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SUSTAINABLE PRODUCT DESIGN AND DEVELOPMENT

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ABSTRACT-

Sustainable product design and development is a vast field of research. So far, no study has been conducted on the sub-field of research. Typically, each scholar conducts research based on his/her point of view and expertise. This paper aims to compile sustainable product design and development categorization into topics, objectives, methods, and contributions. Based on a literature review of sustainable product design and development, several research sub-categories were found: Process, life cycle assessment, eco-design, design strategies, multi-criteria decision making, performance measurement, customer's side, and miscellaneous that covers various study areas. This categorization provides benefits to researchers in a category to focus more on choosing the appropriate literature. In addition, it is easier for scholars to identify knowledge gaps in a category for future research.

INTRODUCTION-

Research in the broad topic of product design and development spans a variety of disciplines and backgrounds. The design and development of sustainable products is one area of this scientific discipline. The extent of this field of study is still very broad. Subfields of inquiry in this field of study have not yet been the subject of any studies. Research is often conducted by each scholar according to his or her area of competence and point of view.

Consequently, there is disagreement on the study areas that are covered by the science of sustainable product development and design. Publications in the field of sustainable product design and development will continue to be dispersed and extremely broad if there is no agreement on classification. Scholars will dedicate more effort to gathering relevant material and identifying gaps in the corpus of knowledge. When assembling research proposals, classification facilitates the identification of knowledge gaps by researchers because the material has already been sorted into a certain category.

As a result, the goal of this study is to organize the subject of sustainable product design and development using a review of the literature that has been created by academics. This includes organizing the area into categories, goals, approaches, and research contributions. The creation of a product in accordance with the designer's skills and future consumer demands is the aim of product design and development. There are many commonalities in the process of making the product, despite the fact that every designer has unique tastes and areas of skill. Consequently, one of the most important areas for study is the process of creating and developing these goods.

Product design also goes through stages of development, including initiate, grow, mature, and decrease, before returning to the beginning for a new product. The term "product life cycle" refers to this cycle. Comparably, the idea behind a life cycle evaluation encompasses a number of resources, as well as the product's processing, production, distribution, usage, and end of life, as well as tracking the disappearance of an item when it is no longer in use. The life cycle idea is applicable to researchers studying product design and development from various educational backgrounds.

The foundation of the entire process, which is supported by other processes, is the product development stage. A background knowledge-based scholar's competence determines which publications focus on the design approach and which ones concentrate on the eco-design itself. Currently, there are a lot of possibilities and hazards associated with the many approach alternatives. Choosing wisely will open up the possibility of the product being offered in the marketplace. However, if the wrong choice is made, the product may lose its appeal to buyers and may even fail. Decisions must be made for this reason, and every choice has an impact. Considering the significance of making wise judgements, the use of decision analysis science is crucial.

The process of developing new products is continuously evaluated through performance assessment, consumer impression surveys, and behaviour observation. We are able to determine the success or failure of product development through these evaluations. The remaining subjects include a wide range of subjects, including occasionally designing a product, using certain scientific methods like lean and six sigma, developing instructional materials, and attempting to digitize the process of designing and developing products.

METHODOLOGY-

Framework for Sustainable Design: The Natural Step (TNS)

The Natural Step (TNS) framework offers a methodical way to direct product designers toward making genuinely sustainable designs. It complies with the four requirements listed below for a sustainable system:

1. **System Conditions:**
 - **No systematic chemical produced by human activity shall be discharged into the environment at amounts higher than the background values.** Toxins and contaminants in materials and processes must be avoided.
 - **It is not appropriate to gradually reduce nature's ability to provide sustainable resources.** This promotes ethical sourcing methods and the utilization of renewable resources.
 - **There should be no systematic degradation of the biodiversity and physical integrity of the natural world.** Minimizing resource depletion and planning with the least amount of environmental effect are emphasized.
2. **Four System Limits:** Throughout the course of the product lifecycle, designers should take into account the four limits defined by the TNS framework:
 - * The Cradle to Cradle concept states that products should be made to be safely biodegraded or disassembled and reused within the system.
 - * Safe Substitutes: For any material that presents a danger to the environment or human health, find and use a safer substitute.
 - * Dematerialization: Reduce material use while preserving functionality. Examine methods for making designs more useful and lightweight.
 - * Constant Improvement: The pursuit of sustainability is a lifelong endeavor. Evaluate the product's influence on the environment on a regular basis and work toward ongoing improvement.
3. **Back casting:** Rather than merely responding to issues, TNS promotes "back casting." This entails determining a sustainable future state for the product and then identifying the design decisions that must be made in order to bring that vision to fruition.

By following these principles and utilizing the four system boundaries, designers can create products that align with the core tenets of sustainability.

Case Studies: Learning from Sustainable Design Success Stories

One of the most effective ways to acquire and apply sustainable design principles is to examine successful case studies. These are a couple of possible case studies:

- **Patagonia Retool™ program:** Customers may send in their worn-out Patagonia gear for repair or refurbishing through Patagonia's Retool™ program. This encourages a circular economy, decreases waste, and increases the lifespan of things.
- **Philips EcoCare Lamps:** Philips EcoCare lights are made with easy recycling and energy efficiency in mind. They are a more sustainable lighting alternative since they need less energy over the course of their lifetime and have fewer potentially dangerous ingredients.
- Designers can pinpoint crucial tactics like product longevity, repairability, recycling, and energy efficiency by analyzing these successful situations. They may then use these lessons to solve their own design problems.

Life Cycle Assessment (LCA) Tools: Measuring Environmental Impact

A quantitative method called life cycle assessment (LCA) is used to evaluate a product's environmental effect over the course of its whole life cycle. LCA software aids in the analysis of:

- **Resource consumption:** This covers the energy and raw material consumption for the whole life of the product, from extraction to disposal .
- **Emissions:** In the phase of manufacturing, usage, and end-of-life, LCA contributes to the quantification of air and water pollution.
- **Waste generation:** Every phase of the product's life cycle is evaluated in terms of the quantity of solid waste generated.

Designers may pinpoint opportunities for improvement throughout the life cycle of the product by using LCA tools. Their ability to make well-informed decisions about material selection, manufacturing procedures, and end-of-life alternatives is facilitated by this data-driven approach, which eventually results in a more sustainable product design.

LITERATURE REVIEW –

In response to urgent environmental and social issues, sustainable product design and development has drawn more and more attention. This new approach to manufacturing and design places a strong emphasis on integrating social, economic, and environmental factors at every stage of a product's lifespan. Frameworks for evaluating and improving the sustainability performance of goods are provided by important approaches including Life Cycle Assessment, Design for Environment, and Cradle-to-Cradle design principles.

Sustainable Product Design and Development is important, but there are a number of obstacles in the way of its general acceptance. The main obstacles include financial limitations, the scarcity of renewable resources, and organizational inertia. Innovative ideas, teamwork, and regulations that encourage sustainable behavior across industries are needed to address these issues.

Future studies and practices in sustainable product design and development are well-positioned to take advantage of new possibilities and tackle enduring problems. Technological developments in materials

science, digital design tools, and cooperative methods provide potential for improving goods' sustainability performance. Furthermore, mainstreaming Sustainable Product Design and Development concepts into design practice requires building a sustainable culture via training, education, and stakeholder involvement.

A revolutionary approach to sustainable production and consumption, sustainable product design and development offers possibilities to create societies that are more just and resilient. Through the integration of environmental and social factors into the design process, Sustainable Product Design and Development helps to improve resource efficiency, reduce negative environmental effects, and advance socio-economic well-being. To advance sustainable design principles and meet global sustainability concerns, more research and innovation in sustainable product design and development are needed.

Importance of Sustainable Product Development-

To add on to the importance of incorporating sustainability into product development and the rationale for sustainable product design, the main reasons for sustainable product development exist are largely manifold, multifaceted and interlinked. Nowadays, people are increasingly becoming more aware of the importance of preserving the natural environment. As such, both consumers and producers are more inclined towards the acquisition and production of environmentally friendly products. From a market-oriented perspective, by designing and producing products that speak to this growing consumer demand for sustainable products, companies can gain a competitive edge in the market. Especially in today's world whereby many developed nations, such as Australia, are experiencing a saturation of traditional markets and hence businesses are driven to explore and enter new emerging markets, the potential for companies to expand and acquire new customers through sustainable product development is significant. From an environmental perspective, it is unequivocally essential for sustainable methodologies in product design and development to be adopted. Continuous modernization and the increasing human population has inevitably put greater strains on the Earth's natural resources and environment. By designing and manufacturing products sustainably, we can help to lessen our impact on the environment and contribute to the preservation of natural resources and ecosystems for the benefit of future generations. Last but not least, many materials and resources are becoming increasingly scarce and expensive as the demand for non-renewable resources continues to rise. By embracing sustainable product development and focusing on the use of renewable materials and improving energy efficiency in the production of goods, companies can protect themselves against the volatility of material prices and contribute to a more stable economy.

Benefits of Sustainable Product Design

The book provides an overview of the benefits of incorporating sustainability into product development, which can be summarized in the following three major categories. First, practicing sustainable product design can lead to reduced energy and resource usage. Because sustainable product design emphasizes the use of renewable materials, sustainable sourcing practices, recycling and up cycling, and energy-efficient or water-conserving manufacturing techniques. Secondly, it helps to minimize or eliminate the impacts of the products on the environment and human health throughout their life cycles. Sustainable products are designed to provide environmental, social and economic benefits while protecting public health, welfare, and the environment over their whole life cycle, from the extraction of raw materials until the final disposal. This in turn can create a healthier indoor environment for the users. Last but not least, it can drive technological innovation and creativity, by means of utilizing the latest development in the relevant fields as well as encouraging the design and production teams to try new things. When consumer education and awareness, sustainable product choices and communication of environmental impact are built in, through the use of the state-of-art technologies and more sustainable materials and processes, new products with higher standards in both sustainability and creativity can be developed. These advantages have important implications for both product designers and decision makers, and they can hopefully contribute further to the development and assessment of sustainable products.

CONCLUSION –

Sustainable Product Design and Development stands at the forefront of efforts to reconcile industrial progress with ecological preservation and social equity. Throughout this research paper, we have delved into the foundational principles, methodological frameworks, challenges, and future prospects of Sustainable Product Design and Development, shedding light on its multifaceted significance in contemporary manufacturing and design practices.

Sustainable Product Design and Development embodies a holistic approach that transcends traditional design paradigms by incorporating environmental, social, and economic dimensions into the product development process. By optimizing material selection, manufacturing processes, and end-of-life considerations, Sustainable Product Design and Development strives to minimize environmental footprints while maximizing societal benefits. Methodologies such as Life Cycle Assessment, Design for Environment, and Cradle-to-Cradle design principles serve as indispensable tools for evaluating and enhancing the sustainability performance of products across their entire lifecycle.

Yet, despite the compelling rationale and growing momentum behind Sustainable Product Design and Development, formidable challenges and barriers persist. Financial constraints, market pressures, and a lack of standardized metrics often impede the adoption of sustainable design practices. Moreover, the complexity of global supply chains and entrenched organizational cultures pose formidable obstacles to systemic change. Overcoming these challenges demands a concerted effort from stakeholders across industries, including policymakers, businesses, academia, and civil society.

Looking ahead, the horizon for Sustainable Product Design and Development brims with both promise and urgency. Rapid advancements in materials science, digital technologies, and collaborative innovation hold transformative potential for enhancing the sustainability performance of products. From bio-based materials to additive manufacturing and circular economy models, a plethora of opportunities awaits exploration and implementation. Moreover, fostering a culture of sustainability through education, awareness-raising, and stakeholder engagement is paramount for effecting lasting change.

Sustainable Product Design and Development embodies a vision of progress that transcends mere technological innovation to encompass broader notions of ecological resilience, social equity, and economic prosperity. By harnessing the power of design to harmonize human activities with natural systems, Sustainable Product Design and Development offers a compelling blueprint for steering humanity towards a more sustainable future. As we stand at the crossroads of environmental crisis and technological advancement, the imperative for embracing Sustainable Product Design and Development has never been more urgent. Through collaborative action, innovation, and unwavering commitment, we can forge a path towards a world where products not only meet human needs but also safeguard the planet for generations to come.

Furthermore, the transformative potential of Sustainable Product Design and Development extends beyond its immediate impact on product design and development. It serves as a catalyst for reimagining entire systems of production, consumption, and waste management. By advocating for closed-loop systems and cradle-to-cradle approaches, Sustainable Product Design and Development challenges the linear 'take-make-dispose' model that underpins conventional industrial practices. In doing so, it paves the way for a transition towards a circular economy—a regenerative system that aims to decouple economic growth from resource depletion and environmental degradation.

Moreover, Sustainable Product Design and Development holds the promise of fostering resilience in the face of global sustainability challenges. As climate change, resource scarcity, and social inequality loom large, the imperative for sustainable solutions has never been more pressing. By embedding resilience into the design of products and systems, Sustainable Product Design and Development contributes to building adaptive capacity and mitigating risks associated with environmental and social disruptions. From resilient infrastructure to disaster-resistant housing and climate-smart technologies, Sustainable Product Design and Development offers a toolkit for navigating an uncertain future with confidence and foresight.

Sustainable Product Design and Development embodies a vision of progress that transcends narrow definitions of efficiency and profit. It represents a holistic approach to innovation—one that seeks to harmonize human aspirations with planetary boundaries and societal needs. As we embark on the journey towards a more sustainable future, Sustainable Product Design and Development serves as a guiding beacon, illuminating pathways for transformation and renewal. By embracing the principles of Sustainable Product Design and Development and forging partnerships across sectors, we can usher in an era of prosperity that is inclusive, regenerative, and enduring.

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