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A pre-assessment of past research on the topic of environmental-friendly electronics

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ABSTRACT

Environmental-friendly products, processes, tools, methods and etc… have been under the interest of both industry and academy. However, this interest has not been analyzed systematically for the academic studies. On the other hand, bibliometric analyses have been a widely used approach to measure and to analyze the interest of academic world on a certain topic. In this regard, this study intends to provide insight about the research on environmental-friendly electronic using the related literatures from the Thomson Reuters Web of Knowledge database during the period of 1980–2016. This study consists of two parts. In the first part, 7288 academic papers having the "environmental" and "electronic" phrases on "Title", "Abstract" or "Keywords" were retrieved and analyzed using bibliometric analysis methodology. These two adjectives has been selected on purpose since current studies on textual analysis indicate that phrase building most frequently starts after adjectives. In the second part of this work, Singular Value Decomposition (SVD) method, concept extraction and k-means clustering method was performed to gain more insight about the textual structure of the retrieved articles. Findings indicate that, approximately one third of publications were written by the authors addressing USA. It is also clarified that the topic was not in the agenda of researchers between 1980 and 1990. The number of publications on the area had significantly increased and had reached its peak in 2014. Text mining results showed that, the most important research focus was on "life-cycle" that was followed by "e-waste, sensor, recycling and solder" respectively.

1. Introduction

The growth of greenhouse gas emissions affects the entire world in a negative way. Therefore, developing novel green strategies and policies have been very significant factor of maintaining sustainability. Such strategies are expected to avoid companies from wasteful and environmentally harmful production and thereby canalize them to the resource efficient consumption alternatives.

In parallel to these sustainability issues, quality perspectives of consumers have significantly changed excessively. The concept of quality has evolved over the years. Formerly, the quality was approximated by the measures like: production volume, the cost-competitive advantages that make a firm superior to its competitors. In the early 2000s, quality of products, companies' quick response and adaptation of firms to the changes and innovativeness were the significant indicators showing the evolution in quality perception. However, this perspective has continued to evolve in the recent years. Nowadays, issues related to environmental considerations have become an increasingly important discussion topic and have taken the attention of policy-makers in the developed and developing countries. Since increasing the quality of product and process can enhance the organizations productivity, their market domination and profitability; environmental concerns have taken a considerable role in the strategies of the companies.

A number of policies regarding environmental aspects of countries had been announced by the European Union (EU) comprising directives on the limited use of harmful substances in electrical and electronic product and WEEE (waste electronics and electrical equipment) (Tseng et al., 2013). With the help of these directives which push manufacturers attention on minimizing the unwanted environmental impacts of electric and electronic products has been triggered. It has been recognized that, companies will be punished and either comprehensive or selective commercial sanctions will be employed when the companies launch new products to the market containing hazardous ingredients for the

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public health. Besides, increase in conscious of consumers on environmentally-friendly products has positively affected the request of consumers (Kilbourne and Pickett, 2008). Therefore, producing environmentally-sensitive green products and using the environmental processes have been one of the strategically important targets of companies. In this regard, it has been necessary for companies to update their traditional production visions towards the suitable environmental and technology innovation policies. As a result of the fast depletion of the natural resources and increasing amount of various type of waste (industrial, municipal, agricultural, electronic and etc.) creating eco-friendly equipment and developing new techniques for recovering products and management of waste have drawn the researchers' attention to this topic (Gungor and Gupta, 1999).

Today, academic publications and patents are considered one of the most important resources of monitoring the research trends in academic studies (Murray, 2002; Tseng et al., 2007). By analyzing these documents, companies and researchers may get useful information about future technology without wasting time, money and effort and incorporate results with existing knowledge in further R&D activities (Yoon and Park, 2004). It is also important to use the correct methodology to save time, money and effort. In this regard, text mining has been an effective method to deal with large number of documents. Text mining is known to be a useful tool of processing unstructured text with machine support. Moreover, text mining can be helpful to detect the trends in large scale text documents (Miner et al., 2012). Text mining techniques have been widely used by different researchers for different purposes. For example (Daim et al., 2012) used text mining to create linkages between patenting patterns and the crucial events effecting wind energy technologies. Liew et al. (2014) have employed the methodology to identify the top priorities of chemical industries and their sustainability trends. Liu (2013) has performed "a visualization analysis" for terahertz technology. There are also some other studies identifying research trends using publication analysis (Daim et al., 2012, 2006; Tseng et al., 2007; Yoon and Park, 2004).

The aim of this study is to discover the recent trends of researchers and countries related to 'environmental' and 'electronic' between 1980 and January 2016. Bibliometric data were utilized in the characterization of the literature by journals, publication type, language, subject categories, countries, authors and citations. The detailed content analysis of the abstracts and titles of papers was performed by using several text mining methodologies. The documents related with environmental and electronic field were downloaded from Thomson Reuters Web of Knowledge (WoK) database (lists the all articles in the journals indexed by SCI-Soc-SCI Expanded-SCIE published by about 500 publishers). Topic term was selected as "environmental" and "electronic". It is known that the "topic term search" in WoK corresponds to the searches on: "Title", "Abstract", "Keywords" or "Keywords Plus®" fields within a record.

The keywords "environmental" and "electronic" are both adjectives. Previous studies have demonstrated that adjectives are good indicators of subjective, evaluative sentences (Hatzivassiloglou and Wiebe, 2000; Wiebe, 2000). It is remarkable to state that these two adjectives have been selected on purpose since phrases most frequently starts after adjectives and the most of English compound nouns are noun phrases that are described by the adjectives.

In the second part of this work, Singular Value Decomposition (SVD) method, concept extraction and k-means clustering method was performed to gain more insight about the textual structure of the retrieved articles. Frequencies of the words in retrieved articles were also analyzed. The remaining sections of this paper are organized as follows. Section 2 describes the bibliometric and text mining methodologies which is the basis of the analysis. The data employed in this work and the results of bibliometric and text mining analysis are presented in Section 3. Finally, Section 4 reveals the conclusion and discusses future research opportunities.

2. Data retrieval and methodologies

The documents related with environmental and electronic field were retrieved from Thomson Reuters Web of Knowledge (WoK) database (which lists the all articles in the journals indexed by SCI-Soc-SCI Expanded-SCIE published by about 500 publishers). Topic terms were selected as "environmental" and "electronic". They are both adjectives. Previous studies have demonstrated that adjectives are good indicators of subjective, evaluative sentences (Hatzivassiloglou and Wiebe, 2000; Wiebe, 2000). It is remarkable to state that these two adjectives have been selected on purpose, since phrases can be extracted during the process of consecutive word reading and they start most frequently after adjectives (Klinov and Mouromtsev, 2013). Some of the articles that are out of scope have been eliminated after a manual scan (such as the ones including "electronic data", "electronic customers"). Since the purpose of this study is to identify the research on environmental-friendly and electronic "products/devices/equipment/processes/tools/methods and etc", the words used after the given adjective "electronic" in the retrieved articles is illustrated in Table 1.

Subsequent to the query to detect the related articles, two fundamental sections of the papers (title and abstracts of the papers) were downloaded. Complete bodies of papers have not been included since adding them would dramatically increase the time for an automated analysis (due to the tables, images, references, etc.). The study was performed in two stages. The purpose of the first stage was to provide information regarding the characterization of the environmental electronic related studies by the use of bibliometric analysis. For this analysis, all extracted records (7288 papers) were used. In the second stage, text mining analysis was performed for the papers which have accessible abstracts. The number of records was decreased to 7145 after elimination of those papers without an abstract.

2.1. Bibliometric analysis

The term "bibliometrics" is the combination of words "biblio" that refers "books" and "metrics" that refers to "measurement" was first coined by Allan Pritchard in 1969 (Norton, 2000). It is a method that uses both qualitative and quantitative methods to organize, describe, analyze and explore the documents. Bibliometric analysis has been one of the most important methods that are used in measuring scientific progress in the field of information science (Raan, 2005). It helps to clarify the top most active authors, performance of countries, the most cited works, the most trend topic that studied by researchers, the frequent keywords that used by authors and etc. (Daim et al., 2006).

Some papers employing bibliometric analyses on environmental science have been published in the recent years. For example, 8244 publications were analyzed by Du et al. (2012) to discover the characteristics of energy efficiency literature for the years between 1991 and 2010. Similarly, the trends in carbon market from 1992 to 2011 were described by Du et al. (2015), according to their findings, the focus of carbon market related studies were "climate change" and "carbon emissions". Bibliometric analysis and topic modeling approach used by Jiang et al. (2016) to establish academic concerns of the Three Gorges Project (TGP) which is world's largest hydropower project. In the study 8240 abstracts of Chinese articles from 2001 to 2013 in aforementioned topic were used as inputs (Jiang et al., 2016). By using samples of 113,468 publications in a 20-year period the global environmental assessment literature trends were discovered by Li and Zhao (2015).

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