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## Analytic Hierarchy Process and Supply Chain Management: a bibliometric study

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### Abstract

A comparative study was used to outline the literature in the research topic. This paper aims to present a bibliometric study of multi-criteria decision-making methods most applied in publications from 1990 to 2014. Our research presented relations of papers published in the Web of Science Core Collection, regarding the following keywords: Analytic Hierarchy Process and Supply Chain. The research evidenced that the Analytic Hierarchy Process has been the method most applied in publications from 1993. It also showed the analysis of the predecessor and successor citation network for the selected publications under topics as supplier selection, supply development, performance measurement and value chain through the CitNetExplore software.

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Keywords: Analytic hierarchy process; Multi-criteria decision-making methods; Supply chain; Bibliometrics

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### 1. Introduction

Supply chain management is an important subject among researchers as many studies focus on the integration of the supply chain that consists of information and material flows [1]. Other studies focus on the degrees of cooperation of the supply chain through internet-based intra & inter organizational processes [2-3].

According to [4] the importance of selecting suppliers is also an issue very much valued in the supply chain nowadays. The integration strategy and the selection of suppliers are based on multi-criteria and technical decision-making processes [5].

Multi-criteria decision-making, also known as MCDM, is essential in decision-making processes. Analytic Hierarchy Process (AHP) is one of the most commonly used MCDM methods as a management tool in several

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industrial sectors, as supply chain, logistics and training among others, with the aim of assessing strategy and performance [6].

The aim of this paper is to contribute to a bibliometric study of multi-criteria decision-making methods. Our research took into account the AHP application in the Supply Chain in the Web of Science publications using of the CitNetExplore [7], a software for the identification and analysis of citations.

This paper is organized as follows: Section 2 brings the Data Collection of the research performed in the Web of Science considering the following keywords: MCDM, AHP and Supply Chain. Section 3 brings the Data Analysis. The last section is dedicated to the conclusions and references.

## 2. Data Collection

### 2.1. Multi-criteria decision-making methods

More than one criterion is usually needed to reach a decision, therefore making it more complex. Hence, it is important to structure the problem and to explicitly assess relevant criteria before reaching a decision. Several methods have been developed to solve multi-criteria problems, and, common to many of them is the idea that most decision-making can be improved by breaking down the general evaluation of alternatives into evaluations on a number of relevant criteria.

The methods differ on how they assess each criteria and on how they combine the evaluation of criteria to achieve a general evaluation.

A bibliometric study was performed with the aim of comparing which MCDM have been most applied in publications so far. A search was performed in the Web of Science, considering the following keywords: AHP, Analytic Network Process (ANP), Multi-Attribute Utility Theory (MAUT), Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE), Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) and *ELimination Et Choix Traduisant la REalité* (ELECTRE). The reason for our choice of the methods to be applied was due to the fact that all methods are discrete [8], being the research limited to publications in English. The amount of papers with the above-mentioned topics was 9,119. Results can be seen in Fig. 1.

Computer power and internet use have increased considerably throughout the years. Therefore, researchers and business enterprises have developed several software programs in the last decade to assist users on how to structure and solve decision problems. A considerable growth in the MCDM/MAUT applications was observed and is now entering new areas of investigation and application. Among these areas, we can highlight Data Envelopment Analysis (DEA), negotiation science, e-commerce, finance and engineering [9]. These factors have made MCDM more practical and accessible, which might have contributed to the growing increase of publications on the subject.

In Fig. 1 we can observe that, from mid-1993, the AHP has been the most used method in publications. From 2011 to 2014, the AHP achieved the amount of 1,872 papers, being followed by ELECTRE with 201 and MAUT with 61 papers.

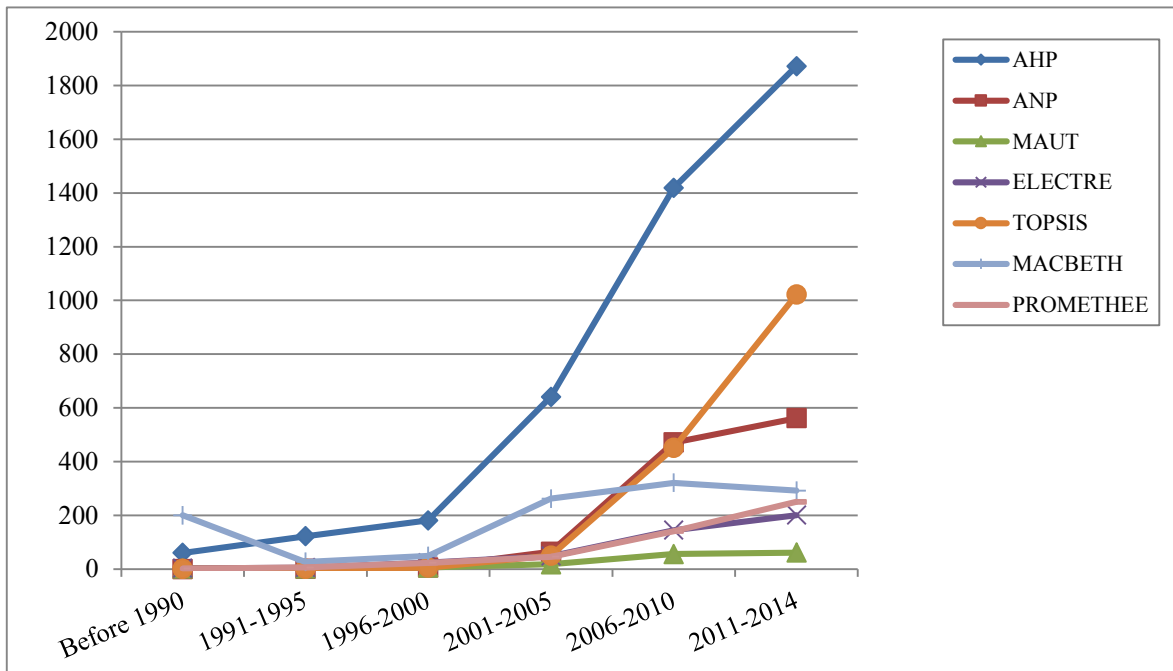


Fig.1. Multi-Criteria Decision-Making Methods

From 1990 to 2014, in the search for AHP, the database with the largest number of results were: Scopus – 2,424; Science Citation Index Expanded – 2,005 and Technology Research Database – with 1,402 papers. The authors with the largest number of publications were: Kou, Gang with 13 papers, followed by Ho, William with 11 papers and Srdjevic, Zorica with 7 papers.

Besides being very popular, the AHP method is applied in a great variety of areas, including planning, selection of the best alternative, resource allocation and conflict resolution, thus being the most applied method, as can be seen in Fig.1. Such method is aimed at establishing priorities or weights to be attributed to different criteria and alternatives, which features a decision and, as consequence, enables the choice of the most suitable alternative. Its steps are based on structuring the problem according to a given hierarchy, calculating priorities on the grounds of pairwise comparison, checking consistency and performing sensibility analysis. The last two steps are optional; however, are recommended to achieve results credibility.

Some of the software used to facilitate the application of the AHP method were: Expert Choice, Decision Lens, HIPRE 3+, RightChoiceDSS, Criterium, EasyMind, Questfox, ChoiceResults and 123AHP, as well as the possibility to adapt a model to the Microsoft Excel [8].

### 2.2. Analytic Hierarchy Process and Supply Chain.

A bibliographic search was performed in the Web of Science Core Collection (1999-2014) having AHP and Supply Chain as keywords. We considered publications in English and the type of paper. Table 1 shows a summary. The research returned 116 papers with 2,856 references cited in the main categories of the Web of Science: Business, Computer Science, Engineering, Management and Operations Research.

Table 1. Summary of dataset

Summary of dataset	Value
Number of papers	116
Number of cited references	2,856
Average of citation	25
h-index	27

The h-index shown in Table 1, is based on a list of publications ranked in descending order according to their number of citations. Therefore, an h-index of 27 means that there are 27 items that have 27 citations or more [10].

The main sources identified in the research were: International Journal of Production Economics; International Journal of Production Research; Production Planning & Control; International Journal of Advanced Manufacturing Technology; Expert Systems with Applications; Computers & Industrial Engineering; Supply Chain Management: An International Journal; Omega: International Journal of Management Science; Journal of Cleaner Production; International Journal of Operations & Production Management and International Journal of Computer Integrated Manufacturing.

According to Fig. 2, publications about AHP and Supply Chain have increased in the last years, going from 5 publications in 2003, to 13 in 2008. The highest result of the period was in 2013 with 19 publications. The number of citations, according to Fig. 3 has also increased in the last years, going from 50 citations in 2005, to 250 in 2008 and reaching a peak of 450 in 2012.

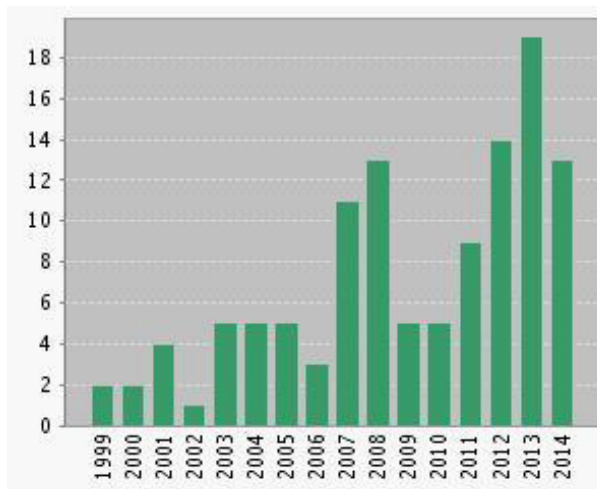


Fig. 2. Number of papers per year of publication

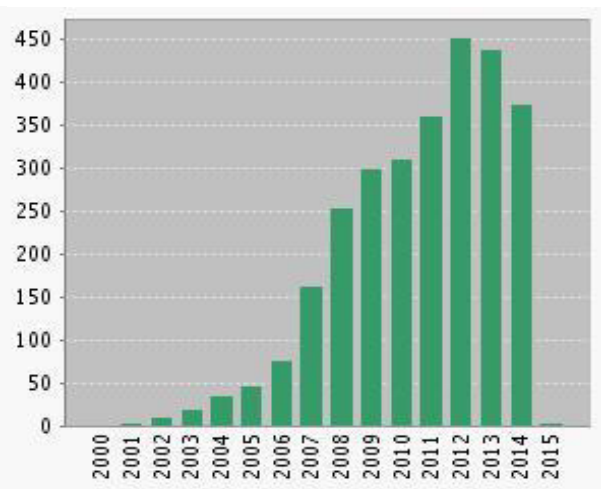


Fig. 3. Number of cited references per year

### 3. Data Analysis

Many times, the great number of relations in the citation net impairs its visualization. The concept of transitive reduction may assist in the visualization, i.e., as long as the essential is considered in the citation relations [11].

The CitNetExplorer solution [7], abbreviation of citation network explorer, applies the concept of transitive reduction can be observed in Fig. 4.

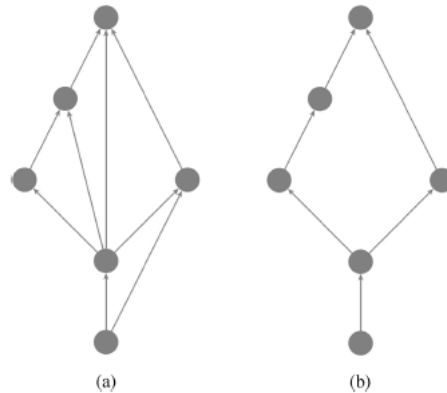


Fig. 4. (a) Original citation network; (b) Transitive reduction of the citation network [11]

The identification of citation in scientific literature from the Web of Science database loaded into CitNetExplorer. Fig. 5 shows the net generated by software from 116 papers between 1999 and 2014, where each circle represents a publication. The publication label brings the surname of the first author. To avoid overlapping, some labels were not shown in the tool. By default, the visualization presents the most frequent papers. Four clusters were identified each consisting of publications that are connected to each other in terms of citation relations, namely: blue, lilac, orange and green, as can be observed in Fig. 5.

In Fig. 5 we can observe that, the horizontal location of a publication can be determined by its citation relations with other publications, whereas the vertical location can be determined by its year of publication and the curved lines represent citation relations. The citing publication is always located below the corresponding cited publication [11]. Each publication in a citation network is assigned to a cluster and consists of publications that are connected to each other in terms of citation relations [11].

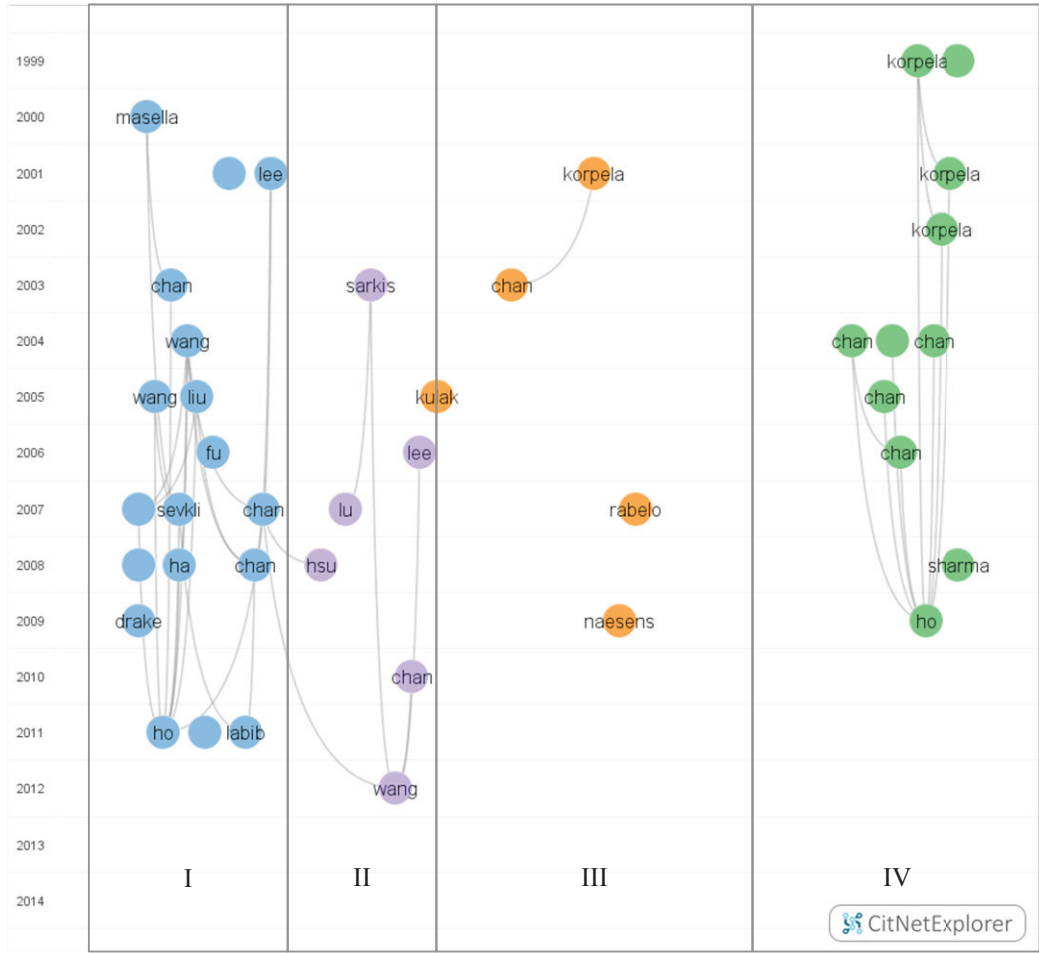


Fig. 5. Citation network

Table 2 shows details of the cluster I. Masella and Rangone are predecessors in the cluster. The main topic identified was the supplier selection with the AHP application. Other combined methods were also applied: Goal programming [16]; Fuzzy logic [19], [22], [25] and [29]; DEA [20] and [21]; Neural network [24] and ELECTRE III [28], as can be seen in Table 2.

Table 2. Cluster I supplier selection

Year	Author	Method	Supply Chain topic
2000	Masella and Rangone [12]	AHP	Vendor selection system
2001	Muralidharan, Anantharaman and Deshmukh[13]	AHP	Vendor rating
2001	Lee, Ha and Kim [14]	AHP	Supplier selection
2003	Chan [15]	AHP	Supplier selection
2004	Wang, Huang and Dismukes [16]	AHP-GP	Product life cycle

2005	Wang, Huang and Dismukes [17]	AHP-GP	Supplier selection
2005	Liu and Hai [18]	AHP	Supplier selection
2006	Fu et al. [19]	AHP-Fuzzy logic	Electronic commerce
2007	Saen [20]	AHP-DEA	Supplier selection
2007	Sevkli et al.[21]	AHP-DEA	Supplier selection
2007	Chan and Kumar [22]	AHP-Fuzzy logic	Supplier selection
2008	Levary [23]	AHP	Supplier selection
2008	Há and Krishnan [24]	AHP-DEA-NN	Supplier selection
2008	Chan et al. [25]	AHP-Fuzzy logic	Supplier selection
2009	Drake and Lee [26]	AHP	Purchasing strategy
2011	Ho, Dey and Lockstrom [27]	AHP	Supplier selection
2011	Ertay, Kahveci and Tabanlı [28]	AHP-Fuzzy logic- ELECTRE III	Supplier selection
2011	Labib [29]	AHP-Fuzzy logic	Supplier selection

Table 3 shows details of the cluster II. Sarkis is predecessor in the cluster. The main topic identified was the Green Supply Chain with the AHP application combined with Fuzzy logic [32], [33] and [35], as can be observed in Table 3.

Table 3. Cluster II in the green supply chain

Year	Author	Method	Supply Chain topic
2003	Sarkis [30]	AHP-ANP	Green supply chain
2006	Lee and Kozar [31]	AHP	E-business
2007	Lu , Wu and Kuo [32]	AHP-Fuzzy logic	Green supply chain
2008	Hsu and Hu [33]	AHP-Fuzzy logic	Green supply chain
2010	Chan , Chan and Hing [34]	AHP	Supplier selection
2012	Wang et al.[35]	AHP-Fuzzy logic	Green supply chain

Table 4 shows details of the cluster III. Korpela, Lehmusvaara and Tuominen are predecessors in the cluster. The identified topics have undergone supply chain development, performance measurement, value chain, collaboration and supplier selection with the AHP application combined with Fuzzy logic [38]; System dynamics and Discrete-event simulation [39], as can be observed in Table 4.

Table 4. Cluster III undergoing supply chain development, performance measurement, value chain, collaboration and supplier selection

Year	Author	Method	Supply Chain topic
2001	Korpela, Lehmusvaara and Tuominen [36]	AHP	Supply chain development
2003	Chan [37]	AHP	Performance measurement
2005	Kulak and Kahraman [38]	AHP-Fuzzy logic	Supplier selection
2007	Rabelo et al.[39]	AHP-SD-DES	Value chain
2009	Naesens, Gelders and Pintelon L [40]	AHP	Collaborative supply network

Table 5 shows details of the cluster IV. Korpela and Lehmusvaara are predecessors in the cluster. The topics identified have undergone supply chain and distribution network, warehouse location and customer service with the AHP application combined with Mixed Integer Linear Programming [41]; Genetic Algorithm [45], [46] and [49]; Goal Programming [51], as can be observed in Table 5.

Table 5. Cluster IV undergoing supply chain and distribution network, warehouse location and customer service

Year	Author	Method	Supply Chain topic
1999	Korpela and Lehmusvaara [41]	AHP-MILP	Warehousing network
1999	Min and Melachrinoudis [42]	AHP	Warehouse location
2001	Korpela, Lehmusvaara and Tuominen [43]	AHP-MILP	Customer service
2002	Korpela, Lehmusvaara and Tuominen [44]	AHP-MILP	Supply chain design
2004	Chan and Chung [45]	AHP-GA	Distribution network
2004	Chan, Chung and Wadhwa [46]	AHP-GA	Supply chain collaboration
2004	Chan and Chung [47]	AHP-GA	Supply chain network
2005	Chan, Chung and Wadhwa [48]	AHP-GA	Supply chain network
2006	Chan, Chung and Choy [49]	AHP-GA	Distribution network
2008	Sharma, Moon and Bae [50]	AHP	Distribution network
2009	Ho and Emrouznejad [51]	AHP-GP	Distribution network

A drill down of the citation network was performed, having identified some publications as successors with the following topics: supplier selection, distribution center network, supply chain integration and collaborative planning, forecasting and replenishment [52], [53], [54] and [55].

#### 4. Conclusion

The research, object of this study, has contributed to the exploration of the literature that uses MCDM and to the bibliometric analysis of AHP in the Supply Chain. Our research evidenced that the AHP has been the most applied method in publications from 1993, while the bibliometric analysis evidenced that the referred method can be combined with different methods, such as: Goal Programming, Fuzzy Logic, DEA, Genetic Algorithm and Neural Network. We identified similarities in the citation network of supply chains with the following topics: supplier selection, supply development, performance measurement, value chain, collaboration and integration, supply and distribution network.

The use of the CitNetExplorer has considerably contributed to the development of our research, to the creation of a citation network and to its visualization in a quite detailed way. Our proposal for further studies is to perform both a qualitative and qualitative-quantitative analysis including the impact factor of publications.

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