations in poor nations are increasingly concentrating on locally accessible green building materials, with a special emphasis on bamboo, to guarantee that housing is both suitable and inexpensive. [14] Architecture values characteristics like robustness and adaptability, emphasizing the necessity of selecting regional construction materials from the surrounding area and putting associated tactics and approaches into practice in green structures. Vernacular architecture principles respect the community's culture and legacy, reverence the natural world, take the climate into consideration, and are user-friendly. as well as the environment. [15] Green Building Rating (GBR) systems streamline standard design processes by offering independent assessment tools. These systems allow for the evaluation of strategies aimed at enhancing sustainability, covering a range of categories from energy efficiency to water resource management. [16] "Green" or "sustainable" buildings utilize resources such as energy, water, materials, and land more efficiently than those constructed to current codes. With enhanced natural light and improved ventilation, green buildings typically promote better health, comfort, and productivity for occupants. [17] These factors are strong incentives for local and foreign companies to make investments in sustainable housing to accommodate the world's expanding population. Recognizing the possible advantages of using green building materials (GBM) will boost customer interest and help enhance demand and the dynamics of green building provision. As demand rises, it creates the need for a corresponding supply in the market. [18] Cracks affect a building's structural lifetime, but they also compromise its structural integrity. Applying a barrier layer to the surface can significantly enhance the effectiveness of eco-friendly, low-energy green building materials by preventing moisture absorption. [19] The Environmental Assessment Methodology for Building Research Establishments (BREEAM) and the Green Star system from the Green Building Council of Australia have emerged to assist the construction industry in adopting green building practices by offering guidelines for green buildings. Among these green standards, the Green Building Standard is considered the most effective green building rating system. [20]

2. MATERIALS AND METHODS

The method centers on evaluating and choosing from a range of options while finding workable solutions to the issue. choice-makers can reach a final choice with the help of competing criteria. An in this case, the closest thing to the optimum solution is referred to as a compromise, which implies a consensus established through reciprocal concessions.

[21] The first example shows how the suggested model works and emphasizes how important it is to choose goal values for the subject. In order to validate the suggested model, Examples 2-4 and the last example shows how the novel approach resolves a significant flaw found in VIKOR. [22] The core idea of the VIKOR technique is to establish both positive and negative ideal solutions. Its primary goal is to prioritize and select from a limited set of workable possibilities that include standards that are incompatible and conflicting. By means of a multi-criteria ranking index, the method evaluates every choice based on how "close" it is. to the "ideal" solution. Every option is assessed across all criteria, allowing for a compromise ranking by comparing their relative proximity to the optimal alternative. [23] In the framework of as a matching tool for Multi-Criteria Decision Making (MCDM), the VIKOR method is provided. It is intended to be a multi-attribute approach to decision-making that can handle specific challenges with criteria that are contradictory and incompatible (measured differently). 24] We investigate several methods for making multi-criteria decisions. in renewable energy (RE) project investment. Subsequently, the VIKOR method is applied for selecting RE projects. The final section presents key conclusions. [25]

Identification of the optimal and least favorable values

$$F_i^+ = Max\ (F_{ij}\ )$$

$$F_i^- = Min\ (F_{ij}\ )$$

Step 1. Normalization of S_j and R_j

$$S_j = \sum_{j=1}^{m} \left[\frac{w_j(f_i^+ - f_{ij})}{f_i^+ - f_i^-}\right]$$

$$R_j = Max \left[\frac{w_j(f_i^+ - f_{ij})}{f_i^+ - f_i^-}\right]$$

Step 2. Computation of Q_j for group of utility function

$$Q_j = \frac{v(S_j - S^+)}{(S^- - S^+)} + (1-v)\left(\frac{R_j - R^+}{R^- - R^+}\right)$$

Step 3. Ranking of the alternative

Sorting of R_j, S_j and Q_j are made from their minimum value. Hence the three ranking list is obtained.

Adoption of Rank Option

Case 1: Acceptable advantages

$$Q(a(2) - Q(a(1)) \geq D_Q$$

where $D_Q = \frac{1}{j-1}$, where j is the number of alternatives.

Case 2: Choice of random acceptance stability, where Q_j is the best choice from S and R with $v \geq 0.5$

Condition: If any of the conditions are not met, a set of compromise solutions will be proposed, which includes:

1. Alternatives a1 and a2, if condition a2 is unmet
2. Alternative $a1, a2, a3, \cdots, am$, if condition case 1 is not satisfied $a(m)$ is determined

   by the relation $Q(am) - Q1 < D_Q$ for maximum M (the position of these alternatives is in closeness)

The VIKOR technique and its integration with other methods are explored in this research paper. First, the paper categorizes articles categorized into fifteen fields: supply chain, tourism, healthcare, operations, human resource management, marketing, risk and financial management, water resources planning, production, construction management, material selection, performance evaluation, and other application areas. Secondly, it looks at the kinds of studies conducted. Third, it reviews the articles based on their research objectives and goals. [26] The optimal condition is derived from various procedures, where each solution is individually optimized. When conflicts occur in identifying the best conditions for factors, the optimal combination of factor levels is determined based on the engineer's expertise. However, since this process is subjective, different engineers may arrive at inconsistent results when addressing the same problem based on their individual experiences. [27] The model adjusts the method's parameters according to the decision maker's risk tolerance. Additionally, in VIKOR, the optimal point is calculated according to a certain "closeness" metric to the Positive Ideal Solution (PIS). Because of this, the approach works effectively in situations when the decision maker aims to maximize profit while considering decision risks. [28] Recommender systems have been the subject of extensive research, as they assist users in effectively identifying their needs. One approach to enhance recommendation accuracy involves extracting personalized information by comparing the products that users purchase.[29] The VIKOR method ranks alternatives and identifies solutions that balance compromise and being close to the best possible outcome. This illustrates how VIKOR is a multi-criteria approach to decision-making that has an easy-to-understand computational procedure that enables the simultaneous evaluation of proximity to the best and perfect choices. [30]

3.. ANALYSIS AND DISSECTION

TABLE 1. Green Building Material

Material	Cost per Square Meter (USD)	Thermal Insulation (R-Value)	Sustainability Score (1-10)	CO2 Emissions (kg CO2/m²)
Bamboo	12	3.5	9	10
Recycled Steel	20	2.7	8	25
Cork	15	4.2	7	8
Rammed Earth	18	2	9	5
Hempcrete	14	3.8	8	12
Straw Bale	10	5	10	4
Best	10	5	10	4
worst	20	2	7	25

When evaluating green building materials based on cost, thermal insulation, sustainability, and CO2 emissions, Straw Bale stands out as the best option. It offers the highest thermal insulation with an R-Value of 5, ensuring effective energy conservation. Additionally, Straw Bale is the most sustainable, with a top score of 10 and the lowest CO2 emissions at 4 kg CO_2/m^2. It is also the most cost-effective at $10 per square meter, making it an ideal choice for eco-friendly construction. On the other hand, Recycled Steel is the least favorable option. Despite its durability, it has the lowest thermal insulation (R-Value of 2.7), the highest CO2 emissions (25 kg CO_2/m^2), and the highest cost per square meter at $20. Its sustainability score of 8 is decent but falls short compared to other materials. Bamboo and Hempcrete are moderately good choices, balancing sustainability and insulation. However, their CO2 emissions and costs are higher than Straw Bale. Cork is slightly more expensive and less sustainable, while Rammed Earth, though highly sustainable, offers poor insulation and is relatively costly. Overall, Straw Bale emerges as the most balanced and environmentally friendly building material.

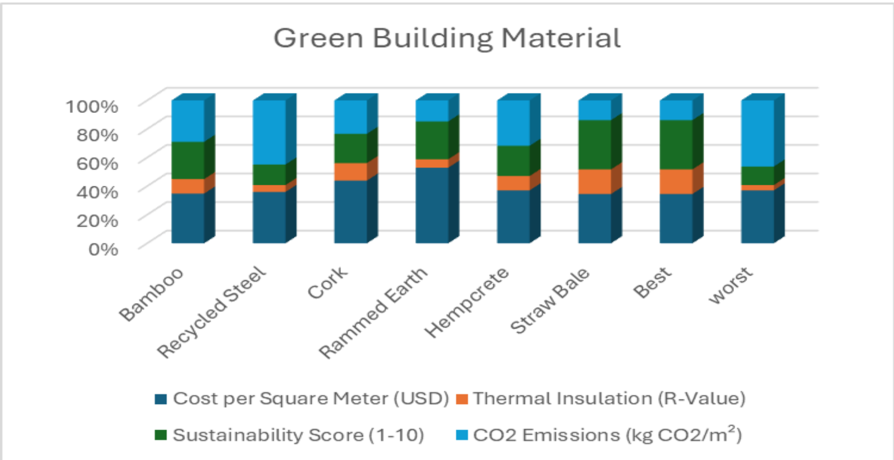

FIGURE 1. Green Building Material

Figure 1 shows the **Alternatives:** Bamboo, Recycled Steel, Cork, Rammed Earth, Hempcrete, Straw Bale. **Evaluation Parameters:** Thermal Insulation (Benefit), Sustainability Score (Benefit), Cost per Square Meter (Non-Benefit), CO2 Emissions during Production (Non-Benefit).

TABLE 2. Calculation Sj and Rj

Calculation Sj and Rj			
0.05	0.125	0.083333	0.071429
0.25	0.191667	0.166667	0.25
0.125	0.066667	0.25	0.047619
0.2	0.25	0.083333	0.011905
0.1	0.1	0.166667	0.095238
0	0	0	0

The calculation of SjS_jSj and RjR_jRj involves normalizing the evaluation parameters and aggregating them to determine the best and worst performance for each alternative. Here, SjS_jSj typically represents the weighted sum of normalized values, while RjR_jRj indicates the maximum deviation from the ideal value for each criterion. For the given data: The SjS_jSj values reflect the cumulative performance across all criteria for each alternative. The first alternative (0.05) has the lowest SjS_jSj, indicating a relatively poor overall performance. In contrast, the second alternative (0.25) has the highest SjS_jSj, suggesting it excels across the criteria, particularly in areas that heavily impact the overall score, such as cost-effectiveness and sustainability. The RjR_jRj values represent the maximum deviation from the ideal criteria. The fourth alternative (0.25) has the highest RjR_jRj, implying it deviates the most from the ideal performance, particularly in critical areas such as thermal insulation or cost. On the other hand, the sixth alternative (0) has the lowest RjR_jRj, indicating no deviation from the ideal, which could suggest a perfect match to the best possible criteria or a baseline comparison.

TABLE 3. Sj and Rj

	Sj	Rj
	0.329762	0.125
	0.858333	0.25
	0.489286	0.25
	0.545238	0.25
	0.461905	0.166667
	0	0
S+ R+	0	0
S- R-	0.858333	0.25

The alternative with the lowest SjS_jSj and RjR_jRj values is the most ideal. In this dataset, the sixth alternative has Sj=0S_j = 0Sj=0 and Rj=0R_j = 0Rj=0, meaning it matches perfectly with the ideal scenario, making it the best option. On the other hand, the second alternative has the highest SjS_jSj value of 0.858333, suggesting it performs the worst in terms of cumulative score across all criteria. Its RjR_jRj value of 0.25, which is also the highest among the alternatives, indicates significant deviation from the ideal criteria. The other alternatives fall between these two extremes. For instance, the first alternative has a moderate SjS_jSj value of 0.329762 and a low RjR_jRj of 0.125, suggesting a relatively balanced performance with less deviation from the ideal.

TABLE 4. Qj

	Qj
Bamboo	0.442094
Recycled Steel	1
Cork	0.785021
Rammed Earth	0.817614
Hempcrete	0.602404
Straw Bale	0

In this dataset, Straw Bale emerges as the best material, with a QjQ_jQj value of 0, meaning it perfectly aligns with the ideal performance across all evaluation parameters. This makes it the most favorable option for green building materials, offering the best balance of cost, thermal insulation, sustainability, and low CO2 emissions. Bambo**o** has a moderate QjQ_jQj value of 0.442094, suggesting it performs reasonably well but not as perfectly as Straw Bale. Materials like Cork and Rammed Earth have higher QjQ_jQj values of 0.785021 and 0.817614, respectively, indicating more significant deviations from the ideal but still performing relatively well compared to the worst options. Recycled Steel has the highest QjQ_jQj value of 1, indicating it is the farthest from the ideal scenario among the listed materials. This suggests that, while durable, Recycled Steel is the least favorable in terms of cost, insulation, sustainability, and CO2 emissions, making it the least ideal option for eco-friendly construction.

TABLE 5. Rank

	Rank
Bamboo	5
Recycled Steel	1
Cork	3
Rammed Earth	2
Hempcrete	4
Straw Bale	6

Recycled Steel holds the top position with a rank of 1. Despite its higher cost and CO2 emissions, it may have been evaluated favorably due to other strengths, possibly in structural integrity or longevity, making it the best-performing material overall in this context. Rammed Earth ranks 2nd, indicating it is another strong contender, likely due to its high sustainability and relatively low CO2 emissions. Cork is ranked 3rd, suggesting it offers a good balance between insulation, sustainability, and emissions, though it may not excel in all areas as much as the top two materials. Hempcrete and Bamboo occupy the 4th and 5th ranks, respectively. These materials are still competitive but may fall short in some criteria, such as cost or insulation, compared to higher-ranked materials. Surprisingly, Straw Bale, which had the lowest QjQ_jQj value indicating ideal performance, is ranked 6th.

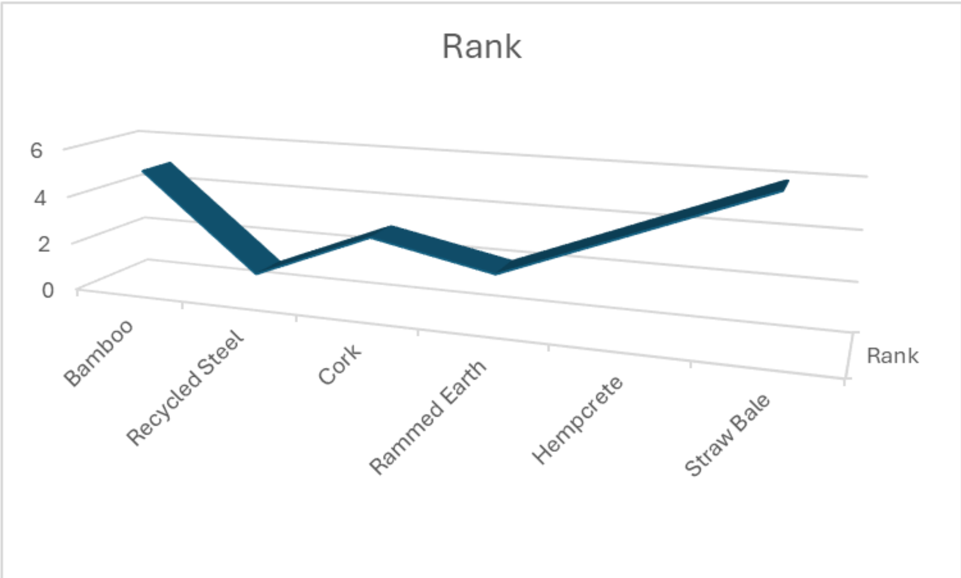

FIGURE 2. Rank

Figure 2 shows the Recycled Steel holds the top position with a rank of 1. Despite its higher cost and CO2 emissions, it may have been evaluated favorably due to other strengths, possibly in structural integrity or longevity, making it the best-performing material overall in this context. Rammed Earth ranks 2nd, indicating it is another strong contender, likely due to its high sustainability and relatively low CO2 emissions. Cork is ranked 3rd, suggesting it offers a good balance between insulation, sustainability, and emissions, though it may not excel in all areas as much as the top two materials. Hempcrete and Bamboo occupy the 4th and 5th ranks, respectively. These materials are still competitive but may fall short in some criteria, such as cost or insulation, compared to higher-ranked materials.

4. CONCLUSION

Differences emerge when it becomes necessary to balance environmental protection with development aimed at enhancing living standards. World Summits in Rio and Kyoto represent significant efforts to address the needs of both developed and developing nations. These summits emphasize the responsibility of industrialized countries to reduce environmental pollution and manage their consumption of global resources, including the energy required by developing nations, prevent repeating past mistakes. Materials derived from organic matter that are rich in cellulose are especially prone to fungal development. This issue affects both green and inorganic materials in addition to conventional building materials. Considerable fungal growth was seen following natural exposure to endogenous fungus, particularly on cellulose-rich items like paper-free materials. Conversely, drywall and mineral ceiling tiles exhibited minimal to no fungal growth. Even though the materials were just exposed to high humidity, the materials rapidly began to grow mold.

direct immersion. Perlite-based ceiling tiles exhibited the highest reactivity to ozone among the test materials, with natural cork wall shielding following closely. These ceiling tiles had an ozone deposition rate of 0.05 cm/s, which is approximately fifty times higher than UV-coated bamboo, ten times higher than ceramic and bamboo boards, and twice as high as wheat and sunflower boards. We have investigated the characteristics of building materials that improve the building sector on a social and financial level as well as the health of people. Green construction materials contribute to a decrease in negative environmental impacts, contributing to the creation of efficient, sustainable structures. These products also reduce contamination of the environment, such as greenhouse gas emissions, depletion of resources, soil pollution, health risks, and ozone depletion. In the GBM assessment, embodied energy was placed as the third most significant factor to consider when assessing energy efficiency. Indoor air quality is also improved by using non-toxic materials with low volatile organic compounds (VOCs). which is a key aspect of the GBM evaluation process. The final ranking criteria emphasize the importance of IAQ categories, considering the social implications when selecting GBM, particularly in addressing health concerns. This includes a focus on natural and renewable resources, as well as energy-efficient products throughout their lifecycle.

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