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MULTI-CRITERIA DECISION MAKING APPLICATIONS IN GREEN GROWTH: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Nowadays, growing population and manufacturing causes an increase in industrial activities. As a result of the increase in industrial activity, it is observed that high levels of CO2 emissions. Therefore many environmental problems have been observed including global warming. In this context, countries tend to prefer production technologies which aim to minimize CO2 emissions. As a result of environmental and economic problems in recent times, green growth and green economy concepts have emerged. Green growth can be defined as a point of encouraging production and consumption of goods and services to minimize damage to the environment. It is possible to increase the economic development and employment opportunities and environmental sustainability by this approach. Short and long term using of environmental and economic problems with green growth, the increase of product characteristics and firms, and the variability of product features have led to the need for multi-criteria decision. Therefore, caring the multiple criteria and the alternatives, the multi-criteria decision making techniques are taken to the scope of application with green growth. In this paper, green growth's studies in literature are examined in three main topics as Green Manufacturing, Green Supplier Selection and Green Energy. The purpose of the study is to determine the most popular area of green growth and to find out the inadequacy in order to lead researchers efforts to this field. Besides, criteria which are commonly used in each main topic are indicated to help researchers.

Keywords: Multi-Criteria Decision Making, Green Growth, Green Manufacturing, Green Supplier Selection, Green Energy

JEL-Classificaton: Q29, Q51, Q53, Q56

Yeşil Büyümede Çok Kriterli Karar Verme Uygulamaları: Sistematik Bir Literatür Taraması

ÖZET

Günümüzde nüfus ve buna bağlı olarak üretim ihtiyacında meydana gelen artış endüstriyel faaliyetlerdeki artışı da beraberinde getirmektedir. Endüstriyel faaliyetlerde meydana gelen

artış ise CO2 salınımını yüksek seviyelere çıkarmaktadır. Bu durum çeşitli çevresel ve ekonomik problemlere yol açmaktadır. Son zamanlarda çevresel ve ekonomik problemlerin yaşanmasının bir sonucu olarak yeşil büyüme ve yeşil ekonomi kavramlarına olan ilgi giderek artmaktadır. Yeşil büyüme kavramını çevreye minimum düzeyde zarar verecek ürün ve hizmetlerin kullanımını teşvik eden bir yaklaşım olarak tanımlamak mümkündür. Diğer taraftan, çevresel ve ekonomik problemlerin yeşil büyüme kavramı ile birlikte değerlendirilmesi sonucunda, çevreye minimum zararı verecek üretim sistemlerinin ve tedarik zinciri unsurlarının seçimi problemleri çok kriterli karar verme ihtiyacını doğurmuştur. Bu nedenle çalışma kapsamında, çoklu kriterleri ve alternatifleri dikkate alan çok kriterli karar verme teknikleri yeşil büyümeyle beraber ele alınmıştır. Bu çalışmada literatürde yer alan yeşil büyüme uygulamaları; yeşil üretim, yeşil tedarikçi seçimi ve yeşil enerji olmak üzere üç ana başlık altında incelenmiştir. Bu çalışma ile yeşil büyümenin en önemli ve eksik alanlarını belirleyip araştırmacıların bu alana yönelmesini sağlamak amaçlanmıştır. Bunun yanında her ana başlık altında genel olarak kullanılan kriterler ifade edilerek araştırmacılara yol göstermek hedeflenmiştir.

Anahtar Kelimeler: Çok Kriterli Karar Verme, Yeşil Büyüme, Yeşil Üretim, Yeşil Tedarikçi Seçimi, Yeşil Enerji

1. Introduction

With the increasing population and resource usage, protecting the environment became a serious issue. The rise in the production levels results in high volumes of CO2 release which causes many environmental problems. Countries and organizations allocate some resources to ensure a sustainable development and environmental protection. In addition to that, they are more inclined to use the production technologies that ensure lowest level of greenhouse gas release. Recently, the motivation for environmentally sensitive productions/services leaded to the concept of green development. Green development is an approach that advocates minimizing the environmental damage caused by any activity.

To use the word ‘green’ along with the supply chain, energy, and production concepts becomes more popular. In the recent years, the problems such as identification of the best green energy alternative, the selection of a green supplier, and the evaluation of green production activities are encountered more often. Most of these problems contain multiple criteria requiring multiple criteria evaluation to obtain their solutions. Multiple-criteria decision making (MCDM) is the selection of the best alternative by evaluating several alternatives according to certain criteria. Thus, MCDM methods are helpful as a decision-aiding tool for these kinds of problems.

In this study, green development concept is analyzed by dividing it into the sub-concepts: green manufacturing, green energy, green supply chain and green innovation. We focus on the importance of these concepts for the minimization of the environmental problems and analyze the studies that use MCDM techniques. By studying the topics and dates of the studies, we aim to identify the most common MCDM techniques used for these concepts. By bringing the studies together, we aim to help the researches working in this area.

The study comprises of four sections. In the second section, the sub-concepts of green development are explained in more detail. The third section presents the summaries of the studies used MCDM techniques on the green development concept and an explanatory analysis of these studies. The study is concluded by the conclusion and assessment in the fourth section.

2. Green Approach

The rapid development in the technology and the overpopulation resulted in an increase in the uncontrolled usage of the natural resources and the important environmental and resource problems threatening the world. Nowadays, the most important factor concerning producers and consumers is the natural balance and ecological elements in the world. Green development is one of the topics that organizations and consumers concern in the 21st century. The increasing environmental awareness caused the producers to consider this concept in their production design and strategies, and the consumers to investigate whether the products, that they are interested, harm the environment or not. Especially, the increased environmental awareness of consumers and their preference towards environmentally friendly products lead producers to develop strategies in this direction. The green development concept has mainly appeared in the literature under the titles of green production, green supplier selection, green energy and green innovation.

2.1. Green Manufacturing

The customer preference towards environmentally friendly products resulted in a new competitive environment for organizations. Organizations have realized that by taking simple precautions, they can stop the waste in their production processes and decrease the waste production at the same time. This idea has been followed by replacing the existing resources with the environmentally less harmful ones and decreasing the water and energy needs for the production. As a result, the efforts for avoiding the pollution, increasing the recycling, and environmentally friendly product design have improved and named as ‘green production’ recently (Shamdasani et. al., 1993).

2.2. Green Supply

Supply chain management is defined by American Production and Stock Control Association (Cox et al. 1995) as “the functions that operate through the value chain and the processes that connect suppliers and organizations from the raw material until the end product”. The increasing environmental problems and the rapid decline in the natural reserves caused the firms to become more conscious towards the environmental issues and take the necessary actions. Green supplier selection aims to increase the firms’ profit and market shares while selecting the suppliers that have the minimum environmental damage (Van Hoek 1999).

2.3. Green Energy

Today, one of the most important factor for development and competency of the countries worldwide is energy. Continuous and affordable energy supply is among the issues to be solved in each country. Gradually running out of fossil fuel reserves meeting a large part of

the energy demand and increasing air pollution as a result of the carbon emissions from fossil fuels usage lead to the choice of "green energy-renewable energy" sources increasingly in recent years.

2.4. Green Innovation

In rapidly changing environmental conditions, enterprises on the one hand trying to adapt to the changes occurring in their environment, on the other hand, they try to fulfill the requirements of the competition. In this regard, one of the most important elements of the global competition is to become innovation-oriented. Innovation is the realization of new or significantly improved products, processes, a new marketing method or a new organizational method in internal applications, workplace organization or external relations (OECD, 2006). With the increasing importance of environmental issues in recent years, as a new form of innovation "green innovation" concept has emerged. Green innovation enables the discovery of new ways to reduce waste and to find new energy sources (Cheng & Shiu, 2012). In this context, many companies, by including the green concept into the innovation, are trying to differentiate itself from competitors as well as to achieve competition advantage.

2.5. Others

In recent years, green concept became a serious issue in many areas such as green manufacturing, green supplier selection, green energy and green innovation. Hence an increase in a number of activities which are based on environmental awareness is observed. Green logistics, green marketing and green initiative are samples of these activities. Green marketing concept in purchasing behavior and product preferences of consumers, is enhanced by energy efficient appliances, choosing products with paper packaging and recycled which have the negative environmental impact. Green marketing, which exist in the advertising perception, product packaging, the manufacturing strategy and several areas, is defined as an approach which takes into account ecological factors. Green logistics is a rising concept due to customer satisfaction, and profitability of companies', increasing in their market share and providing a competitive advantage. Green logistics may be defined as measuring the negative effects of logistics activities on environment and minimizing these effects. Preferring environmentally friendly motor vehicles (vehicles with Euro 5), environmentally friendly recycling , leading reverse logistics activities , preferring vehicles with environmentally friendly fuel for production and shipment (LPG, CNG, etc.), using eco-friendly efficient transportation and distribution systems have appeared in applications which are performed in that field. As for green initiative, it consists of entrepreneurial activities for sustainable production and consumption, works minimizing the negative effects on environment, both performing the goals to make profit and also activities by creating a positive contribution to society.

3. A Systematic Literature Review

Firstly, we made a comprehensive literature survey. Green growth papers are investigated under green manufacturing, green supply, green innovation and green energy topics between 2001 and 2015.

Khan et al. (2001) suggest a systematic methodology for process design that considers the assessment and minimisation of the environmental impacts of the complete process system (including upstream processes). It incorporates life cycle analysis principles within a formal design process and optimisation framework. The proposed process design methodology with minimum environmental impact extends to a complete description of the environmental impact of the process and its associated activities.

Khan et al. (2002) evaluate available option of urea manufacturing considering all the possible constraints. The assessment of their study includes the entire life cycle of the product, process or activity encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use, recycle, and final disposal. The GreenPro-I is proposed as a decision-making tool for designer, regulatory agencies, and business organizations.

The use of MCDM methods in an integrated assessment (IA) framework is investigated by Greening and Bernow (2004). They offer a typology for the broad class of models, suggest some of the types of problems that may be analyzed with these methods, and recommend the implementation of several MCDM methods in currently evolving IA frameworks.

Sadiq et al. (2005) presents decision-making under uncertainty based on life cycle analysis and considering economical, environmental and technological drivers in the analysis. The methodology, GreenPro-1, can be used to evaluate the environmental burdens of a product and to identify and assess opportunities to make improvements. In their studies, life cycle analysis, fuzzy composite programming and risk-based MCDM and fuzzy composite programming are used. As a result of studies different alternatives are evaluated and they have demonstrated a new methodology.

Doukas et al. (2006) study is to put on the map the sustainable technologies for electricity generation through the formulation of a collective interactive supportive framework. The method of Promethee II is used in their study. Different sustainable technological alternatives are evaluated in Greece.

Wang and Lin, (2007) presents a methodological framework for the triple bottom line accounting and management of industry enterprises. Suistainable optimization model was created with MCDM and a new accounting methodology has been developed.

Lu et al. (2007) presents an innovative method using simple and efficient procedures to evaluate the effectiveness of projects supplying green supply chain (GSC) concept. Multi-objective decision making process for GSC management is presented to help the supply chain manager in measuring and evaluating supplier's performance based with an AHP method.

Ravi et al. (2007) a combination of analytical network process (ANP) and zero one goal programing (ZOGP) was used as solution methodologies to deal with the problem. As a result of studies, reverse logistics has been made appropriate choice for computer with hybrid approach using ANP and ZOGP.

In the paper of Lee et al. (2009), a model is proposed to select the factors for evaluating green suppliers, and to evaluate the performance of suppliers. In this model, the Delphi method is applied first to select the most important sub-criteria for traditional suppliers and for green suppliers. Then the results for green supplier are applied to construct a hierarchy for green supplier evaluation problem. A fuzzy extended analytic hierarchy process (AHP) model is constructed next based on the hierarchy to evaluate green suppliers for an anonymous TFT–LCD manufacturer in Taiwan.

Hsu and Hu, (2009) present an ANP approach to incorporate the issue of hazardous substance management into supplier selection. In this study, a MCDM model including five main criteria and 19 sub-criteria is proposed is proposed. Then, an illustrative example in an electronics company is presented.

Li et al. (2010) propose a methodology for selecting a green technology portfolio from an environmental strategic perspective, the objective of which is to maximize the economic benefits and environmental benefits of an enterprise. The synergy effect coefficient of the green technology in each portfolio is presented and is formulated based on the more accurate preference elicitation technique ANP.

Gao et al. (2010) construct a fuzzy technique for order preference by similarity to ideal solution (TOPSIS) model to evaluate a set of feasible green design alternatives to determine a priority ranking for alternatives selection. The performance evaluation for the product green design scheme selection factors are determined as environmental impact of materials, disassembly performance, recycling performance, energy efficiency, noise, pollutants to the environment and functional value. A case study is given to validate the application of the methodology as a useful design guideline for scheme selection in green design.

Tseng (2011) focuses on developing a quantitative evaluation of environmental practice in knowledge management capability (EKMC) measures. A novel hybrid MCDM model is used to address the dependence relationships of criteria with the aid of the ANP and Decision-Making Trial and Evaluation Laboratory (DEMATEL) in uncertainty. This approach can be applied to evaluate and determine a firm's EKMC capabilities to reduce the firm's risk in decision making.

Lin et al. (2011) combine ANP and importance–performance analysis into a single study criteria framework to build a visual map and to evaluate green business innovation capabilities. Their study tackles the evaluation assessment using fuzzy set theory, ANP and importance–performance analysis. The analytical results indicate that the proposed hybrid method is a suitable and effective method for identifying and analyzing the strategic competitiveness.

Shaik and Abdul-Kader (2011) present a comprehensive framework for green supplier selection that incorporates the traditional aspects, the environmental and the social factors. Their paper proposes a generic framework consisting of E-G-O (environmental, green and

organizational) factors with relevant criteria and attributes for selecting green suppliers, which adds knowledge to this area. Their study utilizes and validates the decision-based analysis tool of multi-attribute utility theory for the green supplier selection process.

In the study of Tseng, (2011) a method proposed to select green supplier in the presence of incomplete information and linguistic preferences using multiple green supply chain management (GSCM) criteria. In this method, the weights of GSCM criteria are described using linguistic preferences and fuzzy set theory is used for resolve these prefences. Subsequently, the rank of each alternative was calculated from incomplete information by applying a grey degree.

In the study of Wu et al. (2011), the fuzzy DEMATEL method is used to find influential factors in selecting GSCM criteria. The results show that the satisfy customer needs criteria has the greatest influence among the criteria for selecting suppliers and could directly or indirectly influence many others factor.

Hsu et al. (2012) propose how the best selection can be implemented for enhancing and increasing the efficiency of using resources in the manufacturing process through recycled materials. In their paper, an empirical study is used to demonstrate the application of a hybrid MCDM model combining DEMATEL, ANP and VIKOR methods.

Tseng and Chiu's (2012) study evaluates the ability of different criteria that will enable focal electronic manufacturing firms to adopt green innovation practices. They integrated MCDM techniques that are grey theory, entropy weight and the ANP together to evaluate the green innovation practices under uncertainty. Hence, the objective is to select an alternative in the presence of incomplete information using multiple green innovation criteria.

Çiftci and Büyüközkan (2012), utilize AHP technique in their study on the selection of green suppliers. To cope with the linguistic variable and imprecise data they set use fuzzy set theory. In their paper, Çiftçi and Büyüközkan (2012 a) propose an evaluation model based on group decision making and fuzzy AHP to determine the criteria for evaluating green suppliers and to evaluate the performance of suppliers.

Büyüközkan and Çiftçi (2012 a), propose a novel hybrid approach including fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSİS techniques in their study on the selection of evaluation of green supplier. The combined fuzzy ANP and fuzzy DEMATEL approaches used in this study offered a more precise and accurate analysis by integrating interdependent relationships within and among a set of criteria. The proposed model is applied to Ford Otosan which is the Turkey's leading automobile manufacturer.

Wang et al, (2012) propose a fuzzy AHP model in their study on risk assessment of initiative practices in green fashion supply chain management. They developed a hierarchical structure model taking into account several angles in implementation of various green initiatives.

Tseng et al (2012) utilize gray relation analysis with entropy weight method in their study on green innovation for environmental management. They firstly determine and weight appropriate green innovation criteria then prioritize alternative suppliers using gray relation analysis with entropy weight method. They implemented the proposed method in a company producing printed circuit boards in Taiwan.

In the paper of Büyüközkan (2012), green supplier evaluation is studied using an integrated fuzzy MCDM approach. Fuzzy AHP is applied to determine the relative weights of the evaluation criteria and an axiomatic design based fuzzy group decision making (GDM) approach is applied to rank the green suppliers. Then, a case study is given to demonstrate the potential of the methodology.

Kaya (2012) stated that management of waste of electrical and electronic equipment (WEEE) is a critical and important decision in terms of environmental management. Because of that, he analyzes an outsourcing decision for the management of WEEE and proposes a methodology based on fuzzy AHP and GDM approach to evaluate and to select the appropriate WEEE outsourcing firm. In application case, he compares five firm alternatives for outsourcing of the management of WEEE process in Turkey.

In their paper, Shiue and Lin (2012) presents a method applying a combination of the benefits, opportunities, costs and risks and balance scorecard and ANP in the decision-making process to evaluate recycling strategies for obtaining optimal strategies in the solar energy industry. The results of the study showed that the most important perspective is “Benefits;” the most crucial criterion of the 20 criteria is “economic and financial benefits;” and the best strategy is “In-house”.

Büyüközkan and Çifçi (2012 b) examine the components and elements of GSCM and suggest a GSCM evaluation framework. The fuzzy extension of the ANP method is preferred to cope with ambiguity and vagueness of the decision maker’s evaluations. They also provide a real-case study of Ford Otosan, to illustrate the industrial application of the model.

Chen et al, (2012) focus on a green strategy selection for industry from the internal environment viewpoint in their study. They propose a network to clarify managerial levels and firm-related content. It derives four business functions from product lifecycle management: design, purchasing, manufacturing, and marketing and service—and associates their related activities with ‘‘greenness’’. These functions and activities are a network’s clusters and elements in an ANP model with dependent relations.

Tseng and Chiu (2013) propose a GSCM hierarchical framework that integrates environmental and non-environment supply chain management criteria in a single framework and develop valid and reliable measures based on expert’s qualitative preferences together with quantitative data. A hybrid method is presented to solve the supplier selection problem given linguistic constraints.

A fuzzy hierarchical TOPSIS approach is proposed by Wang and Chan (2013) in order to achieve sustainable economic and environmental performance. It provides a novel approach to examine various challenges that firms might be faced with when implementing green supply chain management initiatives and it enables organizations to identify improvement areas required for adopting green initiatives.

Yazdani-Chamzini et al. (2013) have proposed a model that uses hybrid COPRAS and the AHP method for selection of the best renewable energy projects. The results showed the model's effectiveness and adequacy in the selection of the most appropriate renewable energy alternative.

The aim of the paper of Ertay et al. (2013) is to evaluate the renewable energy alternatives as a key way for resolving the Turkey's energy-related challenges. In order to realize this aim, they comparatively use MACBETH and AHP-based multi criteria methods for the evaluation of renewable energy alternatives under fuzziness. They use 4 main attributes and 15 sub-attributes in the evaluation. The potential renewable energy alternatives in Turkey are determined as Solar, Wind, Hydropower, and Geothermal.

The aim of study of Demirtaş, (2013) is to determine the best renewable energy technology for sustainable energy planning. For this aim, he used AHP methodology, which is MDCM method. In the proposed method, the weights of the selection criteria are determined by pairwise comparison matrices of the AHP. Results indicate that wind energy is the most appropriate renewable energy option in this study.

Tseng et al. (2013) proposes to evaluate green innovation practices with a particular focus on the managerial, process, product and technology innovation aspects. This study identified the appropriate green innovation aspects and criteria for the case firms and, subsequently, developed the following hybrid method: (i) evaluate the weights of the aspects and criteria as described by linguistic preferences; and (ii) use ANP with entropy weights to evaluate the proposed framework.

Oztaysi et al. (2013) used fuzzy ANP method as one of the fuzzy MCDM methods to rank green energy alternatives. They presented a case study to evaluate green energy alternatives in terms of technical, economic and environmental criteria in Turkey.

Shen et al. (2013) examined GSCM to suggest a MCDM approach in order to evaluate green suppliers. Fuzzy set theory is used to transform subjective assessments to crisp values. TOPSIS method is utilized to determine a performance value for each supplier.

Kabak and Dağdeviren (2014) propose an integrated model based on Benefits, Opportunities, Costs and Risks (BOCR) and ANP to determine Turkey's energy status and prioritize alternative renewable energy sources. 19 criteria are used to assess five alternative renewable sources (Hydro, Geothermal, Solar, Wind and Biomass).With this methodology, measures could be taken against possible risk and the effectiveness of the decision by allowing participation of different experts increase.

Dabbaghian et al. (2014) aimed to find solution some shortcomings of current approaches by suggesting an improved quantitive sustainability evaluation framework for green building technologies. The proposed model includes AHP method. They showed the utility of this approach by comparing sustainability performance of conventional roof system and green roof systems.

Kaa et al. (2014) made a study based on photovoltaic technology selection with MCDM approach. They used AHP and fuzzy logarithmic preference programming methods. At the end of study the best one of 5 photovoltaic technologies is determined with AHP and fuzzy logarithmic preference programming methods by means of expert opinions.

Yazdani (2014) studied to find the right supplier based MCDM. AHP method is used to calculated criteria weights and fuzzy TOPSIS method is utilized to rank alternatives. It is aimed to perceive the model better with an implementation for automobile manufacturing supply chain.

Zhao and Gao (2014) proposed an integrated MCDM approach which combined fuzzy entropy and fuzzy TOPSIS methods to select green supplier.

Hsu et al. (2014) presented a model to assess carbon and energy management performance of suppliers by using MCDM approach. They used DEMATEL method to determine weights of criteria and relations among them. Dematel based ANP and VIKOR methods are used to determine weights and performance of suppliers.

Kannan et al. (2014) suggested a framework which used fuzzy TOPSIS method to select green supplier for an electronic company in Brasilia. They ranked alternatives with TOPSIS method and obtained two ranks with graded mean and geometric mean methods. Then, they compared these two ranks with the rank which obtained from proposed method. Finally, they analyzed the statistical difference among three ranks by means of a Spearmann rank correlation parameter.

Chuang and Yang (2014) made a study about key success factors in green manufacturing systems applications. They proposed a 3-tier model to evaluate performance of green manufacturing systems and used ANP method. The weights for each tier are calculated with ANP method.

Tasri and Susilawati (2014) aimed to improve a selection methodology and to determine the best renewable energy sources for electricity generation in Indonesia. They determined hydraulic energy as the best alternative with the help of AHP based selection methodology. Hydraulic energy is followed by geothermal energy, solar energy and biomass energy respectively.

Govindan et al. (2015) aimed to select the most appropriate green manufacturing application through an integrated MCDM model which used DEMATEL based ANP and PROMETHEE methods.

Chithambaranathan et al. (2015) proposed an integrated grey based framework to assess environmental performance of supply chains. They used ELECTRE and VIKOR methods with grey approach.

Govindan et al. (2015) make an investigation to define 12 common factors of green manufacturing by means of expert opinions, ındustrial managers and literature. They helped to companies to adopt green manufacturing faster and better.

Kannan et al.(2015) suggested fuzzy axiomatic design MCDM method to select the best green supplier for a plastic manufacturing company in Singapore.

Mangla et al. (2015) presented a flexible decision model which use AHP and Interpritive Ranking Process methods concurrently about performing green supply chain applications. Proposed flexible risk assessment model is applied in an Indian plastic manufacturing company.

Kuo et al. (2015) suggested a hybrid MCDM method to assess green suppliers for an electronic company. An integrated DEMATEL-ANP method is utilized to examine relations among criteria and to calculate criteria weights. They also used VIKOR method to evaluate environmental performance of suppliers.

Rostemzadeh et al. (2015) improved an evaluation model to measure uncertainty of GSCM activities and applied an approach based on VIKOR method to solve green MCDM problem. At the end of study they obtained alternative ranks for 4 companies which evaluated according to their green supply chain performance. Besides, they determined the rank which related to main criteria as economic design, green manufacturing, green purchasing, green recycling, green transportation and green warehousing.

Akman (2015) clustered suppliers of a company which operates in automotive industry with c-means clustering method. The suppliers which have good performance are evaluated in terms of environmental criteria and divided into three groups as good, medium and poor. Finally, the suppliers which located in poor group are ranked via VIKOR method to add green improvement programme.

Ren et al. (2015) made a study based upon determining priorities in low carbon energy sources to increase energy safety in China. They used AHP and TOPSIS methods. They determined potential weights of energy sources with AHP method and utilized TOPSIS method to select most appropriate energy potential.

Sengul et al. (2015) aimed to improve a MCDM framework to rank renewable energy supply systems in Turkey. They utilized fuzzy TOPSIS method to evaluate alternatives. Besides, they used interval Shannon Entropy method to calculate criteria weights. At the end of study hydraulic energy station is selected as the best alternative.

Banaeian et al. (2015) suggested a model which includes general and green criteria to select green supplier in food industry. They used AHP and Delphi methods to determine criteria weights. Then, they utilized fuzzy grey relationship analysis to rank suppliers. Besides, they also used fuzzy linear programming to select the best supplier and to allocate orders among them.

Ren and Sovacool (2015) used AHP to calculate the relative weights of the qualitative metrics to dimensions of energy security for each of their five low carbon energy sources. Then, they determine energy security performance by aggregating multiple, weighted metrics into a generic index based on the method of TOPSIS and then tweak with a sensitivity analysis.

3.1. Descriptive Statistics

Figure 1 provides the distribution and cumulative distribution of the articles based on the year in which they are published. As seen in figure, an increasing trend is existed over the years. In figure 2, subfield distribution of green growth papers is presented. We also have to note that green supply studies are superior in terms of number compared to the other subfield. The rate for the green supply studies is 43%. Rate 43% divulges that; this topic has the most prominent importance between green growth studies.

Figure 1. Chronological distribution of green growth papers.

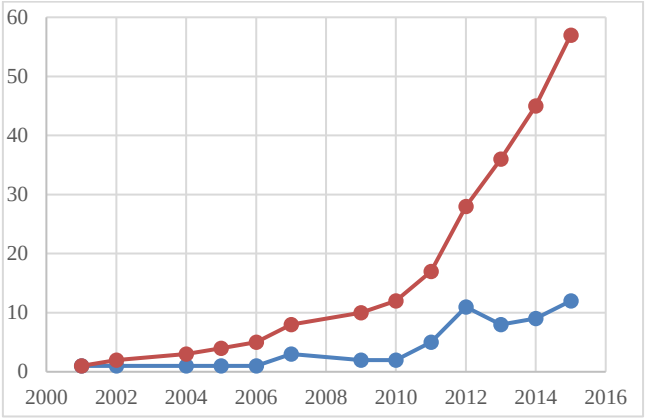
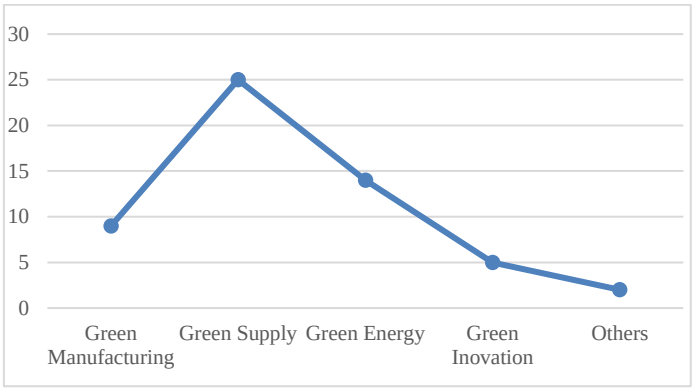


Figure 2. Sub-field distribution of green growth papers.



In 52% of the reviewed articles, fuzzy approach has been used beside various MCDM methods. In green growth studies, 23 hybrid approach existence is observed in a rate of 40%

while. From the investigated studies, it is clear that AHP technique is preferred mostly in a rate of 31%. Another remarkable point is that; ANP technique is almost equally scattered with TOPSIS technique in terms of their rates about 18%. Whilst the rate of VIKOR method for green approach is drastically decreased to 10%.

It should be also mentioned that green growth studies are interpreted in a wide range of international journals. International Journal of Production Research, Journal of Cleaner Production, Renewable and Sustainable Energy Reviews, Renewable Energy, Resources, Conservation and Recycling are more than half of these studies.

4. Conclusion

Nowadays, environmentally friendly production technology has become more popular with the increasing number of environmental problems. This technology results in the development of the concept of green growth. Similarly green manufacturing, green supplier, green energy and green innovation issues are being addressed as multi-criteria decision problems. In this study, green approaches studies used with MCDA methods were analyzed. Methods used in the literature were examined and identifying the main and sub criteria in these studies is aimed. Generally four main criteria are determined as environmental, economic, technological and social.

The main sub criteria used for green manufacturing are product/service providing, product maintenance, product packaging, product distribution and product life cycle. The main sub criteria for green supply are energy consumption, quality, waste control, emissions, cost and used materials. As for green energy, environmental impact, climate change, reducing energy dependence, investment costs, productivity, sustainability, prevention capacity of pollution, company compatibility, contribution to region and creating job opportunities are determined as sub criteria. The main sub criteria used for green innovation are resource capability, emissions, recycling, product life and technology. Lastly, others consisting of green economy, logistics, marketing and initiatives, sub criteria are energy consumption, resource capability, cost, using fields and emission rate.

In this paper, green growth studies applying with MCDM methods between 2001 and 2015 were examined and methods are determined in these studies and results have been interpreted. The studies of researchers and practitioners were regarded in detail, the main criteria are classified and it is aimed to help the researchers working in this field. Hence, these efficient criteria may be considered by researchers and more reliable results may be obtained. The results divulge that the green supply field is preferred mostly between green growth topics in a rate of 43%. More than half of the studies are existed since 2012. The consideration about green growth becomes a significant issue and we may also note that the importance of this topic will increase positively over years.

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