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Game Theory Applications in Disaster Management Research

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Abstract

Natural disasters are sudden, dangerous events that affect nations and cause disasters in the human life. The research on effective planning and response to natural disasters is vital. Managing effective humanitarian operations is an important part of disaster management. Therefore, research on effective planning and response to natural disasters is quite important. In this paper, the literature on disaster management has been categorized. The studies on disaster management were examined using scopus and web of science databases. Statistical analysis of eligible studies selected according to keywords was made with the VOS viewer. As a result of the article analysis, it was seen that the articles on the subject decreased in the last 2 years, and the analyzes revealed that more studies should be done and that there is a work gap on the subject. It is aimed to present this study as a contribution to disaster management studies and literature.

Keywords: disaster, disaster management, game theory, data analysis, network

1. Introduction

The disaster causes enormous loss of life and property. Considering the disasters such as flood, tsunami, typhoon, earthquake and landslide in the past years, it is seen that serious damage has occurred in the regions where the said disasters occurred It is guite important that the location of the disaster, its duration, the number of people affected, the extent of the damage, the location of the aid resources, and similar information are up-to-date and reliable in order to respond adequately and necessaryly to the places where disasters occured [1]–[3].

In recent years, frequent natural disasters and man-made atastrophic events have brought great loss to human beings. Any occurrence of natural disasters, such as earthquakes, typhoons, floods, or drought, cause huge property damage and human injuries [4]. Effective and rapid response to natural disasters is of great importance as many people are seriously affected by such events. Disaster response includes a range of activities that help minimize the impact of disasters, such as search and rescue operations, evacuation of affected people, food, water, medical aid. If these effectively planned interventions are not implemented in a timely manner, the situation will worsen for the survivors [5].

Disaster management involves a systematic approach to deal with natural and man-made disasters. The cycle of disaster management consists of four main phases: mitigation, preparation, response and recovery. Disaster Management Cycle is shown in Figure 1. If the stages are defined; The mitigation phase can be defined as long-term efforts to prevent disasters from occurring or to reduce their effects. Preparedness is the stage where various strategic (long-term) decisions and procedures are designed before a disaster occurs. The response phase includes operational decisions of relief supplies in affected areas after a disaster occurs, and finally the recovery phase can be defined as the activities undertaken to restore the previous condition of the affected areas.

Figure 1. Disaster Management Cycle

Duran et al. (2013) suggest three core stages of disaster relief management; The stages given in Figure 2.

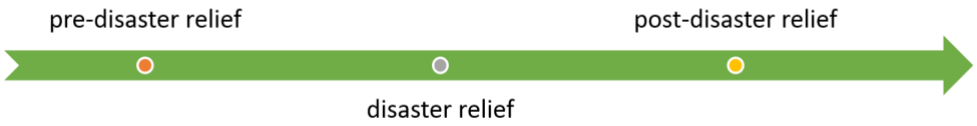

Figure 2. Disaster relief management stages

Many studies have been carried out on disaster management and strategy formulation. Goli and Alinaghian (2017) investigated an indefinite integrated model was examined for the simultaneous location of temporary health centers in the affected areas, allocating the affected areas to these centers and determining routes to transport necessary goods [6]. Goli and Keshavarz (2022) examined a parallel machine queue dependent group scheduling problem was investigated in order to minimize the total weighted earlyness and latency [7]. Goli et. al. (2019) were examined of this study is based on the application of a hybrid improved artificial intelligence and robust optimization and presenting a new method for calculating the risk of a product portfolio [8]. Goli et. al. (2021) were examined an integrated framework based on statistical tests, time-series neural networks, and improved MLP, ANFIS, and SVR with novel meta-heuristic algorithms in order to obtain the best prediction of demand for dairy products in Iran [9]. Goli and Malmir (2020) an optimization method based on reliability theory are designed and an allocation and routing model is presented for relief vehicles in areas affected by a disaster [10]. Goli and Muhammedi (2021) improved a new method the supply chain performance based on its sustainable strategies is proposed [11]. Tirkolaee et. al. (2022) were developed a novel mathematical model to design a sustainable mask Closed-Loop Supply Chain Network (CLSCN) during the COVID-19 outbreak for the first time [12].

A well-designed disaster relief process should involve the following key activities, Relief process shown in Figure 3.

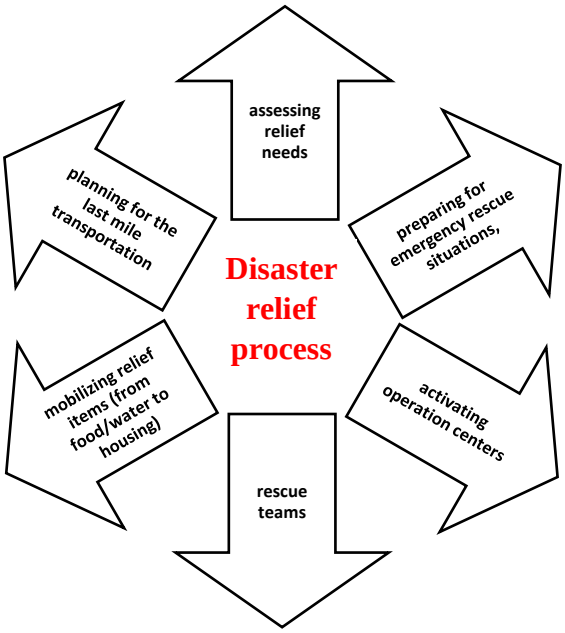

Figure 3. Disaster relief process [13].

Post-disaster management has different approaches and different priorities in countries. Different views and interpretations in countries also create differences in post-disaster management and strategies [14].

Game theory is concerned with the analysis of individuals strategies for overcoming competitive situations and is highly useful in a variety of applications [15].

One of the most important and urgent problems in post-disaster management is the supply of necessary materials to the disaster area. In most cases, supplies of essential goods enter the affected area from the nearest port or airport. Materials are then sent to a pre-warehouse near the affected area and delivered from that warehouse to a series of final warehouses. The aim here is to provide the right services and materials on time [16].

Although game theory is actively used in many areas, there is still very limited use of game theory approaches to disaster relief and management, but there is new literature. This article aims to draw attention to this gap by evaluating academic articles on game theory and disaster management with data sources and statistical analysis.

2. Game Theory

Game theory is a method derived from Mathematical Sciences where it is used in the competitive or collaborative position to find the most appropriate choices to lead to the desired outcome. Each game will feature at least two players who will walk to maximize their own interests in relation to the opponent's decision. In fact, it is becoming popular and interesting in some areas, such as economics, sociology, construction, politics and Management Sciences. In the areas mentioned, Game Theory can be used to predict the best outcome [17].

Typically, in game theory models, the "players" in the game are identified with their strategies, reflected by the variables they control, and the objective functions they individually try to optimize, often represented as utility functions. It depends on your strategies and the strategies of other players. Also, each player in the game has strategies that are subject to restrictions. There are non-cooperative games and cooperative games in which players compete with each other. In a sense, game theory problems and models are based on classical optimization models in which there is a single decision maker trying to determine an optimal solution given an objective function, variables, and constraints [18].

It shows new possibilities in solving problems encountered in disaster management situations with Game Theory applications. These are management and construction etc. They are initiatives aimed at providing maximum benefit in the conduct of their business [19].

Game theory makes it possible to simply model human behavior from a rational perspective and works according to a logic of equilibrium to achieve this [20].

3. Data source and statistical analysis

In this article, data from the Social Science Citation Index (SSCI) and the Science Citation Index Expanded (SCI-E) scopus base in the Web of Science database were used. Analysis search query is set to "TS = (Game theory) AND TS = (disaster or disaster management)". The 1983 to 2021 interval has been determined as the research period. After the necessary adjustments were made, 1115 articles were left for analysis in the data set. Figure 4 shows the number of articles working on game theory and disaster.

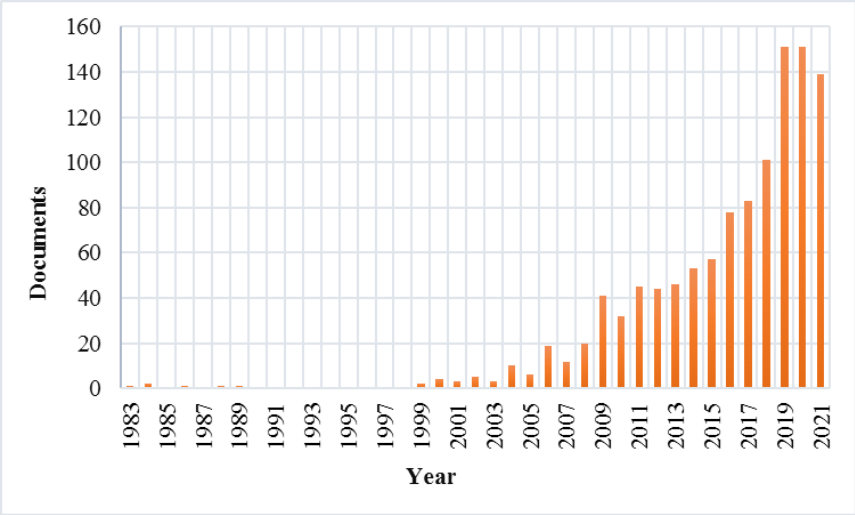

Figure 4. The number of articles working on game theory and disaster.

As seen in Figure 4; rom 1999 to 2020, there has been an increase in the number of articles on this subject. The same number of (151 articles) was published in 2019 -2020. In 2021, this number is currently seen as 139. that is, there has been a decrease in the number of articles on the subject.

It can be thought that the reason for this decrease in this subject, which is still lacking in studies, in the last year, has recently turned the direction of scientists to look at a current issue, Covid-19.

In addition, when the percentage of articles published by fields is examined, it is seen that the articles in the field of engineering constitute 21.1% of the total number of newspapers, followed by the field of computers and mathematics. This shows that game theory and disaster issues have been studied extensively by scholars in this field. The Documents types by area is shown in Figure 5.

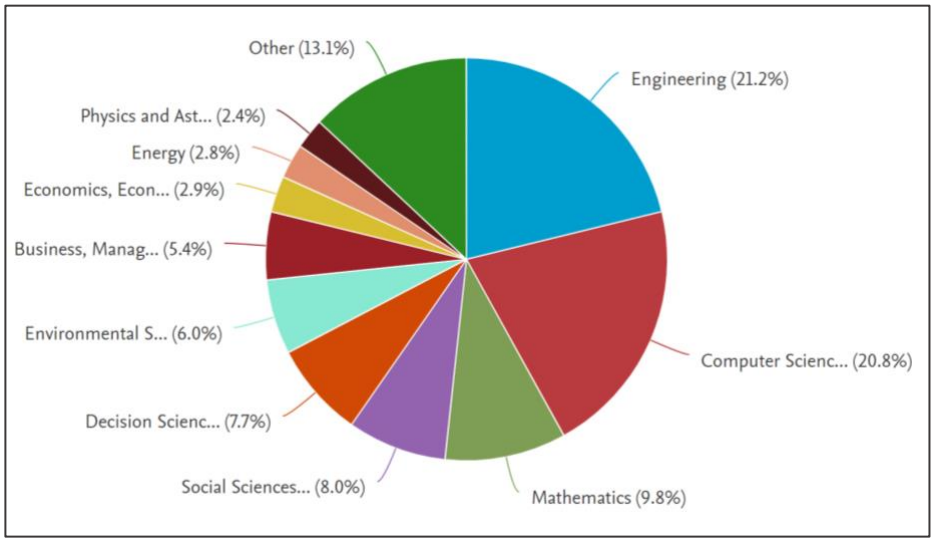

Figure 5. Documents types by area

4. Data analysis

VOSViewer can be defined as a knowledge mapping tool for co-authoring and co-occurrence analysis. can create visual meshes with nodes and links in this tool. Nodes represent references, authors, and journals. Links show the relationship between nodes [21].

4.1. Keyword co-Occurrence Analysis

Keywords represent the most important information about an article. Therefore, keyword co-occurrence network can be applied to analyze the research trend in the field of game theory. In the generated network, keywords are represented by nodes, the size of the nodes changes according to the frequency of keyword usage.

Depending on the keywords used in the articles and the frequency of their use in the same article group, the co-occurrence relationship between the keywords can be determined. Frequencies are taken into account in this analysis and accordingly a network of keyword co-occurrence is created.

The size of a node is positively correlated with the frequency of occurrence of the keyword, and each node in the network represents a keyword.

The keyword co-occurrence network created by VOSViewer as a result of the analysis are shown in Figures 6 to 8.

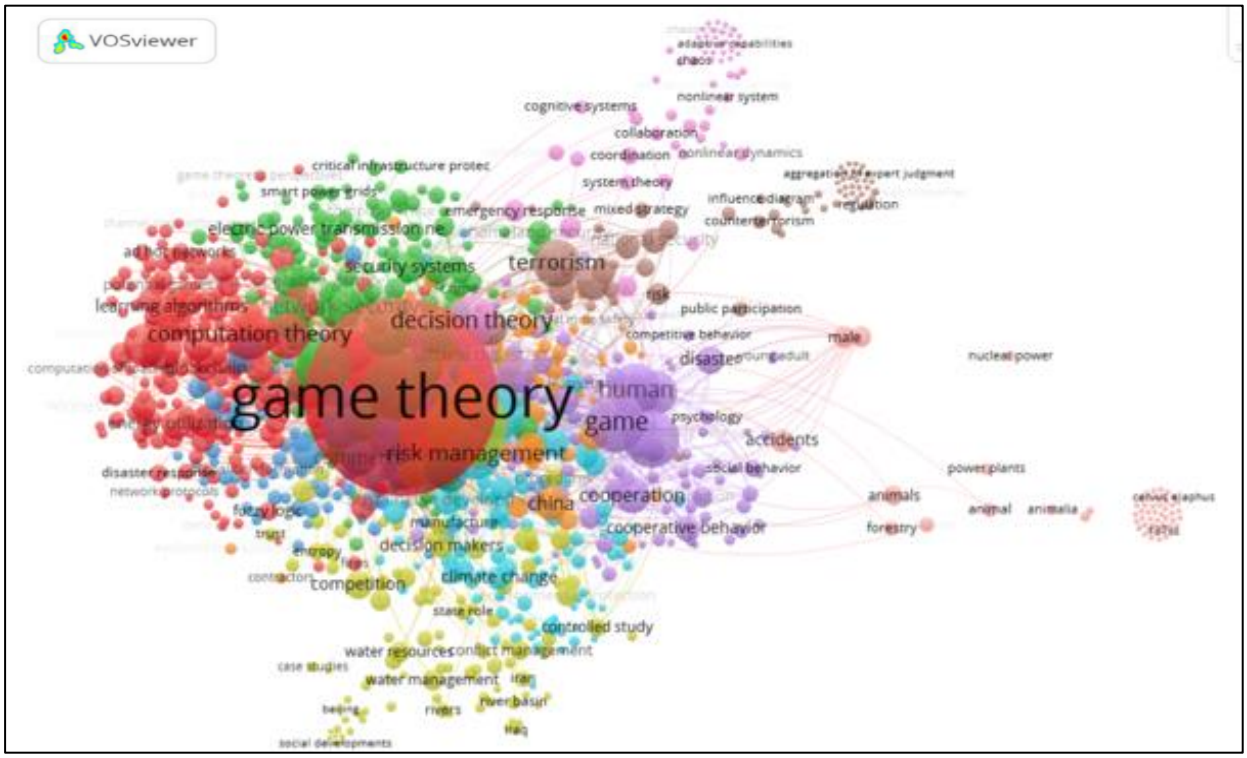

Figure 6. Keyword co-occurrence network Visualization

Looking at the relationship of keywords co-occurring over the years from the overlay visualization section, it can be seen from the contour coloring that the frequency of use increased between 2016 and 2019.

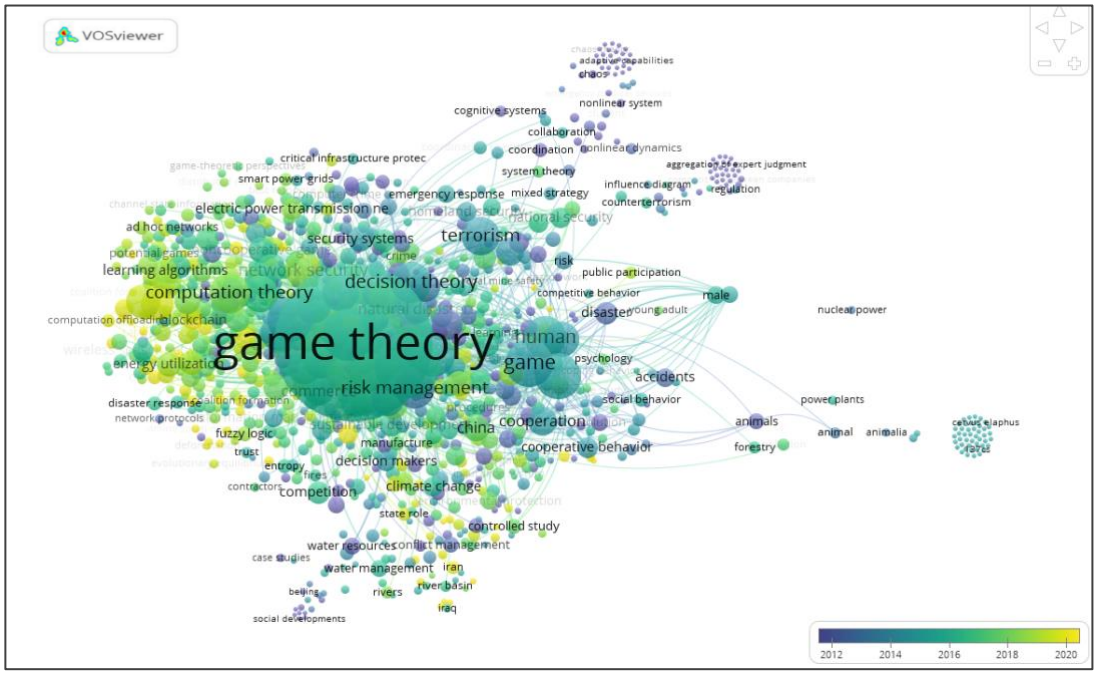

Figure 7. Game Theory and disaster Keyword co-occurrence Overlay Visualization

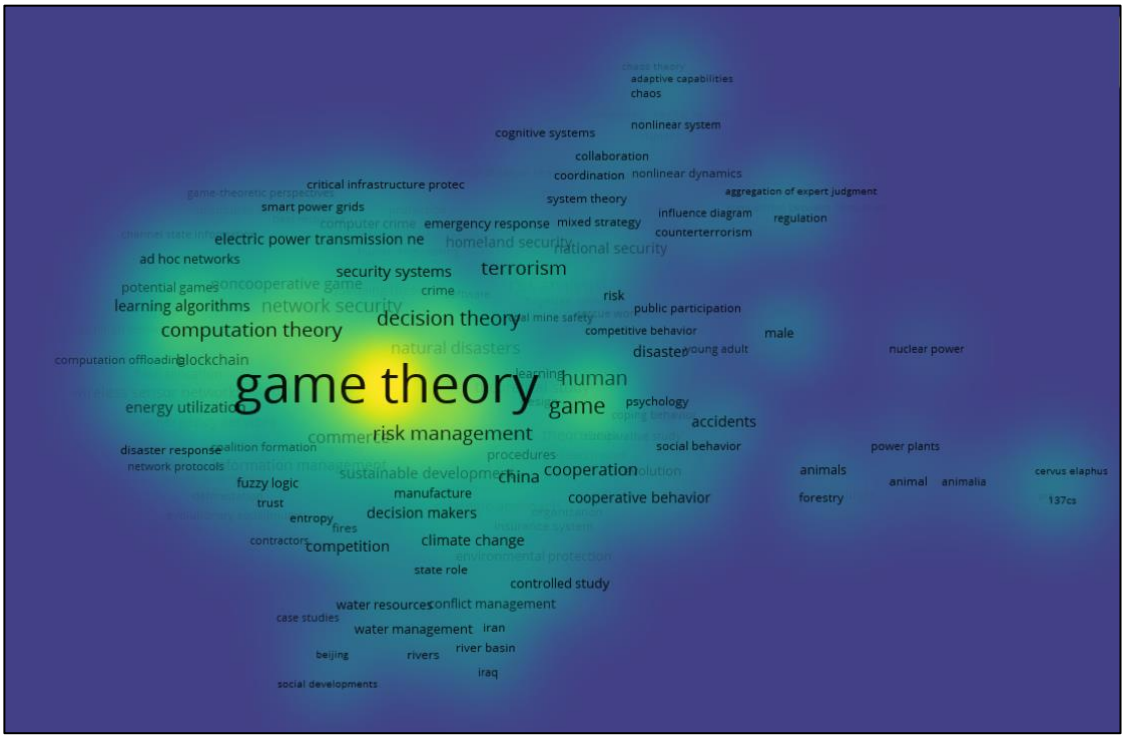

Figure 8. Keyword co-occurrence Density Visualization

Looking at the relationship of keywords co-occurring over the years from the overlay visualization section (in Figure 6 to 8), it can be seen from the contour coloring that the frequency of use increased between 2016 and 2019.

When we boundry the keywords to only game theory and disaster, we can easily see from the Figures 9 to 11 that the networks and studies decrease.

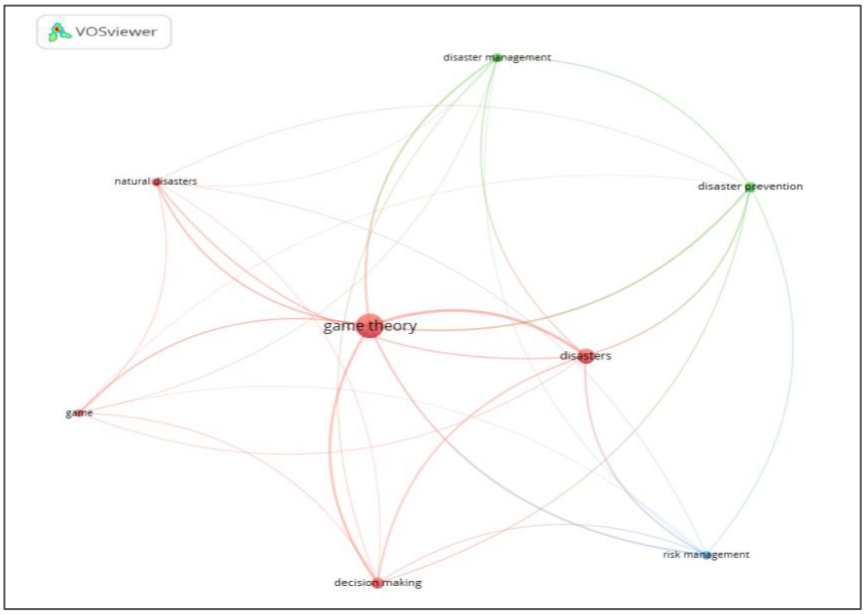

Figure 9. Game Theory and disaster Keyword co-occurrence network Visualization

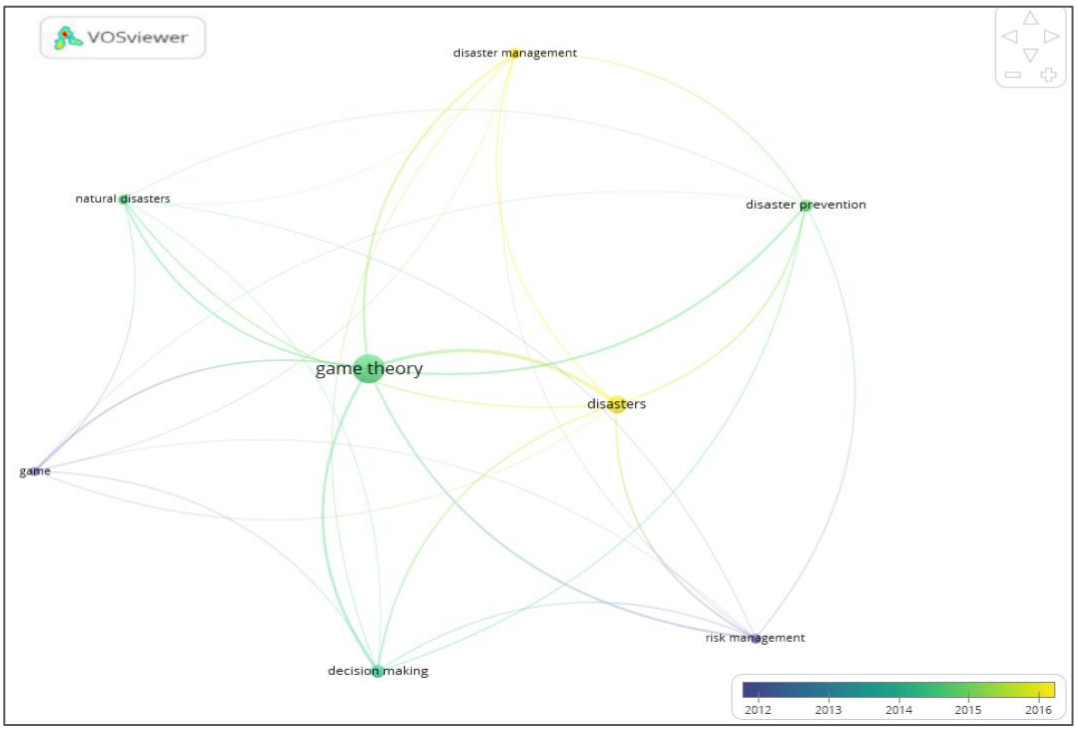

Figure 10. Game Theory and disaster Keyword co-occurrence Overlay Visualization

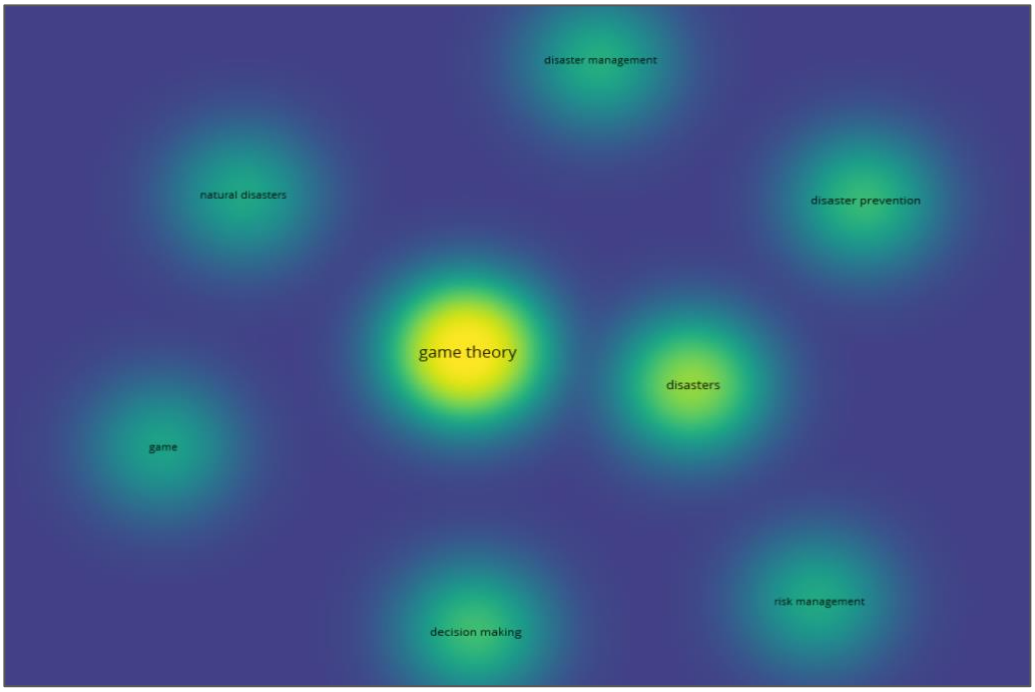

Figure 11. Game Theory and disaster Keyword co-occurrence Density Visualization

When we boundry the keywords to only game theory and disaster, we can easily see from the Figures 9 to 11 that the networks and studies decrease.

4.2. Bibliographic Coupling Countries Analysis

While analyzing this section, it was limited to a maximum of 25 articles from each country, and after this ranking, 39 countries remained in the list. Among these countries, United States, China, United Kingdom are seen as the first three countries with the most studies. Turkey, on the other hand, remained in the 36th rank among these countries. Bibliographic coupling analysis results are shown in Figures 12 to 13.

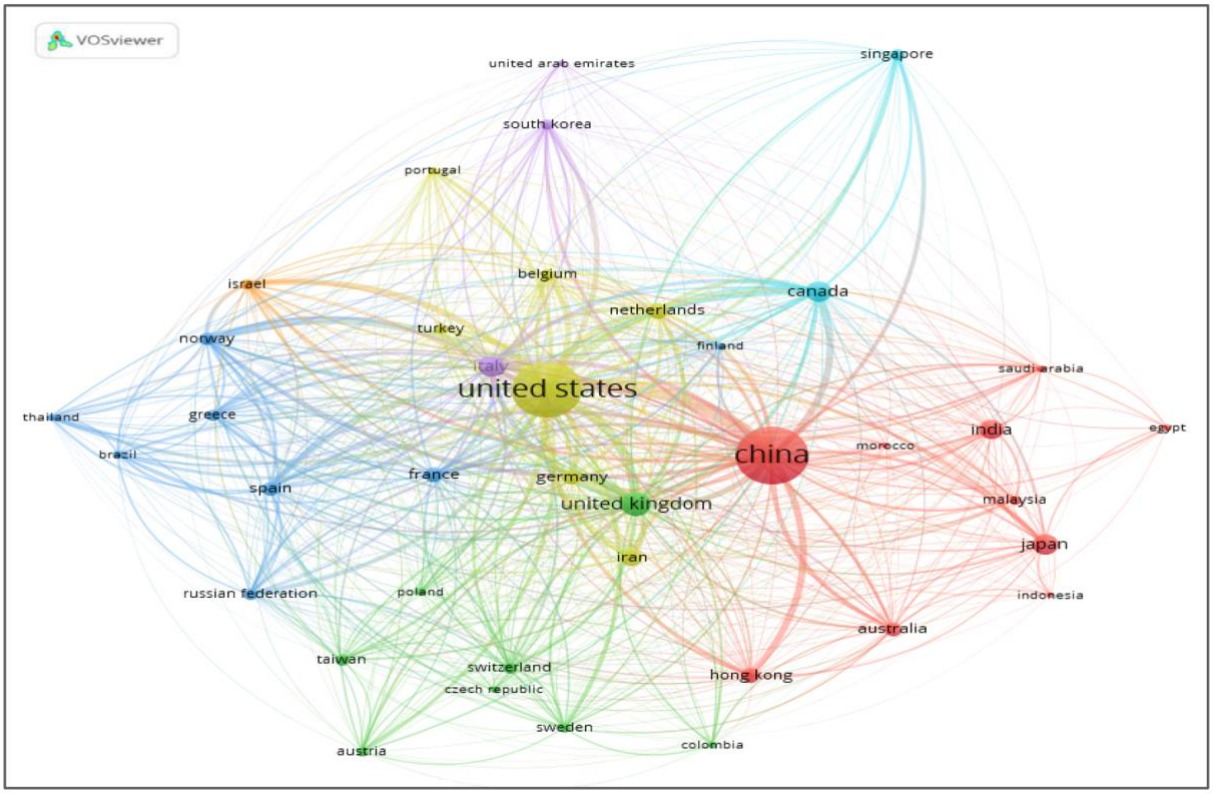

Figure 12. Bibliographic Coupling Countries Analysis Network Visualization

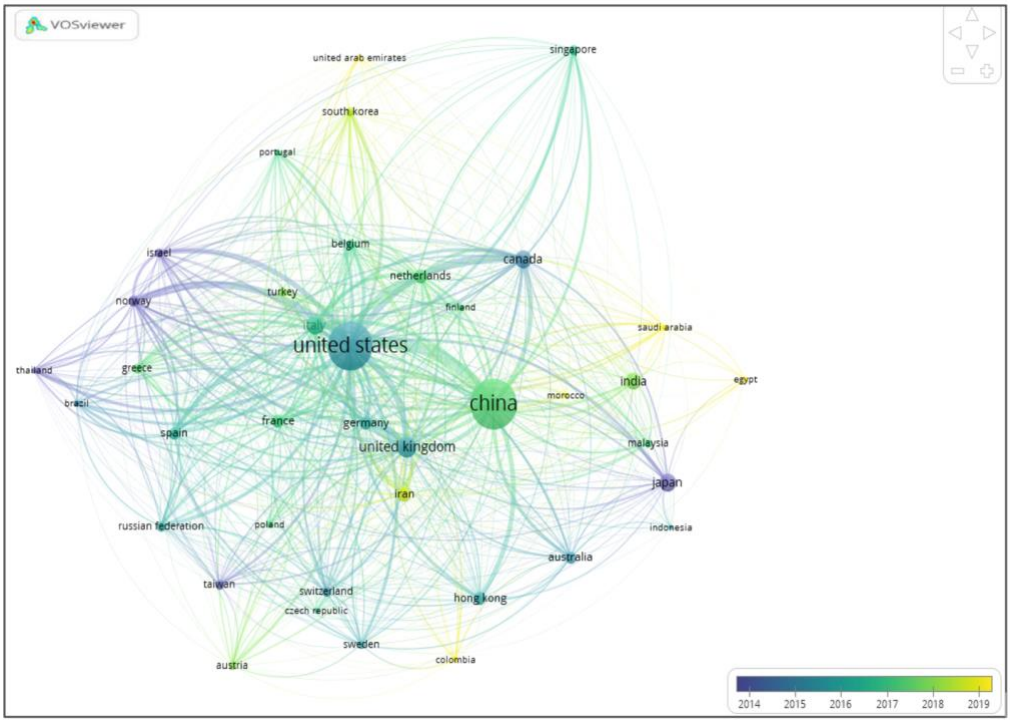

Figure 13. Bibliographic coupling Countries Analysis Overlay Visualization

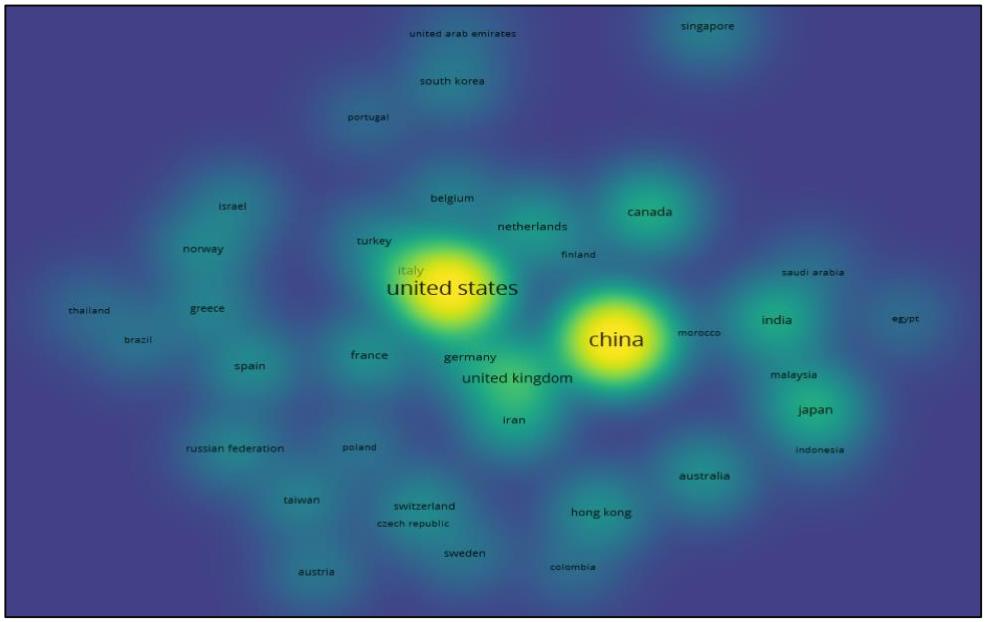

Figure 14. Bibliographic coupling Countries Analysis Density Visualization

Among the countries, United states, china, united kingdozm are seen as the first three countries with the most studies. Turkey, on the other hand, remained in the 36th rank among these countries.

4.3. Co-Autorship Analysis

The principle of author co-citation analysis is almost the same as for reference co-citation analysis. Objects selected here are associated with Author co-citations. While analyzing this section, the number

of authors' citation frequency was limited to more than 50. As a result of this limitation, it was seen that 135 of all authors met the criteria. Author co-citation network. Author co-citation analysis results are shown in Figure 15.

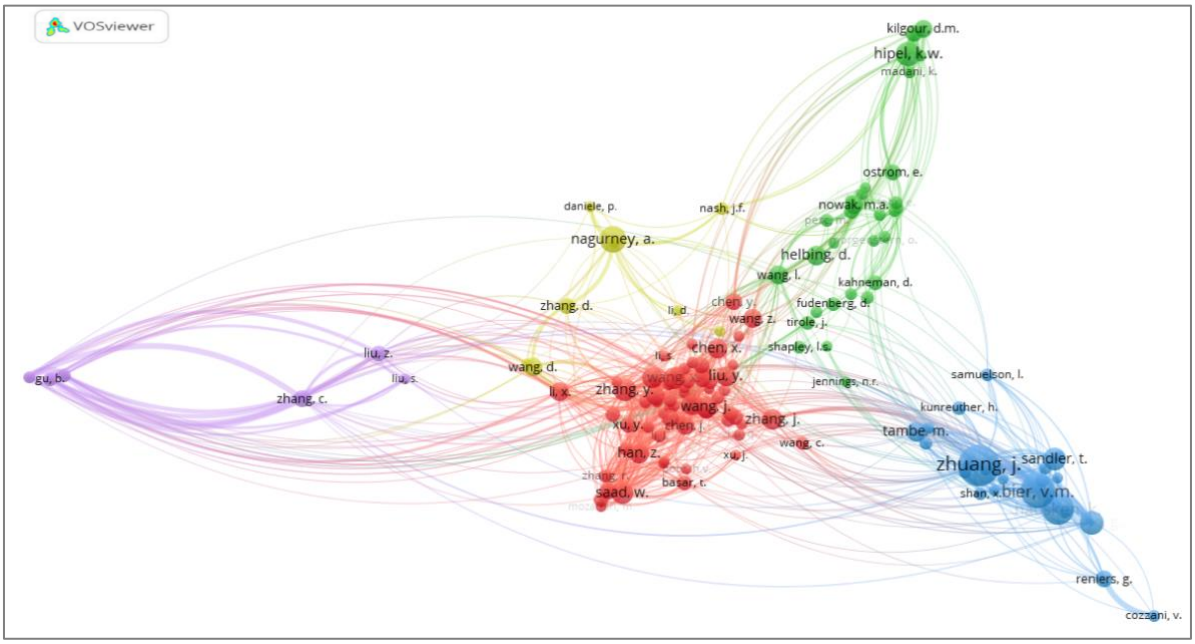

Figure. 15. Author co-citation network

As seen in the figüre 15, each author is represented by nodes in the network. The thickness found in these conductnets and ties is directly related to the number of citations. Writers in the field of game theory and disaster can be grouped into six groups. Among all networks, Zhuang is the strongest networked author with 697 citations, followed by Gu, B. and Tanaka, C. They can be listed as the authors with the strongest network. While Zhuang has worked in many areas related to game theory, he has made valuable and highly cited articles on disaster.

5. Results

In recent years, many studies have been carried out related to humanitarian or disaster relief logistics. The existing studies may be categorized based on their focus on the subject. In this section, we review some of the contributions in the game theory approach and disaster management problems. Some of the valuable studies on game theory and disasters are shown in the Table 1. When these studies are examined, it is possible to identify the issues that are lacking and that need more work and focus.

Table 1. Literature Studies

Author-Year	Paper· Title	Subject
Hausken et al. (2009) [22]	Defending against terrorism, natural disaster, and all hazards. In: Bier VM, Azaiez MN (eds) Game theoretic risk analysis of security threats.	Natural disaster
Zhuang and Bier (2007) [23]	Balancing terrorism and natural disasters defensive strategy with endogenous attacker effort	Cost of natural disasters

Zhuang et al. (2012) [24]	Strategic interactions in disaster preparedness and relief in the face of man made and natural disasters.	Cost of natural disasters
Eid et al. (2015) [25]	Evolutionary stable strategy for postdisaster insurance: game theory approach.	Disaster mitigation
Yan and Fengyong (2008) [26]	Analysis of the mechanisms of emergency management based on game theory.	Disaster management
Chen et al. (2015) [27]	Robust supply chain strategies for recovering from unanticipated disasters.	Disaster disruption
Mulyono (2015) [28]	Mutual support in energy sector: toward energy resilience	Disaster disruption
Peng et al. (2014) [29]	The feasibility of concentrated rural settlement in a context of post-disaster reconstruction: a study of China.	Disaster recovery
Peng et al. (2014) [30]	Modeling the integrated roles of insurance and retrofit in managing natural disaster risk: a multi-stakeholder perspective.	Natural Disasters
Haphuriwat and Bier (2011) [31]	Trade-offs between target hardening and overarching protection	Disaster management
Ahmed, 2011 [32]	An overview of post-disaster permanent housing reconstruction in developing countries	Disaster
Zawawi et al., 2018 [33]	Adoption of post-disaster waste management plan into disaster management guidelines for Malaysia	Disaster management
Seaberg et al., 2017 [34]	A review of game theory applications in natural disaster management research	Natural disaster management
Madu and Kuei, 2014 [16]	Disaster relief supply chain quality management (QRSCQM)	Disaster relief
Kaklauskas et al., 2009 [14]	Knowledge model for post-disaster management	Post disaster management
Du et al, 2016 [35]	Post-disaster building repair and retrofit in a disaster-prone historical village in China: A case study in Shangli, Sichuan	Post-disaster management
Ahmadi et al, 2015 [36]	A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on San Francisco district	Disaster relief operation
Celik, 2017 (37]	A cause-and-effect relationship model for location of temporary shelters in disaster operations management	Disaster operations management
Kova'cs and Spens, 2007 (38]	Humanitarian logistics in disaster relief operations	Disaster relief operations
Hosseini et al, 2016 [39]	Multi-criteria decision-making method for assessing the sustainability of post-disaster temporary housing unit technologies: A case study in Bam 2003	Post-disaster

6. Conclusions

Recently, Turkey, like many countries in the world, has been struggling with disasters such as earthquakes and floods. These disasters show that the issue should be dealt with in more detail, before and after. because countries still have deficiencies in disaster management. Therefore, there is a need for all kinds of useful studies that can be done on this subject. In addition, the analyzes made in this article show that studies on disaster in Turkey are quite lacking. Analysis in this article based on data from Scopus and Web of Science. Based on data from Web of Science, bibliometric approaches, including reference co-citation analysis, author co-citation analysis, and keyword association analysis were applied.

When the data obtained from the bibliographic coupling Country Analysis results are examined, the countries that conduct the most research are determined as the USA, China and the United Kingdom. When the data obtained grom the Co-Authorship results are examined, the author that strongest network is determined as Zhuang. This situation reveals that the researches on game theory should be increased.

In this article, the use of game theory in disaster management is discussed. Studies in the field of game theory and disaster have been analyzed from different perspectives and statistically. In addition, some

of the most interesting articles in the field have been researched and presented in tables for more detailed analysis.

In this article, researches related to the subject are introduced and the importance of disaster management is taken into consideration. It is thought that the study will make a new contribution to the literature on the subject. In addition, it can lead to new and useful approaches in this regard by drawing attention to post-disaster studies, which are quite costly.

With this study, gaps in the field of disaster management will be identified and work can be started in these gaps. so that research studies on the subject can focus on less-represented stages in meat management.

The variety of disasters and the intensity of these disasters are different for each country. Therefore, deficiencies in the literature can be identified separately for country-specific disasters in future studies. This situation will provide for more detailed data analysis.

Contribution of Researchers

All researchers have contributed equally to writing this paper.

Conflicts of Interest

The authors declare no conflict of interest.

Referances

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