Estudos em Ciências Exatas e da Terra

Desafios, Avanços e Possibilidades

Alireza Mohebi Ashtiani
(organizador)

VOL III

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PRÓLOGO

O volume III de **Estudos em Ciências Exatas e da Terra: Desafios, Avanços e Possibilidades** reúne um conjunto plural de pesquisas que refletem a vitalidade, a complexidade e o caráter interdisciplinar das ciências contemporâneas. Os dez capítulos aqui apresentados, provenientes de diversos países e contextos institucionais, oferecem um panorama abrangente dos desafios científicos atuais e das soluções inovadoras que emergem do diálogo entre matemática, física, química, engenharia, geociências, sustentabilidade ambiental e desenvolvimento territorial, reafirmando a amplitude teórica e aplicada dessas áreas.

Para favorecer a leitura e destacar as afinidades conceituais entre os temas, a obra foi organizada em três eixos temáticos que evidenciam os diferentes modos pelos quais o conhecimento científico se articula com problemas reais e necessidades sociais urgentes, propondo uma aproximação integradora e contemporânea das Ciências Exatas e da Terra.

1. Modelagem Matemática, Simulação, Processos Físicos e Engenharia Aplicada

O primeiro eixo reúne estudos orientados pela lógica da modelagem, da caracterização de materiais e da investigação de sistemas físico-químicos complexos. Aqui, a matemática desempenha um papel central, seja na descrição do crescimento populacional, na interpretação de curvas de relações molares ou na análise termoestrutural de concretos refratários usados na indústria siderúrgica. A ênfase comum está na busca por métodos rigorosos de análise, na construção de modelos interpretativos e na compreensão dos comportamentos materiais sob diferentes condições. Esses capítulos mostram como a formulação matemática e a experimentação se complementam, de forma decisiva, na explicação de fenômenos fundamentais para a ciência e a engenharia, evidenciando a potência dos métodos quantitativos na resolução de problemas complexos.

2. Sustentabilidade, Meio Ambiente, Tecnologias de Remediação e Ecodesign

O segundo eixo destaca pesquisas alinhadas aos desafios ambientais contemporâneos, trazendo propostas inovadoras para o desenvolvimento de tecnologias limpas, novos materiais sustentáveis e soluções de remediação ecológica. Os capítulos abordam desde práticas de ecodesign em produtos plásticos, passando pela criação de adsorventes de origem agroindustrial, até aplicações de biomassa vegetal para remoção de contaminantes e estratégias que ampliam o desempenho energético de sistemas fotovoltaicos, articulando ciência de materiais e preocupações ambientais. O núcleo unificador deste eixo é o compromisso com a sustentabilidade, com a valorização de resíduos, com a mitigação de impactos ambientais e com a promoção de alternativas tecnológicas responsáveis e acessíveis que dialogam diretamente com demandas sociais emergentes.

3. Território, Geociências e Desenvolvimento Agrário-Industrial

O terceiro eixo aborda temas relacionados à organização do espaço, à história das indústrias de base e às dinâmicas socioeconômicas ligadas ao uso da terra. Os capítulos discutem a trajetória de figuras marcantes das geociências, analisam políticas e práticas de consolidação fundiária em escala nacional e refletem sobre as transformações industriais que moldam setores-chave como o agrícola e o petrolífero. Ao articular perspectivas históricas, econômicas e territoriais, este eixo evidencia como as ciências exatas e da terra também se expressam na compreensão dos processos sociais e produtivos que estruturam países e regiões, demonstrando que a pesquisa científica contribui igualmente para interpretações críticas sobre o desenvolvimento nacional.

A estrutura temática proposta pretende, portanto, facilitar a leitura e realçar o alcance multidisciplinar das pesquisas reunidas. Cada eixo demonstra, a seu modo, como o rigor científico pode contribuir para o entendimento de problemas concretos e para o desenvolvimento de soluções inovadoras, sejam elas de caráter teórico, tecnológico ou socioambiental, reforçando o papel estratégico da ciência na construção de futuros possíveis.

Esperamos que esta obra inspire pesquisadores, estudantes e profissionais a aprofundar o diálogo entre diferentes áreas do conhecimento e a reconhecer, na diversidade temática aqui apresentada, novas possibilidades de investigação e ação.

Desejo a todos uma excelente leitura!

Alireza Mohebi Ashtiani

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ABSTRACT: In a context where plastic is often negatively perceived for its environmental impact, there's a noticeable trend towards replacing it with alternatives like paper or composites. However, these transitions often occur without thorough assessment, potentially leading to the development of new products that may not be environmentally beneficial. Ecodesign emerges as a key solution for sustainability. This research highlights innovations and best practices for designers working on plastic-centric projects. It explores how ecodesign utilizes technological advances to reduce the environmental impact of plastic products. Emphasizing early-stage research and planning, the research advocates principles like life cycle assessment, biomimicry, and circular economy, demonstrating their integration for projects with environmental, social, and economic responsibility. To demonstrate the practical application of this approach, the PRR "NIRVANA" project will serve as a reference and result to analyse the development of sustainable modular systems for more sustainable hydroponics.

KEYWORDS: ecodesign; plastic; sustainability; education; biomimicry.

[1] Uma versão anterior deste trabalho foi publicada em DESIGN COMMIT – 1st International Conference on Design and Industry, 2024.

1. INTRODUCTION

During the 18th and the 19th century, the world underwent significant industrial evolution. New technologies were developed, mass production increased significantly, and urban spaces expanded as well. This evolution, despite being of great importance for technological and economic progress for humanity, also posed a significant environmental threat (Allen, 2017). It wasn´t long until industrial growth started to affect the environment with severe problems. The entire bionetwork and natural system components like water, air, soil and bio-diversity started to face relentless consequences. Realizing the seriousness of the problem, the impacts needed to be analysed and there was a demand for conscious environmental response or solution (Patnaik, 2018). Ecodesign has emerged as a proposed solution to these current problems. It seeks to combat the adversities resulting from industry and excessive consumption by developing alternatives or improving existing products with a smarter and more environmentally responsible approach (Dewberry, 1996). Sustainable design, or ecodesign, is based on fundamental rules that assist in making informed decisions regarding the product under development. These 'rules' must be based on facts, and therefore, extensive preliminary research is necessary to ensure that the product will truly be more sustainable than its competitor (DeArmitt, 2020).

It could be argued that industrial design is one of the most harmful professions towards the planet, however industrial designers can be the problem as well as the solution (Papanek, 2005). With this said, designers have a huge opportunity to propose solutions that could mitigate the global ecological crisis and improve the quality of life for the future. This should be the design challenge of this generation (Ramirez, 2007).

This research will explore this theme focused on a specific type of material: polymers, delving into their various applications, environmental impact, public perception, and, most importantly, how they can be utilized as a more sustainable alternative.

2. ECODESIGN

In the search for a solution to the ascending environmental threats, the United Nations held the Conference on the Human Environment in Stockholm in 1972. This event allowed for the worldwide recognition of the importance of protecting the environment, changing habits and approaches with this goal in mind, and adopting more environmentally responsible measures. It was during this conference that sustainable development was brought up for the first time (Handl, 2012). Later it was described in this manner:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (*UN World Commission on Environment and Development, Ed., Report of the World Commission on Environment and Development*, 1987)

In the subsequent years, efforts were made to thoroughly understand the problem and explore ways to address it. It was concluded that some of the main issues included the indiscriminate extraction of limited natural resources, excessive production, dangerous emissions, improper waste disposal, and the widespread use of toxic chemicals (Patnaik, 2018). In response to this adversity, the concept of ecodesign emerged. It seeks to combine the principles of industrial design with environmental ideologies by developing products that take into account their entire life cycle, materials, waste, applications, and production from an early stage. This type of design is considered an integral part of global efforts to combat climate change and preserve the environment. Furthermore, it is increasingly recognized by businesses and governments as a sound investment, as it also meets the demands of environmentally conscious consumers. Ecodesign is a concept that integrates multifaceted aspects of design and environmental considerations and the objective is to create sustainable solutions that satisfy human needs and desires Its main goal is to develop products that contribute to sustainability by reducing its environmental impact throughout the life cycle, along with requirements such as functionality, quality, safety, cost, ease of production, ergonomics and aesthetics (Karlsson & Luttropp, 2006).

2.1. ECODESIGN TOOLS

When discussing ecodesign it's essential to highlight the importance of the research phase, since it plays a pivotal role in the design process by providing a foundation for informed decision-making. With this in mind, a series of processes were developed to serve as ecodesign tools. These tools must be integrated into the product development process as early as possible to avoid possible errors in a more advanced phase of the development, implying larger costs and risks (Camocho, 2022).

> "Rational planning constitutes an essential tool for reconciling any conflict between the needs of development and the need to protect and improve the environment." – (*Report of the United Nations Conference on the Human Environment, Stockholm, 5-16 June 1972*, 1972)

In addition to guidelines, which will also be presented, there are two very useful tools for this purpose.

2.1.1. Life cycle assessment (LCA)

Life-cycle assessment (LCA) is a process created to evaluate the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. It attempts to measure the total environmental effects of a product "from cradle to grave" (Duda & Shaw, 1997). It is used to analyse and quantify environmental impacts in various categories, such as natural resource consumption, greenhouse gas emissions, air and water pollution, among others. This analysis has a major importance for the development of products since it provides lots of information to the developers about the impact of the product in each stage of its life cycle. The general categories of environmental impacts in need of consideration are human health, use of resources and ecological consequences. This knowledge is vital to understand what needs to be improved and to compare the impact of different materials, manufacturing processes allowing the designer to make more conscious choices when developing a product (Klöpffer & Grahl, 2014).

The life cycle of a product can be based on a linear economy or in a circular economy. In a linear product life cycle, the product is designed in a way that it is produced, distributed and discarded as waste after it is used or after it stops serving its purpose. This type of economy is known as a non-sustainable one because it shortens the product life cycle, it generates more waste and it causes pollution and resource depletion (Nasir et al., 2017).

Nowadays, when developing eco-friendly products, the goal is to bet in a circular economy. This model pretends to minimize waste and environmental impact by aiming to keep products and materials in use for as long as possible. It promotes a "cradle to cradle" approach implying that, at the end of a life cycle, the product doesn't need to turn into full waste, and instead it can be repurposed (Mestre & Cooper, 2017)

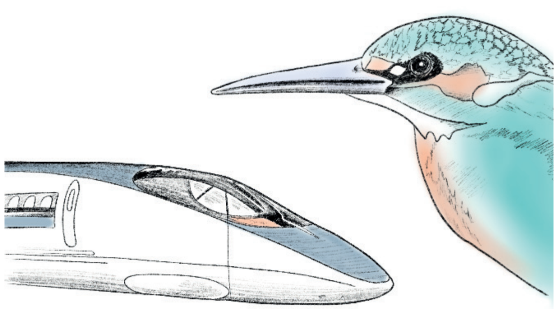
After understanding what is a product life cycle, it's possible to comprehend how a LCA (Life Cycle Assessment) is made. In a simplified manner, when making a LCA it's necessary to collect data on everything involved (energy, materials, waste ...) at every stage of the cycle, study this information and analyse the impact on the environment (emissions, resource use...), understanding what the results mean and in which stages the product is more impactful, etc (Duda & Shaw, 1997). After having a well-done LCA it's possible to improve the product in a much more informed and intelligent manner. Understanding what stages are the most impactful in a product life cycle can result in upgrades adjusted to that data.

2.2. BIOMIMICRY

Biomimicry can be defined as a branch of science that emulates nature in the search for optimized solutions to a variety of problems. It is often considered a tool or approach within the field of ecodesign and its underlying concept is that designers and engineers pay attention to the details and designs of natural systems, using them as a source of inspiration for effective, sustainable and renewable solutions to problems that compete with environmental sustainability. (Kennedy et al., 2015).

A good example of biomimicry being used for ecodesign is the design process in the development of the "Shinkansen" the Japanese Bullet Train inspired by the kingfisher. The kingfisher is a bird that is able to cut through the air and dive into the water to catch prey without causing any splashes. Many tests were conducted and the conclusion was that aquatic kingfishers had improved drag reduction properties in their beak structures and thus were more suited for diving in comparison to their terrestrial relatives. Using biomimicry principles, the front part of the train was redesigned to resemble the shape of the kingfisher's beak. This adaptation massively decreased the drag, improving the speed and fuel economy (Sreeramagiri, 2021).

Fig. 1. Japan's Shinkansen Bullet Train and a kingfisher - Biomimicry example.



2.3. ECODESIGN GUIDELINES

Nowadays where environmental sustainability is paramount, the concept of Ecodesign has emerged as a powerful tool for fostering innovation and reducing the environmental impact of products. In an effort of developing a simple tool in ecodesign education, the checklist and guidelines approach started to be used for a quick evaluation of the product's environmental profile. The purpose of these guidelines is to present to designers intelligent questions and suggestions for the design team to consider to solve problems. Many checklists and guidelines were formulated, however the Ten Golden Rules, proposed by Luttropp and Lagerstedt (2006), represent the most significant example of this typology of design recommendations (Rossi et al., 2016). By adhering to these principles, we can not only mitigate the environmental footprint of our creations but also align our efforts with the global imperative for a more sustainable future.

2.3.1. "Ten Golden Rules" by (Luttropp & Lagerstedt, 2006)

1 - Do not use toxic substances and utilize closed loops for necessary but toxic ones.

When developing a product, it's important to plan it with its potential environmental risks in mind so that they can be eliminated or minimized. Many times products end up in the municipal household waste. The consequence is that valuable materials are not recovered and hazardous substances will be problematic at disposal. An appropriate ecodesign strategy should focus on minimizing the content of materials with a heavy "ecological rucksack" as these are not always recycled, and of hazardous materials which cause additional expenses and efforts in treatment processes. It's possible to reduce of negative environmental impacts through the use of environmentally friendly materials, recycled materials, renewable raw materials so when the use of this kind of materials is possible, it should always be pursued. However, in cases in which this substitution is not possible, it's important to find ways to minimize the use of these materials and ways to reuse them (Schischke et al., 2005).

2 - Minimize energy and resource consumption in the production phase and transport through improved housekeeping.

If it's the manufacture stage that's making the most trouble, the focus should be in studying the possibility of using manufacture procedures that use less resources (energy, water...) or that bet on renewable energy sources, Designing the product so that the material needs to go through less manufacturing processes, can also have a big influence on sustainability of its production. Increasing material efficiency through sorting and recycling of waste is a good way to keep the materials in a circular economy and it could also bring economic benefits to the company. The distribution can also be a problematic stage, ecodesign can be used to soften its impacts by designing the products in a shape that optimizes its organization so that a single truck, for example, can transport more units at a time, or by making the product lighter so that the fuel consumption is lower (Nebe et al., 2018).

3 - Use structural features and high-quality materials to minimize weight in products, if such choices do not interfere with necessary flexibility, impact strength or other functional priorities.

By reducing the required amount of material in a product and its packaging, the start and the end of the life cycle of the product can be greatly improved since it would now be possible to produce more products with the same amount of material. This can be done through design for optimum strength, integration of functions, etc. Nowadays a new design assisting process is in use: Topology optimization is a mathematical method that has been used to reduce material usage of a given structure through optimizing its design considering a given set of loads, boundary conditions or constraints. The technique has been used in the mechanical, civil, and the aerospace industries improving fuel efficiency by reducing the weight of its mechanical parts without compromising the strength (Lee et al., 2023) .

4 - Minimize energy and resource consumption in the usage phase, especially for products with the most significant aspects in the usage phase.

Even though energy is consumed across all of the phases of a product life cycle the level of energy consumed in each phase varies significantly depending on the product. Electrical products are typically great contributors to environmental impact due to the consumption of electricity during the "use stage". To prevent and reduce ecological consequences of a product when it is being used the design can be really useful. The handling of products can be improved through adaptability, ergonomics, short set-up time, ... Principles of action aiming at waste prevention should be applied so that waste resulting on the use of the product can also be minimized. For example, when developing a coffee maker, the capsules should also be considered and designed in an ecological way since they will produce most of the waste during the product use stage (Seow et al., 2016).

5 - Promote repair and upgrading, especially for system-dependent products. (e.g. cell phones, computers and CD players).

Improved functionality through up-grading, multiple functions, can have positive impacts in the planet. An example of an improvement like this is when a product has more than one functionality, this type of products can substitute many different products possibly reducing the demand for their production. Facilitating reparability and easy-maintenance in eco-design is essential for promoting sustainability. Products that are easy to repair extend their useful life, reduce the need for frequent replacements and minimise environmental impact. By making products easy to maintain, we promote repairability, extending their useful life and reducing the environmental impact associated with manufacturing and disposal. This approach is in line with a circular economy, encouraging responsible consumption and the conservation of resources. The maintenance of a product can be improved by choosing or developing replaceable components, ensuring maintenance with standard tools, betting on a design for assembly and disassembly, etc (Kishore, 2022).

6 - Promote long life, especially for products with significant environmental aspects outside of the usage phase.

When developing a product, it´s crucial to ensure it has an appropriate life time. A bad design practice regarding this topic is programmed obsolescence which refers to the design and production of goods with the intention of having a limited lifespan, becoming obsolete or non-functional after a certain period. This business strategy aims to create mass consumption harming the environment. A result of shorter lifespan is that more waste is produced which in many circumstances ends up in landfills. From a life cycle thinking perspective, the resource efficiency of such systems is said to be very low (King et al., 2006). With this in mind, it's easy to recognize that the product's lifespan from the outset is an important factor in the sustainability of a product, which should be extended as much as possible (Rivera & Lallmahomed, 2016).

7 - Invest in better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear, thereby ensuring reduced maintenance and longer product life.

The selection of the materials for a product can represent a great improvement in the sustainability of a product. When a material is better and able to resist the loads and environment that the product will be exposed to, the product life-cycle can be extended without needing much maintenance or substitution of components (Luttropp & Lagerstedt, 2006).

8 - Prearrange upgrading, repair and recycling through accessibility, labelling, modules, breaking points and manuals.

The upgrading and repairability of a product can and should be facilitated by making the accessibility to components easy, clear labelling for identification and sorting, modular design for disassembly, strategically placed breaking points to aid in disassembly, and comprehensive manuals to guide users through maintenance and repair processes (Luttropp & Lagerstedt, 2006).

9 - Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys.

When developing a product, it's advisable to minimize the number of materials used, favouring simple material compositions, giving priority to recycled materials, avoiding blended materials, and refraining from using alloys, which can complicate recycling processes. The use of recyclable materials helps divert waste from landfill, conserves resources and reduces the environmental impact associated with the extraction of raw materials and manufacturing. Recycling plays a crucial role in promoting a circular economy, closing the loop on the use of materials and encouraging a more sustainable approach to resource management. (Pigosso et al., 2010)

10 - Use as few joining elements as possible and use screws, adhesives, welding, snap fits, geometric locking, etc. according to the life cycle scenario.

Facilitating disassembly in design involves making products easy to take apart for maintenance, repair or recycling. This approach enhances sustainability by promoting resource recovery, recycling efficiency and reducing environmental impact. Design for disassembly can be applied by minimizing the use of joining elements, especially the ones that require the use of an extra component or material (Favi et al., 2019).

3. POLYMERS

The German chemist Hermann Staudinger presupposed, in 1920, the existence of lengthy molecules. The idea was that macromolecules could be made by stringing together a chain of many short molecules, causing some skepticism amongst his peers. In 1950 the term "polymer" was internationally adopted as the standard for this type of material (Lintsen et al., 2017). It was discovered a way to produce man-made polymers which are typically addressed as plastics.

> "Polymers can be defined as macromolecules formed by linking together repeating monomer units. This definition may seem a little daunting and confusing to those unfamiliar with this field, but it turns out that polymers are all around us and are present in nature." (DeArmitt, 2020)

This discovery has boosted many technological advances that resulted in a huge improvement in our quality of life since they are very versatile materials. In the field of medicine, plastics played a huge role and contributed to reduce the risk of infection and improved healthcare since it can be found in lots of equipment. Its use revolutionized the food industry, its use in the packaging extended the shelf life of the products and, in consequence, food waste was reduced. The use of plastics in transportation made vehicles lighter, safer and more efficient. In short, with the appearance of this new material in the industry, it was possible to innovate in product design, architecture and technology since it was now possible to create things that previously would not have been possible or as efficient (DeArmitt, 2020).

3.1. SUSTAINABILITY IN POLYMERS

Since plastics started being used their growth hasn't stopped. Their many properties and applications aligned with the easy and cheap manufacturing are greatly related to this increase. In a time where environmental awareness and sustainability are key topics in society, the public is demanding for environmental change. This well-intentioned goal, when driven by misconceptions and poorly supported info, can inadvertently lead to the opposite effect increased waste, carbon emissions, and pollution. With this in mind the question arises: Are plastics sustainable?

Considering the materials and manufacture involved it's possible to conclude that the main starting material used for plastics is crude oil. The current reliance on crude oil for plastic production is unsustainable, as the rate of consumption far outpaces the natural formation of fossil fuels, however it's also important to keep in mind that only 4% of crude oil is applied in plastics. On top of that, the refining of crude oil releases SO_2 contributing to acidification and the production of plastics as a whole also releases chemicals. On the other hand, there's room for improvement in the manufacturing of plastics. The emissions resulting from plastics manufacturing have been reducing noticeably during the last 20 years. The crude oil can be substituted by other materials like coal, which has much larger reserves, natural gas or, ideally, vegetable raw materials that are biodegradable. Biologically degradable plastics may represent a great approach relating to the disposal and use of limited resources but when they are analysed in LCA they tend to have a negative result caused by the energy expenses associated with agriculture. It's also critical to consider that the use of crude oil to make plastics is preferable than direct burning since it may save energy during the period of use and some energy can be exploited at the end of the life cycle. This small advantage in plastic waste incineration will decrease in importance since nowadays energy is turning renewable making it an extra way to emit CO_2 and other harmful gases (Mulder, 1998).

Regarding the distribution phase of plastic products, these represent great improvement. Their low weight represents a reduction of costs regarding fuel and energy of transportation (Mulder, 1998). Moreover, the significant design flexibility offered by plastic can be harnessed to create products that are easier to arrange, thereby optimizing space and allowing for the transportation of more products in a single shipment.

Single-used products also represent a problem in plastic usage. Although some products need to be single-use (due to hygiene or health reasons for example) there are many products that should be developed to sustain a longer use stage (DeArmitt, 2020). It is estimated that 50% of plastic objects are developed for single-use and just 20% to 25% is intended for long-term use. The best way to combat this problem is to invest in producing products that are able to endure a long time in use. When a good material selection is made it is possible to respond to this requirement successfully since plastics have many qualities that make them durable (Geyer et al., 2017).

According to Industrial Ecology Professor Roland Geyer, despite the potential for recovery, approximately 50% of the plastics produced lack sufficient value to make their recovery economically viable. As a result, only 2% of the plastic waste generated since the 1950s has been recycled, while 6% has been incinerated, and the vast majority (about 92%) has been landfilled or disposed of in the natural environment. (Geyer et al., 2017). According to the book "The Plastics Paradox" by Chris DeArmitt, a leading authority in materials engineering, it doesn't take too much energy to recycle most plastics many times and without a major loss in properties. About 87% of plastics, type one through six, can be recycled. Given this perspective, Chris DeArmitt argues that the United States has the potential to significantly increase its recycling efforts, especially considering that Europe is way ahead in recycling rates. One factor contributing to this gap is the higher cost of recycled plastic, coupled with its less appealing colour options, which presents challenges in marketing and selling of these materials. (DeArmitt, 2020) (Wecker, 2018).

The end of the life cycle of plastic products sparks lots of controversy and contradictory information making it harder for most people to understand what is true or false. When reading an article like "Plastic: Reduce, Recycle, and Environment" it's implied that plastics take roughly 500 to 1000 years to break down into little pieces making them not biodegradable. With this in mind it is also recommended to ban polystyrene shopping bags and the increasing level of plastic manufacturing until the recycling process is greatly improved or another solution comes up (Bano et al., 2020). In contrast Chris DeArmitt states that the claims suggesting that plastics persist for 1000 years are unfounded, that plastics are unstable materials and a regular grocery bag breaks down and disappears in less than a year when left outside (DeArmitt, 2020).

3.2. PUBLIC PERCEPTION

Plastics have been a subject of public scrutiny, often blamed for environmental issues without substantial evidence. One example of poor decision due to lack of proper research done beforehand is the substitution of plastic bags for paper bags in some supermarket brands. This change is seen as sustainable and a good initiative by the general public since plastics are usually perceived as the worst material for the environment unlike paper. However, upon conducting thorough research on the subject and analysing numerous life cycle assessments (LCAs) of plastic bags produced with various materials, it becomes evident that this decision leans more towards being a marketing strategy rather than an ecological one. (DeArmitt, 2020)

By consulting many LCA it's possible to conclude that both of the materials with the least ecological impact were plastics: the standard polyethylene bag emerged as the most environmentally sustainable option when used singularly but the eco-friendliness of a reusable polypropylene bag surpassed that of its single-use counterpart after several uses. Considering the paper bags that emerged as an alternative, it is confirmed that even when produced from recycled material, these represent a significantly greater environmental impact than plastic since it demands higher energy consumption increasing CO2 emissions, uses more water, and involves a greater quantity of chemicals. Another disadvantage of this alteration in material is that paper bags are more fragile making its reutilization harder than a plastic bag. (Kimmel, Sc.D., 2014; Morris & Seasholes, 2014; O'Farrell, 2009)

> "The study results support the conclusion that any decision to ban traditional polyethylene plastic grocery bags in favour of bags made from alternative materials (compostable plastic or recycled paper) will be counterproductive and result in a significant increase in environmental impacts across a number of categories from global warming effects to the use of precious potable water resources." (Franklin Associates & Council for Solid Waste, 1990)

To consider if a change in a product is for the better or for the worst it's necessary to study a LCA of the current product and a LCA of the product with the change implemented to understand which version is the most sustainable. On top of choosing the right material, it's vital to understand that it is the human behaviour that is primarily responsible for littering and not the material itself. Education and responsibility are considered key to addressing the litter problem. (DeArmitt, 2020)

4. RESULTS "NIRVANA"

To demonstrate the practical application of this approach, the "NIRVANA" project will serve as a reference to analyse the development of modular systems for more sustainable hydroponics.

Currently, in line with the increasing need for higher and more efficient water management, coupled with a growing demand for large quantities of quality agricultural products, hydroponic farming has been gaining more prominence compared to traditional agriculture. Here, we propose the development of a system using recycled plastic as a base instead of the typical metallic materials used in similar products.

Within the Sustainable Plastics project, under PPS8: NIRVANA, led by the Logoplaste Innovation Lab, as part of the Mobilizing Agendas (PRR) for Sustainable Plastics, several ecodesign principles were implemented in the development of this product. The co-promoters of this project are "J.Prior", "PIEP" and "Prilux". A life cycle assessment (LCA) will be conducted to ensure its sustainability. The plastic will be chosen with durability and recyclability in mind, with the aim of achieving 100% recyclability and incorporating recycled materials. The design was optimized for assembly and disassembly, allowing for easy distribution and storage by ensuring that the systems fit together seamlessly. Transitioning from metallic to polymeric materials also aids in distribution. Additionally, these systems facilitate a semi-closed water cycle for hydroponics, prolonging water reuse and reducing waste.

In order to fulfil the objective of having a reduced weight and at the same time improving the structural performance of the system, the methodology of combining engineering with eco-design was applied. This was achieved using structural simulations to analyze the forces applied to the gutter during the hydroponic process in order to understand where it was possible to remove material without compromising the performance.

Fig. 2. Concepts for ribs in the "W" profile.

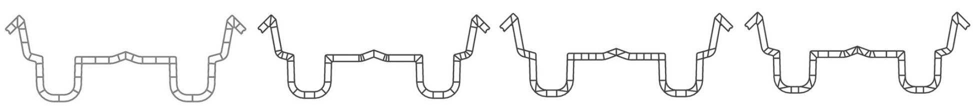
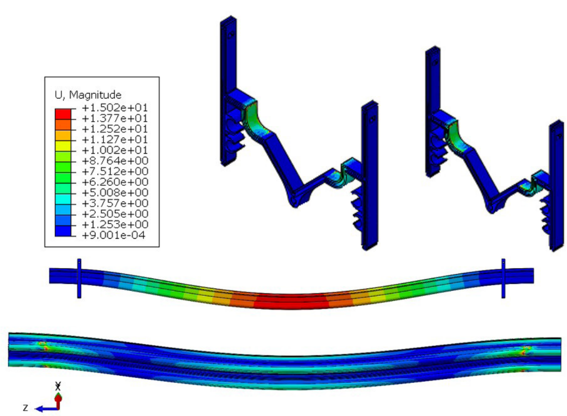


Fig. 3. Structural simulation of selected concept.



All case studies were subjected to a load equivalent to the weight of the plantings (70kg/3m), and the maximum displacement of each concept was analyzed, searching for the one that would have the lowest maximum displacement. The concept selected was the third one because it had the lowest weight with the best performance ratio. This decision was done having in mind the durability, performance and the material usage. These measures not only seek to optimise the system's efficiency, but are also in line with ecodesign principles, promoting sustainability and efficiency throughout the product's life cycle (Luttropp & Lagerstedt, 2006).

5. DISCUSSION

In light of this, it's accepted that the materials as a whole are not the enemy and they need to be well understood to use them in the most responsible way. Plastics, even though they have an infamous reputation, offer lots of advantages. They have very versatile properties so they can be used to perform the same function as other materials using less quantity, making it lighter and with less residue and they contribute greatly to the sustainability of many products. Overall, this material can enable a modern lifestyle while also protecting the environment as long as it's used in a responsible manner. This can only be done by understanding the impacts and characteristics of the polymer intended to use to make sure it is a good option that will allow the production of a product as functional and ecologic as possible.

Designers bear significant responsibility as they are instrumental in shaping the future products, which should prioritize sustainability. Plastics, in many instances, can offer the most appropriate and environmentally friendly solution. It is up to us to discern these instances and leverage this material to safeguard our environment. For this to happen, it's important that information about material impacts gets clearer and free from misinformation so that everyone can better understand materials and make informed decisions, not only in the development of new products but also in their acquisition. When people lack sufficient knowledge about something, it becomes easier to manipulate their perception of it, and individuals typically gravitate toward things they believe they understand better.

6. RECOMMENDATIONS FOR FUTURE WORK

Concerning the "NIRVANA" project, there are opportunities for enhancement. Improving the stackability of the gutters through minor modifications can ensure seamless fitting during distribution. Additionally, developing the gutter in two separate parts could facilitate the separation of black and white components for recycling. An intriguing solution to explore could involve developing a bio-based polymer for certain components, utilizing bio-waste generated during cultivation.

Research and innovation should be encouraged to continue to seek and develop materials with better environmental outcomes. These efforts and transitions should be incentivized and embraced by product developers in order to contribute to change.

7. CONCLUSION

Ecodesign has the potential to significantly improve the environmental condition of the world. For it to be effectively implemented, it is important for it to be integrated into the education of designers and consistently encouraged and valued. In the decision-making process of product development, all stages of its lifecycle should be considered. The manufacturing processes, materials, and morphology should be adjusted to ensure the product is as environmentally friendly as possible while remaining economically viable. With these concepts as a foundation, understanding which materials to apply in specific situations is crucial. Often, plastic will be the chosen material, and for it to be applied responsibly, understanding its properties and impacts is essential. When materials are well understood, they can be utilized to maximize their benefits and contribute to a greener future.

This research also explores the intersection between engineering and eco-design, using the project “NIRVANA” project as a practical example to develop modular systems for more sustainable hydroponics. Faced with the growing importance of sustainability in product design, the combination of these disciplines emerges as a multifaceted approach to address both ecological concerns and consumer demands. The paper sets out a new approach that seeks to optimise the structure of the product, reduce its weight, making it more durable and recyclable.

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