



10th INTERNATIONAL WORKSHOP ADVANCES IN CLEANER PRODUCTION

“TEN YEARS WORKING TOGETHER FOR A SUSTAINABLE FUTURE”

A reflection on the product development process integrated with sustainability

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Abstract

The academic debate on sustainability plays a significant growth in several segments. Among these, there is the debate on integrating sustainability into the Product Development Process (PDP). Thus, the present study aims to identify which are the connecting elements between these two areas of knowledge. The work was carried out through a systematic bibliographic research and resulted in 14,891 searches, of which 101 were classified. The research covered the studies published in the period from 2006 to 2016. Finally, the research result describes that the dedication to the study is relevant. Study on the integration of sustainability into the product development process, based on the need for further studies in this field and also for its constant growth, thus proving to be an area with opportunities for future research.

Keywords: *Sustainability; Product Development Process (PDP); Systematic Bibliographic Research.*

1. Introduction

The integration between sustainability and innovation compose a field of research with continuous growth. For example, in order to improve the competitiveness of firms, the combination of these two themes aims to increase the percentage of firms' competitive capacity, making it essential for the improvement of their performance (D'Ippolito, 2014, Hallstedt et al., 2013, Curwen et al., 2012; Trappey et al. Al., 2011). In this sense, as a result of the interdisciplinarity of the subject, several discussions about its applicability were fomented. Among these debates are studies on the use of the topic in the Product Development Process (PDP). Thus, a multiple search approach that explores, for example, the use of sustainability as sustainable PDP models (Brones and Carvalho, 2015, Luttrupp and Lagerstedt, 2006). Also as an update to the tools used in the PDP (Chang et al., 2014; Carnevall and Miguel, 2008).

From this perspective, this union of knowledge can stimulate companies to elaborate their products in order to provide a new and more sustainable consumption option (Bhuijan and Thomson, 2010). In this way, the result of the new PDP with sustainable characteristics can add a long-term competitive advantage to the company (Driessen and Hillebrand, 2012; Moreno et al., 2011; Bevilacqua et al., 2007; Campbell, 2007; Maxwell and van der Vorst, 2003).

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However, as previously described, the integration of sustainability into the PDP has several orientations in order to remedy the differences between theory and practice in the use of the theme. Therefore, the integration of sustainability into the PDP remains a challenge for both the professional and the academic side (Keskin et al., 2012; Carter and Rogers, 2008; Karlsson and Luttrupp, 2006, Kleindorfer et al., 2005). Thus, in this context, the present research aims at identifying which are the main references focused on the discussion of the integration of sustainability in the product development process.

2. Methodology

The research presented here is categorized as being of an applied nature, since it is intended to devote itself to designing knowledge for the understanding and practical application of solutions (GIL, 2010). Therefore, the research has a qualitative approach, aiming to answer the questions with information that can not be fully quantified (GRAY, 2012). Thus, the scientific objectives of the research are to explore and understand phenomenon studied. Therefore, systematized bibliographical research and content analysis are used as a technical procedure in order to identify and classify the studies found.

3. Systematic Bibliographic Research

Systematic bibliographic research was done through the CAPES / MEC Periodicals Portal; A virtual library that brings together and makes available international scientific content to educational and research institutions in Brazil, comprising 123 reference bases, 11 bases dedicated exclusively to patents, books, encyclopedias, technical standards, statistics and audiovisual content.

The research presented here is categorized as being of an applied nature due to its dedication to conceiving knowledge for the understanding and practical application of solutions to the influence that the integration of sustainability has on the product development process. Therefore, systematic bibliographical research is used as a technical procedure, which was developed and structured by its authors especially to obtain this research. That is, in order to be able to apply this study, the authors conceptualizing themselves in other models of bibliographical research, constructed the model of the systematic bibliographic research especially to be adapted the means of application obtained.

In this way, the systematic bibliographic research was structured by the question: what are the main discussions about the integration of sustainability in the PDP portrayed in recent research?

The survey applied three filters as refinement: (1) the time cut over the last ten years in order to understand what are the recent discussions being analyzed by the academy. (2) research area: engineering and (3) keywords.

The keywords used in this research were obtained from research recognized as relevant because of the number of citations and / or because they were the first to discuss the topic in question. From this, one can observe the relationship between three research fields, forming three groups, which are: (1) product; (2) sustainability and (3) consumption. Table 1 shows the keywords used in the groups.

Table 1 - Groups of keywords.

| Product | Sustainability | Consumption |
|-----------------------------------|---------------------------------|--------------------------------|
| Product Development Process (PDP) | Sustainability | Competitive Advantage |
| Product Creation Process (PCP) | Sustainable | Willingness to Pay |
| Product Design (PD) | Triple Botton Line (3BL) | Value |
| Project Management | Footprints | Green Consumption |
| Quality Function Deployment (QFD) | 10 Golden Rules | Green Marketing |
| Life Cycle Assessment (LCA) | Industrial Ecology (IE) | Market-oriented sustainability |
| Lean Product Development (LPD) | Design for Environment (DFE) | |
| | Green Product Development (GPD) | |

Source: Authors.

The first group consists of keywords related to product development. While the second group is comprised of sustainability-driven keywords involved in product creation. While the third group is formed by keywords linked to the market segmentation for the consumption of these products.

The search was developed by combining these keywords into two layouts. Initially, by combining the keywords of the same group and then by combining the keywords between the groups.

After obtaining the result, the researches were analyzed and from this stage, it was observed that there were other relevant keywords that had not been applied in the search phase. Then these were concentrated to form the fourth group, group of resulting keywords. Table 2 lists the resulting set of keywords.

Table 2 - Group 4.

| Group of resulting keywords | |
|---|------------------------|
| - Green Design | - Industrial Design |
| - Ecological Design | - Manufacturing Design |
| - Environmental Design | - Design Innovation |
| - Environmentally Sustainability Design | - Strategic Design |
| - Design for Sustainability | - Design Assesement |
| - Development New Product | |

Source: Authors.

4. Results

In this section we present the results obtained in each combination applied and, later, the refinement of the researches obtained through content analysis.

4.1 Disposition 1

The first arrangement of combinations (with keywords of the same group) in the Product group totaled 850 surveys that were evaluated and classified according to the scope of the study proposed here. Thus, the first survey resulted in 169 surveys. In this first step, the Sustainability group resulted in 6,164 searches. This high number was due, in addition to the repetition in the listing, to the fact that even limiting research by area of interest, the survey obtained articles that were directed to other areas of knowledge. Thus, the group finalized with a list of 412 searches. The next group,

Consumption, added 1,086 searches that resulted from 55 searches. The reduction in the number of papers was due to the fact that many of them were dedicated to specific studies or case studies divergent to the purpose of the research.

4.2 Disposition 2.

Then, the second arrangement of the keywords (combinations between groups) was developed. Altogether, this second stage expanded the search result with more 1,750 searches. The final result of these added 209 searches. Subsequently, with the formation of the fourth group of keywords, the same combination procedures were applied. Thus, the addition in the search found 2,606 searches. Of which 158 were added to the list of relevant surveys. In this way, the search totaled 14,891 searches, of which 1,003 were classified as relevant.

4.3 Content Analysis

After this step, the articles found were refined by content analysis. Qualitative method applied to the description of objective content. With this refinement, the total number of surveys increased from 1,003 to 465. Of these, according to table 3, they have been growing since the year 2011.

Table 3 - Number of articles per year.

| Groups/Year | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|--------------------|------|------|------|------|------|------|------|------|------|------|------|------------|
| Product | 7 | 2 | 8 | 11 | 11 | 22 | 24 | 33 | 22 | 15 | 0 | 155 |
| Sustainability | 4 | 5 | 2 | 4 | 5 | 5 | 10 | 10 | 12 | 19 | 0 | 76 |
| Consumption | 2 | 1 | 1 | 3 | 3 | 10 | 8 | 13 | 8 | 4 | 1 | 54 |
| Disposition 2 | 4 | 3 | 1 | 1 | 2 | 15 | 11 | 21 | 29 | 22 | 2 | 111 |
| Resulting keywords | 2 | 1 | 4 | 1 | 2 | 15 | 11 | 16 | 16 | 16 | 0 | 84 |
| Total | 19 | 12 | 16 | 20 | 23 | 67 | 64 | 93 | 87 | 76 | 3 | 465 |

Source: Authors.

The table also illustrates that the field with the greatest development was the Product and, in contrast, the group with the least advance was the Consumption. Then, the 465 searches were categorized according to the following areas:

Area 1: classifies the surveys that cover the process of development of sustainable products until the production phase, that is, from the planning of the process to the final result of the product;

Area 2: addresses research that covers the process of developing environmentally sustainable products;

Area 3: research that covers the process of developing socially sustainable products is restricted;

Area 4: portrays the surveys that cover the consumption of sustainable products, as well as the profile of the consumer and the value added to the product;

Area 5: refers to research that covers strategic planning for the development of sustainable products until distribution in the market, in other words, the final result of the product its presentation and targeting the market;

Thus, with the filtering by the framing in the areas that the study focuses on and the content analysis, the number of searches resulted in 101. Table 4 shows the research framework by area.

Table 4 - Framing of research by area.

| Group | Area 1 | Area 2 | Area 3 | Area 4 | Area 5 |
|--------------------|--------|--------|--------|--------|--------|
| Product | 16 | 13 | 1 | 3 | 7 |
| Sustainability | 26 | 14 | 4 | 9 | 17 |
| Consumption | 5 | 3 | 0 | 10 | 3 |
| Disposition 2 | 14 | 3 | 1 | 5 | 6 |
| Resulting keywords | 19 | 7 | 2 | 7 | 11 |

Source: Authors.

Within these 101 works, the percentage by areas resulted in: area 1 (38.83%); area 2 (19.42%); area 3 (3.90%); area 4 (16.50%) and area 5 (21.35%). The study's progress rate after content analysis continued to be more significant as of 2011, as shown in table 5:

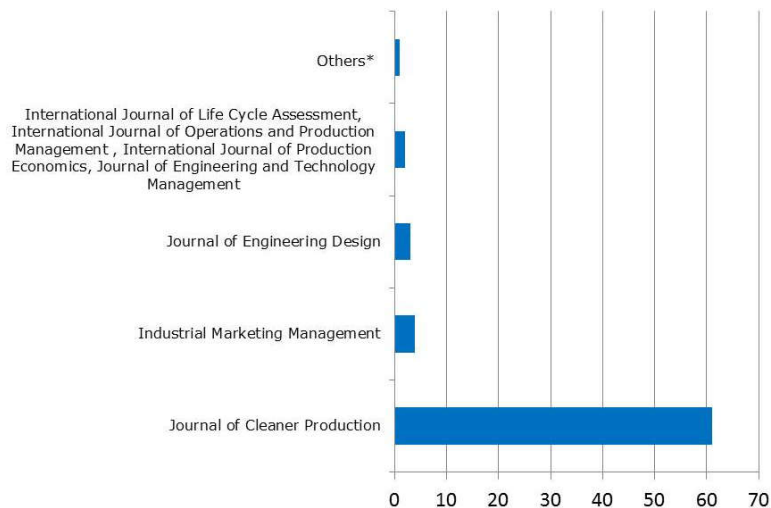
Table 5 - Number of articles per year.

| Groups/Year | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|--------------------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|------------|
| Product | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 4 | 3 | 1 | 0 | 20 |
| Sustainability | 3 | 4 | 1 | 1 | 4 | 2 | 4 | 2 | 5 | 3 | 0 | 29 |
| Consumption | 1 | 0 | 0 | 0 | 2 | 3 | 2 | 1 | 1 | | 1 | 11 |
| Disposition 2 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 4 | 4 | 5 | 0 | 17 |
| Resulting keywords | 2 | 1 | 1 | 0 | 2 | 3 | 1 | 2 | 7 | 5 | 0 | 24 |
| Total | 8 | 6 | 3 | 3 | 10 | 13 | 12 | 13 | 21 | 15 | 1 | 101 |

Source: Authors.

Regarding the number of journals in which the 101 totaled surveys were presented, as shown in graph 1, it is possible to observe that at the end were 32 journals involved in the study. Of these, the vast majority of research belongs to the Journal of Cleaner Production. However, it should be emphasized that although research is largely attributed to a journal, there is a second importance of research that each belongs to a journal. Therefore, it can be seen that the development of this area of knowledge is divided, although with lower index, in several periodicals.

Graph 1 - Published journals.

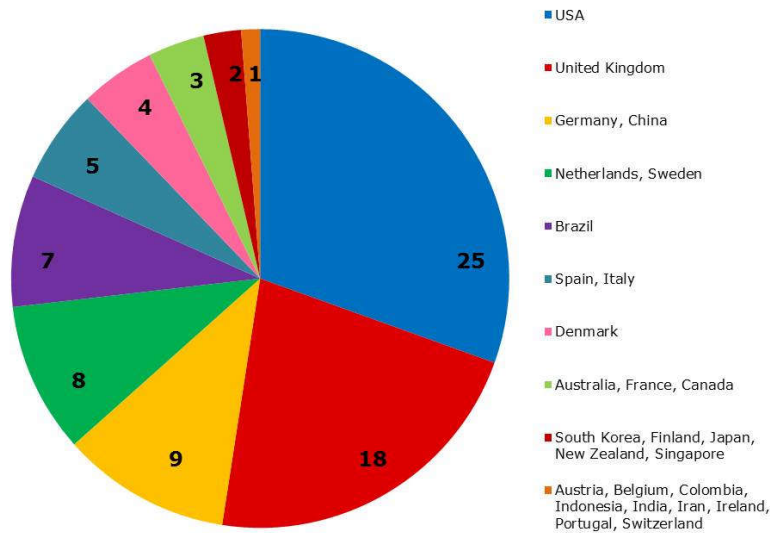


* Expert Systems with Application, Design Studies, MIS Quartely, Journal of Industrial Ecology, Concurrent Engineering: Research and Applications, Research-Technology-Management, Clothing and Textiles Research Journal, IEEE Transactions on Engineering Management, Technovation, Benchmarking: An International Journal, Marketing Intelligence & Planning, Journal of Macromarketing, Journal of the Academy of Marketing Science, Business Strategy and Environment, Management Decision, European Business Review, CoDesign, Industrial Management & Data Systems, Annual Review of Environment and Resources, European Journal of Operational Research, Bulletin of Science, Technology e Society, Ecological Engineering, European Journal of Innovation Management, International Journal of Design, Computers and Chemical Engineering

Source: Authors.

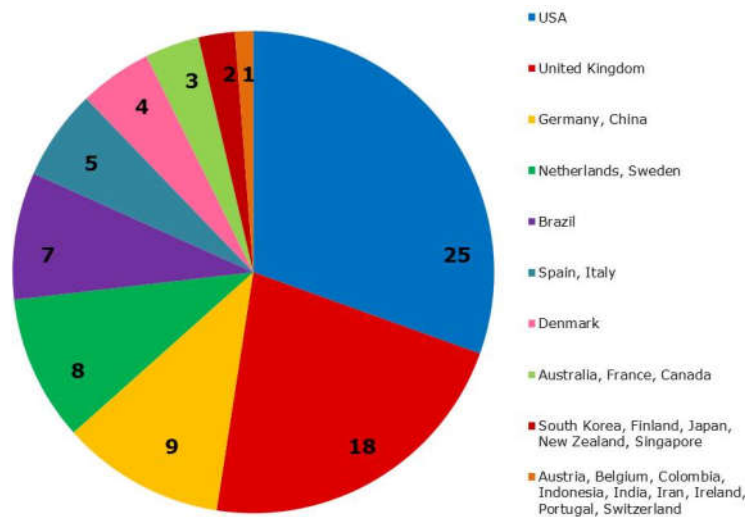
Therefore, in addition to these observations, it was possible to observe the geographical division of the study development. According to graph 2, in all there are 27 countries. The continent with the highest concentration by number of countries involved was Europe with a total of 13 countries, followed by the Asian continent with 6 countries. With regard to the index of research by continent, Europe is also the continent with the largest number of surveys conducted. Regarding the number of surveys per country, the highest index was the United States, with a total of 25 surveys.

Graph 2 - Geographic distribution.



Source: Authors.

Graph 3 - Areas of knowledge.



Source: Authors.

Finally, the results on the main discussions about the integration of sustainability in the PDP portrayed in the recent surveys, according to the graph 3, we can analyze that the three approach with more emphasis are, respectively: the decision making; Ecodesign and environmentally sustainable production. It is also interesting to note that the percentage of marketing over the junction is more balanced with the value added for the products generated than with the approaches to the consumption of these products.

5 Final Considerations

In summary, the present study aimed to identify the main discussions regarding the integration of sustainability into the product development process. Thus, through the systematic bibliographical research, 101 researches were found. In addition, it is possible to reflect that the methodology constructed for the systematic bibliographic research has proved to be effective in meeting both the objective of the work and the obtaining and generation of additional research data, which are relevant for the branching and analysis of future opportunities. From the result, several relevant information were identified and, thus, it can be concluded that despite the concentration being higher in certain locations and in some periodicals, the index of development of studies dedicated to the subject is increasing and more expressive from 2011. Also, the debate continues to be distributed, indicating that there is a common and multidisciplinary interest in advancing the debate. Demonstrating to be an area with opportunities for future research. Therefore, for the future directions of the study presented here, the following are listed: the deepening and detailing of the content analysis of each research found and the identification of the relationships between the identified areas.

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