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Sustainable Consumption and Ecodesign: a Review

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Abstract. Sustainable products have arrived on the market and faced competition with traditional products with one extra challenge: they normally tend to be more expensive than traditional ones. Customers are yet to pay more for these products as they are alerted for environmental impacts. However, the gap between knowledge and action is being decreased slowly. One of the factors for this sluggish behavior is that the standing economic equation does not cover environmental issues. Traditional approaches for feasibility studies are yet to be changed, as initiatives such as the eco-cost emerge. From a Product Development Process point of view, customer satisfaction and selling price are two very important inputs that drive the process from the early beginning and determine whether the resulting product will achieve market success or not. A more sustainable product tends to be more durable as it reduces scrap. Currently, the world economic chain is configured respecting the pace in which products are consumed, as consumers are accustomed with traditional products and their durability. As the world grows more sustainable, the economic chain will be sustainability-driven and therefore, require more durable products and services. Using a bibliometric approach, this article proposes a review of sustainable product development and its interface with these economical and customer perception issues. First, research domains were prescribed and keywords were defined to narrow the search. Databases were selected and researched using boolean codes. The resulting list was finally reviewed and filtered, as to refine the search accordingly after defined criteria. Findings include (but are not limited to) a growth in the number of published articles year after year and also a list of journals with most publications in this research field. Finally, this article points new trends to be explored inside product development.

Keywords. ecodesign, sustainable consumption, willingness to pay.

Background

Efforts for a more sustainable society still find many barriers. Ljungberg [1] defined four major problems left with no solution: excess of consumption, resource depletion, air pollution and population growth. These problems can be directly linked with the standing global economical development model, which sets a highly accelerated consumption pattern and high competition levels between enterprises, causing deep environmental damages, resource scarcity and many other undesirable side effects.

For any company to succeed in the business market, cost-benefit balance is of extreme importance, and every new product under development affected [2]. In 2001 only 15% of the companies based their price formation on potential customers' behavior [3], generating "flaw" products, which in turn will probably cause a lot of environmental damage and, most importantly, be referred as accountable for such damage [4].

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Product Design and Development appears as one of the critical moments to come up with sustainable issues. The earliest one can come up with solutions to drive product development towards a better environmental performance, the better. Ecodesign emerges as the ensemble of tools and methods, which intends to deploy sustainable issues during the early stages of product design and development.

But is that enough to effectively diminish environmental damages? If customers support sustainability as a concept, but are not purchasing the sustainable product instead of the traditional one, there's no decrease in environmental impacts. That means customers are still shy to move from ideology to action [5]. Understanding the factors that influence market performance of these products is essential [6], or a sustainable product is about to become another ecological burden, generating more environmental impact instead.

The goal of this research is to present results for a bibliometric-based review in this context and to point trends for future researches within Sustainable (and Competitive) Product Development. The methodology used as the basis for this article is commonly known as **ProKnow-C**, a systematic flow chart for state-of-the-art reviews. Due to the huge amount of articles retrieved, no article was read in full.

The present article is structured as the following: section 1 reviews the literature; section 2 covers the findings and section 3 contains the conclusion and future trends; last, references are presented.

1. Literature Review

Bibliometric research is a quantitative disclosure process using a well defined article base for information and knowledge management of a certain scientific matter, achieved after document accounting [8, 9]. **ProKnow-C,** developed by MCDA (Multicriteria Methodology Decision Support Lab) of Federal University of Santa Catarina, is a methodology that defines a flow chart for bibliometric review. This research was undertaken following some of its procedures, described by Tasca et al. [8]:

1.1. Bibliographic Portfolio Creation

To identify the state-of-the-art research is a specific context, a raw article database was obtained after defining research domains (also called research axes). Based on the procedures taken in Hare, McAloone [10], the starting point was to define three domains of research, according to the main purpose of investigation: the relation between consumption, product development and strategic management. Then, keywords were proposed for each domain, as presented in Table 1.

Next, Boolean codes were defined as recommended in ProKnow-C. Research databases were chosen considering their connection with the engineering area of research, and are listed below:

- Emerald Insight;
- Engineering Village;
- IEEE;

- Periodicos Capes;
- Proquest (ERIC);
- Scopus;
- Science Direct;
- Springer;
- Web of Science;
- Wiley.

Keywords were combined in a search sentence with the booleans: (i.e. "willingness to pay" OR "value" OR "competitive advantage") AND ("eco-innovation" OR "cradle-to-cradle" OR "ecodesign" OR "eco-design" OR "Life cycle Assessment" OR "resource depletion") AND (sustainability) AND ("product design" OR "project management"). For each database, articles were retrieved and every search result was combined in proper article management software (e.g. Mendeley).

Table 1. Research domains and associated keywords.

Domain	Keywords
Strategic Management	Competitive advantage Willingness to pay value
Sustainable Development	cradle-to-cradle ecodesign eco-design eco-innovation sustainability lifecycle Assessment
Engineering Design	product design project management

The chronological period selected for this research was from 2004 to 2015. Next, repetition was excluded and citation counting was performed, as each and every article was researched in Google Scholar for citation number.

1.2. Articles base filtering – Repository K

By using appropriate criteria, articles went through a filtering process. First criterion used was: article title aligned with research objective. Then, representativeness was evaluated based on a Google Scholar search for number of citations per article and ratio from the total. A minimum representativeness factor of 15 citations was defined. This number was used to split the entire list into two repositories: K - articles with confirmed scientific recognition (444 articles) and P - articles with scientific recognition yet to be confirmed (1075 articles). After reading the title of all articles in repository K, all present authors were considered as inside the Authors' base. For the K repository, every abstract of every article was read and a finer evaluation was taken, considering its relationship with the research objective.

1.3. Articles base filtering – Repository P

Repository K was divided in two groups: articles older than two years were assessed to check if they were written by any author present in the author's base, or else it was excluded; articles newer than two years were evaluated for potential future scientific recognition – others were excluded. Then, articles in repository P were split into two groups: articles with less than two years and with more than two years. This last group was confronted with the author's base and all articles not written by any of these authors were excluded.

2. Findings

The first results found for each database are presented in table 2, in a total of 1,686 articles. Science Direct has returned the majority of articles, followed by Springer, Wiley and Emerald Insight. Capes (Brazilian portal which combines results from multiple databases) didn't retrieve a significant quantity, and IEEE only returned one result.

Table 2. Returned articles per database researched.

Database	Number of articles returned
Science Direct	696
Springer	500
Wiley	249
Emerald Insight	100
Proquest	77
Scopus	28
Engineering Village	21
Web of Science	8
Capes	6
IEEE	1
Total	**1,686**

The total number of articles published per year is presented in Figure 1. As a major trend, the amount of published articles yearly is steadily growing year, as environmental damage grows.

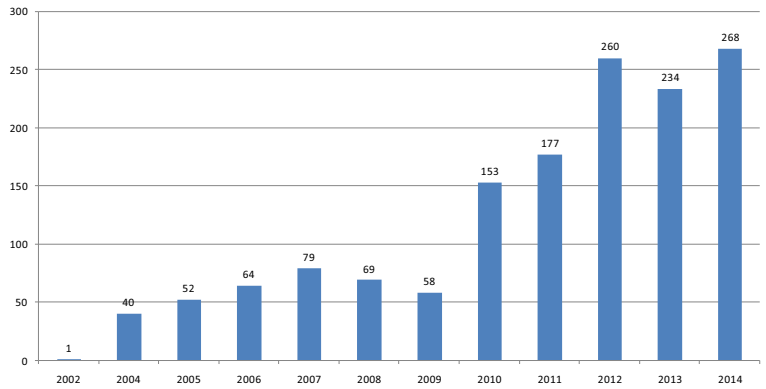

Figure 1. Number of articles published per year.

Publications with the most number of published articles are presented in Table 3, together with the impact factor. The journal that published the highest quantity is the JCP – Journal of Cleaner Production, which also stands for the highest Impact Factor of all – 3.590. Some of the publications refer to book chapters, as they are not granted an impact factor. Procedia CIRP, refers to Proceeding compilations and also doesn't have a JCR Impact Factor.

Table 3. Number of published articles per publication with impact factor.

Journal name	Number of published articles	Impact Factor(1)
Journal of Cleaner Production	254	3.590
Journal of Industrial Ecology	45	2.713
Business Strategy and the Environment	40	2.877
Resources, Conservation and Recycling	36	2.692
Design for Innovative Value Towards a Sustainable Society	33	0(2)
Glocalized Solutions for Sustainability in Manufacturing	30	0(2)
The International Journal of Life Cycle Assessment	29	3.089
International Journal of Production Economics	24	2.081(3)
Materials & Design	16	3.171
Clean Technologies and Environmental Policy	16	1.671
Procedia CIRP	14	0(4)
Leveraging Technology for a Sustainable World	14	0(4)
Total	**551**	

(1) Information taken from Journal webpage.
(2) Compilation books from Springer.
(3) Data obtained from 2013 JCR Impact factor list.
(4) CIRP-related proceedings publications.

Table 4 shows the 10 most cited articles for this research. Most of the articles refer to reviews of methods and tools. Others discuss the application of sustainability in decision-making, stakeholder influences and business strategy. The most cited, [11], brings insights about the challenges that organizations will have to beard with the rising of sustainability. It covers business network challenges, strategy proposals and it defines an Ecosystem framework based in interconnectiveness and sustainable creativity and innovation drivers that can help enterprises adapt to these market transformations.

Source [12] investigates PSS (Product-Service Systems) and delivers a classification of eight types of PSS that exists in SusProNet, a sustainability network inside EU. It also defines economic and environmental potential for each type after defined criterion. It concludes that many of these types only bring results (although some contradiction is found) in the environmental aspect and only one could really deliver economical improvements. It concludes proposing that there are opportunities for research concerning customer value – intangible value in this case - for PSS users.

Another article than has to be highlighted is [13], that reviews sustainable assessment methodologies, including indicators for different purposes (including "level-4" step points Supply Chain and Product Life-Cycle Indicators), assessment frameworks from GRI (Global Reporting Initiative), UNCSD (United Nations

Commission for Sustainable Development and many others, depending on the type of study one intends to perform.

Table 4. Most cited articles[1].

Article	Google Scholar citations	Publication Type	Year
The keystone advantage: what the new dynamics of business ecosystems mean for strategy, innovation, and sustainability	661	Book	2004
Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet	571	Paper	2004
Stakeholder influences on sustainability practices in the Canadian forest products industry	568	Paper	2005
An overview of sustainability assessment methodologies	508	Paper	2010
Sustainable construction—The role of environmental assessment tools	432	Paper	2008
Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art	390	Paper	2010
Industrial Product-Service Systems—IPS2	383	Paper	2010
Application of multicriteria decision analysis in environmental decision making	381	Paper	2005
A survey of unresolved problems in life cycle assessment	378	Paper	2008
PROMETHEE: A comprehensive literature review on methodologies and applications	373	Paper	2010

[1] As of March, 2015.

One of ECMPRO (Environmental Conscious Manufacturing and Product Recovery) reviews [14] also features the progress within its field of research: the paper describes areas that have developed and also new areas of study. It highlights the need for research of methodologies that consider both product and process designs and also the need for introducing inside engineering curriculums sustainable principles and concepts, to improve Sustainability consciousness.

This research was conducted in a similar way as seen in [10]. Nonetheless, in this work domain "Environmental Science" was replaced by "Sustainable Development". The keywords selected within each domain were also changed accordingly. Methodological procedures were also different: this work makes references for the Pro-Know-C bibliometric review method. This research aimed to identify opportunities where Ecodesign meets Market competitiveness and Consumption, whereas the main target for [10] was to define trends for eco-innovation research.

3. Conclusions and Further Research

The review procedures and keywords have brought many results concerning the implementation of eco-design in product development processes and systems. It means that maybe with narrower domains and keywords choice, results would have been better driven towards the competitiveness of sustainable products.

A challenge in this research was the need to exchange between data management tools. Mendeley permitted list consolidation, but not for results found in Springer. It didn't allow to compile and organize the list with citation number classification criterion either. Microsoft Excel was used instead, in order to fulfill such needs.

There is a considerable number of trends being investigated in the context of this review. Five trends are featured and described in the topics below, selected for its level of challenge, innovation, effectiveness and criticality. A more specific focus has been given to Strategy and Early Product definition than in [10], where Eco-innovation approaches were identified.

- **Sustainable Costing:** One of the major challenges for sustainability is to be able to define the "non-sustainability" cost for any product or strategy. There are a few attempts in this research field; one that is very much considered is the Eco-cost/Value Ratio [15], which aims to establish a relationship between environmental gains and economical investments. Other attempt is the LCCA (Life Cycle Cost Analysis) that tries to identify costs related to all lifecycle phases of a product. There is an opportunity of research here, and one of the major difficultiesis to establish a way to define what is the economical value gained with the implementation of sustainable initiatives.

- **Consumption Degrowth:** degrowth stands for a paradigm that contradicts traditional politic ideologies (capitalism, socialism and others) which have been proven "incapable of delivering balance for human kind" [16]. This is a difficult concept to be understood, especially in developing countries. In [17], increased product lifecycle span leads to Sustainable Consumption, an in-between 'Green growth' and 'Recession'. These concepts would certainly have major impacts in Ecodesign activities, therefore lodging a research opportunity.

- **Sustainable Design Education:** there is a need for higher education to develop sustainability conscience and competences with students, especially Engineering courses. Some initiatives have been proven effective, engaging students in industrial and environmental Product Design challenges, with excellent results [18].

- **Green Supply Chain Performance:** is it possible for a supplier to increase environmental and economical performance at the same time? Some studies [19] already suggest that this is possible, other studies are focused on metrics to measure it [20] and therefore it is a trend to be explored.

- **Resource depletion mapping:** as resources grow scarce, some of them even appear to vanish completely – the non-renewable resources. Understanding which, how and when it could happen is of extreme importance to take countermeasures, like governmental policies. Some work has already started with some of the most used substances: minerals and metals [21], but there are many yet to be explored. In terms of Product Development, these initiatives can be combined with Consequential LCA methods for decision-making processes.

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