Knowledge Dissemination of Sustainable Product Development

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Abstract: Current environmental regulations and customer expectations force manufacturing companies to develop new products considering ecological, social, and economic issues. At present, product sustainability, time-to-market, and profit are equally important factors in the new product development process. Consequently, product design should embrace issues related to sustainability in the entire product life cycle. These issues refer to manufacturing processes, product use, and the post-use phase, including product reuse, remanufacturing, recycling or disposal. Product design considering these issues is called sustainable design or eco-design. The product development process aims to create a new product that can be a modification of existing products or be completely new for a company and market. Innovations are widely used as a key component for addressing sustainable development concerns. The role of product design and innovation in the quest for sustainability has received considerable attention among researchers and businesses in recent years. This research is a novel bibliometric analysis of sustainable product development, product design, and product innovation in the last 30 years, from 1993 to 2022. The results of data analysis embrace trends regarding the yearly number of publications devoted to sustainable product development, sustainable product design, and sustainable product innovation. Moreover, the collected publications were classified into subject areas, source titles, and source type. The bibliometric analysis reveals the most popular journals to knowledge dissemination of sustainable product development, sustainable design, and sustainable innovation. The results show that the increase of publications devoted to sustainable product design and sustainable product innovation is particularly strong in the last 5 years. Moreover, the number of publications related to sustainable product design is over ten times larger than related to sustainable product innovation.

Keywords: New product development, Product design, Product innovation, Sustainability

1. Introduction

Nowadays, customers are more and more aware of a need of protecting the environment, and the concept of sustainable development. As a result, companies are interested in improving sustainability performance of their products and business processes, including product development, manufacturing, and transportation. Companies are trying to fulfil customer expectations through developing a framework for incorporating sustainable-oriented changes at the product design stage, and measuring the level of sustainability performance. A number of studies dedicated to sustainable products is constantly increasing in the last years. The goal of this research is the comparison of knowledge dissemination in the aspect of sustainable product development, product design, and product innovation.

New product development includes a few stages related to idea generation, concept screening, feasibility analysis, product design, prototype tests, and commercialization. Product design seems to be a crucial factor from the perspective of incorporating sustainable-oriented changes into a product. The concept of sustainability should refer to the complete product life cycle, from new product development through manufacturing, packaging, and transportation, up to its disposal or recycling. Many authors indicate the importance of sustainable-oriented design thinking (Ceschin and Gaziulusoy, 2019; Mihelcic and Zimmerman, 2021; Shapira et al, 2017; Soomro et al, 2021). In recent years, sustainable manufacturing is often linked with the closed-loop and the circular economy concept (Jawahir and Bradley, 2016; Sartal et al, 2020). In this paradigm, product sustainability is expanded from the 3R principles (reduce, reuse, and recycle) to the 6R methodology (3R principles plus recover, redesign, and remanufacture). As a result, the design process should consider issues related not only to manufacturing and using a product, but also issues related to its utilization by consumers, ultimate reuse, recycling, remanufacturing, and even disposal. Consumer behaviours in the aspect of hoarding, throwing away, and sustainable product disposal are presented in (Sarigollu et al, 2021).

Ceschin and Gaziulusoy (2019) described sustainability transitions in product design from green design to design for increasing sustainable behaviour. They proposed a multi-level framework of design for sustainability from material/component level, through product level, to socio-technical system level. Mihelcic and Zimmerman (2021) presented the importance of design and innovation in advancing sustainability and frameworks for sustainable design. Their principles of green engineering refer, for example, to separation and purification operations as a component of the design framework, and design that bases on renewable and readily available inputs throughout the product life cycle. In turn, design thinking in the context of creating innovation is considered in (Adams et al, 2016; Cillo et al, 2019; Nakata and Hwang, 2020). Advantages of design thinking in the aspect of eco-products within the automotive industry are presented in (Relich, 2014).

Additionally, there were carried out investigations within identifying relationships between eco-innovation and product success (Díaz-García et al, 2015; Relich, 2015; Hermundsdottir and Aspelund, 2021).

Tello and Yoon (2008) defined sustainable innovation as the development of new products, processes, services and technologies that contribute to the development and well-being of human needs and institutions while respecting the words' natural resources and regenerative capacity. As drivers of sustainable innovations, they indicate government regulations, social activism, technology advance, customer demand, supply chain, and corporate social responsibility initiative. In turn, Bos-Brouwers (2010) defined sustainable innovations as the renewal or improvement of products, services, technological or organisational processes that deliver not only an economical performance, but also an improved environmental and social performance, both in the short and long term. Varadarajan (2017) presented types of sustainable product innovations that can include reduction of resource use (e.g., product miniaturisation), elimination of resource use (e.g., ecologically harmful ingredient elimination), and substitution of resource use (e.g., product digitalisation, biodegradable packaging materials). There was also discussed a model of sustainable innovations, and its implications for theory, research, and practice. A typology of innovations for sustainable development was discussed in (Silvestre and Ţîrcă, 2019). There were divided innovations into four groups: traditional, social, green, and sustainable innovations, which strongly emphasise both environmental and social concerns.

This study is concerned with investigating knowledge dissemination in the aspect of sustainability related to product development, product design, and product innovation. The literature review has revealed that the majority or scientific works refer to knowledge transfer towards improving performance of innovations. A knowledge transfer framework for supporting small and medium-sized enterprises in developing sustainable innovation was presented in (Adams and Comber, 2013). Moreover, knowledge transfer between green thinking, lean thinking, and product development was descripted in (Oliveira et al, 2018). It is noteworthy that there was some research on knowledge discovery in the context of identifying critical success factors in new product development (Lane and Flagg 2010; De Medeiros et al, 2014; Relich and Bzdyra 2015). Thomé et al (2016) presented a longitudinal review for sustainable new product development in years 1993–2015. However, there is the lack of research strictly devoted to the presentation of current knowledge dissemination from the perspective of sustainability within product development, product design, and product innovation. This was a motivation to investigate knowledge dissemination in the mentioned areas.

The paper is organised in the following parts: Section 2 presents materials and methods, including description of keywords for the database search in the aspect of sustainable product development, product design, and product innovation. Section 3 presents the results of data analysis and discussion, whereas Section 4 – conclusion and further research.

2. Materials and Methods

Gathering data for this research was based on the functionality of advanced search in Scopus. In May 2023, the Scopus database includes over 44,000 journals, book series, conference proceedings, books, etc. These publications are provided by the main publishers such as Elsevier, Emerald, Springer, Taylor and Francis. The search used two criteria regarding years and keywords that are sought in titles, abstracts, and keywords of publications.

The main goal of this study aims to investigate knowledge dissemination of sustainable products in the last 30 years, from 1993 to 2022. The publications from the first months of year 2023 were omitted in research to ensure the year-to-year comparison of the results. The aspect of sustainable products was divided into three areas: product development, product design, and product innovation. The additional goal of this study is to compare knowledge dissemination among these three areas. Product development is the broader concept than product design that is only one of activities in the NPD process. However, product design is the key factor in this process, incorporating the concept of sustainability into products. Product development is also the broader concept than product innovation, because not each new product is an innovation. In fact, the majority of new products are modifications of past or existing products, and they can be only new for a company.

The aspect of sustainability within product development, product design, and product innovation was sought through keywords related to environment, ecology, and the triple bottom line concept. There were performed four analyses, separately for product development, product design, product innovation, and together for these three areas. Pseudo-codes related to keywords for these four analyses were presented below.

The search of publications for the 1st analysis:

TITLE-ABS-KEY ((*"product development"*) AND (*"sustainab* development"* OR *"environment*"* OR *"ecolog*"* OR *"triple bottom line"*)) AND PUBYEAR > *1992* AND (EXCLUDE (PUBYEAR , *2023*))

The search of publications for the 2nd analysis:

TITLE-ABS-KEY ((*"product design"*) AND (*"sustainab* development"* OR *"environment*"* OR *"ecolog*"* OR *"triple bottom line"*)) AND PUBYEAR > *1992* AND (EXCLUDE (PUBYEAR , *2023*))

The search of publications for the 3rd analysis:

TITLE-ABS-KEY ((*"product innovation"*) AND (*"sustainab* development"* OR *"environment*"* OR *"ecolog*"* OR *"triple bottom line"*)) AND PUBYEAR > *1992* AND (EXCLUDE (PUBYEAR , *2023*))

The search of publications for the 4th analysis:

TITLE-ABS-KEY ((*"product development"* OR *"product design"* OR *"product innovation"*) AND (*"sustainab* development"* OR *"environment*"* OR *"ecolog*"* OR *"triple bottom line"*)) AND PUBYEAR > *1992* AND (EXCLUDE (PUBYEAR , *2023*))

Data analysis refers to the number of publications in years 1993–2022, main subject areas, and main source titles. Moreover, there is investigated the number of publications in the aspect of their source type (journal, books, etc.). The results of research embrace the comparison of sustainability within areas regarding product development, product design, and product innovation. The aim of data analysis is the presentation of research interests in publishing scientific works dedicated to the mentioned areas of sustainability. This presentation can be considered in the aspect of knowledge dissemination among researchers, and it is the first step towards future research regarding customer expectations for sustainable products, and corporate social responsibility within developing and manufacturing more sustainable products.

3. Results and Discussion

This study is concerned with investigating knowledge dissemination of sustainable product issues within three areas related to product development, product design, and product innovation. Moreover, data analysis also includes the results for merging all of these three areas. Hence, data analysis consists of four parts that are presented below in subsequent subsections.

3.1 Sustainable Product Development

The results of data analysis refer to the number of publications in the last 30 years, source of publication, and subject area. Figure 1 presents the number of publications devoted to sustainable product development in years 1993-2022. There were 13,386 publications in the considered period.

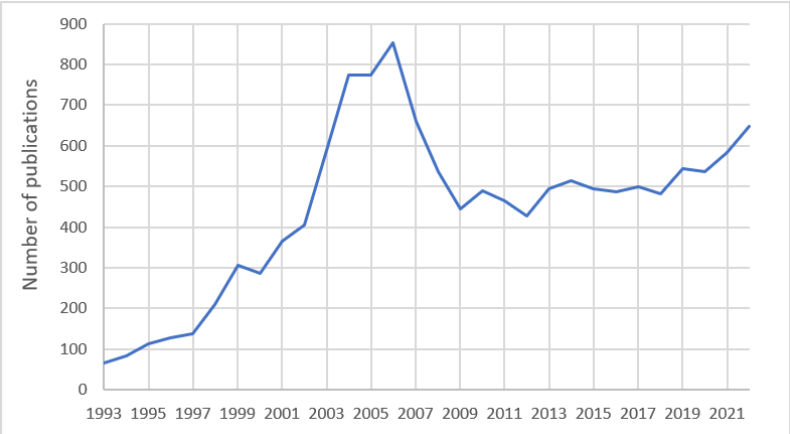

Figure 1: Number of Publications Devoted to Sustainable Product Development

The number of publications had the significant increase from 1993 to 2004, reaching the largest level in years 2004–2006. In years 2009–2018, the trend was rather constant, whereas from 2019 the number of publications is increasing.

Figure 2 illustrates the number of publications relating to various subject areas. The majority of publications are related to journals addressed to engineering, computer science, and business, management and accounting. It is noteworthy that a single publication can be classified to a few subject areas.

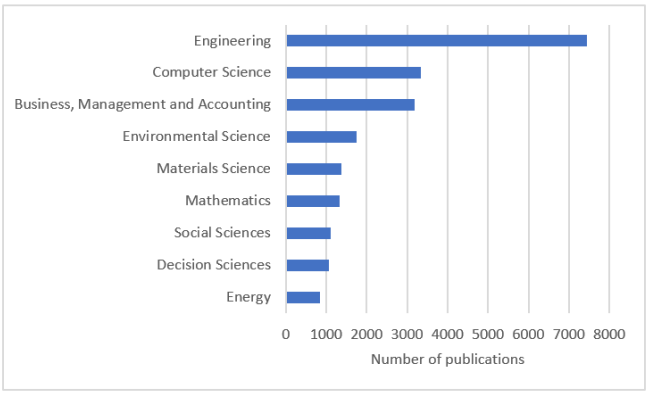

Figure 2: Number of Publications Relating to Different Subject Areas

Figure 3 illustrates the number of publications relating to the source title (i.e., the name of journal, book series, proceedings), in which scientific works were published. The source titles presented in Figure 3 refer to about 9% of all publications.

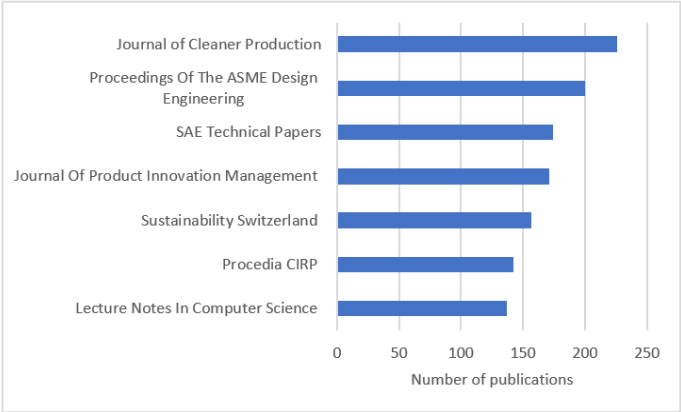

Figure 3: Number of Publications Relating to the Source Titles

3.2 Sustainable Product Design

Figure 4 presents the number of publications devoted to sustainable product design in years 1993–2022. In this period, there were 19,231 publications, so more than publications dedicated to sustainable product development.

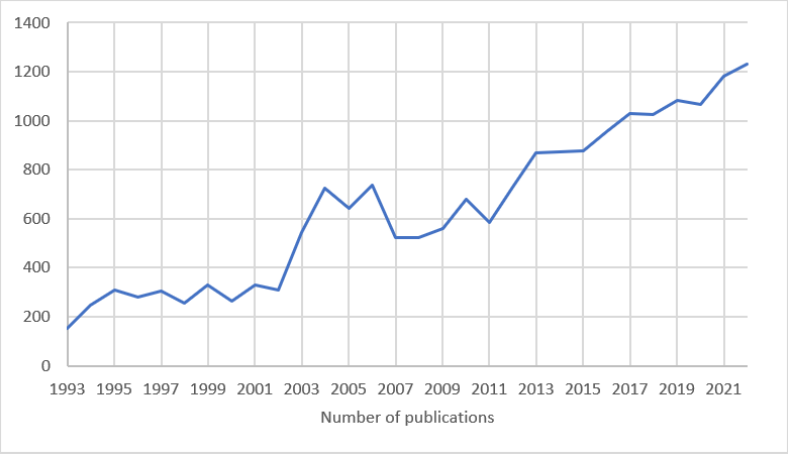

Figure 4: Number of Publications Devoted to Sustainable Product Design

The number of publications had the significant increase in years 2003–2004, and from year 2015. There were above 1,200 publications devoted to sustainable product design in 2022.

Figure 5 illustrates the number of publications relating to various subject areas. The majority of publications are related to journals addressed to engineering and computer science.

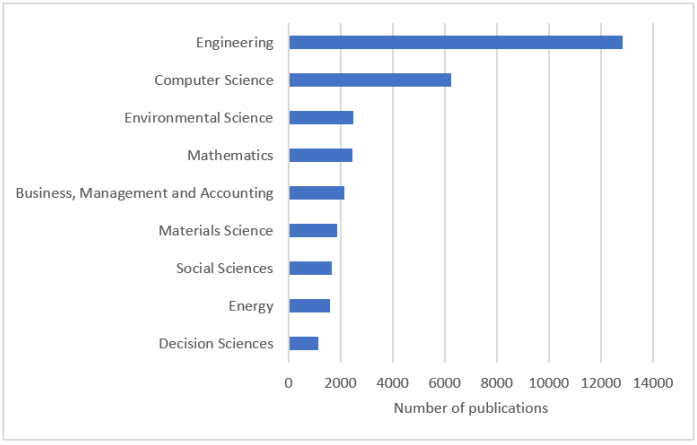

Figure 5: Number of Publications Relating to Different Subject Areas

Figure 6 illustrates the number of publications relating to the source titles that were most often chosen by researchers. The source titles presented in Figure 6 refer to about 11% of all publications.

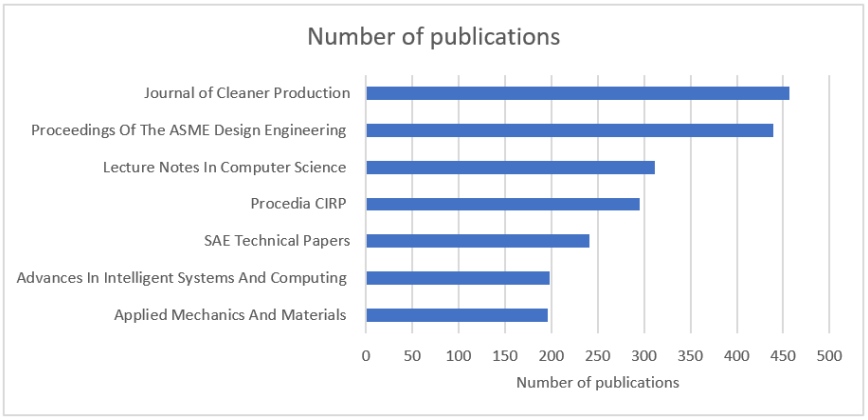

Figure 6: Number of Publications Relating to the Source Titles

3.3 Sustainable Product Innovation

Figure 7 presents the number of publications devoted to sustainable product innovations in years 1993–2022. There were 1,689 publications in the considered period, with the largest number of publications in 2022.

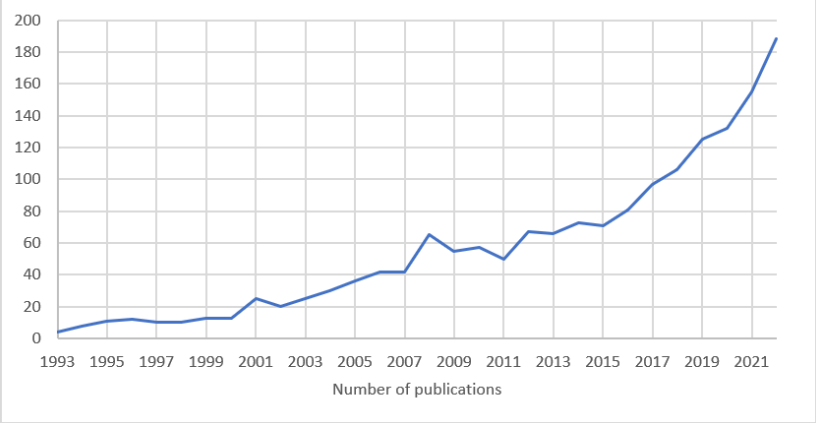

Figure 7: Number of Publications Devoted to Sustainable Product Innovations

The number of publications had rather the constant growth from 1993 to 2007, whereas the observable increase is from year 2016. The trend was rather constant in years 2008–2015.

Figure 8 illustrates the number of publications relating to various subject areas. The majority of publications are related to subject area of business, management and accounting. This subject area is different compared to the results obtained for product development and product design.

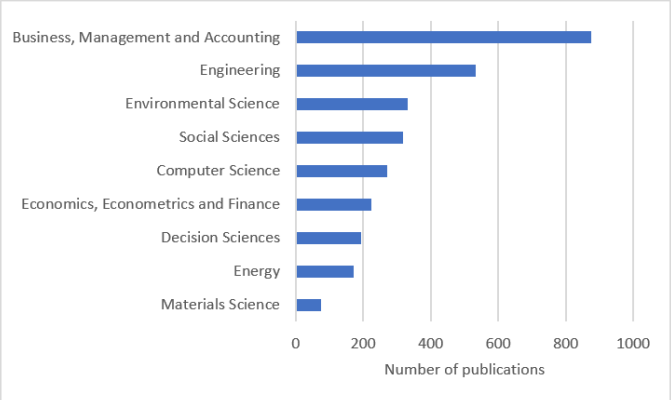

Figure 8: Number of Publications Relating to Different Subject Areas

Figure 9 illustrates the number of publications relating to the source titles that were most often chosen by researchers. The source titles presented in Figure 9 refer to about 15% of all publications.

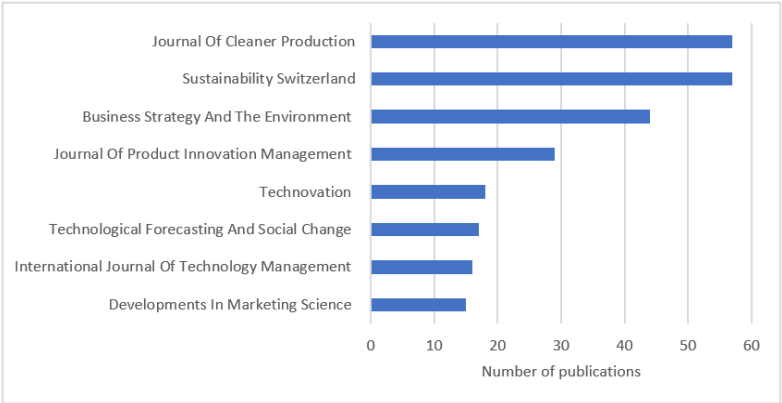

Figure 9: Number of Publications Relating to the Source Titles

3.4 Sustainable Product Development, Design, and Innovation

Figure 10 presents the number of publications devoted to sustainable product development, design, and innovations in years 1993–2022. There were 30,725 publications in the considered period, with the largest number of publications in 2022.

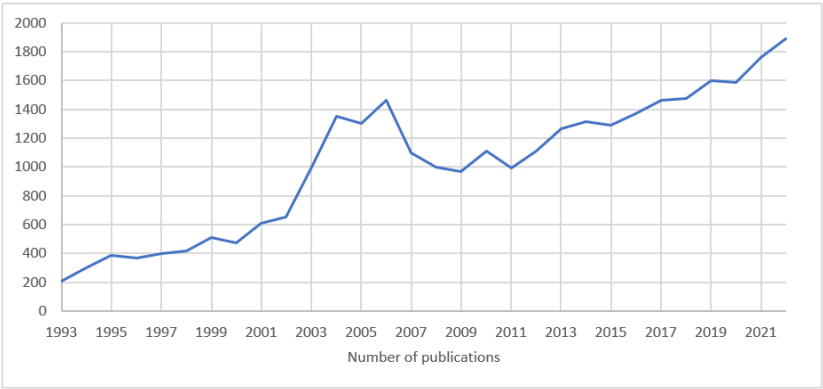

Figure 10: Number of Publications Devoted to Sustainable Products

The number of publications had rather the constant growth from 1993 to 2002 and from 2012 to 2022. The significant increase was in years 2003–2004, whereas the trend was rather constant in years 2007–2011.

Figure 11 illustrates the number of publications relating to various subject areas. The majority of publications are related to subject areas such as engineering, computer science, and business, management and accounting. This configuration is the same as for the results obtained for sustainable product development.

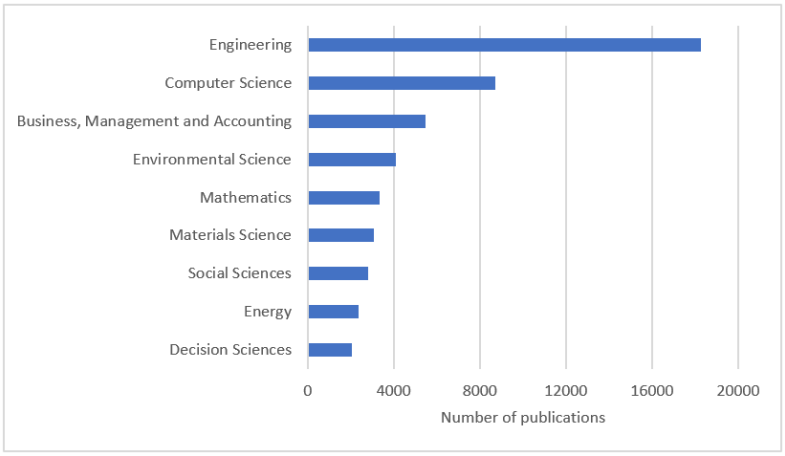

Figure 11: Number of Publications Relating to Different Subject Areas

Figure 12 illustrates the number of publications relating to the source titles, in which scientific works were published. The source titles presented in Figure 12 refer to about 34% of all publications.

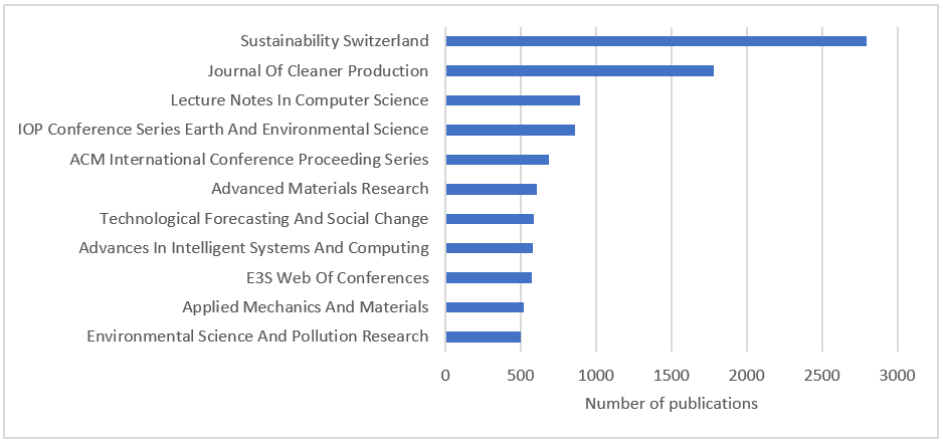

Figure 12: Number of Publications Relating to the Source Titles

Figure 13 illustrates the number of publications relating to the source type, among which the overwhelming part consists of journals and conference proceedings.

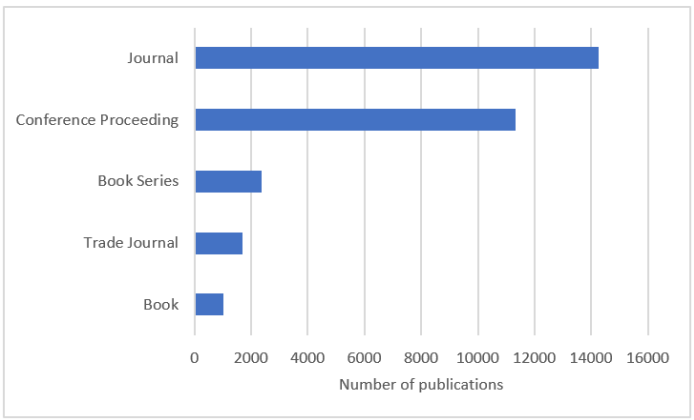

Figure 13: Number of Publications Relating to the Source Type

The results obtained in this study illustrate the continuous increase of publications devoted to sustainable product development. These results are similar to the results presented by Thomé et al (2016) for sustainable new product development in years 1993–2015. They divided publications into two periods for years 1990–2009 and 2010–2015, and investigated, among other things, the number of publications, citations, and h-index for thematic clusters such as life cycle assessment, design, innovation, and human. In period 1990–2009, they also distinguished thematic clusters related to standards and innovation, whereas in period 2010–2015 clusters for supply chains, sustainable products, product life cycle, and renewable resources. Their results of data analysis referred to the general concept of design and innovation (including not only the product aspect, but also economic growth and social aspects), whereas the results presented in this study are strictly related to product design and product innovation.

A review of sustainability management research, including themes of innovations, industrial ecology, and social-ecological systems, in years 1990–2015 was showed in (Williams et al, 2017). A longitudinal review of business innovation and sustainable development in period 2010–2019 was also presented in (Maier et al, 2020). There were investigated the number of publications from general topics related to innovation and sustainability, up to topics strictly related to business innovation and sustainable development. Science category was there limited to business, management, and economics. Data analysis includes most cited papers, authors, and journals, in which articles were published. The growth of publications related to sustainable innovation was also presented in (Hermundsdottir and Aspelund, 2021). This study referred to publications from 2005 to 2020, and it presented a systematic analysis of the key terms related to sustainable innovation and its impact on competitiveness. Similar to data analysis presented in this research, their results also show the increase of publications devoted to innovation and sustainability in recent years.

A bibliographic analysis of green product innovation in years 1991–2013 was presented in (Dangelico, 2016). In turn, sustainable product development in the context of eco-innovation was investigated in (Gbededo et al, 2018). There was proposed an eco-innovation approach, which includes the aspect of eco-design and circular economy minimising the use of materials, energy, toxicity, and waste. A literature review contains data from 2006 to 2015, and refers to sustainable product development and sustainability assessment techniques. Moreover, there was examined sustainable manufacturing methodologies and approaches. They also considered a collected set of publications in the aspect of economic, environmental, and social dimensions. Contrary to their approach, this study considers all publication together within the triple bottom line.

A systematic review of sustainable design methods and tools was presented in (Faludi et al, 2020). They investigated the needs and values of industry regarding sustainable design, improvements in sustainable design methods and tools, and ways to integrate sustainable design more effectively into industry. The improvements in sustainable design methods and tools referred to issues regarding business integration and communication support. In turn, integration into industry was related, among other things, to knowledge dissemination within best practices for scaling industry self-training on sustainable design methods and tools. Moreover, Ahmad et al (2018) presented a literature review of tools and case studies for sustainable product design in years 2007–2017. Based on the criteria of sustainability dimensions, they proposed a generic classification scheme to enhance the understanding of the mentioned tools in manufacturing companies. In this study, knowledge dissemination is also addressed to manufacturing companies within areas related to sustainable product development, including product design and product innovations.

The results of data analysis indicate that knowledge management in the aspect of sustainable product development was in years 1993–2022 presented in 377 papers, in the aspect of product design in 305, and in the aspect of product innovations in 49 scientific works. Issues related to knowledge management in the aspect of product development and product design were mainly published in subject area referring to engineering. In turn, issues related to knowledge management in the aspect of product innovations were mainly published in subject area referring to business, management, and accounting.

Knowledge management in the sustainability related issues refers mainly to the aspect of sustainable development of a manufacturing company and product innovation. Abbas and Sağsan (2019) investigated the impact of knowledge management on green innovation and corporate sustainable development. They used structural equation modelling to determine to what extent knowledge creation, acquisition, sharing and application affect green technology innovation and green management innovation, as well as environment, social, and economic aspects of sustainability. Rabal-Conesa et al (2022) investigated the relationship between organizational agility and the successful development of new green products. The results of this study indicate the impact of external knowledge on the success of eco-innovation. Moreover, internal environmental

knowledge positively affects the success of sustainable products. In turn, Estrada et al (2016) presented the results of a significant positive impact of competitor collaboration on product innovation performance only when internal knowledge sharing and formal knowledge protection mechanisms are incorporated in manufacturing companies.

4. Conclusion

Sustainable product development has become a significant research area in recent years. Sustainable products should include all three dimensions of sustainability (environment, society and economy) throughout their complete life cycle, from material extraction, manufacturing, product packaging and transportation, use, up to recycling or product disposal. The majority of the sustainability-related issues is decided at the product design stage. As a result, this stage is a key factor in drifting business strategy towards achieving sustainability in manufacturing companies. Designing sustainable products should ensure lowest negative environmental impacts, and providing economic and social benefits to the stakeholders. The interest of researchers, businesses, and policy-makers for sustainable development, sustainable design, and sustainable innovations is increasing in recent years. Practitioners need approaches for their businesses for reducing material and energy consumption, and improving the level of eco-friendly materials and packaging. These approaches can facilitate developing sustainable innovations that aim to increase competitive advantage not only through the growth of sales and market share, but also through non-financial values related to the improvement of product quality, customer satisfaction, and ultimately, business reputation and image.

The presented study is a novel bibliometric analysis of sustainable product development, product design, and product innovation in the last 30 years, from 1993 to 2022. The results of data analysis reveal the trends in publishing scientific works devoted to sustainable product development, sustainable design and product innovations, as well as the most popular sources for knowledge dissemination. The results also show differences in the growth of publications for sustainable product design and product innovation in recent years. This research is a preliminary study for further research regarding the development of business models for sustainable innovations dedicated to the Industry 4.0 environment. Moreover, future research will be referred to investigation of the impact of knowledge management on the improvement of product innovation in sustainability related aspects.

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