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Practical Aspects of Sustainability: A Discussion of product design with recyclable materials

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Abstract. Sustainable development is one that can meet the needs of the present generation without compromising the resources needed by future generations (1). The industry represents a great agent in the pursuit of sustainable development, yet only 30% of these companies seek opportunities to invest in sustainability (2). The search for sustainable development associated to the increase in technological power has stimulated the use of raw materials that add greater value to products and that meet environmental, social and economic specificities. In Brazil 352 thousand tons of flexible packaging were consumed in 2014, including long-life packaging (3), which can be used as technological alternatives, mainly for the use of paper, polyethylene and aluminum compounds. The objective of this work is to evaluate a sustainable product design from the discussion of the design of a stool produced with low density polyethylene and aluminum composite, resulting from the recycling process of the long life packaging (Tetra Pak). The project adopts two methodological approaches: the first theoretical, through an exploratory bibliographical research, that works the fundamentals and applications of sustainability, product design planning and production processes, with a sustainable material resources and recycling. The second path works the practice, through a study of the modeling in SolidWorks model of a stool for future prototyping..

Keywords. *Sustainable Development, Sustainability, Sustainable Product Design, Recycling Process.*

Introduction. Sustainable development is one that can meet the needs of the present generation without compromising the resources needed by future generations (1). Since the industry has too much control over the use of inputs and the emission of waste, it represents a great agent in the quest for sustainable development. It is known that more than 50% of the world's leading companies believe that sustainability plays an important role in many areas of the business sector. However, only 30% of these companies seek opportunities to invest in sustainability (2).
The growing search for sustainable development associated with the increase of technological power has stimulated a search for raw materials that add greater value to products and that meet environmental, social and economic specificities. In Brazil 352 thousand tons of flexible packaging were consumed in 2014, including long life packaging (3). There is an opportunity for the use of long life packaging as a raw material in technological alternatives for the use of its rejects composed of polyethylene and aluminum.

Thus, the analysis of the literature on the various methods and tools available for the development of sustainable products leads to the systematization of this literature, so that a method for sustainable product design can be easily used in companies. In this context, the objective of this work is to discuss the sustainable design of a stool produced from low density polyethylene and aluminum composite, resulting from the recycling process of the long life packaging (4) replacing the traditional plastic stools.
Benches are widely used products, mainly because they are easy to transport, with a reduced weight and a more affordable price. However, tests conducted by the National Institute of Metrology, Quality and Technology (INMETRO) indicated that 80% of the samples tested showed nonconformity, highlighting problems such as ergonomic deficiencies, low resistance and low durability. Moreover, since these plastic benches are produced and discarded in bulk, they cause serious environmental problems and prove the need for a product with a longer life.
The article adopts two paths: The first theorist through an exploratory bibliographic research, which works the fundamentals and applications of sustainability, product design planning and production processes, with recyclable material resources; already the second path works the practice, through a case study. Thus, a modeling was developed in SolidWorks, which generated models for a future prototyping of a stool made from recycled material.

Main text. According to the World Commission on Environment and Development (1), sustainability is related to sustainable development and is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their needs." Its importance was elevated to the business reality since large companies interact too much with the environment and with the communities of their surroundings, requesting a great financial investment.

On the other hand, the growing creation of socio-environmental laws and regulations results in a business environment in which sustainable issues are mandatory points to be taken by companies. Thus, for companies sustainability is characterized by being a vision, a strategy and even a way of survival in the market. (5).

The design has a systemic vision and is an interdisciplinary area, thus, an important point to create companies that generate sustainable values, and gain a competitive advantage in the market. It should be a strategic factor of the company, which projects efficient and effective products, always emphasizing sustainability and social responsibility. By producing cleaner and more economically viable projects, a path is created to generate an ecological mentality (6). The design, then, is directly related to the final product and its development process, and should be used with a competitive strategy. For this, it is necessary that the company is innovative, that is, the organization should be supportive to creativity. Innovation is a competitive differential facing the market and changes must be explored as an opportunity for a different business, product or service.The product design must meet the needs and expectations of the market, using a compatible design cost and quality. In addition, the project must indicate a production that meets the technological, quality and cost restrictions of the corporation. Thus, with the analysis of different models of product design, it is noted that there are similar activities in different

literatures. The project is a sequence of intercommunicating activities. This analysis can be summarized in table 1.

Table 1. Product design models

Clark e Fujimoto (1991)	**Krishnan e Ulrich (2001)**	**Pahk e Beltz (1996)**	**Kaminski (2000)**	**Crawford (2000)**	**Kotler (1998)**	**Bonsiepe (1984)**
Concept	**Development of concept**	**Project specification**	**Need Specification**	**Identification of opportunities**	**Generating ideas**	**Problematization**
Product Planning	Supply Chain Design	Design Conception	Feasibility study	Concept Generating	brainstorming	Analyse
Product Engineering	Product Development	Preliminar Design	Basic Design			Problem Definition
Process Design	Test and Performance	Detailed Design	Executive Design			
Pilot Production	Launch					

Product designs can encompass three major steps: designing, developing and detailing the product. The design stage collects all the data necessary for the development of the project, paying attention to the purpose of the product, market needs and expectations, in order to evaluate problems and create solutions. The product development stage consists of specifying and detailing the project from the analysis of existing projects. Developing projects in scale, creating models that generate solutions for the client. Already in the step of product detail, the parts of the project are broken and individually represented, the solutions created are again evaluated in order to provide the finalization of the project (7).

In this scenario, the search for a sustainable product is not only restricted to replacing the materials, it is necessary to integrate the stages of industrial design and the production process.

Thus, sustainable product designs should be guided by the reduction of materials and energy consumption, the application of low environmental impact materials, optimization of production and distribution, and the improvement of the use and the useful life of the product. For this, companies should seek a strategy that combines the already existing design process with the search for more adequate environmental solutions, and ecodesign is the methodology that addresses all these principles (6).

Generally, ecodesign is the principle that recognizes the impact of a new product on the environment during the design specification phase (8). The term also refers to any form of design that minimizes the destructive impacts of the environment, whether on new products, maintenance of existing products, reusable products or components, and recyclable materials. Thus, ecodesign seeks to reduce negative impacts throughout the production chain, from raw material acquisition, through processing and production, transportation and arrival to the final consumer, to collection after use, and can be reused or recycled. This idea is illustrated in the life cycle diagrammed in Figure 1.

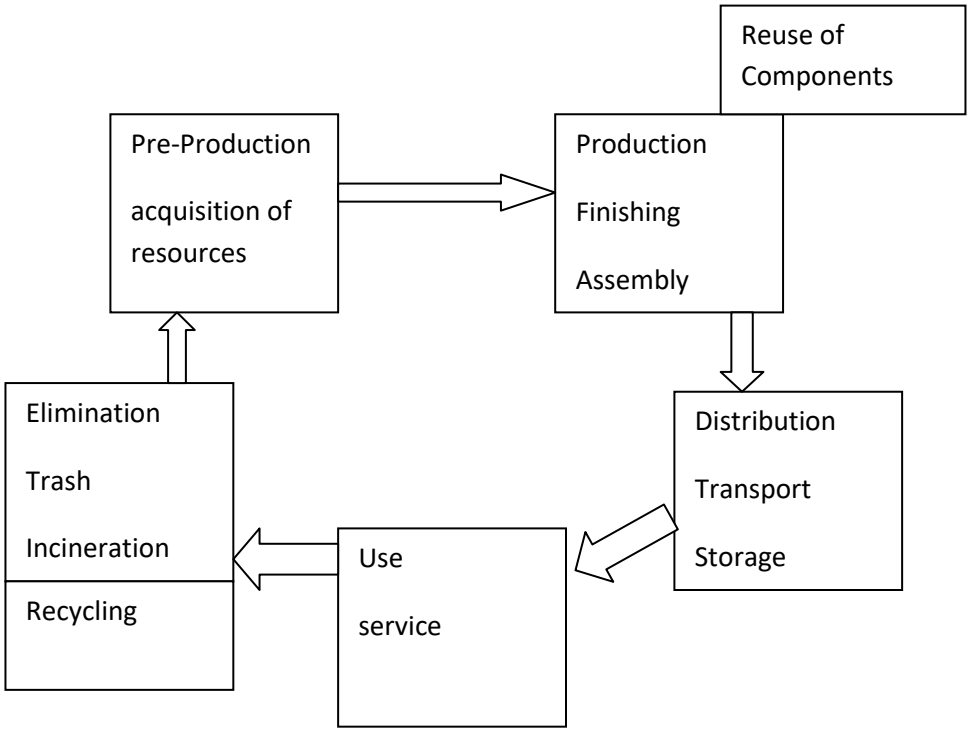

Figure 1. Products Lifecycle according to Ecodesign.

The methodology adopted was an exploratory research and case study from a re-reading of the typical bar chairs projects, placing it as an alternative idea in the segment of plastic chairs. On the other hand, the study makes considerations about the raw material used as well as highlights the reverse logistics, as factors of great impact for the discussion of product design.

Plastic benches are products of the monobloc plastic chair set, defined by the National Institute of Metrology, Quality and Technology (INMETRO) as "one in which their seat and legs are constituted in a single piece, with or without arms". The Brazilian Association of Technical Standards (ABNT) defines the monoblock plastic chair as a "chair produced in a single step, with the back in a fixed position, without moving parts with or without an arm, by the injection process, intended for the person regardless of its design or format ".

Long Life or carton packs were designed by the Swedish multinational Tetra Pak, being an invention of Ruben Rausing and began to be commercialized in Sweden in 1952. First it had a tetrahedral format and they were made from waxed cardboard. They acquired the shape of the milk cartons currently known only in 1963. In Brazil, these packages were introduced in 1957 and were well accepted by the market (9). Figure 3.2 exemplifies packaging models produced by Tetra Pak.

It consists of three different materials arranged in six layers: duplex paper (long fiber), low density polyethylene and aluminum, figure 3.3. The paper is responsible for the structure of the packaging; the polyethylene by the impermeability and adhesion between the layers; and aluminum, which forms a barrier against oxygen, light and contamination (9). Thus, to pack a liter of a food, only 28 grams of material is used, and this mass is composed of approximately 75% of paper, 20% of polyethylene and 5% of aluminum (10).

Longa Vida packaging is 100% recyclable and recycling 1 ton of this product generates 650kg of paper, avoiding the cutting of 20 trees (9). Despite this, according to regulations of the National Sanitary Surveillance Agency (Anvisa), packaging used in food can not use recycled materials in its composition. Thus, products from the recycling of Longa Vida packaging are used in the manufacture of bags, pens, office items, brooms, garbage collectors and tiles (ENVIRONMENTAL CULTURE IN SCHOOLS, 2009). In 2014, 651 thousand tons of Tetra Pak packaging were recycled worldwide, which represents only 26% of the total produced by the company. In the same year in Brazil, only 76,000 tons of Tetra Pak packaging were recycled (4).

The process of separating Long Life Packaging is simple. To demonstrate this process, the packages were submerged in water for approximately 12 hours. After this period, the layers could be easily separated, figure 3.4.

The reverse logistics of post-consumer Long Life Packaging is related to the collection, separation and recycling of the three materials - paper, polyethylene and aluminum - that make them up. The whole process of recycling these packages begins with the post-consumption collection, through the selective collection. Recycling is divided into two stages, where in the first step the paper is separated from the other materials and in the later stage aluminum and polyethylene are recycled. The second step may occur in different ways, according to (10), "the recovery of energy from aluminum and polyethylene by incineration in biomass boilers, the recovery of aluminum in pyrolysis furnaces or the manufacture of parts by processes extrusion or thermoinjection ".

After selective collection and separation of the discarded packaging in the cooperatives, the packages are sent to the paper mills. In this step, the paper fibers are extracted through the

disintegration process, where there is separation of the materials from the packaging layers, Figure 3.6 (11). These fibers are then sent to the paper machine and used for the production of cardboard boxes (9). At the end of this process, there is a material composed of 80% of polyethylene and 20% of aluminum (11).

After reuse of the paper, polyethylene and aluminum go to other production processes, such as recycling via thermal separation (plasma technology), pressing for the manufacture of slabs and tiles, processing for the production of pellets.

The project proposed in this article should be guided by ecological and technological norms and standards, both Brazilian and international. The project prioritizes the well-being of the population and care for the environment, focusing its technical characteristics on the use of recycled material from the long-life packaging. On the other hand, the product resulting from the design meets a durable design that does not have strong fashion characteristics, so as not to be discarded quickly.

Conclusion. Through the researches carried out and the study of case worked, there is a base to propose steps for a methodology of development of sustainable products. In addition, by idealizing the products in references with only one type of recyclable material, it opened a range of hypotheses about the behavior of the material during processing and the product in use by the consumer.

The Sustainable Product Project is defined in five steps: project goal and scope; structure of the product and its components; function of each component of the product; environmental factors and objectives of each component of the product; and proposals and measures for solving problems.

Already during the development of the project, one must think about the life cycle of the product, the materials that will be used and the production process always seeking sustainability. A relevant aspect is whether the material already comes from a sustainable source, a recycling or reuse process, as well as whether it is a product that respects the three pillars of sustainability.

Thus, the use of a sustainable product development methodology is an opportunity for the company to innovate and overcome the challenges that sustainability imposes, always aiming at the benefits that this new culture brings.

Sustainable practices are rare and irreplaceable, because their characteristics are difficult to reproduce and endowed with specificities. Therefore, the development of a sustainable product design methodology becomes a strategy within an organization, which has specifics that can invalidate traditional methods of product design. This point reaffirms, therefore, the objective of this project to present a discussion of a about a model for development of new products from the recycling of long life packaging. However, implementing it is not an easy task, since it requires an organizational and cultural change throughout the company, since it needs to be incorporated into its strategy and be part of the routine of all employees.

During the research, it was clear that there are initiatives to recycle these wastes, however the proportion of recycled packaging compared to the quantity produced is less. However, thinking about recycling, it is perceived that it is a process that reduces the need for extraction of new raw materials, but at the same time, recycling actions spend energy and water. Thus, a topic for future research would be a new way of returning the materials that make up the long life packages to the life cycle of a product, since the material of the packages is still little studied, for a better validation of the project a research is necessary on the mechanical properties of the polyethylene and aluminum granulates for the application in the production of stools.

In addition, it is suggested a research on methods of test and adaptation of equipment for recycled materials. Since the case study object of this article was the product design, it will be necessary to make prototypes to validate the manufacturing processes and the products, besides executing technical tests to prove the hypotheses expected here, that the projected stools are endowed of greater resistance and consequently of a longer useful life. As an initial suggestion, the prototype should be subjected to tests of tensile strength, bending and determination of the flame surface propagation index.

It has been seen that the process of separating the materials from the long life packaging by plasma technology completely separates the aluminum from the polyethylene, whereby the recycled polyethylene could be applied in the production of the filaments used in the 3D printer.

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