A RESEARCH INVESTIGATION INTO DESIGNED FOR SUFFICIENT PRODUCTION: INCORPORATING SUSTAINABLE MATERIALS AND MANUFACTURING METHODS IN INDUSTRIAL PRODUCT DESIGN.

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ABSTRACT

The major focus of this study, which explores the principles and practices of sustainable manufacturing, is industrial product design that uses environmentally benign materials and current production methods. Finding and evaluating design strategies that reduce environmental impact and increase manufacturing process efficiency is the main objective. This research takes a multi-faceted approach to answering the following question: "How can innovative materials and methods be integrated into product design in industrial contexts to minimise environmental impact, increase resource efficiency, and support long-term sustainability goals?" from a variety of perspectives. This study examines current methods and case studies in an effort to identify effective design solutions that address both environmental concerns and realistic production needs. Industries are seeking sustainable solutions for their production processes due to the increasing awareness of environmental deterioration and resource depletion. With the goal of minimising production's negative impact on the environment without sacrificing product quality or usefulness, this research investigates how sustainable production methods and environmentally friendly materials might be included into industrial product design. Materials that are renewable, recyclable, and non-toxic are the main emphasis of the study, along with manufacturing processes that minimise waste, energy consumption, and emissions. Other sustainable design concepts are also examined. Key possibilities and constraints in implementing sustainable manufacturing techniques are identified via an examination of current industry practices, case studies, and expert interviews. According to the results, a comprehensive strategy that takes into account both economic and environmental factors is necessary when creating products, as it is important to think about the whole product life cycle, beginning with the procurement of raw materials and ending with disposal or recycling. To help designers and manufacturers incorporate environmentally friendly materials and methods into product creation, the research also offers practical suggestions. This will encourage creativity while simultaneously encouraging sustainability. The ultimate objective of the study is to help create a framework for sustainable manufacturing that doesn't compromise economic efficiency but instead lowers industrial waste, helps achieve long-term ecological balance, and is in line with global environmental goals.

Keywords: Renewable Design, Environmentally Conscious Materials, Producing Methodologies, Commercial Products.

INTRODUCTION

When it comes to the sustainability movement, the design and manufacturing industries have been leading the way recently. It includes a broader perspective on product development that takes into account the product's impact on society, the environment, and companies during its whole existence (Adekanmbi & Wolf, 2024). A product's sustainability performance is heavily influenced by decisions taken at several points in its life cycle, including when opportunities are identified, when ideas are created and chosen, and throughout the development of both the product and the technology. Sustainable design considerations should steer the development process in the direction of better long-term solutions. There has been a noticeable shift in industrial design towards more sustainable approaches due to the increased awareness of environmental challenges such as pollution, resource depletion, and climate change. Designers and manufacturers are beginning to understand the need of minimising a product's negative impact on the environment throughout its lifespan. Environmental scientists, materials scientists, industrial designers, and engineers were just a few of the specialists that needed to collaborate on this transformation. Collaborative efforts across disciplines may provide innovative solutions that take into account social, environmental, and economic aspects in a balanced manner. The characteristics of sustainable production include economic vitality, cultural sensitivity, social cohesiveness, resourcefulness, and ecological conscience. Promoting optimisation in industrial structures, balancing economic growth with population rise, protecting the environment, and effectively extracting and allocating resources are all possible steps towards a more sustainable path of economic development. It may also have far-reaching effects on energy use, industrial development, the production and consumption of eco-friendly products, and the expansion of cultural and tourism activities (Al-Nuaimi, S.R., & Al-Ghamdi, 2022).

BACKGROUND OF THE STUDY

Concern about the effects of corporations and consumer products on society and the environment is growing. High levels of carbon dioxide, methane, and nitric oxide not seen in 800,000 years are mostly driven by human-induced greenhouse gas emissions, according to the IPCC. Environmentalists are pressuring companies and people to reduce their emissions of greenhouse gases to an unprecedented degree. In the late 1980s, academics took the lead in getting people all around the world to rally for environmental change. A new era of sustainability has been ushered in by new global agreements and collaborative projects, such as the Paris Agreement and the United Nations Sustainable Development Goals (SDG). A growing number of academics have focused on the extent to which eco-design is integrated into product production in

the corporate sector. The acceptance rate and degree of implementation of eco-design approaches are rather low, despite the fact that many organisations have announced their desire to do so. Proponents of eco-design point to the slow adoption of eco-design practices and technology as evidence that the field is failing to meet its goal of building a sustainable society (Awan & Sroufe, 2022).

PURPOSE OF THE RESEARCH

Industrial product designs that employ eco-friendly materials and manufacturing techniques might be more sustainable in the long term, according to the research team behind this initiative. Investigate and evaluate possible environmentally friendly materials for use into product ideas. Their biodegradability, recyclability, and reduced carbon footprint are important environmental factors to think about. To make manufacturing less harmful to the environment, look at both old and new ways of producing goods. Waste reduction, energy efficiency, and environmental friendliness are all factors that are being examined. Provide specific recommendations for incorporating eco-friendly materials and production processes into the design process. Integral to this is providing the resources necessary for designers and manufacturers to include these environmentally beneficial practices. Find out how successfully and advantageously eco-friendly materials and processes were included into the product design process. Part of this procedure is figuring out how the entire thing will affect things like product efficiency, cost-effectiveness, and environmental sustainability. Incorporate sustainable practices into production and design processes by providing practical advice based on the study's findings to manufacturers and industrial designers.

LITERATURE REVIEW

Sustainable manufacturing has grown in popularity as a means for companies to lessen their impact on the environment and maximise the efficiency of their resource use. This literature review explores how industrial product design may include environmentally friendly materials and production techniques, drawing on current research and achievements in the field. Minimising the detrimental effects of industrial activities on the environment without compromising product performance or functionality is the fundamental idea of sustainable manufacturing. Sustainable materials should be prioritised in product design, according to a large body of evidence. The development of materials that may lessen waste and carbon emissions is a growing area of study. Among them are biodegradable polymers, recyclable metals, and natural fibres. The materials have the ability to reduce lifetime effects, according to several research (e.g., Hopewell et al. and Derkzen et al.), yet issues like pricing and performance have also been brought to light. Innovations in production methods have also been very beneficial to sustainability. Some groundbreaking methods have emerged, such additive manufacturing (3D printing) that allows for precise material utilisation with little waste and closed-loop

manufacturing systems that enable recycling and reuse of resources. These techniques save waste while increasing manufacturing efficiency and adaptability (Bontempi et al., 2021).

RESEARCH QUESTIONS

What is the impact of Production Supply on the integration of eco-friendly materials?

RESEARCH METHODOLOGY

RESEARCH DESIGN

Analyses of quantitative data were conducted using SPSS version 25. To measure the strength and direction of the statistical association, the researchers used the odds ratio and the 95% confidence interval. The scientists established a threshold that was deemed statistically significant at $p < 0.05$. Key aspects of the data were identified by a descriptive analysis. Data collected via surveys, polls, and questionnaires, as well as data processed using computing tools for statistical analysis, are often assessed using quantitative methods.

SAMPLING

Research participants filled out questionnaires to provide information for the research. Using the Rao-soft programme, researchers determined that there were 623 people in the research population, so researchers sent out 635 questionnaires. The researchers got 557 back, and they excluded 32 due to incompleteness, so the researchers ended up with a sample size of 525.

DATA AND MEASUREMENT

Data for the investigation came mostly from a questionnaire survey. A participant's basic demographic information was requested first. After that, participants were given a 5-point Likert scale to use in evaluating the online and offline channels. For this secondary data set, the researchers combed through a number of resources, most notably internet databases.

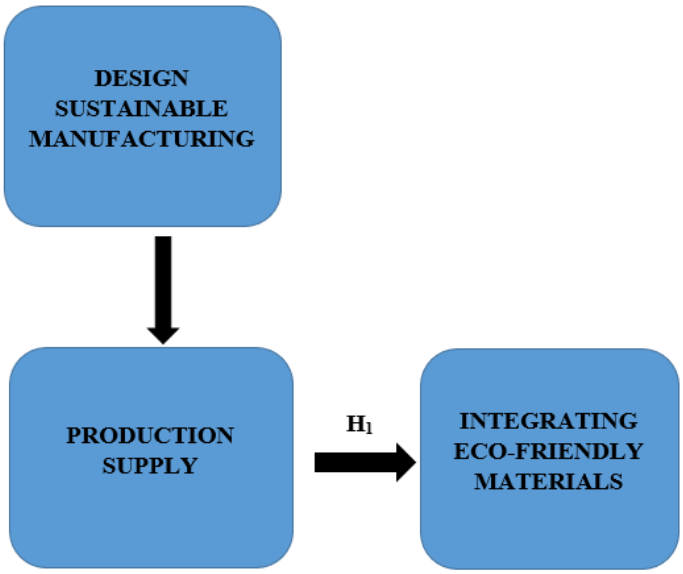
STATISTICAL SOFTWARE

The statistical analysis was conducted using SPSS 25 and MS-Excel.

STATISTICAL TOOLS

To grasp the fundamental character of the data, descriptive analysis was used. The researcher is required to analyse the data using ANOVA.

CONCEPTUAL FRAMEWORK



RESULT

Factor Analysis: One typical use of Factor Analysis (FA) is to verify the existence of latent components in observable data. When there are not easily observable visual or diagnostic markers, it is common practice to utilise regression coefficients to produce ratings. In FA, models are essential for success. Finding mistakes, intrusions, and obvious connections are the aims of modelling. One way to assess datasets produced by multiple regression studies is with the use of the Kaiser-Meyer-Olkin (KMO) Test. They verify that the model and sample variables are representative. According to the numbers, there is data duplication. When the proportions are less, the data is easier to understand. For KMO, the output is a number between zero and one. If the KMO value is between 0.8 and 1, then the sample size should be enough. These are the permissible boundaries, according to Kaiser: The following are the acceptance criteria set by Kaiser:

A pitiful 0.050 to 0.059, below average 0.60 to 0.69

Middle grades often fall within the range of 0.70-0.79.

With a quality point score ranging from 0.80 to 0.89.

They marvel at the range of 0.90 to 1.00.

Table1: KMO and Bartlett's Test

Testing for KMO and Bartlett's

Sampling Adequacy Measured by Kaiser-Meyer-Olkin .980

The results of Bartlett's test of sphericity are as follows: approx. chi-square

df=190

sig.=.000

This establishes the validity of assertions made only for the purpose of sampling. To ensure the relevance of the correlation matrices, researchers used Bartlett's Test of Sphericity. Kaiser-Meyer-Olkin states that a result of 0.980 indicates that the sample is adequate. The p-value is 0.00, as per Bartlett's sphericity test. A favourable result from Bartlett's sphericity test indicates that the correlation matrix is not an identity matrix.

Table 1: KMO and Bartlett's.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.980
Bartlett's Test of Sphericity	Approx. Chi-Square	3252.968
	df	190
	Sig.	.000

Bartlett's Test of Sphericity further confirmed the overall significance of the correlation matrices. The Kaiser-Meyer-Olkin sample adequacy value is 0.980. The researchers identified a p-value of 0.00 via Bartlett's sphericity test. The correlation matrix was shown to not be a valid correlation matrix by a significant result from Bartlett's sphericity test.

INDEPENDENT VARIABLE

Design Sustainable Manufacturing: Their goal in developing sustainable manufacturing practices is to make things that don't harm the environment or people by using as little resources as possible without sacrificing quality. Lessen the researcher's impact on the environment by making use of renewable, recyclable, or eco-friendly materials. Make sure they use manufacturing-specific energy-saving tactics and technology. Developing goods and procedures that simplify recycling or reusing resources should take waste reduction into account. The manufacturing phase is only one part of a product's environmental effect; the whole lifetime must also be considered. Designers may help attain resource preservation and environmental standards by making products and manufacturing systems that include these ideas (Cooke et al., 2020).

FACTOR

Production Supply: The term "production supply" describes the whole inventory of all the things needed to make anything, including raw materials, finished products, and equipment. It includes everything from raw materials to semi-finished items and subcomponents, and all the machinery and human labour needed to transform or put together those basic ingredients into a final product. The goal of production supply management is to keep production on track and problems at bay by coordinating the sourcing, procurement, inventory control, and logistics of all raw materials, components, and finished goods. Optimisation of material flow throughout manufacturing, supplier coordination, and supply chain management are all part of this. Maintaining smooth operations, lowering lead times, minimising costs, and assuring product quality all depend on efficient production supply. This is because production downtime or inefficiencies may be caused by delays or shortages in supply (Hotha, 2023)

DEPENDENT VARIABLE

Integrating Eco-Friendly Materials: The core of eco-friendly material integration in industrial product design is selecting and using materials that minimise environmental impacts during their entire lifecycle. Their use of renewable resources or recycled materials means reduced reliance on non-renewable supplies. Designed to break down naturally, lessening its long-term effect on the environment. Free of any contaminants that might pose a threat to people or the environment. Manufactured in a way that minimises the impact on the environment by reducing energy consumption and greenhouse gas emissions. Some of the benefits include reduced pollution, fewer waste, and more effective use of resources. The researcher faces challenges in achieving full utilisation of eco-friendly materials, such as higher costs, limited performance, and the need for innovative production techniques (Ilugbusi et al., 2020).

Relationship Between Production Supply and Integrating Eco-Friendly Materials: It is important to match resource procurement and manufacturing processes with sustainability objectives in order to integrate eco-friendly resources into production supplies (Van Dam et al., 2020). Cost, availability, and performance are the three main criteria used to choose raw materials, components, and resources in a conventional manufacturing supply chain. When using eco-friendly materials, however, the emphasis moves to finding long-term solutions that lessen the product's negative effect on the environment without sacrificing its usefulness, quality, or economy. Manufacturers may lessen their impact on the environment, preserve natural resources, and cut down on pollution and waste by using environmentally friendly products in their manufacturing supply chain. This might include using less resource-intensive and emission-generating manufacturing methods or acquiring renewable, biodegradable, or recyclable materials. For instance, instead of using solvents, producers may use water-based paints, include energy-efficient technology, or employ biodegradable polymers or recycled materials. Production

supply chain integration using environmentally friendly materials also necessitates changes to inventory management, supplier relationships, and procurement methods. To ensure the environmental integrity of the materials they source, companies should either invest in certifications and procedures or collaborate closely with suppliers that specialise in sustainable materials. To make sure production schedules are maintained and waste is minimised, it is vital to manage the flow of these resources properly. The significance of sustainable resource management in manufacturing is ultimately shown by the link between production supply and the integration of eco-friendly materials. As stakeholders and customers place a higher value on ecologically responsible goods, businesses may gain an advantage in the market and help the environment at the same time by integrating eco-friendly materials into their manufacturing supply chains. Industry and the environment both gain from this partnership's promotion of a circular production model that makes better use of resources, produces less waste, and has a smaller overall environmental effect (Tiwari, 2023).

Because of the above discussion, the researcher formulated the following hypothesis, which was analyse the relationship between Production Supply and Integrating Eco-Friendly Materials.

"H_{01}: There is no significant relationship between Production Supply and Integrating Eco-Friendly Materials."

"H_1: There is a significant relationship between Production Supply and Integrating Eco-Friendly Materials."

Table 2: H_1 ANOVA Test.

ANOVA					
Sum					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	39588.620	101	5655.517	1153.184	.000
Within Groups	492.770	423	5.356		
Total	40081.390	524			

There will be substantial findings from this investigation. F=1153.184, with a p-value of.000 (below the.05 alpha threshold), meets statistical significance. What this implies is that the **"H_1: There is a significant relationship between Production Supply and Integrating Eco-Friendly Materials"** is accepted and the null hypothesis is rejected.

DISCUSSION

Although sustainable industrial design has made great strides, it still faces several challenges. Using sustainable resources and green manufacturing practices is one approach. The researcher in this study compiled the most crucial findings from

recent studies and analyses their implications for industrial product design moving forward. Industrial product designers are increasingly turning to more eco-friendly materials as consumers become more aware of the damage that traditional materials do to the planet. Research indicates that materials such as biodegradable polymers, recyclable metals, and natural fibres might be useful. Reduced waste and carbon emissions are only two of the numerous ways in which these materials contribute to broader sustainability goals. For example, biodegradable polymers may break down more quickly in natural environments, lowering long-term pollution, while recycled metals can save resources by decreasing the energy required for extraction and processing. In the meanwhile, using these materials isn't exactly a walk in the park. A big barrier to the widespread use of ecologically friendly materials, according to researchers, is the increased initial cost necessary to obtain them. Another consideration is that sustainable materials may not always perform as well as conventional materials, which raises the question of whether they are suitable for certain applications. To address these challenges, there has to be ongoing research into methods to improve material characteristics while reducing costs via technological developments and economies of scale (Vincent et al., 2021).

CONCLUSION

Studies on green production methods and materials have shown both new opportunities and persistent obstacles. Opportunities to lessen environmental impacts have arisen as a consequence of developments in production techniques and materials; nevertheless, obstacles, such as concerns about the product's price and performance, must also be considered. A comprehensive design process, realistic implementation methodologies, and ongoing research and innovation are all essential for industrial product designers to achieve sustainability objectives. If these obstacles can be removed, the industry has a better chance of moving towards environmentally friendly methods that can adapt to a dynamic world.

REFERENCES

1. Adekanmbi, A.O., & Wolf, D. (2024). Solid Mineral Resources Extraction and Processing Using Innovative Technology in Nigeria. ATBU Journal of Science, Technology and Education, 12(1), 1-16.
2. Al-Nuaimi, S.R., & Al-Ghamdi, S.G. (2022). Sustainable consumption and education for sustainability in higher education. Sustainability, 14(12), 7255.
3. Awan, U., & Sroufe, R. (2022). Sustainability in the circular economy: insights and dynamics of designing circular business models. Applied Sciences, 12(3), 1521.
4. Bontempi, E., Sorrentino, G.P., Zanoletti, A., Alessandri, I., Depero, L.E., & Caneschi, A. (2021). Sustainable materials and their contribution to the sustainable development goals (SDGs): a critical review based on an Italian example. Molecules, 26(5), 1407.

5. Cooke, S.J., Nguyen, V.M., Anastakis, D., Scott, S.D., Turetsky, M.R., Amirfazli, A., Hearn, A., Milton, C.E., Loewen, L., Smith, E.E., & Norris, D.R. (2020). Diverse perspectives on interdisciplinary from Members of the College of the Royal Society of Canada. Facets, 5(1), 138-165.
6. Hotha, K.K. (2023). Unleashing the Power of Innovation in CDMOs through Customer-Centricity and Culture of Service. American Journal of Industrial and Business Management, 13(4), 234-246.
7. Ilugbusi, S., Akindejoye, J.A., Ajala, R.B., & Ogundele, A. (2020). Financial liberalization and economic growth in Nigeria (1986-2018). International Journal of Innovative Science and Research Technology, 5(4), 1-9.
8. Roy, M., & Roy, A. (2021). The rise of interdisciplinarity in engineering education in the era of industry 4.0: implications for management practice. IEEE Engineering Management Review, 49(3), 56-70.
9. Tiwari, A. (2023). Advancement of Materials to Sustainable & Green World. Advanced Materials Letters, 14(3), 2303-1724.
10. Van Dam, K., Simeone, L., Keskin, D., Baldassarre, B., Niero, M., & Morelli, N. (2020). Circular economy in industrial design research: a review. Sustainability, 12(24), 10279.
11. Vincent, A.A., Segun, I.B., Loretta, N.N., & Abiola, A. (2021). Entrepreneurship, agricultural value-chain and exports in Nigeria. United International Journal for Research and Technology, 2(08), 1-8.