METHODOLOGY FOR DESIGNING INDUSTRIAL DESIGN OBJECTS BASED ON THE PRINCIPLES OF ECO-ADAPTABILITY AND RECYCLING

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Summary

The research presents a comprehensive methodological framework for industrial design, integrating environmental sustainability into the early stages of product development. The study shifts the focus from purely aesthetic considerations to a systemic life-cycle approach.

Keywords: *industrial design, eco-adaptability, recycling, secondary raw materials, corrugated cardboard, sustainable development.*

Резюме:

Статья посвящена разработке научно-обоснованного подхода к эко-дизайну. Основное внимание уделено морфологической адаптации объектов — их способности трансформироваться и модернизироваться в процессе эксплуатации. Автор доказывает, что проектирование «от обратного» (с учетом будущего демонтажа) является ключевым фактором устойчивого развития. Практическая значимость работы заключается в возможности внедрения предложенных конструктивных решений в производство мебели, систем хранения и упаковки из эко-картона.

Ключевые слова: промышленный дизайн, эко-адаптивность, рециклинг, вторичное сырье, гофрокартон, устойчивое развитие.

The Post-Industrial Awakening (1960s – 1970s).The roots of ecological awareness in design emerged as a reaction to the "planned obsolescence" of the 1950s. A pivotal moment was the publication of Victor Papanek's seminal book, "Design for the Real World" (1971). Papanek was one of the first to argue that designers have a moral and environmental responsibility, criticizing the industry for creating "wasteful gadgets." During this period, the 1973 Oil Crisis further forced designers to reconsider energy efficiency and material scarcity.

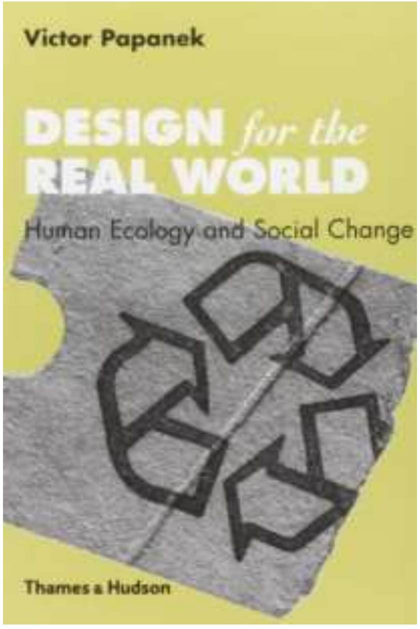

Fig 1. Victor Papanek's invention for eco-adaptive design.

The main characteristics of the eco-design:

1. Design for Disassembly (DfD) .This is the most critical technical feature of eco-adaptive design. It ensures that at the end of its life, a product can be quickly and easily separated into its constituent materials without specialized heavy machinery.

Principle: Avoiding permanent joining methods like industrial glues, welding, or rivets in favor of mechanical fasteners (screws, snap-fits, or magnetic joints).

Scientific Value: This reduces "material contamination." For example, a plastic shell with glued-on foam is unrecyclable, but a shell with a snap-on cushion can be separated into two pure recycling streams.

2. Material Monism and Bio-Compatibility.

This principle dictates the "material health" of the object. A common mistake in traditional design is the use of "monstrous hybrids"—mixtures of technical and biological materials that can never be separated.

Principle: Using a single type of material (monomateriality) for the entire product or ensuring that all materials used belong to the same recycling category.

Scientific Value: It simplifies the logistics of recycling. If a chair is made entirely of one grade of polypropylene, it has a 100% recycling efficiency compared to a chair made of five different types of bonded plastics.

3. Emotional Durability and Aesthetic Longevity. Eco-adaptability is not just about physical recycling; it is about preventing the object from becoming "psychological waste."

Principle: Designing forms that transcend short-term fashion trends and using materials that "age gracefully" (like wood, stone, or high-quality metals) rather than degrading into "ugly" waste (like cheap cardboard or low-grade plastics).

Scientific Value: This extends the First Life Cycle of the product. If a consumer keeps a product for 20 years instead of 2 years because they still find it beautiful and functional, the environmental impact is reduced by 90% before recycling is even necessary.

In the context of the global environmental crisis and the transition to a circular economy, traditional industrial design methods oriented toward excessive consumption are losing their effectiveness. This article addresses the pressing issue of integrating the principles of eco-adaptability and recycling into the core of the design process.The aim of the study is to provide a theoretical foundation and develop a methodological algorithm for design that minimizes the anthropogenic impact of an industrial product on the environment without compromising its functional or aesthetic qualities. Within the framework of this methodology, recycled multi-layer corrugated cardboard was selected as the primary structural material. This choice is driven by its unique environmental and physical-mechanical properties.

Fig 2. Top Liner (Recycled Kraft)

Here is Practical Approbation of the Methodology of Cardboard System.The project of a modular storage system made of eco-cardboard serves as an example of the practical implementation of this methodology.

Structural Solution: Instead of standard fasteners, the "tongue-and-groove" (interlocking) principle was utilized. This allows the user to independently modify the object's configuration (increasing height or changing shape), practically realizing the principle of eco-adaptability.

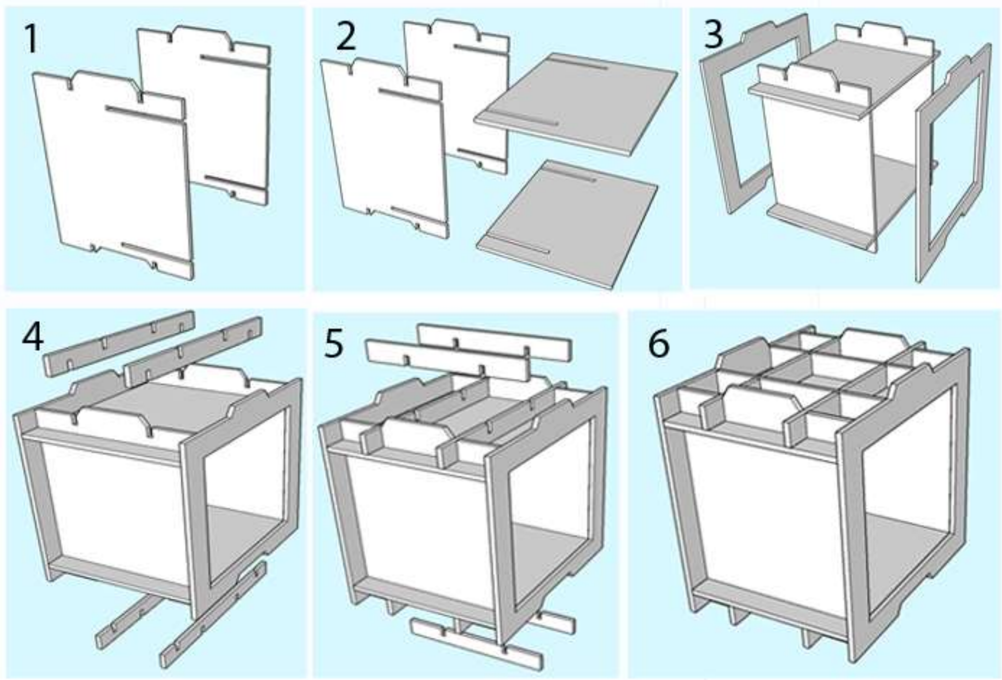

Fig. 3. Exploded view of a modular eco-cardboard design, demonstrating the concept of "Design for Disassembly" and adhesive-free connections.

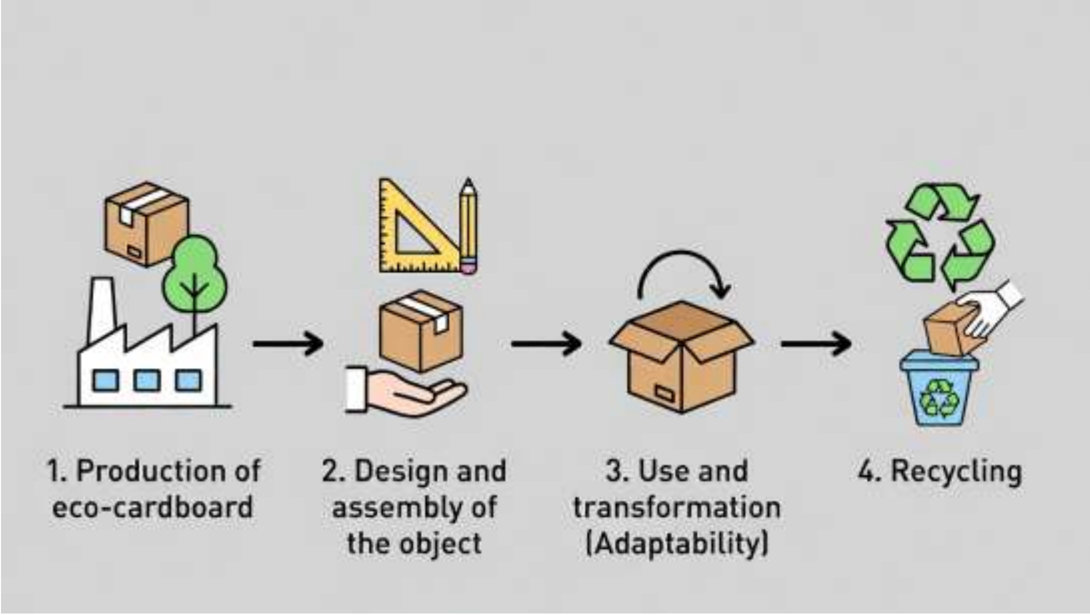

Fig. 4. Schematic of the closed-loop cycle, integrating eco-adaptability and preventive recycling for secondary cellulose raw materials.

Elements of novelty include:Integrated Approach,for the first time, "adaptability" (the ability of an object to transform) is proposed not merely as a decorative feature, but as a strategic tool for extending the product's life cycle, directly reducing environmental impact.Moreover, a system of structural joints specifically designed for cellulose-based sheet materials (eco-cardboard) has been developed, eliminating the need for non-recyclable adhesives and glues.

Limitations and Disadvantages. Despite its high environmental efficiency, the use of eco-cardboard and adaptability principles involves certain limitations that must be considered in industrial production:

Hygroscopicity (Moisture Sensitivity): The primary disadvantage of cardboard products is the loss of structural integrity in high-humidity environments. This limits the use of such objects in outdoor settings without the application of eco-friendly waterproof coatings.

Wear of Connection Nodes: Frequent reconfiguration (assembly and disassembly) can lead to the deformation of cardboard joints, which may reduce the overall rigidity of the structure over time.

Load-Bearing Constraints: Unlike metals or polymers, eco-cardboard has a lower tensile strength limit, requiring precise engineering calculations when designing large-scale or heavy-duty objects.

Consumer Perception Barriers: There remains a psychological barrier where many users perceive cardboard as a "temporary" or "cheap" material. This necessitates the development of additional marketing strategies to promote the value of high-end eco-design.

Conclusion:

This research developed and substantiated a design methodology for industrial objects based on the synergy between eco-adaptability and recycling technologies. Using recycled corrugated cardboard as a primary example, the study demonstrates that replacing permanent joints with modular structures not only extends a product's lifespan but also ensures its complete disposal without environmental harm.The author concludes that implementing the proposed algorithm into industrial design practices facilitates the transition toward a "circular economy" model. Despite the identified material limitations, such as hygroscopicity and load-bearing constraints, eco-cardboard serves as a promising foundation for creating adaptive interior systems and next-generation packaging. The findings of this study can be utilized by design firms and manufacturing enterprises to enhance the environmental competitiveness of their products.

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