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# A Bibliometric Analysis of Possibilistic Portfolio Selection Models

## Olabilirlik Portföy Seçim Modellerinin Bibliyometrik Analizi

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**Abstract**

*Possibility theory is one of the most used uncertainty theories in decision-making. This study aims to examine possibilistic portfolio selection models. In this context, we perform their bibliometric analysis with the Web of Science (WOS) data, using the Bibliometrix, without limiting the timespan. We get many results by analyzing the data of 303 documents, of which timespan is from 1995 to 2023. We see that W. G. Zhang is the most influential author in this field. The paper introducing the possibilistic mean-variance (MV) model is the most influential document in this field. The paper introducing Markowitz's MV model is the most influential reference. China is the most productive country in this field, whereas The South China University of Technology is the most productive institution in this field. Fuzzy Sets and Systems is the most influential journal in this field. Variance originated from Markowitz's MV model is the most critical keyword plus in this field. It has also maintained its trend topic position for a long time. To the best of our knowledge, this is the first paper making a bibliometric analysis of possibilistic portfolio selection models.*

**Keywords:** *Bibliometric Analysis, Fuzzy Set, Optimization, Portfolio Selection, Uncertainty.*

**Jel Codes:** *C44, C61, G11.*

**Öz**

*Olabilirlik teorisi karar vermede en çok kullanılan belirsizlik teorilerinden biridir. Bu çalışma olabilirlik portföy seçim modellerini incelemeyi amaçlamaktadır. Bu bağlamda bunların bibliyometrik analizi, zaman sınırlaması olmadan, Web of Science (WOS) verileriyle, Bibliometrix kullanılarak yapılmıştır. Zaman aralığı 1995'ten 2023'e kadar olan 303 belgenin verileri analiz edilerek birçok sonuca ulaşılmıştır. Bu alandaki en etkili yazarın W. G. Zhang olduğu görülmüştür. Olabilirlik ortalama-varyans (OV) modelinin tanıtıldığı makale bu alandaki en etkili belgedir. Markowitz'in OV modelinin tanıtıldığı makale en etkili referanstır. Çin bu alandaki en üretken ülke iken, The South China University of Technology bu alandaki en üretken kurumdur. Fuzzy Sets and Systems bu alandaki en etkili dergidir. Markowitz'in OV modeli kökenli olan varyans, bu alandaki en kritik anahtar kelime "plus" olarak bulunmuştur. Varyans aynı zamanda trend konu konumunu uzun süre korumuştur. Bildiğimiz kadarıyla bu çalışma, olabilirlik portföy seçimi modellerinin bibliyometrik analizini yapan ilk çalışmadır.*

**Anahtar Kelimeler:** *Bibliyometrik Analiz, Bulanık Küme, Optimizasyon, Portföy Seçimi, Belirsizlik.*

**Jel Kodları:** *C44, C61, G11.*

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## 1. INTRODUCTION

Portfolio selection is a critical decision-making problem. Probabilistic models are usually preferred for it. Markowitz's (1952) mean-variance (MV) model is the most known of them. There are different model classes for portfolio selection. Possibilistic models, credibilistic models, uncertain models, etc., are essential classes of portfolio selection. These classes are based on optimization problems, which are solved analytically or numerically. The scope of this study is possibilistic portfolio selection models. The reader may refer to Gunjan and Bhattacharyya (2023) and Zhang et al. (2018) for the other portfolio selection models.

Possibility theory is the most straightforward uncertainty theory. The concept of possibility is associated with plausibility, referring to the tendency of events to occur. In this theory, the possibility (necessary) measure represents an event's plausibility (certainty). These measures, defined with the possibility distributions, determine the lower and upper bounds for the imprecise probability (Dubois, 2006: 48). These distributions are generally given with fuzzy numbers, the particular case of fuzzy sets (Souliotis et al., 2022: 1). Thus, possibility theory is associated with probability theory and fuzzy set theory.

Bibliometric analysis is used for analyzing scientific data (Donthu et al., 2021). Thus, it is popular for many research areas, such as portfolio selection. For example, Singhania et al. (2023) use it for sustainable investment. Milhomem and Dantas (2020) apply it to new portfolio selection models. Ghanbarimundi et al. (2023) utilize it for risk measures in portfolio optimization. Marzuki et al. (2023) use it for responsible investing. Gupta et al. (2021) apply it to noise trading. Mundi and Kumar (2023) utilize it for alternative investments. Gallucci et al. (2022) use it for ESG risks in portfolio studies. Zaimovic et al. (2021) apply it to portfolio diversification. Zhou et al. (2020) utilize it for fuzzy portfolio selection. Eskorouchi et al. (in press) use it for robust portfolio optimization. Although the class of possibilistic models is an essential class of portfolio selection, there is no bibliometric analysis of possibilistic portfolio selection models in the literature. The primary motivation of this study is to fill this gap. Thus, based on the WOS data, we implement a bibliometric analysis of possibilistic portfolio selection models.

The rest of the paper is organized as follows. Section 2 briefly gives a literature review of possibilistic portfolio selection. Section 3 briefly gives the steps of bibliometric analysis. Section 4 shows the results of the bibliometric analysis of the possibilistic portfolio selection models. Section 5 discusses the results and concludes the paper.

## 2. LITERATURE REVIEW

Tanaka et al. (1995) use possibility theory in portfolio selection for the first time in the literature. The possibilistic portfolio selection models proposed by Tanaka and Guo (1999) and Tanaka et al. (2000) are based on Principal Components Analysis (PCA). Inuiguchi and Ramík (2000) apply possibilistic linear programming to portfolio selection like Inuiguchi and Tanino (2000).

Using trapezoidal fuzzy numbers, Carlsson et al. (2002) introduce the possibilistic MV model, the counterpart of Markowitz's MV model in possibility theory. Zhang et al. (2007) form two possibilistic models based on the lower/upper possibilistic means and variances. Zhang (2007) analyzes these models when the possibility distributions are given with

trapezoidal fuzzy numbers. Zhang and Xiao (2009) define the weighted lower/upper possibilistic means and variances. Zhang et al. (2009) apply a SMO algorithm to the possibilistic MV model. Chen (2009) forms two possibilistic models using the known definitions. Liu et al. (2015) introduce new definitions and propose a three-moment model. Taş et al. (2016) analyze the possibilistic MV model when the possibility distributions are given with triangular fuzzy numbers. Göktaş and Duran (2019) introduce another possibilistic MV model based on PCA, whereas Göktaş and Duran (2020) form its robust version. Göktaş (2023) proposes the orthogonal possibilistic MV model.

Vercher et al. (2007) use the L-R type fuzzy numbers, the possibilistic mean, and a downside risk measure. Deng and Li (2012) form a quadratic optimization model using trapezoidal fuzzy numbers. Zhang et al. (2012) propose a possibilistic model for multi-period portfolio selection based on entropy. Zhang and Zhang (2014) introduce the possibilistic absolute deviation as a risk measure. Despite transaction costs, Liu and Zhang (2015) propose a multi-period possibilistic portfolio selection model. Liu and Zhang (2019) examine the influences of higher moments on multi-period possibilistic portfolio selection. Hu et al. (2021) apply the interval numbers to portfolio selection. Deng and Lin (2022) benefit from possibility theory for responsible investing.

## 3. METHOD

Donthu et al. (2021) deeply discuss the theory and practice of bibliometric analysis, which involves the quantitative techniques' application to bibliometric data. It aims to compile huge volumes of bibliometric data. It is done to display a field's (topic's) current state and new trends. It is preferred when the scope is too broad for the classical review. Thus, it should not be preferred for specific topics. Its tools are quantitative techniques, which are in two main categories: performance analysis and science mapping. The qualitative techniques are only used for interpretation. In summary, bibliometric analysis is utilized for broad scope and large data to summarize the bibliometric data using only quantitative techniques. Its steps are as follows (Donthu et al., 2021).

**Step 1:** The bibliometric study's aim and scope are defined.

**Step 2:** The techniques for bibliometric analysis are chosen to satisfy the conditions in Step 1.

**Step 3:** The data for bibliometric analysis is collected.

**Step 4:** The bibliometric analysis is implemented using the collected data and the chosen techniques. Then, the results are reported.

We implement a bibliometric analysis of possibilistic portfolio selection models using the following steps.

**Step 1:** The scope of this study is possibilistic portfolio selection models. The aim of this study is to make their bibliometric analysis for the first time in the literature. The research questions are listed below.

- Q1: What are the numbers and types of the documents in this field?
- Q2: Who are the influential authors in this field? What are the connections between them?

- Q3: Which papers are this field's influential documents and references? What are the connections between them?
- Q4: What are the important keywords plus (determined by WOS) in this field? What are the connections between them? What are the trend topics?
- Q5: Which countries are the productive countries in this field?
- Q6: Which journals are the influential journals in this field?
- Q7: Which institutions are the productive institutions in this field?

**Step 2:** The techniques used for performance analysis are the number of documents and citations. The techniques used for science mapping are listed below.

- Three-field plot is related to Q4, Q5 and Q6.
- Tree map, trend mapping, co-occurrence map, factorial analysis, and thematic map are related to Q4.
- Co-citation network is related to Q3.
- Collaboration network is related to Q2.

**Step 3:** We collect the bibliometric data from the WOS, which is the oldest and most popular bibliometric database (Pranckute, 2021). On 6 January 2024, we search for "possibili*" and "portfolio selection" topics together without limiting the timespan. Using "possibili*" in searching, we consider "possibility" or "possibilistic" topics separately. We collect the data from 305 documents in this way. Then, we exclude two of them since they are editorial material.

**Step 4:** Using the chosen techniques and the data from 303 studies, we run the Bibliometrix (Aria & Cuccurullo, 2017). Then, we report our results in the following section.

## 4. RESULTS

The documents' timespan is from 1995 to 2023, whereas the number of yearly documents peaked in 2009. The number of sources (journals, books, etc.) is 186. The number of documents is 303. The average age of the documents is 11,2 years. The average number of citations per document is 20,66. The total number of references in the documents is 5807. The number of keywords plus (determined by WOS) is 400. The number of keywords (determined by the authors) is 768. The number of authors is 485. The average number of authors is 2,54. The number of articles, books, book chapters, and proceeding papers are 200, 1, 11, and 91, whereas their percentages are 6,0%, 0,3%, 3,6%, and 30,0%, respectively.

The local citation is from the bibliometric data (303 documents). The number of documents published in Fuzzy Sets and Systems is 14, with 887 local citations. The number of documents published in European Journal of Operational Research is 12, with 766 local citations. The number of documents published in Expert Systems with Applications is 8, with 192 local citations. The number of documents published in Mathematical Problems in Engineering is 8, with 7 local citations. The number of papers published in Applied Mathematics and Computation, Journal of Computational and Applied Mathematics, and Applied Soft Computing equals 7, with 195, 105, and 58 local citations, respectively. The number of documents published in Fuzzy Optimization and Decision Making is 6, with 57 local citations. The number of papers published in Information Sciences and Annals of Operations Research equals 5, with 268 and 71 local citations, respectively.

Figure 1 presents the three-field plot based on the keywords plus (IDs). Selection, management, model, and optimization IDs are due to portfolio selection. Risk and variance IDs are due to the risk analysis in portfolio selection. Possibility distributions and (fuzzy) numbers IDs are due to possibility theory. The two most common sources are from the fuzzy set theory and operational research disciplines: Fuzzy Sets and Systems, European Journal of Operational Research. The most productive country is China, whereas Turkey ranks ninth. The South China University of Technology, Osaka University, and Hebei University are the most productive institutions, with 50, 18, and 9 publications, respectively. Osaka University is in Japan, whereas the other two are in China.

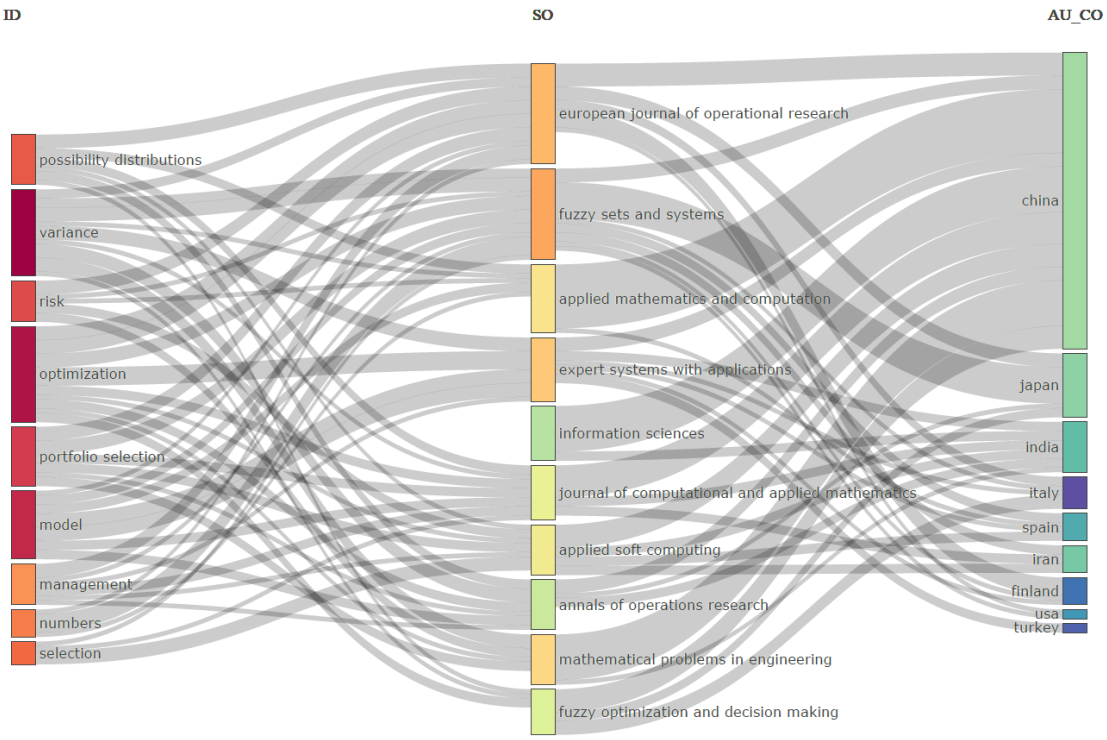


**Figure 1.** Three-Field Plot

Bradford's Law is used to identify the core journals in a field and divides the journals into three distinct regions (Batra et al., 2022). In addition to the journals given in Figure 1, the Journal of Intelligent & Fuzzy Systems and Soft Computing with 5 documents, Computers & Industrial Engineering, Insurance: Mathematics and Economics, and International Journal of Fuzzy Systems with 4 documents are also at Zone 1, which can be interpreted as the core sources.

Figure 2 shows the country collaboration based on the corresponding author's country, where SCP (MCP) is the single-country (multiple-country) publications. China dominates this field, whereas Turkey has a nonnegligible place. On the other hand, Turkey does not collaborate with other countries in this field. It is an important deficiency for Turkey.

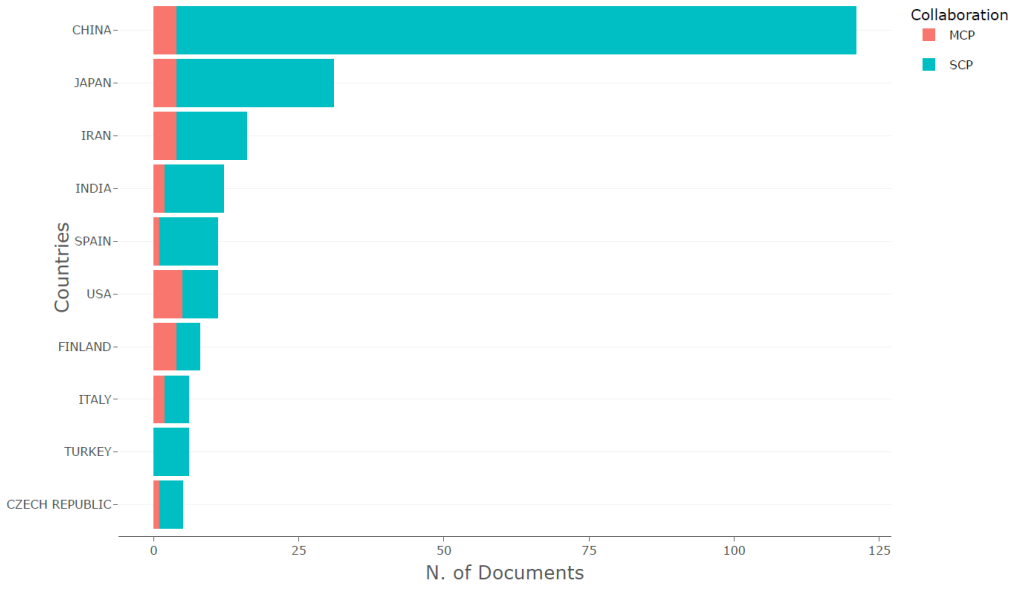


**Figure 2.** Country Collaboration

Figure 3 shows the word cloud based on the keywords plus (IDs), whereas Figure 4 shows the tree map based on IDs. Possibility distributions, variance, risk, optimization, model, and portfolio selection IDs are central to this field. Algorithm, (portfolio) management, utility, uncertainty, investment, (fuzzy) numbers, transaction costs, and (efficient) frontier are also important IDs. Clearly, these IDs are general for portfolio selection except for possibility distributions and (fuzzy) numbers. Possibility distributions ID is the unique ID specific to the possibilistic models. We note that fuzzy numbers ID is also related to the credibilistic models, uncertain models, etc.


**Figure 3.** Word Cloud

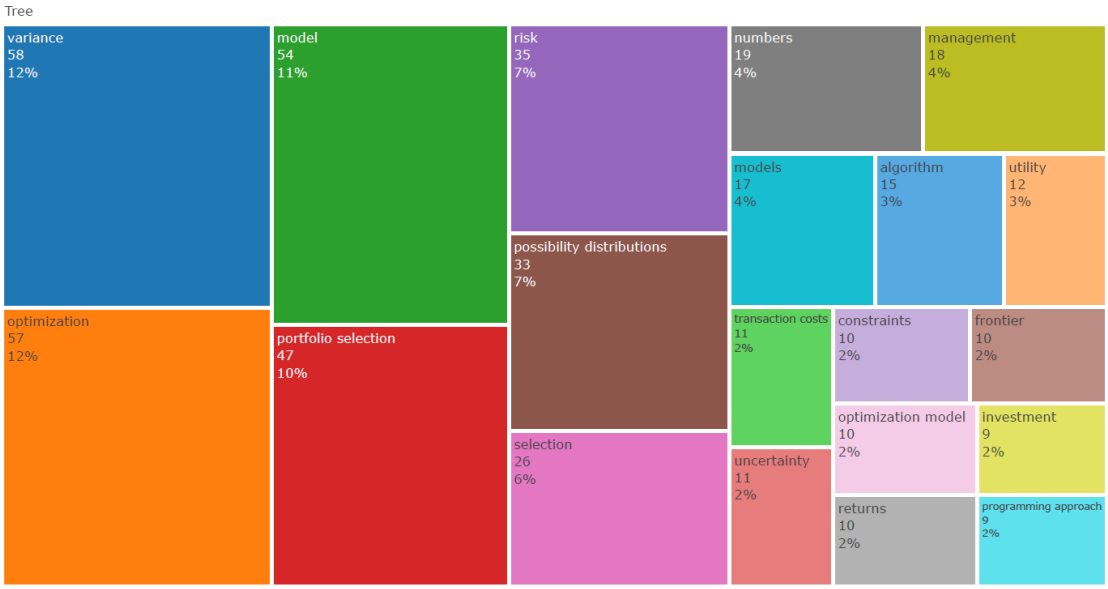


**Figure 4**. Tree Map

Figure 5 shows the trend topics based on IDs. Variance, risk, optimization model, (portfolio) selection, and (portfolio) management IDs have been the trend topics of this field until 2020. In order for there to be a trending topic, there must be a certain number of articles for that year. That is why, it is not on the chart before 2006 and after 2020.

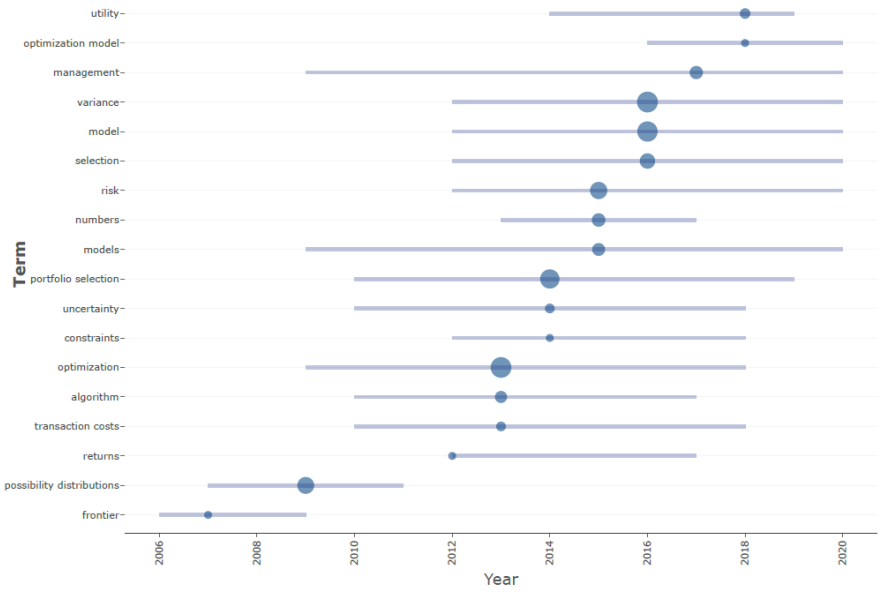


**Figure 5.** Trend Mapping

Figure 6 shows the co-occurrence map based on IDs. Variance, possibility distributions, and optimization are the primary IDs of their clusters. Variance ID is from the finance discipline, optimization ID is from the operational research discipline, and possibility distribution ID is from the fuzzy set theory discipline. Data Envelopment Analysis (DEA), efficiency, consumption, and choice IDs are separated from these clusters.

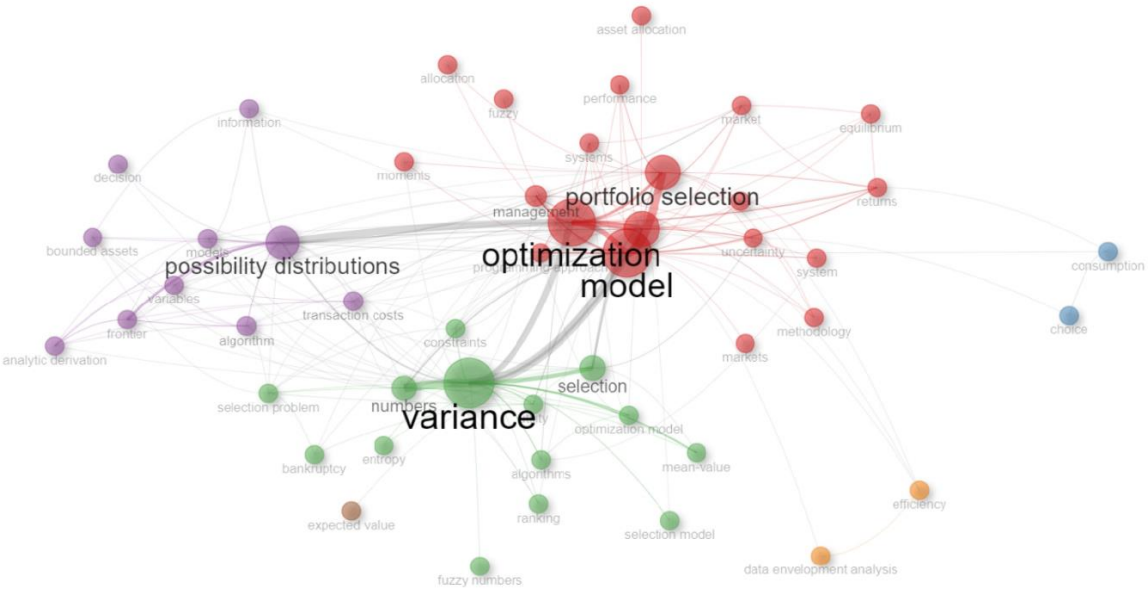


**Figure 6.** Co-Occurrence Map

Motor themes are relatively developed and important, whereas emerging themes are relatively undeveloped and unimportant. The niche themes are relatively developed and unimportant, whereas basic themes are relatively undeveloped and important (Cobo et al., 2018). Figure 7 shows the thematic map based on IDs. Optimization, model, and risk IDs are the basic themes of this field. Possibility distributions, models, and algorithm IDs are the motor themes. Liquidity ID is a niche theme, whereas fuzzy ID is an emerging theme.

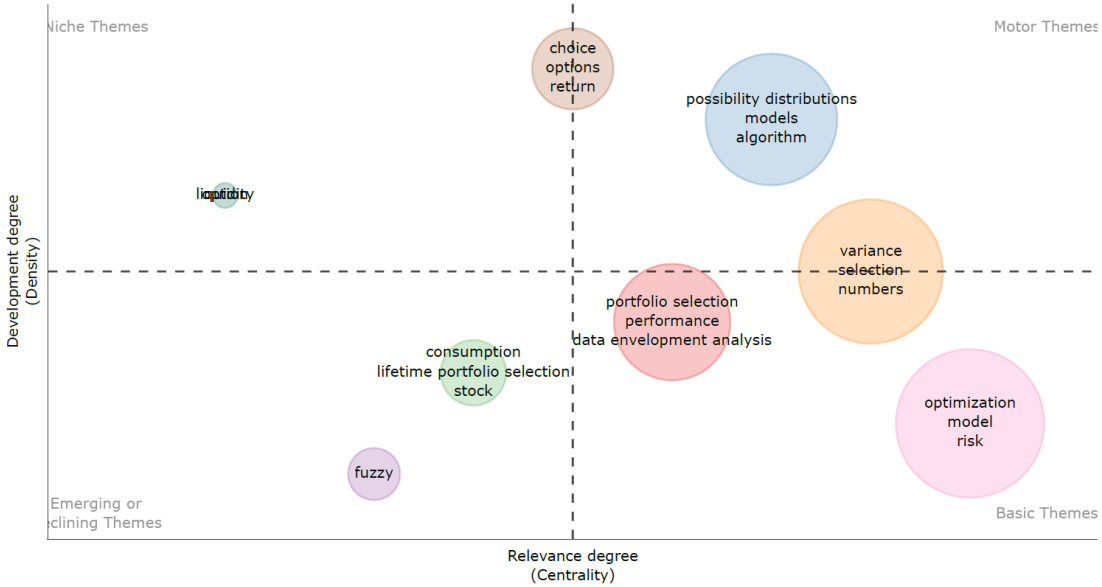


**Figure 7.** Thematic Map

The factor analysis is a data interpretation technique based on dimension reduction. It determines the basic dimensions that reveal the relationships between many variables using statistical procedures such as PCA (Tavakol & Wetzel, 2020). Figure 8 shows the factor loads of IDs for Factor 1 and Factor 2. Factor 1 explains 36,13% of the total variance, whereas Factor

2 explains 30,78% of the total variance. These two factors explain 66,91% of the total variance, whereas they can not explain 33,09% of the total variance. Algorithm ID is highly explained by Factor 1, whereas utility ID is highly explained by Factor 2. We note that algorithm ID is from the operational research discipline, whereas utility ID is from the finance discipline.

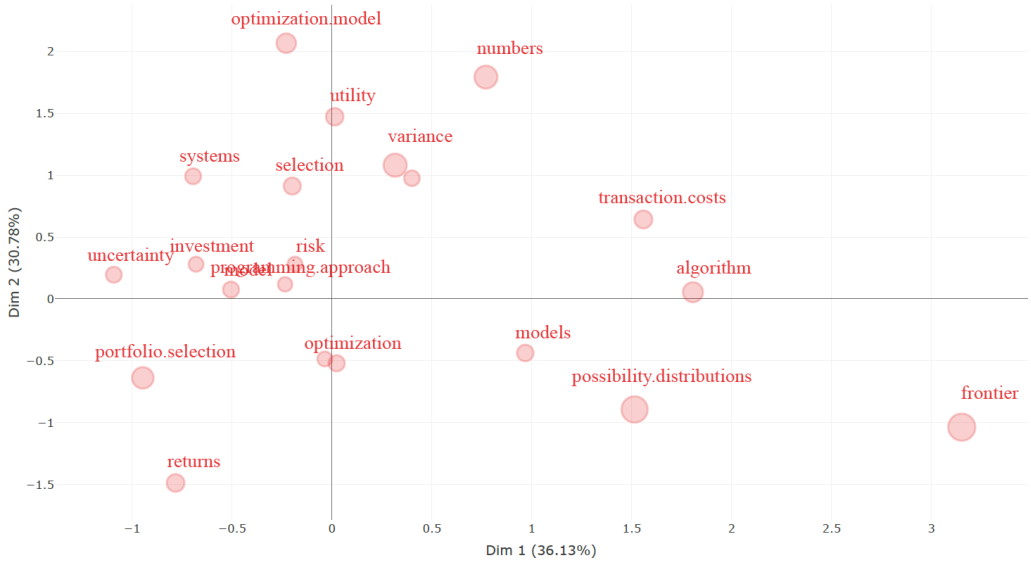


**Figure 8.** Factor Loads

The most locally cited document is by Carlsson et al. (2002), with 82 citations. Tanaka et al. (2000) rank second with 79 local citations. Tanaka and Guo (1999) rank third with 68 local citations. Inuiguchi and Ramík (2000) rank fourth with 51 local citations. Inuiguchi and Tanino (2000) rank fifth with 50 local citations. Vercher et al. (2007) rank sixth with 41 local citations. Zhang et al. (2007) rank seventh with 37 local citations. Zhang (2007) ranks eighth with 25 local citations. Zhang et al. (2012) rank ninth with 23 local citations. Zhang et al. (2009) rank tenth with 18 local citations. Markowitz (1952), the most locally cited reference, has 152 local citations. Carlsson and Fuller (2001) rank second with 90 local citations. Zadeh (1965) ranks fifth with 75 local citations. Markowitz (1959) ranks seventh with 65 local citations, whereas Watada (1997) ranks eighth with 61 local citations. The other five most cited references belong to this field and are given above.

Figure 9 shows the co-citation network. Markowitz (1952), Tanaka et al. (2000), Carlsson and Fuller (2001), and Carlsson et al. (2002) are central to this network. Modern Portfolio Theory (MPT) has been introduced by Markowitz (1952) and developed by Markowitz (1959). These papers form a basis for possibilistic portfolio selection from the finance and operational research perspectives. Zadeh's (1965) introduction of fuzzy set theory and Zadeh's (1978) introduction of possibility theory form a basis for possibilistic portfolio selection from the fuzzy set theory perspective. Carlson and Fuller's (2001) introduction of possibilistic mean and variance is important for possibilistic portfolio selection models.

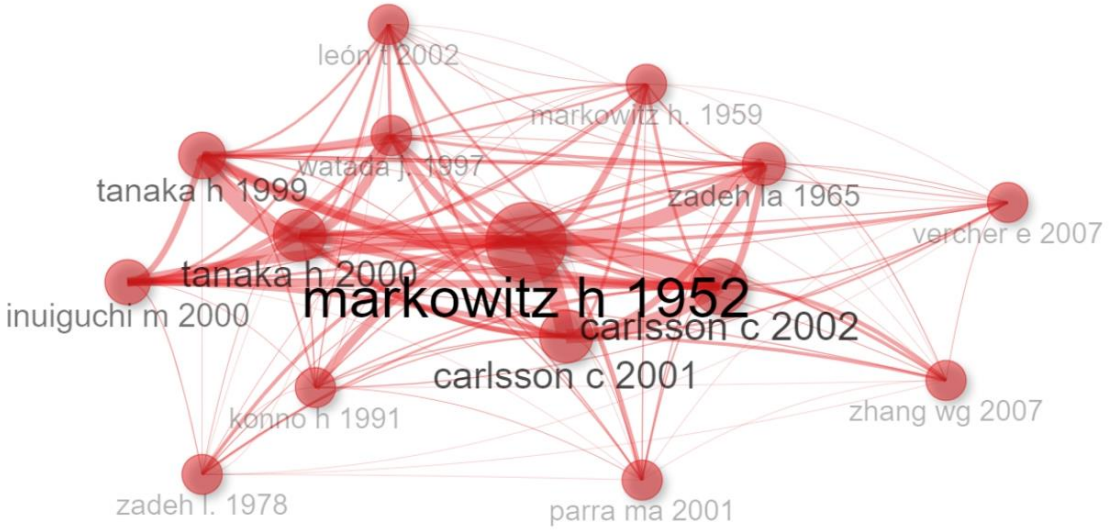


**Figure 9.** Co-citation Network

W. G. Zhang ranks first with 36 documents and 243 local citations. H. Tanaka ranks second with 5 documents and 148 local citations. P. Guo ranks third with 4 documents and 147 local citations. M. Inuguichi ranks fourth with 7 documents and 102 local citations. R. Fuller ranks fifth with 6 documents and 98 local citations. C. Carlsson ranks sixth with 5 documents and 98 local citations. P. Majlender ranks seventh with 3 documents and 93 local citations. Y. L. Wang ranks eighth with 5 documents and 86 local citations. E. Vercher ranks ninth with 8 documents and 77 local citations. J. D. Bermudez ranks tenth with 7 documents and 77 local citations. Based on this information, we can say that W. G. Zhang is the most influential author in this field. Furthermore, there is not an author approaching him.

Figure 10 shows the collaboration network with four clusters. According to the results mentioned before, we know that each cluster is related to one of the most influential papers in this field. We also know that W. G. Zhang is the most influential author in this field, whereas C. Carlsson and R. Fuller are the authors of the most influential paper in this field.

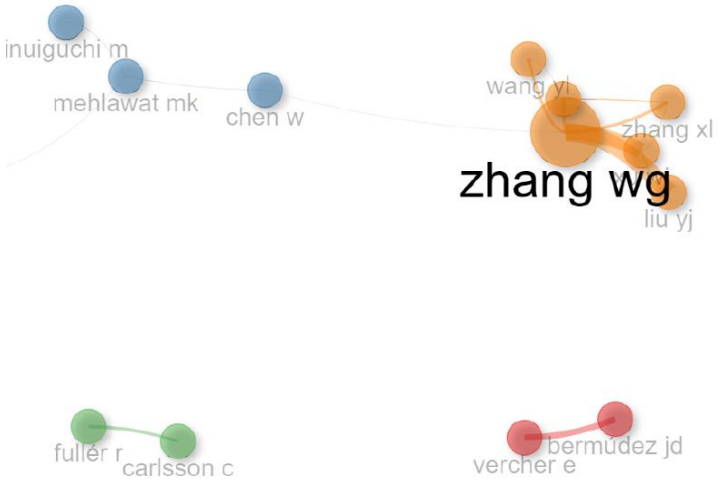


**Figure 10.** Collaboration Network

## 5. DISCUSSION AND CONCLUSIONS

This study implements a bibliometric analysis of possibilistic portfolio selection models for the first time in the literature. We collect the data from 303 documents in the WOS without limiting the timespan. Then, we quantitatively analyze the bibliometric data using the Bibliometrix. Based on these analyses, we get many results.

We find that W. G. Zhang is the most influential author in this field. Furthermore, there is not an author approaching him. Carlsson et al.'s (2002) introduction of the possibilistic MV model is the most influential document in this field. Tanaka et al. (2000) and Tanaka and Guo (1999) are close to this paper. Thus, we conclude that these three papers are the trivets of this field. Although W. G. Zhang is the most influential author in this field, his papers are not as influential as them. This is because his papers are mostly application-oriented. Thus, we conclude that if the new research directions are theoretical rather than application-oriented, it will likely be more attractive.

Markowitz's (1952) introduction of MPT is the most influential reference. Carlsson and Fuller's (2001) introduction of the possibilistic mean and variance is the second influential reference. The possibilistic mean and variance concepts are also used in other decision-making problems, such as multi-criteria decision-making (MCDM). Since the number of papers in this field peaked in 2009, and there are no trend topics after 2020 in this field due to the low number of papers, new research directions are necessary to raise the number of papers in this field. It could be a new direction to integrate fundamental analysis and/or sustainability analysis into possibilistic portfolio selection using MCDM or adding new dimensions to the portfolio selection model. The reader may refer to Göktaş and Güçlü (2024), and Pedersen et al. (2021) for guiding papers. We note that these papers are theoretical papers rather than application-oriented papers.

China dominates this field. No country approaches China, whereas Turkey ranks ninth. By collaborating with other countries, Turkey may get into the front rows since Turkey is a unique country that does not collaborate with other countries in the top ten. Finland, USA, and Italy are the most collaborative countries in the top ten. We think these countries are convenient for Turkey's collaboration in this field.

Fuzzy Sets and Systems is the most influential journal in this field. European Journal of Operational Research follows it. The other journals are far from these journals. Since possibilistic portfolio selection is related to three disciplines: fuzzy set theory, finance, and operational research, we conclude that finance journals are lagging behind fuzzy set theory journals and operational research journals. This is because possibilistic portfolio selection relies highly on expert knowledge rather than past data.

Keywords plus (IDs), determined by WOS, are more objective than the author's keywords (DEs). Variance, which is the most critical ID in this field, has maintained its trend topic position for a long time. Possibility distribution, optimization model, risk, and portfolio selection/management are other important IDs. They have also maintained their trend topic positions for a long time except for possibility distributions. Currently, there are no trend topics in this field due to the low number of papers.

These results are based on two issues: the WOS data and the timespan 1995-2023. Thus, they can not be generalized for the other bibliometric databases (Scopus, etc.) and future works (the year 2024 and beyond). We hope that this research may be a guide for future research in this field.

## DECLARATION OF THE AUTHORS

**Publication Ethics Statement:** Publication ethics were taken into consideration at all stages of the study.

**Declaration of Contribution Rate:** The authors have equal contributions.

**Declaration of Support and Thanksgiving:** No support is taken from any institution or organization.

**Declaration of Conflicts of Interest:** The authors declare no conflict of interest.

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