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**Research Article**

# BIBLIOMETRIC OVERVIEW OF OPERATIONS RESEARCH / MANAGEMENT SCIENCE RESEARCH IN TURKEY

**Canser BİLİR*[1], Cengiz GÜNGÖR[2], Özgür KÖKALAN[3]**

[1]*İstanbul Sabahattin Zaim University, Department of Industrial Engineering, Küçükçekmece-İSTANBUL;*
ORCID: 0000-0002-3615-5819
[2]*İstanbul Sabahattin Zaim University, Department of Industrial Engineering, Küçükçekmece-İSTANBUL;*
ORCID: 0000-0003-0536-7795
[3]*İstanbul Sabahattin Zaim University, Department of Business Administration, Küçükçekmece-İSTANBUL;*
ORCID: 0000-0003-2372-9198

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**ABSTRACT**

This paper provides a bibliometric analysis of the articles in the field of Operations Research - Management Science (OR / MS) published between the years 1980- 2017 by researchers from Turkey. The main objective of the analysis is to identify and examine the current state of OR / MS studies in Turkey. The analysis is conducted based on the data from the Web of Science (WoS) databases: Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Science Citation Index (SCI), and Emerging Science Citation Index (ESCI). We found a total of 3,433 papers in 101 different journals in field of OR / MS by researchers from Turkey. The results provide a general picture of the studies classified by the most influential authors, institutions, papers, and journals. The analysis also provided citation statistics of the OR / MS articles in Turkey. The current research trends are identified through an analysis of keywords through years. In the paper the collaboration with foreign countries and institutions are also identified through a collaboration analysis.
**Keywords:** Operation research or management science publication, Turkey, bibliometric, Web of Science (WoS).

## 1. INTRODUCTION AND LITERATURE REVIEW

The number of operations research and management science studies has increased substantially since the official establishment of Operations Research Societies in all over the world [1]. Even though the initial studies were mainly limited to specific regional areas such as United States and United Kingdom, the practice of operations research and management science has seen enormous increase in all over the world including developing countries such as Turkey. Now, operations research studies are considered as an essential part of the economic life in pursuing of the most efficient and productive ways of running businesses.

Bibliometric analysis is receiving increasing attention by the scientific community and motivated by the development of internet and online databases [2]. In literature, there are several

* Corresponding Author: e-mail: canserbilir@gmail.com, tel: (212) 692 96 75

studies providing bibliometric analysis in many research areas, including OR / MS [1], management [3], economics [4], supply chain management [5], political science [6], and pricing research [7]. However, papers presenting bibliometric analysis on OR / MS area is very limited. In one of the papers, authors present a bibliometric overview of research published in operations research and management science in recent decades. Main objective of the study is to identify some of the most relevant research in this field and some of the newest trends according to the information found in the Web of Science Database [1]. In another study, the authors evaluate the distribution of papers published by Asian authors in Operations Research and Management Science (OR / MS) journals from 1968 and 2006. They also compare the impact of OR / MS research in Asia with that of United States and the world. In the study, research trends are also highlighted through an analysis of keywords [8]. In a recently published article [9], authors present a general overview of the European Journal of Operations Research over its lifetime by using bibliometric indicators. They discuss the performance of the journal compared to other journals in the field and identify key contributing countries / institutions / authors as well as trends in research topics.

The aim of this paper is to provide a general overview of research performed in OR-MS in Turkey over the last decades using bibliometric methods. We use the WoS as the database for collecting information. The paper also aims to identify the current research trends of the field in Turkey and compare the impact of OR / MS research in Turkey with that of United States and the world.

## 2. METHODOLOGY

To conduct the bibliometric methods, articles available in the Web of Science (WoS) databases: Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Science Citation Index (SCI), and Emerging Science Citation Index (ESCI) are reviewed and analyzed. WoS database owned by Thomson and Reuters includes studies from a wide range of research areas. There are 252 subject categories under WoS database and OR / MS is one of those categories. At the first step, the studies under OR / MS category have been selected. Then, the publications in 2018 have been excluded since year 2018 has not been completed yet. Since there were very limited articles in 1975, 76, 77, 78 and 79, articles published in those years have been also excluded. After those selections, the list included 288,020 publications, including articles, proceeding paper, reviews, notes etc. To focus on the most influential section of the publications, we selected only articles. Thus, the number of publications reduced to 163,242. Those articles are published in 157 different journals. Because only articles in WoS database included in the analysis, we have not excluded any journal from our analysis. To refine the selection, "Turkey" is selected to have a list of articles which at least one of the authors are from Turkey. That generated a list of 3,433 articles. Those articles are published in 101 different journals.

We also generated a complete list of articles under OR / MS category and published from European countries to compare the results. That list included 61,588 articles from 50 different countries / regions. Top 10 countries account for 80 % of the publications in Europe. In analyzing collaborating countries, institutions, and keywords, we also utilized VOSviewer (Visualizing scientific landscapes tool produced by Centre for Science and Technology Studies).

## 3. RESULTS

The results of the research conducted are presented below in separate subtitles; number of papers, leading journals, most productive authors; citation statistics and most cited articles; most productive institutions, collaboration analysis, and keyword analysis.

### 3.1. Number of OR / MS Papers

The number of papers published in a specific area is an important indicator in scientific research. In order to analyze the number of papers in Turkey, we will first present the number of papers published in the world and then Europe. The below figures present how the number of papers change through years from 1980 to 2017 in the world, in Europe and in Turkey. Figure 1 depicts the number of papers published in the world through years from 1980 to 2017 under OR / MS category in WoS database. As seen on the Figure 1, there is an upward trend in the number of papers under OR / MS category. The slope of the trend is even higher after 2003.

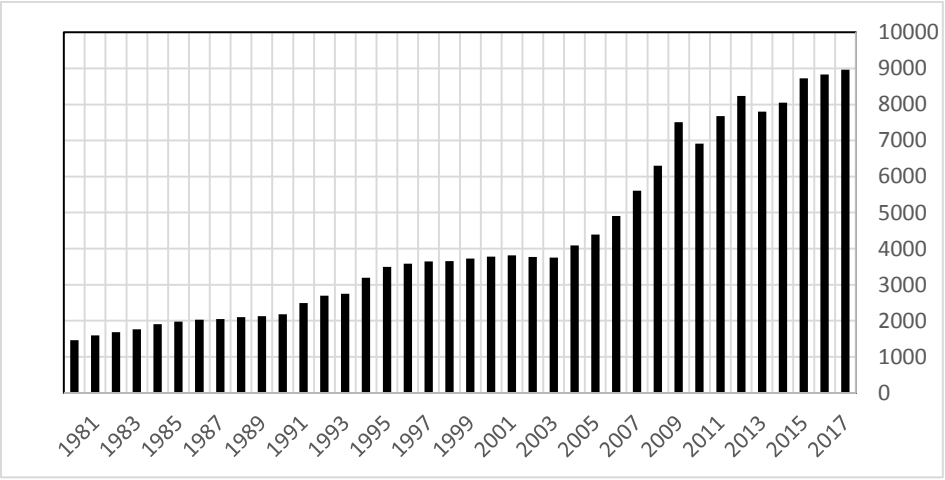


**Figure 1.** The number of papers under OR / MS Category (1980 – 2017)

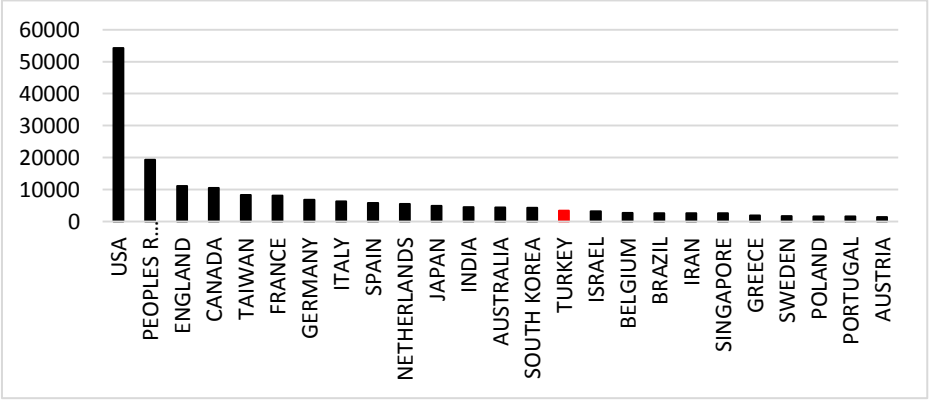


**Figure 2.** The number of papers from 25 most publishing countries

Figure 2 presents the number of papers from top 25 countries in OR / MS field. The results show that one third of the papers have at least one author from USA. Even though USA has a dominating role in OR / MS studies, the ratio of studies from USA is slightly decreasing through decades. China is following USA with 19,355 studies (11.86 %) and sequentially England (% 6.80), Canada (6.45 %) and Taiwan (5.08 %) comes. The number of studies having at least one

European author is 61,490 (37.67 %). However, the ratio of European studies is increasing through decades: the ratio is 28.24 % for 80's, 32.14 % for 90's, 39.67 % for 2000's and 41.25 % for 2010's. As seen, the ratio is substantially increasing through decades. Turkey with 3,433 papers (2.10 %) has the 15th position in country ranking in OR / MS studies (Figure 2). As having had the 17th biggest economy in the world [10], the ranking seems to be reasonable.

The researchers working at Turkish universities have published a total of 3,433 papers under OR / MS category in WoS database in years from 1980 through 2017. Figure 3 shows the development of the number of papers through years from 1980. The number of papers in Turkey sharply increases during 90's and reaches its peak in 2009. Then, it slightly decreases after 2009. That decrease is surprising because the number of papers in other research categories in Turkey do not follow the similar pattern and keep increasing even after 2009, 2010 and 2011.

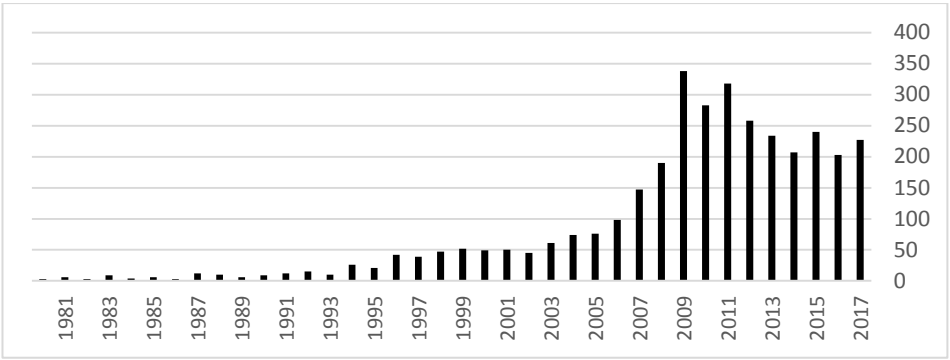


**Figure 3.** The number of papers under OR / MS category published by researchers from Turkey

The development of the number of papers compared to the world statistics is further analyzed in Figure 4.

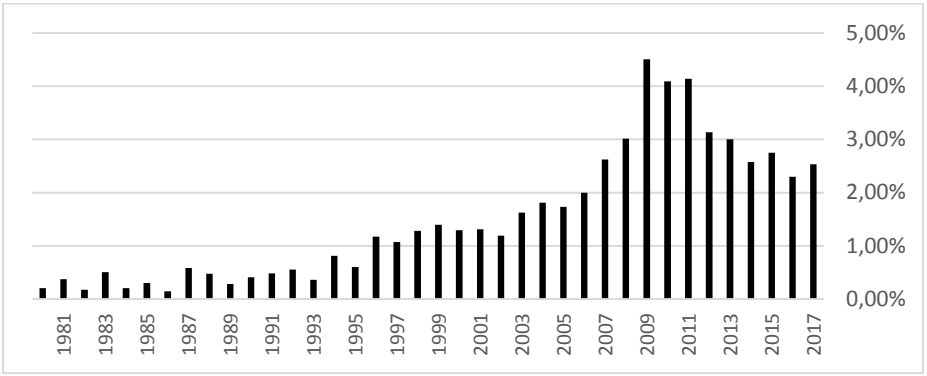


**Figure 4.** The ratio of papers in the world that at least one of the authors are located at Turkish Institutions.

Even though the number of papers in the world increasing substantially through years, Figure 4 shows that there is still an upward trend even in the ratio of studies from Turkey. However, the ratio starts decreasing after 2009.

### 3.2. Leading Journals

The detailed analysis of the 3,433 publications revealed that the researchers have published articles mostly in the Expert Systems with Applications Journal with 791 articles. This number of publications constitutes 23% of all the publications made in this field. The European Journal of Operational Research (356; 10.4%), International Journal of Production Research (282; 8.2%), Computers & Operations Research (175; 5.1%) and International Journal of Production Economics (147; 8.2%) are among the first 5 journals in which the academicians published their articles with the highest rates. The journal with the highest h-index among the ones preferred by academicians is the European Journal of Operational Research (h-index: 211); and the one with the lowest index value is the International Journal of Information Technology Decision Making (h-index: 33). It has been also observed that five journals Turkish researchers published their papers mostly are in the 25% part of the best journals in this field. When all the publications are taken into consideration, it has been observed that 10 of the 25 journals preferred by academicians and approximately 57% of them are among the best 25% of the journals in the field. The analysis also revealed that researchers from Turkey preferred mainly the journals of European origin (especially the Netherlands and the United Kingdom)

25 journals, which Turkish researchers published their papers mostly, are listed by publisher's country, the numbers of the articles and the proportion of these articles among all articles, their h-index value, and the proportion of these articles among all articles, their h-index value, the classification made by WOS and the JRC 2016 Impact Factor values in Table 1.

### 3.3. Productive authors

We ranked the most productive / influential authors both by the number of papers and by number of citations. The author published the most papers in OR /MS category in Turkey is Adil Baykasoglu from Gaziantep University, having published 57 papers. The second ranked author is M. Selim Akturk from Bilkent University with 55 papers. Murat Koksalan from Middle East Technical University attains the third rank with 54 papers. Most publishing authors with their affiliation and the number of papers they published are presented in Table 2 below. Table 2 also ranks the authors by the total number of citations which their papers received. The most cited author is Cengiz Kahraman from Istanbul Technical University with 2,354 citations. The author also has H-index of 25 (the highest value), which shows the h number of papers have at least h number of citations.

### 3.4. Citation statistics and most cited articles

The papers under WoS database in OR / MS field which at least one of the authors are from Turkey have received 66,848 citations so far. Average number of citations per paper is calculated as 19,46. The h-index for the papers is 90; that means 90 of the papers have been cited 90 or more times so far. The papers in WoS database under OR / MS category is also classified by the number of citations received. Thus, the articles that have received most attention by the scientific community have been identified.

A list of 25 the most cited articles is presented between 1980 and 2017 in OR / MS field in Turkey in Table 3. For each article, the journal name, the rank in the list, the number of citations, the title of the paper, the names(s) of the author(s), the year published and the average number of citations per year are provided in the Table.

The most cited article is on artificial bee colony optimization published by Dervis Karaboga and Bahriye Basturk in Journal of Global Optimization in 2007. The article received about 1950 citations. Then a study on fuzzy group decision making comes with about 420 citations by Fatih Emre Boran, Serkan Genc, Mustafa Kurt, et al. The third rank is attained by a paper on neural

network published in Expert Systems with Applications with about 410 citations by Abdulhamit Subasi. As seen in Table 3, the list is dominated by papers published in two journals; Expert Systems with Applications (11 papers) and European Journal of Operations Research (5 papers).

**Table 1.** Most publishing 25 journals

| RANK | JOURNAL NAME | COUNTRY | # OF ARTICLE | % OF 3433 | H İNDEX | QUAR TILE | JCR 2016 IMPACT FACTOR |
|---|---|---|---|---|---|---|---|
| 1 | EXPERT SYSTEMS WITH APPLICATIONS | USA | 791 | 23,0% | 145 | Q1 | 3.768 |
| 2 | EUROPEAN JOURNAL OF OPERATIONAL RESEARCH | Netherlands | 356 | 10,4% | 211 | Q1 | 3.428 |
| 3 | INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH | England | 282 | 8,2% | 107 | Q1 | 2.623 |
| 4 | COMPUTERS & OPERATIONS RESEARCH | England | 175 | 5,1% | 124 | Q1 | 2.962 |
| 5 | INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS | Netherlands | 147 | 4,3% | 141 | Q1 | 4.407 |
| 6 | JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY | England | 129 | 3,8% | 87 | Q3 | 1.225 |
| 7 | ANNALS OF OPERATIONS RESEARCH | Netherlands | 95 | 2,8% | 86 | Q2 | 1.864 |
| 8 | IISE TRANSACTIONS | USA | 91 | 2,7% | 81 | Q3 | 1.759 |
| 9 | NAVAL RESEARCH LOGISTICS | USA | 65 | 1,9% | 58 | Q4 | 0.989 |
| 10 | SAFETY SCIENCE | Netherlands | 62 | 1,8% | 81 | Q2 | 2.835 |
| 11 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE | England | 52 | 1,5% | 59 | Q2 | 2.185 |
| 11 | JOURNAL OF GLOBAL OPTIMIZATION | Netherlands | 52 | 1,5% | 70 | Q2 | 1.407 |
| 13 | OMEGA - INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE | England | 48 | 1,4% | 108 | Q1 | 4.311 |
| 14 | OPTIMIZATION | England | 46 | 1,3% | 34 | Q3 | 1.170 |
| 15 | OPERATIONS RESEARCH | USA | 44 | 1,3% | 115 | Q2 | 1.779 |
| 16 | OPERATIONS RESEARCH LETTERS | Netherlands | 43 | 1,3% | 63 | Q4 | 0.643 |
| 17 | ENGINEERING OPTIMIZATION | England | 41 | 1,2% | 52 | Q2 | 1.622 |
| 18 | PRODUCTION PLANNING & CONTROL | England | 40 | 1,2% | 61 | Q1 | 2.330 |
| 19 | MANAGEMENT SCIENCE | USA | 38 | 1,1% | 209 | Q1 | 2.822 |
| 20 | INTERNATIONAL JOURNAL OF COMPUTER INTEGRATED MANUFACTURING | England | 34 | 1,0% | 44 | Q2 | 1.995 |
| 21 | INTERNATIONAL JOURNAL OF INFORMATION TECHNOLOGY & DECISION MAKING | Singapore | 33 | 1,0% | 33 | Q2 | 1.664 |
| 22 | DECISION SUPPORT SYSTEMS | Netherlands | 31 | 0,9% | 115 | Q1 | 3.565 |
| 22 | JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS | USA | 31 | 0,9% | 74 | Q3 | 1.234 |
| 22 | PRODUCTION AND OPERATIONS MANAGEMENT | USA | 31 | 0,9% | 87 | Q2 | 1.772 |
| 25 | SYSTEMS & CONTROL LETTERS | Netherlands | 29 | 0,8% | 117 | Q1 | 2.656 |

**Table 2.** Most productive authors in OR / MS in Turkey (1980-2017)

| Sort by Number of Papers | | | | Sort by Total Citations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Authors | Papers | Institutions | Rank | Author | Papers | Citations | Citation per paper | Institution | h-index |
| 1 | BAYKASOGLU ADIL | 57 | GAZIANTEP UNIVERSITY | 1 | KAHRAMAN CENGIZ | 33 | 2354 | 71,33 | ISTANBUL TECHNICAL UNIVERSITY | 25 |
| 2 | AKTURK M. SELIM | 55 | BILKENT UNIVERSITY | 2 | KARABOGA DERVIS | 2 | 1975 | 987,5 | ERCIYES UNIVERSITY | 2 |
| 3 | KOKSALAN MURAT | 54 | MIDDLE EAST TECHNICAL UNIVERSITY | 3 | BAHRIYE BASTURK | 1 | 1947 | 1947 | ERCIYES UNIVERSITY | 1 |
| 4 | WEBER GERHARD WILHELM | 52 | MIDDLE EAST TECHNICAL UNIVERSITY | 4 | OZDAMAR LINET | 42 | 1715 | 40,83 | YEDITEPE UNIVERSITY | 21 |
| 5 | SABUNCUOGLU IHSAN | 49 | BILKENT UNIVERSITY | 5 | BUYUKOZKAN GULCIN | 29 | 1558 | 53,72 | GALATASARAY UNIVERSITY | 18 |
| 6 | OZEKICI SULEYMAN | 48 | BOGAZICI UNIVERSITY | 6 | SABUNCUOGLU IHSAN | 49 | 1383 | 28,22 | BILKENT UNIVERSITY | 23 |
| 7 | ALTINEL I. KUBAN | 47 | BOGAZICI UNIVERSITY | 7 | BAYKASOGLU ADIL | 57 | 1245 | 21,84 | GAZIANTEP UNIVERSITY | 21 |
| 8 | AZIZOGLU MERAL | 44 | MIDDLE EAST TECHNICAL UNIVERSITY | 8 | ULUSOY GUNDUZ | 26 | 1159 | 44,58 | SABANCI UNIVERSITY | 16 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | OZDAMAR LINET | 42 | YEDITEPE UNIVERSITY | 9 | SUBASI ABDULHAMIT | 6 | 957 | 159,5 | KAHRAMANMARAS SUTCU IMAM UNIVERSITY | 6 |
| 10 | PINAR MUSTAFA C. | 38 | BILKENT UNIVERSITY | 10 | KARA BAHAR Y. | 30 | 921 | 30,7 | BILKENT UNIVERSITY | 16 |
| 10 | YAMAN HANDE | 38 | BILKENT UNIVERSITY | 11 | EREL ERDAL | 23 | 920 | 40 | BILKENT UNIVERSITY | 17 |
| 12 | ARAS NECATI | 34 | BOGAZICI UNIVERSITY | 12 | AKTURK M. SELIM | 55 | 901 | 16,38 | BILKENT UNIVERSITY | 19 |
| 13 | KAHRAMAN CENGIZ | 33 | ISTANBUL TECHNICAL UNIVERSITY | 13 | UBEYLI ELIF DERYA | 26 | 802 | 30,85 | TOBB EKONOMI VE TEKNOLOJI UNIV | 14 |
| 13 | TAN BARIS | 33 | KOC UNIVERSITY | 14 | KOKSALAN MURAT | 54 | 760 | 14,07 | MIDDLE EAST TECHNICAL UNIV. | 15 |
| 15 | BIRBIL S. ILKER | 32 | SABANCI UNIVERSITY | 15 | ARAS NECATI | 34 | 750 | 22,06 | BOGAZICI UNIVERSITY | 15 |
| 15 | KARAESMEN FIKRI | 32 | KOC UNIVERSITY | 16 | KARSAK E. ERTUGRUL | 17 | 749 | 44,06 | GALATASARAY UNIVERSITY | 13 |
| 15 | KARASAN OYA EKIN | 32 | BILKENT UNIVERSITY | 17 | SEVKLI MEHMET | 8 | 731 | 91,38 | FATIH UNIVERSITY | 8 |
| 18 | KARA BAHAR Y. | 30 | BILKENT UNIVERSITY | 18 | POLAT KEMAL | 21 | 706 | 33,62 | SELCUK UNIVERSITY | 15 |
| 19 | BUYUKOZKAN GULCIN | 29 | GALATASARAY UNIVERSITY | 19 | GUNES SALIH | 21 | 695 | 33,1 | SELCUK UNIVERSITY | 21 |
| 20 | ERYILMAZ SERKAN | 28 | ATILIM UNIVERSITY | 20 | OZEKICI SULEYMAN | 48 | 644 | 13,42 | BOGAZICI UNIVERSITY | 13 |
| 21 | GULLU REFIK | 27 | BOGAZICI UNIVERSITY | 20 | SENGUR ABDULKADIR | 16 | 644 | 40,25 | FIRAT UNIVERSITY | 12 |
| 21 | TARIM S. ARMAGAN | 27 | HACETTEPE UNIVERSITY | 22 | YAMAN HANDE | 38 | 637 | 16,76 | BILKENT UNIVERSITY | 15 |
| 23 | UBEYLI ELIF DERYA | 26 | TOBB EKONOMI VE TEKNOLOJI UNIV. | 23 | AZIZOGLU MERAL | 44 | 588 | 13,36 | MIDDLE EAST TECHNICAL UNIV. | 14 |
| 23 | ULUSOY GUNDUZ | 26 | SABANCI UNIVERSITY | 24 | KARAESMEN FIKRI | 32 | 585 | 18,28 | KOC UNIVERSITY | 14 |
| 25 | AVCI ENGIN | 23 | FIRAT UNIVERSITY | 25 | KURT MUSTAFA | 4 | 515 | 128,75 | GAZI UNIVERSITY | 4 |
| 25 | CELIK METE | 23 | ISTANBUL TECHNICAL UNIVERSITY | | | | | | | |
| 25 | EREL ERDAL | 23 | BILKENT UNIVERSITY | | | | | | | |

**Table 3.** Most cited articles in OR / MS in Turkey (1980-2017)

| RANK | TITLE | AUTHORS | JOURNAL | PUBLICATION YEAR | TOTAL CITATIONS | AVERAGE PER YEAR |
|---|---|---|---|---|---|---|
| 1 | A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm | Karaboga, Dervis; Basturk, Bahriye | JOURNAL OF GLOBAL OPTIMIZATION | 2007 | 1947 | 162,25 |
| 2 | A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method | Boran, Fatih Emre; Genc, Serkan; Kurt, Mustafa; Akay, Diyar | EXPERT SYSTEMS WITH APPLICATIONS | 2009 | 420 | 42,00 |
| 3 | EEG signal classification using wavelet feature extraction and a mixture of expert model | Subasi, Abdulhamit | EXPERT SYSTEMS WITH APPLICATIONS | 2007 | 411 | 34,25 |
| 4 | Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey | Kahraman, C; Cebeci, U; Ruan, D | INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS | 2004 | 326 | 21,73 |
| 5 | Grey system theory-based models in time series prediction | Kayacan, Erdal; Ulutas, Baris; Kaynak, Okyay | EXPERT SYSTEMS WITH APPLICATIONS | 2010 | 311 | 34,56 |
| 6 | A fuzzy optimization model for QFD planning process using analytic network approach | Kahraman, C; Ertay, T; Buyukozkan, G | EUROPEAN JOURNAL OF O.R. | 2006 | 304 | 23,38 |
| 7 | Emergency logistics planning in natural disasters | Ozdamar, L; Ekinci, E; Kucukyazici, B | ANNALS OF OPERATIONS RESEARCH | 2004 | 303 | 20,20 |
| 8 | The multiple traveling salesman problem: an overview of formulations and solution procedures | Bektas, T | OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE | 2006 | 300 | 23,08 |
| 9 | A particle swarm optimization algorithm for makespan and total flowtime minimization in the permutation flowshop sequencing problem | Tasgetiren, M. Fatih; Liang, Yun-Chia; Sevkli, M.; Gencyilmaz, G. | EUROPEAN JOURNAL OF O.R. | 2007 | 294 | 24,50 |
| 10 | Automatic detection of epileptic | Ocak, Hasan | EXPERT | 2009 | 254 | 25,40 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | seizures in EEG using discrete wavelet transform and approximate entropy | | SYSTEMS WITH APPLICATIONS | | | |
| 11 | A two-stage stochastic programming framework for transportation planning in disaster response | Barbarosoglu, G; Arda, Y | JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY | 2004 | 252 | 16,80 |
| 12 | EEG signal classification using PCA, ICA, LDA and support vector machines | Subasi, Abdulhamit; Gursoy, M. Ismail | EXPERT SYSTEMS WITH APPLICATIONS | 2010 | 249 | 27,67 |
| 13 | A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers | Buyukozkan, Gulcin; Cifci, Gizem | EXPERT SYSTEMS WITH APPLICATIONS | 2012 | 243 | 34,71 |
| 13 | Soft set theory and uni-int decision making | Cagman, Naim; Enginoglu, Serdar | EUROPEAN JOURNAL OF O.R.. | 2010 | 243 | 27,00 |
| 15 | Weapon selection using the AHP and TOPSIS methods under fuzzy environment | Dagdeviren, Metin; Yavuz, Serkan; Kilinc, Nevzat | EXPERT SYSTEMS WITH APPLICATIONS | 2009 | 233 | 23,30 |
| 16 | A dynamic logistics coordination model for evacuation and support in disaster response activities | Yi, Wei; Ozdamar, Linet | EUROPEAN JOURNAL OF O.R. | 2007 | 228 | 19,00 |
| 17 | Recurrent neural networks employing Lyapunov exponents for EEG signals classification | Guler, NF; Ubeyli, ED; Guler, I | EXPERT SYSTEMS WITH APPLICATIONS | 2005 | 213 | 15,21 |
| 18 | A survey of the assembly line balancing procedures | Erel, E; Sarin, SC | PRODUCTION PLANNING & CONTROL | 1998 | 209 | 9,95 |
| 19 | Support vector machines combined with feature selection for breast cancer diagnosis | Akay, Mehmet Fatih | EXPERT SYSTEMS WITH APPLICATIONS | 2009 | 198 | 19,80 |
| 20 | Chaotic bee colony algorithms for global numerical optimization | Alatas, Bilal | EXPERT SYSTEMS WITH APPLICATIONS | 2010 | 195 | 21,67 |
| 21 | Effects of innovation types on firm performance | Gunday, Gurhan; Ulusoy, Gunduz; Kilic, Kemal; Alpkan, Lutfihak | INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS | 2011 | 191 | 23,88 |
| 22 | An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations | Barbarosoglu, G; Ozdamar, L; Cevik, A | EUROPEAN JOURNAL OF O.R: | 2002 | 177 | 10,41 |
| 23 | An integrated multiobjective decision making process for supplier selection and order allocation | Demirtas, Ezgi Aktar; Ustun, Oezden | OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE | 2008 | 173 | 15,73 |
| 24 | A survey on the resource-constrained project scheduling problem | Özdamar, L; Ulusoy, G | IIE TRANSACTIONS | 1995 | 172 | 7,17 |
| 25 | Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods | Ertugrul, Irfan; Karakasoglu, Nilsen | EXPERT SYSTEMS WITH APPLICATIONS | 2009 | 171 | 17,10 |

### 3.5. Productive institutions

There are 20 institutions which produced more than 50 papers during the years analyzed. More than 25% of the papers written by only 2 institutions: Ihsan Dogramaci Bilkent University with 469 papers (13,7% of the total) and Middle East Technical University with 431 papers (12,6% of the total). Other institutions with more than 100 papers can be listed as Koc University, Bogazici University, Istanbul Technical University, Sabanci University, Gazi University, Selcuk University and Dokuz Eylul University. Four of these 9 universities are foundation (waqf) based universities and 5 of them are state universities. The list of top 20 institutions, the number of papers published and the percentage of the total are given in Table 4. State University of Florida with 47 papers (1,4% of the total) is the 22$^{nd}$ in the list as a non Turkish institution. The Scientific

and Technological Research Council of Turkey is the 28th in the list as a non-university (research) institution with 39 papers.

**Table 4.** The most productive institutions in the field of OR / MS in Turkey (1980-2017)

| Institutions | Number of papers | % of total |
|---|---|---|
| IHSAN DOGRAMACI BILKENT UNIVERSITY | 469 | 13,7% |
| MIDDLE EAST TECHNICAL UNIVERSITY | 431 | 12,6% |
| KOC UNIVERSITY | 227 | 6,6% |
| BOGAZICI UNIVERSITY | 217 | 6,3% |
| ISTANBUL TECHNICAL UNIVERSITY | 203 | 5,9% |
| SABANCI UNIVERSITY | 164 | 4,8% |
| GAZI UNIVERSITY | 144 | 4,2% |
| SELCUK UNIVERSITY | 118 | 3,4% |
| DOKUZ EYLUL UNIVERSITY | 106 | 3,1% |
| FIRAT UNIVERSITY | 93 | 2,7% |
| GALATASARAY UNIVERSITY | 90 | 2,6% |
| YILDIZ TECHNICAL UNIVERSITY | 84 | 2,4% |
| IZMIR EKONOMI UNIVERSITESI | 80 | 2,3% |
| ERCIYES UNIVERSITY | 79 | 2,3% |
| HACETTEPE UNIVERSITY | 79 | 2,3% |
| TOBB EKONOMI VE TEKNOLOJI UNIVERSITY | 79 | 2,3% |
| OZYEGIN UNIVERSITY | 76 | 2,2% |
| GAZIANTEP UNIVERSITY | 70 | 2,0% |
| ANADOLU UNIVERSITY | 58 | 1,7% |
| ESKISEHIR OSMANGAZI UNIVERSITY | 53 | 1,5% |

### 3.6. Collaboration Analysis

In the analyzed papers, the average number of authors per article is 2.48. A chart of the average number of authors distributed to years are given in Figure 5. Those results show that collaboration among authors tend to show some slight increase through years.

Detailed table of the statistics relating to the number of articles for different number of authors are depicted in Table 5. About 40% of the articles are written by 2 authors, 30% of the articles are written by 3 authors and 15% of the articles have only one author. The maximum number of authors per article is 7. There are only 10 articles with 7 authors.

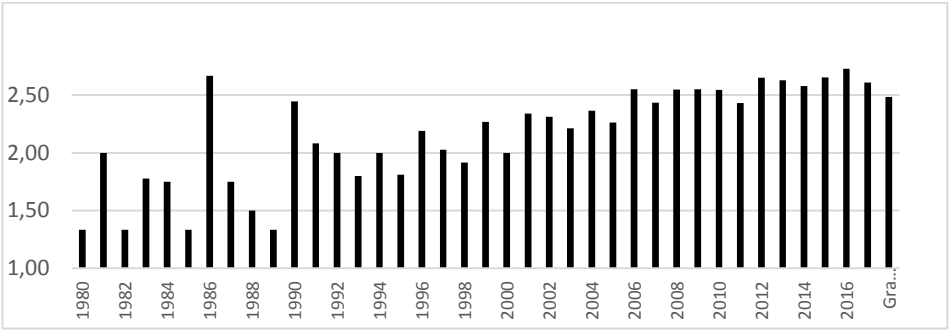


**Figure 5.** Average number of Authors (per article)

**Table 5.** Total number of articles for the each number of authors

| Number of authors | Total number of articles |
|---|---|
| 1 | 519 |
| 2 | 1,393 |
| 3 | 1,031 |
| 4 | 363 |
| 5 | 91 |
| 6 | 26 |
| 7 | 10 |

Among analyzed articles, 1570 of them are written with joint efforts together with researchers working in countries other than Turkey. It has been observed that the researchers working in Turkey performed joint publications with the researchers working in the USA at the highest level (599; 17.4%). It was also determined that Canada (134; 3.9%), England (102; 2.9%), Netherlands (99; 2.8%) and Germany (65; 1.8%) followed the USA, respectively. The information on 12 countries where the academicians working in Turkey performed joint publications at the highest rate is given in Table 6.

**Table 6.** Collaborated Countries

| | **COUNTRY** | **# OF ARTICLES** | **% OF 3433** |
|---|---|---|---|
| 1 | USA | 599 | 17.44 |
| 2 | CANADA | 134 | 3.90 |
| 3 | ENGLAND | 102 | 2.97 |
| 4 | NETHERLANDS | 99 | 2.88 |
| 5 | GERMANY | 65 | 1.89 |
| 6 | FRANCE | 64 | 1.86 |
| 7 | PEOPLES R CHINA | 46 | 1.34 |
| 8 | AUSTRALIA | 38 | 1.11 |
| 9 | IRAN | 29 | 0,84 |
| 10 | IRELAND | 25 | 0,72 |
| 10 | SINGAPORE | 25 | 0,73 |
| 12 | ITALY | 22 | 0,64 |

Figure 6 also presents the collaborating countries in a more presentable way in which the size of the sphere for each country presents the number of collaborated studies.

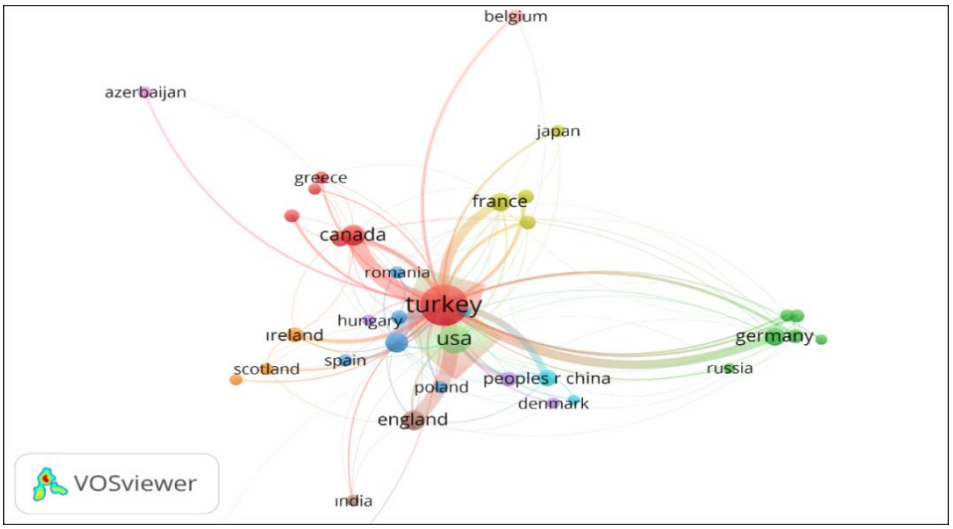


**Figure 6.** Collaborated Countries (25 most collaborated countries) [11]

**Table 7.** Collaborated Institutions

| RANK | INSTITUTION | # OF ARTİCLE |
|---|---|---|
| 1 | STATE UNIVERSITY OF FLORIDA | 47 |
| 2 | UNIVERSITY OF FLORIDA | 36 |
| 3 | GEORGIA INSTITUTE OF TECHNOLOGY | 32 |
| 4 | PENNSYLVANIA COMMONWEALTH SYSTEM OF HIGHER EDUCATION PCSHE | 28 |
| 5 | EINDHOVEN UNIVERSITY OF TECHNOLOGY | 27 |
| 6 | ERASMUS UNIVERSITY ROTTERDAM | 24 |
| 7 | PURDUE UNIVERSITY | 23 |
| 7 | UNIVERSITY OF NORTH CAROLINA | 23 |
| 9 | UNIVERSITY OF TEXAS | 20 |
| 10 | UNIVERSITY OF MONTREAL | 19 |
| 11 | ARIZONA STATE UNIVERSITY | 18 |
| 11 | NORTHEASTERN UNIVERSITY | 18 |
| 11 | OKLAHOMA STATE UNIVERSITY STILLWATER | 18 |
| 11 | PENN STATE UNIVERSITY | 18 |
| 15 | CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS | 17 |
| 15 | RUTGERS STATE UNIVERSITY NEW BRUNSWICK | 17 |
| 15 | UNIVERSITAT SIEGEN | 17 |
| 15 | UNIVERSITE PARIS SACLAY COMUE | 17 |
| 15 | UNIVERSITY COLLEGE CORK | 17 |
| 15 | UNIVERSITY OF ALBERTA | 17 |

In the analyzed studies, the researchers working in Turkey conducted joint studies with the researchers working in many different institutions in this field. It has been observed that the foreign university with which the academicians working at universities in Turkey cooperated at the highest level is the State University of Florida (47). University of Florida (36), Georgia Institute of Technology (32), Pennsylvania Commonwealth System of Higher Education (PCSHE) (28) and Eindhoven University of Technology (27) followed State University of Florida. It has been also observed that the researchers working at the universities in Turkey performed joint publications mostly with the universities located in the USA. The information on

the first 20 universities with which the researchers working at universities in Turkey performed joint publications is given in Tablo 7.

Results also revealed that the university with which foreign universities have performed joint publications the most is Middle East Technical University (METU) with 108 studies. METU is followed by Ihsan Doğramaci Bilkent University, Sabanci University, Koç University, and Boğaziçi University, respectively. It has been observed that all of the universities ranking in the first 5 were among the most reputable universities of Turkey (Table 8). It is considered that the educational language in these universities being English facilitated the communication between the academicians working at these universities and their foreign colleagues.

**Table 8.** Collaborating Institutions

| RANK | PUBLISHING INSTITUTIONS | # OF ARTICLE | QS WORLD UNIVERSITY RANKING IN TURKEY |
|---|---|---|---|
| 1 | MIDDLE EAST TECHNICAL UNIVERSITY (ODTU) | 108 | 4 |
| 2 | IHSAN DOGRAMACI BILKENT UNIVERSITY | 80 | 1 |
| 3 | SABANCI UNIVERSITY | 64 | 3 |
| 4 | KOC UNIVERSITY | 52 | 2 |
| 5 | BOGAZİCİ UNIVERSITY | 29 | 5 |
| 6 | OZYEGİN UNIVERSITY | 26 | |
| 7 | IZMIR ECONOMY UNIVERSITY | 24 | |
| 8 | TOBB UNIVERSITY | 23 | 15 |
| 9 | HACETTEPE UNIVERSITY | 23 | 7 |
| 10 | DOGUS UNIVERSITY | 14 | |
| 11 | ISTANBUL TECHINCAL UNIVERSITY (ITU) | 12 | 6 |
| 12 | GALATASARAY UNIVERSITY | 11 | |

### 3.7. Keyword Analysis

WoS database includes two different types of keywords: Author Keywords and Keywords Plus. Articles discuss which of them is better. For example, according to Zhang et. al. (2015), while Keyword Plus yielded more keywords, author keywords better explained the content of the article. In this research, author keywords from 1998 through 2017 are used.

To analyze keywords, the keywords are first listed from author keyword database and spelling mistakes are corrected. Then, keywords with the same or similar meanings such as MCDM and Multi Criteria Decision Making or AHP and Analytic Hierarchy Process are identified. In addition, keywords like Heuristic, Heuristic Algorithm, Heuristic Algorithms, Heuristic Method, Heuristic Methods, Heuristic Optimization, Heuristic Search, Heuristics are basically the same areas of study used by different articles, so they are all changed to Heuristics. In the analysis, no keyword from any year have been eliminated. Keywords are only examined and changed, corrected or merged to have a common language among articles. After all of these types of changes are made, there were 83 keywords which were repeated more than 15 times. This is used to create the figure showing author keywords relationship diagram (Figure 7) produced with VOSviewer software downloaded from [11].

Tablo 9 depicts a partial list of the number of repetition of the keywords through years from 2000 to 2017. Frequency column sums the number of keywords starting from the year 1988. In this table, only keywords repeated 40 or more times are included.

There are 3 keywords which are repeated more than 100 times: Multi-Criteria Decision Making, Genetic Algorithm and Heuristics. When we compare the most repeated keywords in our studies and keywords in similar studies (e.g. Merigo & Yang, 2017 and Chang & Hsieh, 2008), the results show that there is not much difference between the keywords in the studies in Turkey

and the studies in other parts of the world. That is, the studies under OR / MS in Turkey have the similar keywords, sub research categories in the world. Artificial Neural Networks and Neural Networks has a tendency of high occurrences during the years 2009, 2010 and 2011. That result supports the common idea that, in academic life, there are some trendy subjects that researchers study heavily for a short period of time.

**Table 9.** Author keywords repeated more than 40 times (2000 – 2017)

| Keywords | Freq. | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Multi-criteria decision making | 136 | 12 | 6 | 15 | 7 | 8 | 12 | 17 | 14 | 14 | 9 | 3 | 5 | 5 | 1 | 2 | 0 | 1 | 0 |
| Genetic algorithm | 132 | 6 | 6 | 9 | 10 | 10 | 13 | 19 | 14 | 17 | 8 | 3 | 2 | 3 | 4 | 2 | 2 | 0 | 1 |
| Heuristics | 122 | 7 | 5 | 10 | 8 | 10 | 9 | 11 | 9 | 12 | 9 | 8 | 4 | 4 | 1 | 1 | 1 | 2 | 0 |
| Artificial neural networks | 95 | 2 | 3 | 1 | 4 | 4 | 6 | 18 | 14 | 27 | 4 | 7 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| Scheduling | 90 | 3 | 2 | 4 | 5 | 5 | 4 | 5 | 6 | 6 | 8 | 9 | 2 | 3 | 3 | 2 | 1 | 3 | 1 |
| Integer programming | 84 | 9 | 11 | 7 | 6 | 4 | 6 | 9 | 8 | 6 | 2 | 7 | 3 | 0 | 0 | 1 | 0 | 0 | 0 |
| Neural networks | 83 | 0 | 2 | 2 | 0 | 2 | 4 | 14 | 10 | 24 | 7 | 2 | 4 | 2 | 1 | 0 | 2 | 0 | 3 |
| Simulation | 72 | 4 | 4 | 5 | 2 | 3 | 4 | 5 | 10 | 9 | 6 | 3 | 1 | 1 | 0 | 1 | 3 | 0 | 1 |
| Optimization | 66 | 7 | 3 | 4 | 4 | 7 | 5 | 8 | 9 | 11 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 1 | 1 |
| Inventory | 63 | 6 | 2 | 5 | 9 | 5 | 4 | 3 | 2 | 7 | 5 | 3 | 3 | 1 | 0 | 1 | 0 | 2 | 1 |
| Supply chain management | 60 | 3 | 1 | 3 | 3 | 1 | 3 | 10 | 8 | 7 | 7 | 7 | 1 | 0 | 3 | 1 | 0 | 1 | 1 |
| Mixed integer programming | 56 | 9 | 5 | 3 | 6 | 7 | 3 | 4 | 5 | 3 | 1 | 4 | 3 | 0 | 0 | 0 | 0 | 1 | 0 |
| Analytic hierarchy process | 50 | 3 | 0 | 2 | 2 | 3 | 3 | 11 | 4 | 4 | 1 | 4 | 5 | 3 | 3 | 0 | 0 | 0 | 1 |
| Metaheuristics | 49 | 2 | 5 | 7 | 5 | 2 | 7 | 3 | 5 | 5 | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| Tabu search | 49 | 2 | 1 | 1 | 2 | 4 | 9 | 6 | 4 | 3 | 7 | 3 | 2 | 1 | 1 | 0 | 2 | 0 | 0 |
| Data mining | 47 | 4 | 1 | 1 | 5 | 3 | 9 | 8 | 5 | 5 | 0 | 1 | 3 | 1 | 0 | 1 | 0 | 0 | 0 |
| Dynamic programming | 44 | 5 | 3 | 5 | 2 | 6 | 2 | 4 | 4 | 2 | 3 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| Stochastic programming | 44 | 5 | 3 | 6 | 2 | 5 | 2 | 3 | 6 | 4 | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Branch and bound | 43 | 2 | 1 | 1 | 3 | 1 | 2 | 7 | 3 | 4 | 7 | 2 | 3 | 0 | 1 | 1 | 1 | 0 | 0 |
| Simulated annealing | 40 | 3 | 1 | 4 | 2 | 4 | 4 | 3 | 4 | 2 | 3 | 1 | 2 | 2 | 0 | 0 | 1 | 1 | 2 |
| Support vector machines | 40 | 2 | 0 | 2 | 1 | 1 | 4 | 3 | 9 | 14 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |

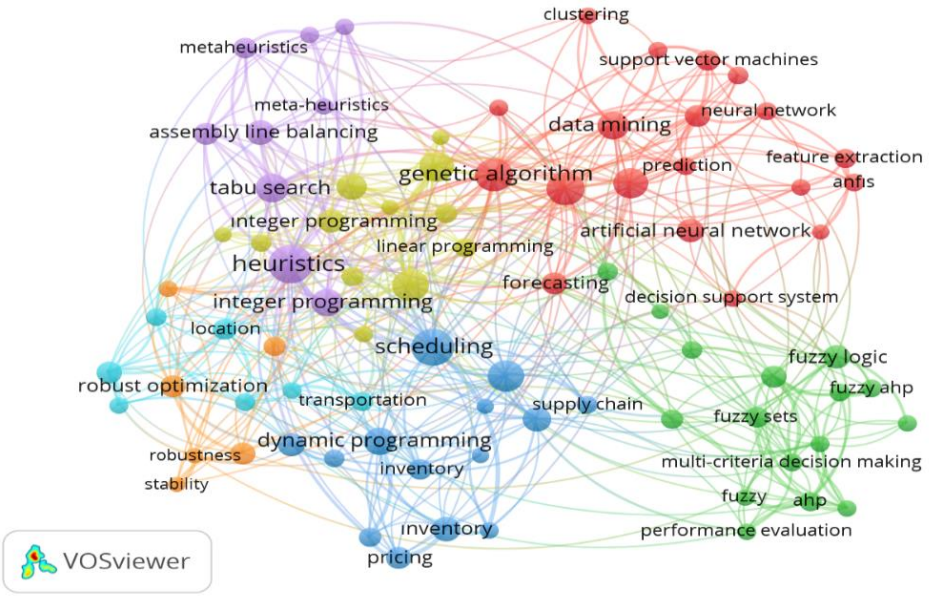


**Figure 7.** Author keywords relationship diagram produced with VOSviewer [11]

## 4. CONCLUSION

This paper provided a systematic bibliometric review of OR / MS studies in Turkey. Even though there are some bibliometric analysis on the OR / MS in the world, this study is the first

paper focusing on one specific country. In conclusion, along with the complete overview of the studies, some major and interesting results are also presented. Between 1980 and 2017, even though only 2.10 % of the papers have at least one author from Turkey, the rate is slightly increasing through years. However, after 2009, the number of papers decreases slightly. Based on the findings presented, it is expected that the number of articles in the field of OR / MS in Turkey and their impact will continue increasing in the next years.

Approximately 57% of these articles were published among the best journals in the field. The researchers have published articles mostly in the Expert Systems with Applications Journal with 791 articles (23% of all the articles made in this field). Average number of authors per article is found as 2,48. Average number of citations per paper is calculated as 19,46. The h-index for the analyzed papers is found as 90. A substantial portion of the studies (1570 articles - approximately 45% of the total articles) is written with joint efforts together with academicians working in foreign countries. The researchers in Turkey performed joint publications with the researchers working in the USA at the highest level (599; 17.4%).

The best two most productive institution in Turkey are Ihsan Dogramaci Bilkent University with 469 papers (13,7% of the total) and Middle East Technical University with 431 papers (12,6% of the total). Only limited numbers of the institutions published an important part of the papers (6 institutions published more 50 % of the papers). The results also revealed that the foreign university with which the academicians working at universities in Turkey cooperated at the highest level was the State University of Florida.

In the keyword analysis, it is also observed that the three keywords that frequently appeared in 2000 –2017 period are 'Multi-Criteria Decision Making', 'Genetic', are 'Heuristics'. When we compare the most repeated keywords in our studies and keywords in similar studies, the results show that there is not much difference between the keywords in the studies in Turkey or in other parts of the world. The results also support that, in academic life, there are some trendy subjects researchers study heavily for a short period of time.

The bibliometric approach used here has one major limitation and covers all the OR / MS studies published only in OR / MS journals. Indeed, Scholars do not necessarily publish their papers only in OR / MS journals which is indexed under WoS. However, there is no practical way of identifying all OR / MS articles published in other journals or indexed by Scopus, ProQuest etc.

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