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PRE-DEVELOPMENT OF PRODUCTS: METHODOLOGY APPLIED IN A PROPOSAL ORIENTED TO THE SUSTAINABLE DEVELOPMENT GOALS

Pré-desenvolvimento de produtos: metodologia aplicada em uma proposta orientada nos Objetivos do Desenvolvimento Sustentável

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ABSTRACT

In a context of growing customer needs and requirements and worsening environmental issues, the Product Development Process must adapt to these circumstances, promoting measures that enable sustainable development, thus maintaining balance and synergy in the environmental, social and economic spheres. For this, it is essential to carry out the pre-development of business proposals. In this context, adopting a holistic approach that interrelates various areas of literature, brings together contributions in order to lead society to a resilient and resource-efficient environment. Thus, this research promotes the interrelationship between the Product Development Process and the Sustainable Development Goals and aims to realize the pre-development of a product under the perspective of the Sustainable Development Goals (SDG). To meet the proposed objective, the methodology adopted consists of the adaptation of a pre-development model, selected through bibliographic analysis. The results of this research present the pre-development of a product willing to meet the goals of SDG 6 (drinking water and sanitation) and SDG 7 (accessible and clean energy). It highlights the use of tools to structure and ensure the assertiveness of the proposal, such as IDEF0, SWOT analysis and FMEA.
Keywords: Product Development Process; Pre-development; Sustainability; Sustainable Development Goals.

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PRÉ-DESENVOLVIMENTO DE PRODUTOS: METODOLOGIA APLICADA EM UMA PROPOSTA ORIENTADA NOS OBJETIVOS DO DESENVOLVIMENTO SUSTENTÁVEL

Pre-development of products: methodology applied in a proposal oriented to the sustainable development goals

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RESUMO

Em um contexto de crescimento das necessidades e exigências dos clientes e de agravamento da problemática ambiental, o processo de desenvolvimento de produtos deve se adequar a estas circunstâncias, promovendo medidas que viabilizem o desenvolvimento sustentável, mantendo assim, o equilíbrio e a sinergia nos âmbitos ambiental, social e econômico. Para tanto, é primordial realizar o pré-desenvolvimento das propostas de negócio. Neste contexto, adotar uma abordagem holística e que inter-relacione diversas áreas da literatura, reúnem contribuições a fim de levar a sociedade a um ambiente resiliente e eficiente em termos de recursos. Assim, esta pesquisa promove a inter-relação entre o processo de desenvolvimento de produtos e os objetivos do desenvolvimento sustentável e tem como objetivo realizar o pré-desenvolvimento de um produto sob a perspectiva dos objetivos do desenvolvimento sustentável (ods). Para atender o objetivo proposto, a metodologia adotada consiste na adaptação de um modelo de pré-desenvolvimento, selecionado através de análise bibliográfica. Os resultados desta pesquisa apresentam o pré-desenvolvimento de um produto disposto a satisfazer as metas do ods 6 (água potável e saneamento) e do ods 7 (energia acessível e limpa). Destaca-se a utilização de ferramentas para estruturar e garantir a assertividade da proposta, como idef0, análise swot e fmea.

Palavras-chave: Processo de desenvolvimento de produtos; Pré-desenvolvimento; Sustentabilidade; Objetivos do Desenvolvimento Sustentável.

INTRODUCTION

The discussion on sustainable development is intensifying (Luz, Francisco, Piekarski, & Salvador, 2018) as demand for products that reconcile innovation and environmental responsibility increases (Uemura Reche, Canciglieri Junior, Estorilio, & Rudek, 2020). In this context, the assessment of the impacts of consumption of products and services, related to SDG 12 (responsible consumption and production), is essential to achieve sustainable development (Hischier, Reale, Castellani, & Sala, 2020). Therefore, to achieve the Sustainable Development Goals (SDG), it is essential to invest in research, innovation and education (Salvia, Leal Filho, Brandli, & Griebeler, 2019).

In order to make the integration of sustainability into the product development process feasible, the need for strategic planning arises (Rozenfeld et al., 2006; Teixeira & Canciglieri Junior, 2019). In view of this, the Product Development Process (PDP) aims to identify market needs and propose solutions through products and services (Rozenfeld et al., 2006), so that the initial stages of PDP (pre-development) are directly related to the strategies and innovation capacity of organizations (Costa & Toledo, 2016).

The Sustainable Development Goals imply the need to identify a combination of processes capable of synergistically converting resources into value-added products (Ahmed Shehab, Al-Mohannadi, & Linke, 2020). In this context, this work aims to carry out the pre-development of a product from the perspective of the Sustainable Development Objectives (SDOs) focused on water and accessible and clean energy.

In order to meet the proposed objective, the methodology used consists of adapting the Costa and Toledo (2016) pre-development model in order to propose a product willing to meet the aims of SDG 6 (clean water and sanitation) and SDG 7 (affordable and clean energy).

In view of the above, this work is organized as follows: section 1 presents a literature review on the Product Development Process (PDP) and on the Sustainable Development Goals (SDG). In the subsequent section, the research methods are described, applied to pre-develop the proposed product, which is presented in section 3 of results and discussions. Finally, the conclusions of this work are presented.

1 BIBLIOGRAPHIC REVIEW

The first section of this chapter (1.1) presents the Product Development Process (PDP), as well as its definition and classification. Section 1.2 addresses the Sustainable Development Goals (SDG). Subsections 1.1.1 and 1.2.2 are more focused on the business proposal of this research, so subsection 1.1.1 discusses the pre-product development process and subsection 1.2 on Goals 6 and 7 of the SDG.

1.1 Product Development Process (PDP)

In a context of increasing the challenges of sustainable development, the reduction of product processing time, quality and environmental certification guarantee the satisfaction of customers' needs and the market competitiveness of companies (Benabdellah, Benghabrit, Bouhaddou, & Benghabrit, 2020).

Consider the entire life cycle of products (Beuren, Gomes Ferreira, & Cauchick Miguel, 2013; Corallo, Latino, Menegoli, & Pontrandolfo, 2020; Iaksch & Borsato, 2019; Reyes, Gouvinhas, Laratte, & Chevalier, 2020) and adopt ecological design correspond to consistent integrations when considering environmental aspects in the Product Development Process (PDP) (Rodrigues, Pigosso, & McAloone, 2019).

Considering the constraints of a project from the beginning of the PDP, problems in the later stages of its life cycle are avoided (Iaksch & Borsato, 2019), so the concept of Life Cycle Design (LCD) is able to reduce the environmental load associated with all stages of the cycle (Manzini & Vezzoli, 2016). The LCD's intention is to adopt a systemic perspective of the product, where the material and energy inputs should be reduced to the minimum possible from the raw material extraction stage to the final disposal (Manzini & Vezzoli, 2016).

For manufacturing to be able to produce and monitor its products, it is necessary to carry out advance planning, capable of ensuring business innovation (Rozenfeld et al., 2006). Rozenfeld et al. (2006) therefore

propose a model for developing new products consisting of three macrophases: pre-development, development, and post-development; which aim to meet the proposal from strategic planning to the final disposal of the product (Rozenfeld et al., 2006).

As the objective of this article is to work with the pre-development of products, the following subsection (1.1.2) highlights this phase of the Product Development Process (PDP).

1.1.2 Pre-development of products

The pre-development stage aims to define the product portfolio of an organization, based on its strategic plan, innovative ideas, opportunities and constraints (De Toledo & Simões, 2010). At this stage of the PDP, the most strategic decisions are made, usually with a high degree of uncertainty (Mendes & Toledo, 2012), but pre-development determines the product specifications, such as materials, concepts and manufacturing processes employed (Rozenfeld et al., 2006). In addition, its strategic bias optimizes future processes, such as production and marketing (Kohlbeck, Baimler, Beuren, Fagundes, & Pereira, 2020).

Through a search in the literature on the pre-development of products, it was found that the model of Rozenfeld et al. (2006) is widely mentioned and used in scientific publications (e.g. Araújo & Costa, 2018; Costa & Toledo, 2016; Souza, 2016; Kechinski, Faccio, Rosa, & Echeveste, 2010; Kohlbeck et al., 2020; Mendes & Toledo, 2012).

This stage of the PDP presents different approaches in the bibliography. Khurana and Rosenthal (1998) group pre-development in four stages: product definition, project definition, product strategy and organizational roles (Khurana & Rosenthal, 1998). Some conceptual models for pre-development management in literature (Mendes & Toledo, 2012), for example Reid and de Brentani (2004) proposed a model directed to the initial stages of pre-development to assist in the decision-making process.

Although several models are proposed by the literature, that of Rozenfeld et al. (2006) is considered the most complete (Nickel, Ferreira, Forcellini, Dos Santos, & Silva, 2010) and most appropriate to structure the Product Development Process (PDP) (Paula & Mello, 2012). Costa and Toledo (2016), in a literature review work, complement the pre-development stage proposed by Rozenfeld et al. (2006), classifying it in seven stages: Identification of opportunities, selection of opportunities, generation of ideas, concept development, concept selection and project planning (Costa & Toledo, 2016).

1.2 Sustainable Development Goals (SDG)

The Sustainable Development Goals (SDG) are considered the most important starting point for the understanding and fulfillment of human and environmental development principles by the year 2030 (Bebbington & Unerman, 2018). The targets of the SDG emphasize the need to engage organizations with innovation in order to create value for the common good, taking as a principle the reduction of poverty, the eradication of hunger and the protection of biodiversity (van der Waal & Thijssens, 2020).

Agenda 2030, established by the United Nations (UN) in 2015, determined 17 Sustainable Development Goals, containing 169 targets, presented in a way that mutually contributes to balance the dimensions of sustainable development: social, environmental and economic (United Nations General Assembly, 2015).

However, for effective delivery of SDG by 2030, multi-sector initiatives, involving governments, the private sector and civil society, restructuring governance and public policy (Florini & Pauli, 2018) are needed. For this, a change in the supply chain paradigm from the perspective of sustainability becomes essential, valuing responsible consumption and production (Silva & Figueiredo, 2020).

Since this work presents the proposal of a proposal that contributes to goals 6 and 7, these are presented in the following subsection (1.2.1).

1.2.1 SDG 6 (clean water and sanitation) and SDG 7 (affordable and clean energy)

The provision of and access to basic water and sanitation services has been recognized as a fundamental right to human survival (Bayu, Kim, & Oki, 2020; Sogbanmu, Aitsegame, Otubanjo, & Odiyo, 2020). According to

research conducted by the United Nations (2020) one in three people in the world do not have access to safe drinking water and three in ten do not have access to safely managed drinking water services.

Under these circumstances, the rainwater harvesting system corresponds to a well disseminated and effective method of collection and storage for later use in different purposes (Alim et al., 2020). This raises the need to consider SDG 6, which focuses on water management (Setty, Jiménez, Willetts, Leifels, & Bartram, 2020). Investments in adequate infrastructure, hygiene incentives and the protection and restoration of aquatic ecosystems are also needed in order to provide safe and accessible drinking water to all people by 2030 (United Nations Development Programme, 2020a).

Similarly, to eradicate energy poverty (Goal 7) by 2030, significant investments will be needed, covering the most diverse regions and local contexts. This will require the development of social innovations and flexible governance approaches, integrated with technological advances (Nathwani & Kammen, 2019). In this context, a sustainable solution for communities in need of energy, corresponds to photovoltaic solar energy (PV) technologies (Joshi, Choudhary, Kumar, Venkateswaran, & Solanki, 2019).

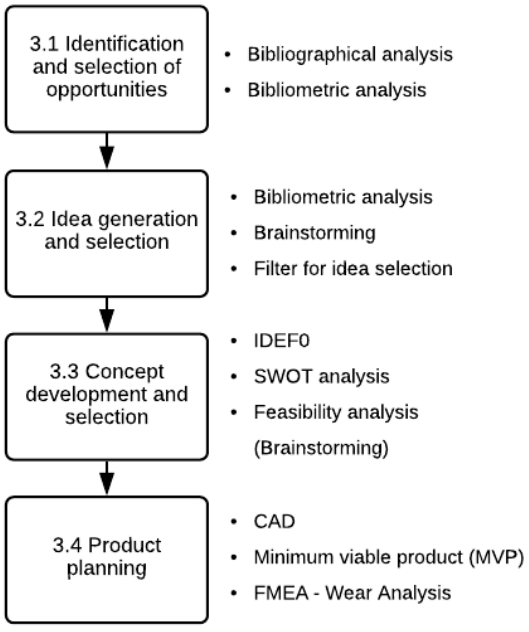
Access to energy is critical to achieving many of the Sustainable Development Goals, such as poverty eradication, health advances, education, water supply and climate change mitigation (United Nations, 2020b). Investments in solar, wind and thermal energy, improving energy productivity and ensuring energy for all is vital to achieve SDG 7 by 2030 (United Nations Development Programme, 2020b).

2 METHODOLOGY

In order to identify the most adequate product development model to structure the proposal of this research (water purifier with photovoltaic cell), a search was made in the Scopus database, since it is considered a primary source in the realization of scientific research (Valderrama-Zurián, Aguilar-Moya, Melero-Fuentes, & Aleixandre-Benavent, 2015). The search revealed that the model developed by Rozenfeld et al. (2006) was considered the most complete (Nickel et al., 2010) and most appropriate for the systematization of the Product Development Process (PDP) (Paula & Mello, 2012).

Among the PDP stages proposed by Rozenfeld et al. (2006) (pre-development, development and post-development), this research focuses on the pre-development stage. Costa and Toledo (2016) developed a literature review work, where they highlight the main stages of pre-development processes, which were adapted for this research (Figure 1).

Figure 1: Research methods



Source: Authors (2020)

2.1 Identification and selection of opportunities

To identify research gaps and development opportunities, VOSviewer® software was used to analyze the grouping of key words, enabling the understanding of the research areas most addressed by the literature in the product development process.

The VOSviewer® corresponds to a tool that allows the creation of graphics for the visualization of bibliometric data (Wong, 2018), indicating the correlation and the connection force between the data through nodes and edges, and the higher the node, the higher the correlation (Eck & Rousseau, 2014).

The following configuration was established in the software: the type of analysis was "co-occurence", the unit of analysis "all Keywords" and the method of counting "full counting", using the same weight for the connection loops.

To obtain the data for the bibliometric analyses, the Scopus database was used for the export of scientific articles. The search in this database was made with the keyword "Product development process" and limited to scientific articles, published in the last ten complete years (2010 to 2019) and written in English. In addition to performing the bibliometric analysis of the exported data, the most relevant works were analyzed, and a brief bibliographic analysis of this search is presented in section 1.1 of this research.

In order to complement the analysis of keywords grouping, a time trend analysis of publications on sustainable development was carried out, using Scopus for bibliometric data export.

2.2 Idea generation and selection

Once the research opportunity was defined and selected (section 2.1), a bibliometric analysis was conducted in order to verify the number of publications on the Product Development Process (PDP) and on the Sustainable Development Goals (SDG) in order to guide the idea generation process. The Scopus and Web of Science databases were used, as they correspond to the largest databases in the literature (Chadegani et al., 2013).

The works identified through the bibliometric analysis were analyzed, contributing to the theoretical basis for the process of generating ideas. To guide this step, the brainstorming technique was used, which is described by Bonnardel and Didier (2020) as a session capable of proposing solutions to a problem, through the combination and development of existing ideas.

To select the most viable option with the greatest development perspective, generated through brainstorming, a filter was used to select the idea to be worked on.

2.3 Concept development and selection

Once the idea to be worked on was established (section 2.2), the product concept proposed in this research (photovoltaic cell water filter) was analyzed, as well as its contribution to the Sustainable Development Goals (SDG).

To represent the operation of the product, the IDEF0 tool was used. According to Ihor, Svitlana, Olena and Maryna (2020), IDEF0 corresponds to a logical notation that provides support during decision making, highlighting information flows, instructions and resources.

In order to complement the strategic analysis of the proposal, the SWOT analysis method was employed. SWOT corresponds to a method that represents the strengths and weaknesses of a business proposal, classified into positive and negative internal factors, i.e., strengths and weaknesses; and external factors, which indicate the opportunities and threats of the proposal to the market (Dulić et al., 2020).

With the use of SWOT analysis, it was possible to verify the feasibility of the proposal (photovoltaic cell water filter), through a brainstorming section, which allowed the analysis of the investment perspective of the product.

2.4 Product planning

Once the concept and operation of the proposal were defined (section 2.3), the product planning was performed. For this, the graphic CAD tool was used. This tool was selected because the bibliometric analysis, performed during the identification and selection of opportunities phase (2.1), pointed out the wide occurrence of this keyword in the bibliometric network.

This tool is widely cited in the literature when referring to the product development process (PDP), as evidenced by the bibliometric results, where several authors highlight the contributions of CAD as a support tool for PDP (Araújo & Costa, 2018; Lupinetti, Giannini, Monti, & Pernot, 2019; Lupinetti, Pernot, Monti, & Giannini, 2019; Rozenfeld et al., 2006).

For this purpose, Inventor Autodesk software was used to design, model and analyze the product dimensions. In order to complement the CAD prototyping process, the Minimal Variable Product (MVP) methodology was used, which is able to promote the implementation with sufficient resources only to meet the initial requirements of the client, in order to generate feedback for the next stages of development (Perez-Vidal et al., 2019). Table 1 presents the materials used in the prototyping stage of the photovoltaic cell water filter.

Table 1: Materials used in prototyping

Materials	
Solar plate 6V	Coal
Voltage regulator	Sand
Plotoboard	Gravel (stone)
Jumper	PVC pipe of 150mm
Bateria	Saw
Cord with 12 LED lamps	Ruler
Disposable Litres of 2.5L	Caneton
1 Coffee filter	Sandpaper
Cotton	

Source: Authors (2020)

To regulate and ensure the operation of LED lamps, the following materials were used: 6V solar panel, voltage regulator, Plotoboard and jumper.

Finally, the Failure Mode and Effect Analysis (FMEA) method was used. According to Kimita, Sakao and Shimomura (2018), the FMEA can identify possible failures and developing measures considering aspects of products and services.

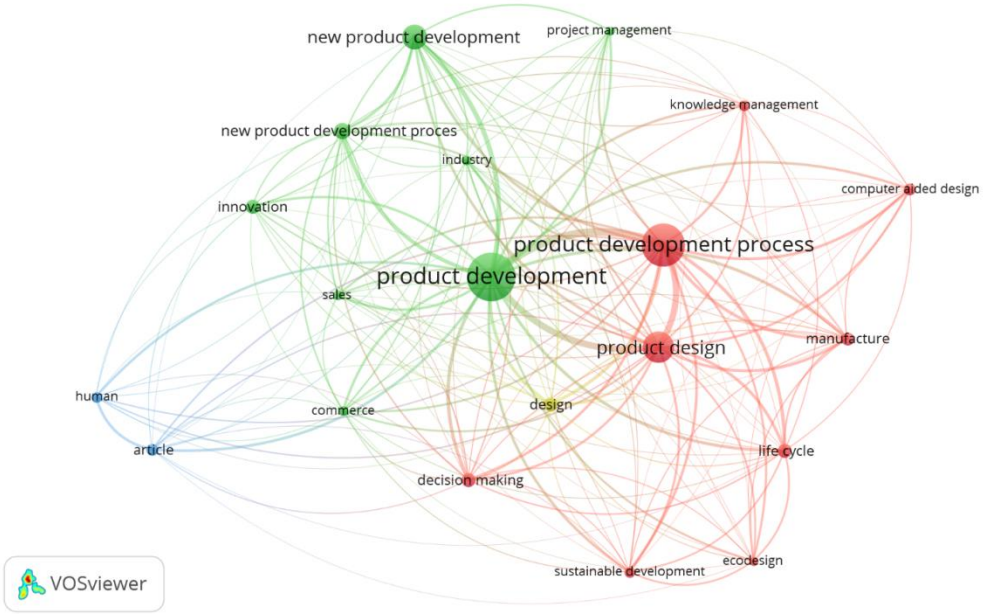
3 RESULTS AND DISCUSSIONS

This section presents the results and discussions of the pre-development stages of the product proposed by this work: photovoltaic cell water filter. The subsections are presented in the same way as they were approached in the methodology of this research, in order to start with the stage of identification and selection of opportunities (3.1).

3.1 Identification and selection of opportunities

The VOSviewer® software was used to map the most explored research topics by grouping keywords in order to identify gaps or research opportunities. The word network (Figure 2) was created with the restriction of presenting at least 30 occurrences, resulting in 20 nodes.

Figure 2: Keywords co-occurence



Source: Authors (2020)

Table 2 - complements Figure 2 with the occurrences and connectivity of keywords.

Table 2: Linking strength and occurrence of keywords

Index	KEYWORD	LINK STRENGTH	OCCURENCES
1	Product development	1082	519
2	Product development process	865	419
3	Product design	687	256
4	New product development	273	171
5	Life cycle	211	65
6	Manufacture	189	60
7	Decision making	186	63
8	New product development process	181	82
9	Design	168	70
10	Sustainable development	149	45
11	Computer aided design	120	48
12	Commerce	113	38
13	Ecodesign	112	30
14	Article	105	50
15	Industry	105	37
16	Knowledge management	103	44

17	Sales	103	37
18	Project managemet	89	32
19	Human	88	42
20	Innovation	87	63

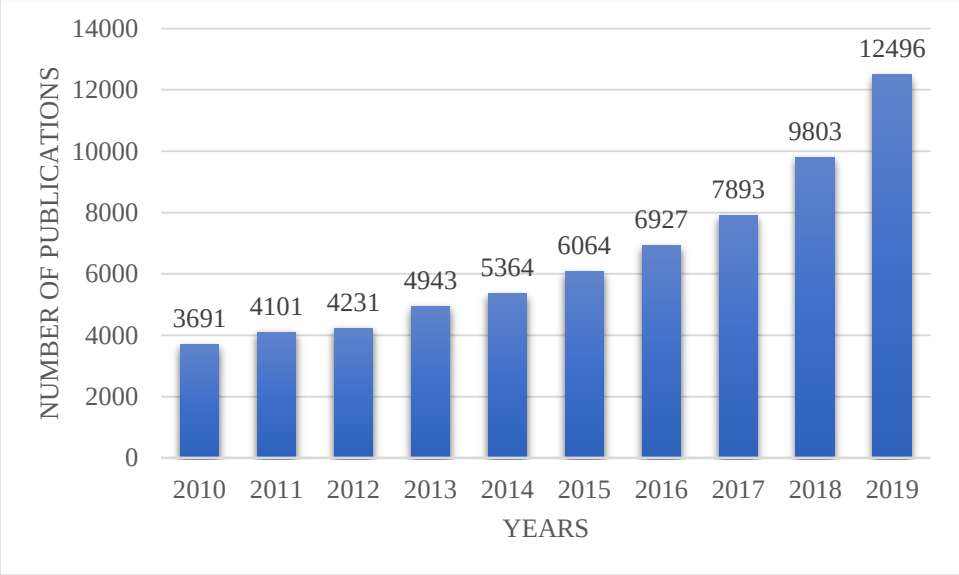
Source: Authors (2020)

The bibliometric network showed that the keyword with the highest connection force (1082) and with the highest number of occurrences (519) was "product development". The occurrence of the keyword "life cycle" in the bibliometric grouping is highlighted, pointing out the academic relevance given to the consideration of the life cycle during the stages of development of products and/or services (Beuren, Sousa-Zomer, & Cauchick-Miguel, 2017; Manzini & Vezzoli, 2016).

In view of this, this research used the product development model proposed by Rozenfeld et al. (2006), considered the most complete (Nickel et al., 2010) and most appropriate to structure the Product Development Process (PDP) (Paula & Mello, 2012). In order to complement the model proposed by Rozenfeld et al. (2006), the pre-development stages cited by Costa and Toledo (2016) were adapted for this business proposal (Figure 1).

The keyword "sustainable development" also stands out, with 45 occurrences and bond strength equal to 149. The literature presented a significant increase in approaches related to sustainable development (Figure 3), where the Sustainable Development Goals (SDG) stand out, since several authors emphasize their contribution in achieving the Sustainable Development Agenda (e.g. Allen; Metternicht & Wiedmann, 2016; Klopp & Petretta, 2017; Rosati & Faria, 2019a, 2019b).

Figure 3: Time trend of publications on sustainable development



Source: Authors (2020)

Scientific productions related to sustainable development showed a sharp growth, so that they rose by 24.2% between 2017 and 2018 and 27.5% between 2018 and 2019. In view of this, there was an opportunity to develop research in this area, given its topicality and academic relevance. In this context, this work identified a research perspective in pre-developing a product according to the Sustainable Development Goals (SDG).

3.2 Idea generation and selection

According to the opportunity identification presented in section 3.1, a search was made in the Scopus and Web of Science databases (Table 3) to analyze the number of publications on the Sustainable Development Goals (SDG) and on the Product Development Process (PDP).

Table 3: Publications on PDP and SDG

Keywords	**Databases**	
	Scopus	Web of Science
"Sustainable development goal*"	4247	4174
"Product development process"	1088	658
"Sustainable development goal*" AND "Product development process"	**1**	**0**

Source: Authors (2020)

Only one publication was observed inter-relating the two approaches worked (SDG and PDP): "A living-sphere approach for locally oriented sustainable design" by Kobayashi, H. and Fukushige, S. The authors propose an approach that assumes the occurrence of a systemic connection between the satisfaction of human needs and the development of products, so that the approach proposed by the authors aims at the elaboration of local and sustainable projects (Kobayashi & Fukushige, 2018).

It was found that publications on SDG and PDP usually occur on an individual basis, since only one work has interrelated these concepts. This lack of interrelated approaches to the concepts worked on pointed to a gap in the literature. Thus, the bibliometric analysis (Table 3) guided the process of idea generation, through the PDP and SDG concepts.

With the bibliographic analysis of the works found in the databases, a theoretical basis was obtained for the idea generation process, aiming at the pre-development of a product. Once the gap and the research opportunity were identified, the Brainstorming technique (Table 4) was used to guide the idea generation process.

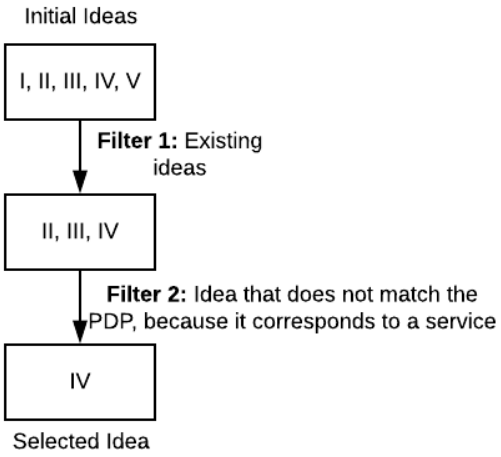
Table 4: Ideas generated through Brainstorming

Index	**Proposal**	**Contribution with SDG**
I	Composer with disposable materials	15
II	Application of aid in the process of generating ideas	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
III	QR Code system for products in the supermarket	3
IV	Photovoltaic cell water filter	6 e 7
V	Solar Powered Lantern	7

Source: Authors (2020)

To select the idea to be worked on, filters (Figure 4) were applied to the proposals generated in the brainstorming, aiming at selecting the most promising idea that best satisfies the objective of this work: pre-developing a product from the perspective of the Sustainable Development Goals (SDG).

Figure 4: Filters for selecting the idea to be worked on



Source: Authors (2020)

With the application of the filters, and with the realization that there is no proposal on the market like the one idealized and explained in this work, the idea IV (photovoltaic cell water filter) was selected for pre-development.

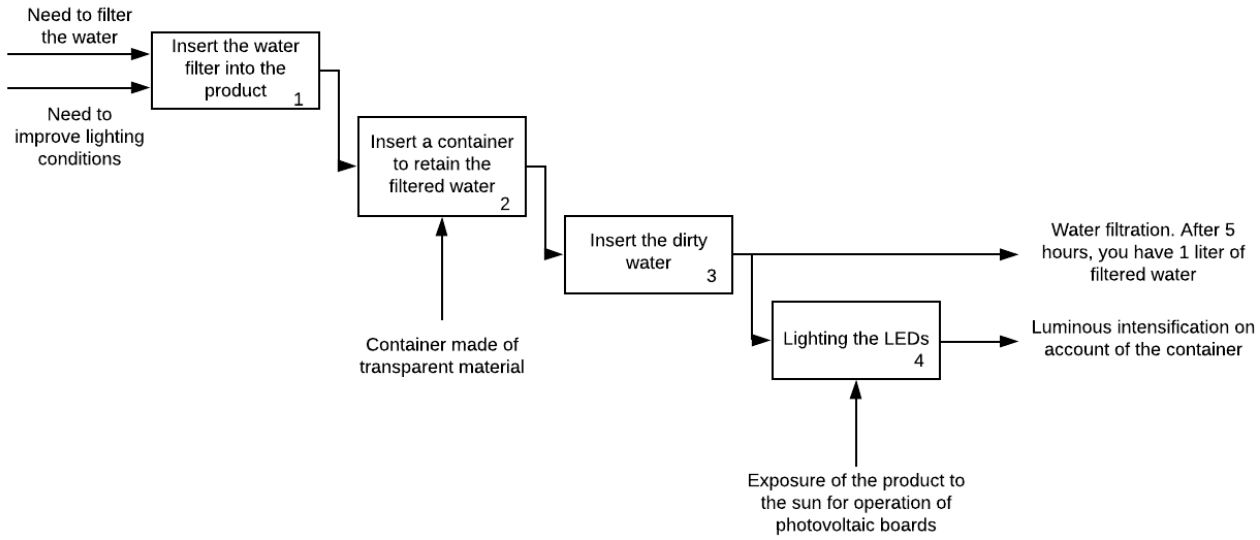
3.3 Concept development and selection

This section highlights the concept of the idea to be worked on (defined in section 3.2), based on a water filter working through a photovoltaic cell. The contribution of this proposal was also analyzed in relation to the Sustainable Development Goals.

The selected idea contributes directly to achieving SDG6 (drinking water and sanitation) and SDG 7 (accessible and clean energy). As indirect but significant contributions to achieving the Sustainable Development Goals, the proposal also contributes to SDG 1 (no poverty) and 3 (good health and well-being).

The functioning of the photovoltaic cell water filter is represented by the IDEF0 tool (Figure 5).

Figure 5: IDEF0 - representation of the product's operation



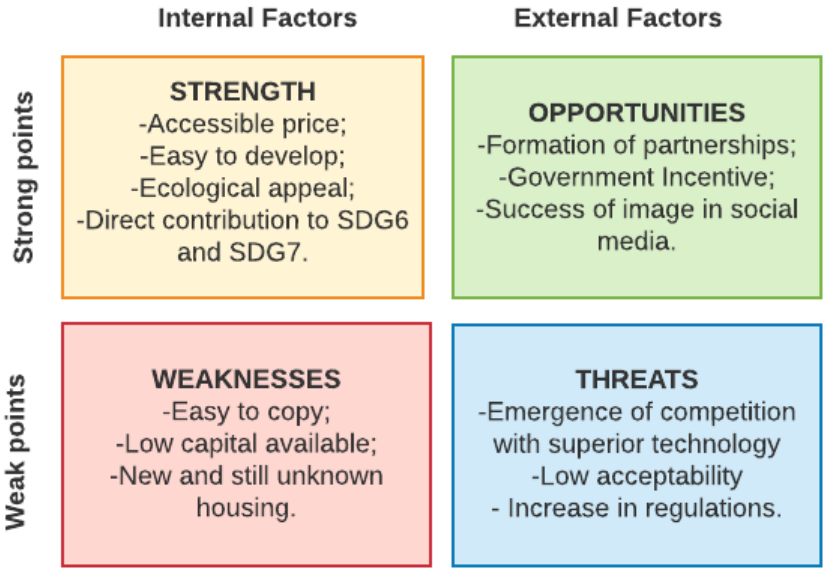
Source: Authors (2020)

Given the need to improve light conditions and to perform water filtration, the proposed product requires that initially a water filter be attached to its structure, as well as a transparent material container, to retain the filtered water. After five hours carrying out the filtering process, we have approximately one liter of water considerably clean and suitable for numerous activities.

The water filter features Light Emitting Diode (LED) lamps, which are lit through a photovoltaic plate, ensuring a clean and renewable energy source. With the LED lamps, inserted below the container with filtered water, the luminous intensity increases.

To contribute to the strategic analysis, identifying strengths, opportunities, weaknesses and threats of the product, the SWOT analysis method (Figure 6) was used, enabling the feasibility analysis of the proposal.

Figure 6: SWOT analysis



Source: Authors (2020)

In relation to the strengths of the photovoltaic cell water filter product, competitive differentials such as affordable price and ease of development stand out. However, the strength that prevails in the proposal is the ecological appeal, because it generates direct contributions to achieve the Sustainable Development Goals.

The opportunities of the proposal refer, mainly, to the formation of partnerships aiming at the ascension of the product and the increase of market competitiveness. Any external forces capable of generating positive contributions, based on research and studies will be added to the proposal, whether they are: government incentives, partnerships in marketing and digital advertising.

The product's weaknesses were identified in order to minimize its effects. Thus, were pointed out: ease of being copied by competitors, little initial investment capital and the fact that the proposed idea is innovative, needing to win the acceptance of the market and consumer for its wide dissemination.

In relation to threats, i.e. external forces that negatively influence the full development of the business, some events were highlighted as possible threats: low market and consumer acceptability, emergence of competition with superior technology and increased regulations, imposing new legal adjustments.

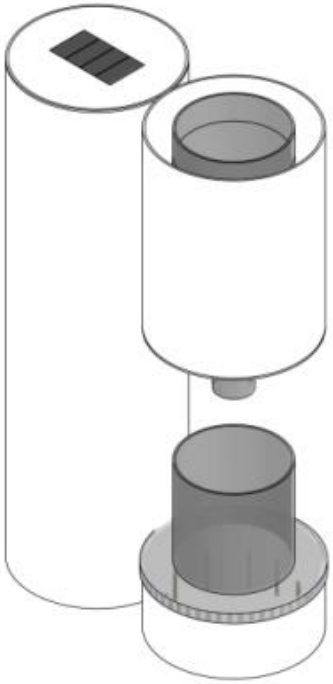
Using SWOT analysis, it is possible to analyze the feasibility of the proposed photovoltaic cell water filter. A brainstorming section was conducted to analyze the strengths and weaknesses of the product, where it is concluded that the strengths and opportunities stand out from the threats and weaknesses, allowing the continuity of studies in relation to the product development process (PDP).

3.4 Product planning

Once the concept of the proposal discussed in this work was defined and the operation of the product was established (section 3.3), the business planning was performed.

For the definition of essential resources, the proposal, the prototyping of the water filter with photovoltaic cell was performed. To assist in this step, a CAD graphic tool (Figure 7) was used to draw, model and analyze the product dimensions, aiming at reducing eventual occurrences of errors during the project elaboration.

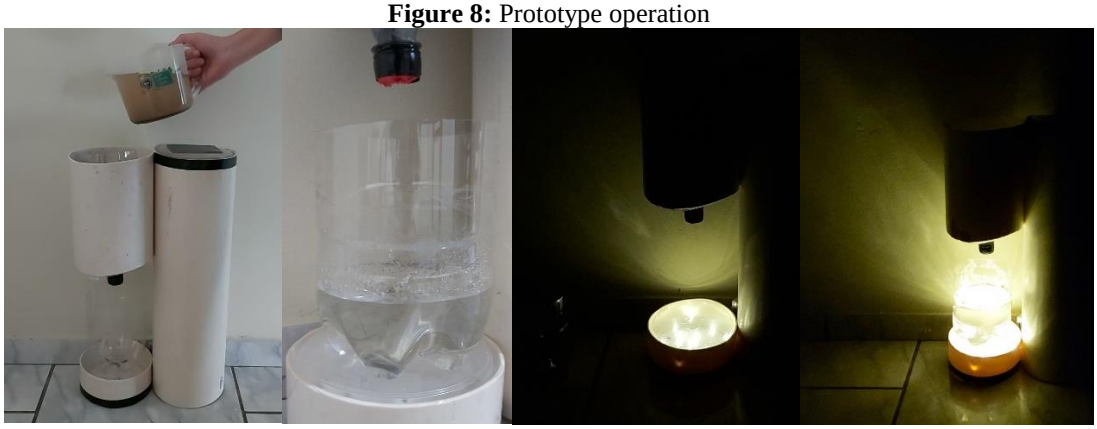
Figure 7: Technical design – CAD



Source: Authors (2020)

In order to complement the CAD prototyping process, the Minimum Variable Product (MVP) methodology was employed, where minimum resources were used during prototyping, in order to perform tests and identify product optimizations. Figure 8 presents the result of the prototyping step of the photovoltaic cell water filter.

Figure 8: Prototype operation



(a) (b) (c) (d)

Source: Authors (2020)

Performed the prototyping of the photovoltaic cell water filter, its functionality was analyzed, so that Figure 8a shows the dirty water being introduced in the filter. In the next step (Figure 8b), it is observed the result of the filtration, where it is noticed a significant difference in the color of the water, which becomes considerably cleaner and appropriate for innumerable activities.

Figure 8c shows the light intensity of the photovoltaic cell. With the introduction of the container with filtered water, the intensity of light emitted by the cell is amplified (Figure 8d).

In this way, the proposed product combines two functionalities: water filtration and light intensity amplification, from a renewable and clean source of energy generation.

The Failure Mode and Effect Analysis (FMEA) method was used to identify wear and eventual failures that the proposal is subject to (Table 5). Thus, the following steps of the product development process (PDP) must be adhered to the highlighted points in order to minimize or solve them.

Table 5: FMEA: Identification of wear and failure

Process or action	Effect of failure	Severi	Basic cause of failure	Detection media	Prevention methods
Parts wear (filter)	Damage the functionality of the product		Misuse / lack of maintenance	Inadequate water filtration	Perform the filter change
				Low product performance	Proper product maintenance
Low adhesion by the product	Low financial return		Inefficient market analysis	Financial problems	Detailed market analysis and establishment of partnerships
					Investment in practical analyses and simulations made directly with possible consumers
					Investment in marketing and advertising

Source: Authors (2020)

CONCLUSIONS

This research aimed to carry out the pre-development of a product from the perspective of the Sustainable Development Objectives (SDOs) focused on water and accessible and clean energy. Thus, a water filter with photovoltaic cell was presented through an adaptation of the stages of pre-development proposed by Costa and Toledo (2016) (Figure 1).

The product demonstrates its relevance by being based on the principles of sustainable development and by designing two main contributions: filtering water and amplifying light intensity. In this way, low-income populations with deficiencies in the lighting and water supply system can benefit from the proposal, but not exclusively, since other publics can also benefit from the product.

The research demonstrated the importance of structuring the proposal according to the stages of the Product Development Process (PDP), ensuring more control and assertiveness in the processes. In the same way, the interrelationship with the Sustainable Development Goals (SDG) proved to be relevant to achieve sustainable principles that support the proposal of this work. Moreover, the use of methods and tools such as IDEF0, SWOT analysis and FMEA contributed with strategic analysis of the proposal, essential in the pre-development stage.

As a suggestion for future studies, it is important to consider inter-relationships between the various areas of literature, such as that established between the Sustainable Development Goals (SDG) and the Product Development Process (PDP). Thus, to achieve the principles of sustainable development, holistic approaches generate mutual contributions between organizations and society.

It is also highlighted the opportunity to carry out a deeper analysis of the proposal, developing research with possible consumers, in order to identify its acceptability and analyze the feasibility of marketing the product, as highlighted in section 4.4, through the FMEA method. In the same way, a research opportunity is to continue this work in the following stages of the PDP (according to the model of Rozenfeld et al. (2006)): development and post development of products.

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