

Research Article

Operations Research/Management Science Research in Europe: A Bibliometric Overview

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This paper provides a bibliometric analysis of the articles in the field of operations research or management science (OR/MS) published in the years 1980–2018 by European researchers. The analysis's objective is to identify and examine the current state of OR/MS studies in Europe, which publishes about 38% of the papers published worldwide. The analysis was based on the data from the Web of Science (WoS) databases. We found a total of 65,352 papers in 148 different journals in the OR/MS field. The results provide a general picture of the studies, which are classified according to the most influential authors, institutions, papers, and journals. The study revealed that the ratio of OR/MS studies having at least one European author has steadily increased over the decades from 28.27% in the 1980s to 41.29% in the 2010s. The analysis also provides citation statistics of the European OR/MS articles. The study concluded that the impact of European publications is less than the impact of U.S. publications. The bibliometric analysis of the studies showed that only a small portion of the countries/regions, institutions, and even authors published a substantial portion of the papers, as indicated by the Pareto rule. The research trends have been identified through an analysis of keyword usage over the years. In keyword analysis, which subcategories are studied together is also identified. In the paper, collaboration among countries and institutions is also identified and depicted by using VOS viewer.

1. Introduction and Literature Review

Operations research and management science (OR/MS) studies are considered an essential part of economic life because organizations are continually looking for the most efficient and productive ways of running their businesses. Therefore, the number of OR/MS studies has increased substantially over the last four decades [1]. Even though the initial OR/MS studies were mainly limited to specific regional areas such as the United States and the United Kingdom, the practice of operations research and management science has seen an enormous increase all over the world, including other developed countries, developing countries, and even underdeveloped countries.

Bibliometric analysis, motivated by the development of Internet and online databases, is receiving increasing

attention from the scientific community, and the number of bibliometric studies is increasing [2]. Several studies provided bibliometric analysis in many research areas, including OR/MS [1], project management [3], management [4], economics [5], supply chain management [6], and pricing research [7]. However, the number of papers presenting bibliometric analysis in OR/MS has been limited. Merigo and Yang [1] presented a bibliometric overview of research published in operations research and management science in recent decades. The paper's main objective was 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 (WoS) Database [1]. Laengle et al. [8] presented a bibliometric analysis in OR/MS to identify the most productive and influential universities between 1991 and 2015. The authors also collected the data from WoS

database; however, the analysis is limited to universities and the location of those universities. Chang and Hsieh [9] evaluated the distribution of papers published by Asian authors in OR/MS journals from 1968 to 2006. The authors also compared the impact of OR/MS research in Asia with that of the research in United States and the world. The study also highlighted research trends by analyzing keywords [9]. Bilir et al. [10] provided a bibliometric analysis of the articles in the field of OR/MS published between the years 1980–2017 by researchers from Turkey. The main objective of the analysis was to identify and examine the current state of OR/MS studies in Turkey. The authors also identified the current research trends through a keywords analysis. However, the study was limited to one country [10]. Laengle et al. [11] presented a general overview of the *European Journal of Operations Research* over its lifetime using bibliometric indicators. They discussed the performance of the journal compared to other journals in the field and identified key contributing countries/institutions/authors as well as trends in research topics. Even though that study provided valuable information about OR/MS studies, it was limited to papers published in the *European Journal of Operations Research*.

Our review revealed that there is no bibliometric study of OR/MS research in Europe even though there is one for the overall world and another study for Asia. To bridge that gap in the literature, in this paper, we aimed to provide a general overview of European OR/MS research over the last decades using bibliometric methods and compare the results of OR/MS research in Europe with that of the world and other regions. We used the WoS as the database for collecting information. Another objective is to identify the research trends in the field in Europe to understand the drivers of the development of European OR/MS studies and to compare the impact of OR/MS research in Europe with that of the United States and the world. Section 2 describes the bibliometric methodology we applied in the analysis. Section 3 contains the results of our analysis. Section 4 summarizes findings and provides suggestion for future research.

2. Methodology

To conduct the bibliometric study, we reviewed and analyzed articles available in the WoS databases, which comprise the Science Citation Index Expanded (SCI-Expanded), the Social Sciences Citation Index (SSCI), the Arts and Humanities Citation Index (A&HCI), the Science Citation Index (SCI), and the Emerging Science Citation Index (ESCI). The WoS database, which is owned by Thomson and Reuters, includes studies from a wide range of research areas (252 subject categories), one of which is OR/MS. In the first step, we selected the articles in that category. We then excluded publications from 2019 because that year is not yet complete. As articles from 1975–79 were very limited, we also excluded those years. The list thus included 299,822 publications, including articles, proceedings paper, reviews, and notes. To focus on the most influential of the publications, we selected only articles. Thus, we reduced the number of publications to 172,535, published in 160 different journals. Because we

included only articles in the WoS database, we did not exclude any journal from our analysis.

To further refine the selection, countries in Europe are selected to have a list of articles in which at least one author is from a European country, where a list of 65,352 articles is generated from 50 different countries, published in 148 different journals. In analyzing collaborating countries and keywords, we also used VOSviewer [12] (a scientific software tool for constructing and visualizing bibliometric networks).

3. Results

We present our research results in the following subsections: number of papers throughout the selected years in Europe compared with the world, leading journals, and most productive authors; citation statistics and most-cited articles; and most productive institutions, collaboration analysis, and keyword analysis.

3.1. Number of Papers. The number of papers published in a specific area is an important indicator in scientific research. To analyze the number of OR/MS papers in Europe, we present the number of papers published in the world and in Europe (Figure 1). The length of each bar represents the total number of papers published in the OR/MS category in the WoS database. The dark-colored bar represents the number of papers published in Europe, whereas the light-colored bar represents the number of papers published in the world. There is an upward trend in the number of papers in the OR/MS category starting from the 1980s whose slope increases further after 2003. The number of studies with at least one European author is 65,352 (37.88%). However, the ratio of European studies to studies worldwide has increased steadily over the decades, from 28.27% in the 1980s, to 32.76% in the 1990s, to 39.68% in the 2000s, and to 41.29% in the 2010s.

Figure 2 presents the number of OR/MS papers from the top 25 most productive countries/regions in the world. The results show that one-third of the papers (56,602) have at least one author from the United States. Although the United States dominates OR/MS studies, the ratio of studies from the United States has been decreasing slightly over the decades. China follows the United States with 21,683 studies (12.57%), followed in turn by the United Kingdom (6.84%), Canada (6.40%), France (5.03%), and Taiwan (4.93%). Thirteen of the top 25 most publishing countries/regions in OR/MS are European (Figure 2).

We also analyzed the number of papers from the top eight publishing countries in Europe and the development of the number of papers throughout the years in those countries (Figure 3) to identify how the number of papers from European countries changes between 1980–2018. Results showed that England is still the leading country in terms of the number of papers published each year; however, the number of papers published from French, German, and Italian researchers are close to the number published by English researchers in recent years. Another conclusion which may be drawn from the is that the number of papers published by researchers from Spain and Turkey was close to

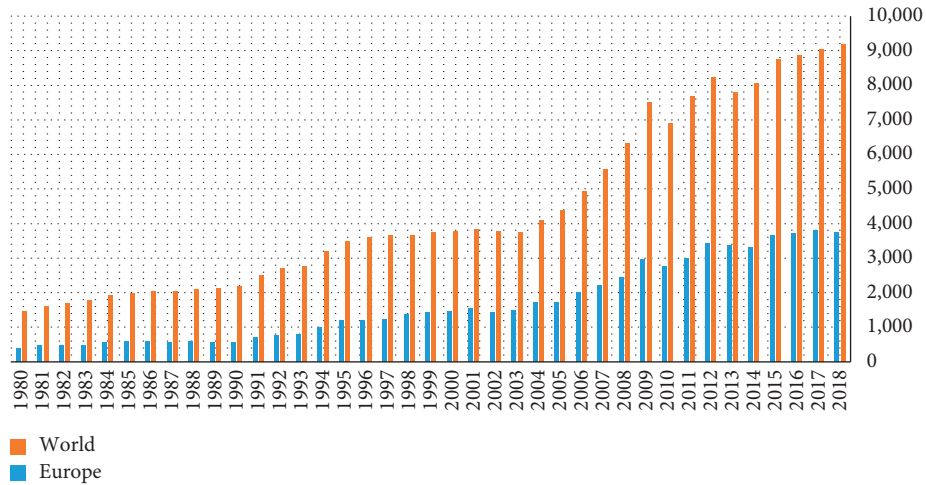


FIGURE 1: Number of papers in the OR/MS category (1980–2018).

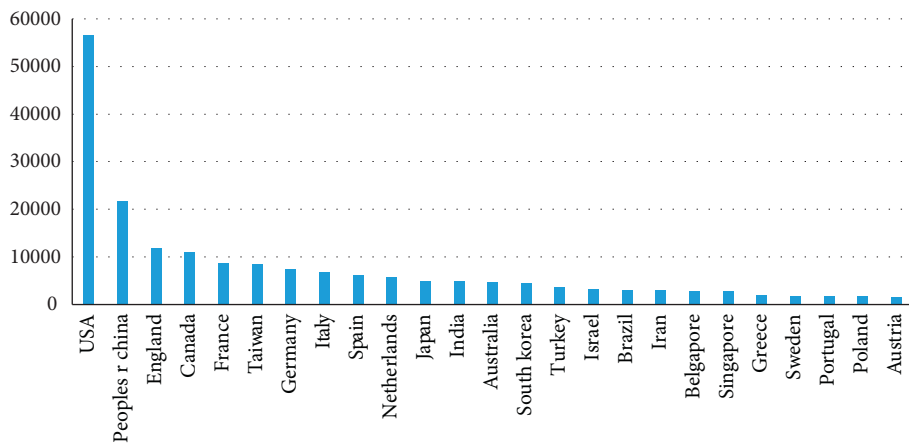


FIGURE 2: Number of OR/MS papers from the 25 most prolific countries/regions (1980–2018).

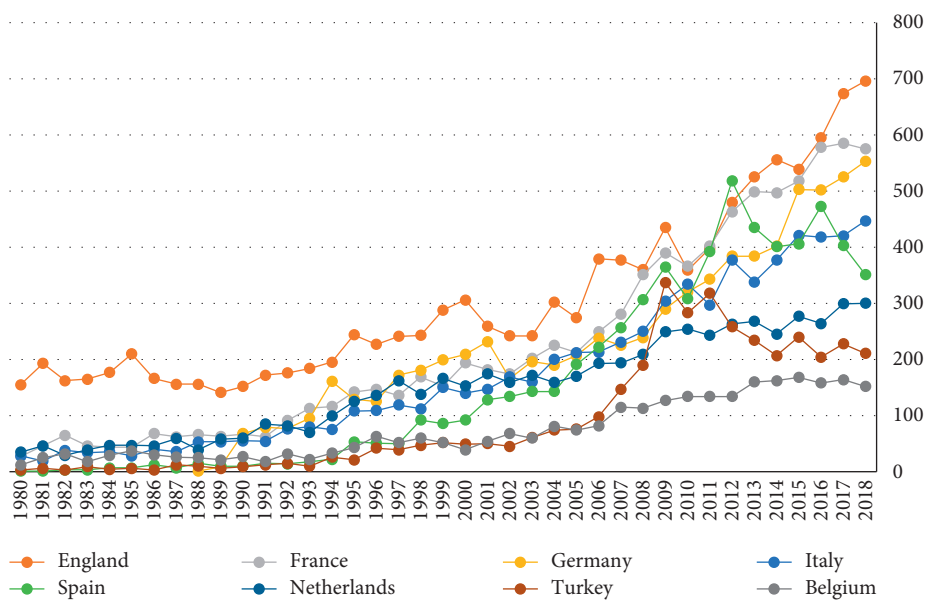


FIGURE 3: The number of papers from the eight top publishing countries/regions in Europe (1980–2018).

the number of papers published by the top publishing countries around 2010; however, the number of papers showed a rapid decline in recent years.

3.2. Leading Journals. Our detailed analysis of the 65,352 publications revealed that the researchers have published articles mostly in the *European Journal of Operational Research* (7,973 articles). The number of publications in this journal constitutes 12.2% of all the publications made in this field in Europe. *Expert Systems with Applications* (3,870; 5.9%), the *International Journal of Production Research* (2,906, 4.5%), the *International Journal of Production Economics* (2,782, 4.3%), and the *Journal of the Operational Research Society* (2,581; 3.9 %) were among the first five journals in which researchers published articles at the highest rates; 30.85% of the total publications appeared in those five journals.

However, Merigó and Yang's [1] analysis identified the three top journals for OR/MS publication as *Management Science*, *Operations Research*, and the *European Journal of Operations Research*. That study showed that researchers from European countries mainly preferred journals of European origin (especially the Netherlands, Germany, and the United Kingdom), more so than did researchers worldwide.

The journal with the highest h-index among those preferred by academicians was the *European Journal of Operational Research* (h-index: 211); the one with the lowest index value was the *International Journal of Technology Management* (h-index: 48). Our study has also revealed that 16 of the 25 most publishing journals are among the best 25% (Quartile 1) of the journals in the field. Table 1 shows the countries/regions in which the articles were published, the numbers of articles, and the proportion of these articles to all articles, their h-index information, the classification made by WoS, and the JRC 2016 Impact Factor values of the 25 journals in which European researchers mostly published.

3.3. Most Productive Authors. We ranked the most productive/influential authors both by number of papers and by number of citations. The author publishing the most papers in the OR/MS category in Europe was Enrico Zio from Politecnico Milano, having published 154 papers. The second-ranked author was Luk N. Van Wassenhove from INSEAD Business School, France, with 122 papers. Wassenhove had two different author name accounts with spelling differences in the WoS database that must be merged. Terje Aven from Stavenger University, Norway, attained the third rank with 116 papers. Table 2 presents most productive authors with their affiliation and number of published papers and ranks them by the total number of citations their papers have received. The most-cited author was Van Wassenhove with 9,684 citations. Van Wassenhove also has the highest H-index value (49), which shows that h number of papers have at least h number of citations. The second-ranked authors by number of citations were Rainer Storn and K. J. Price both from Siemens, Germany, even though they only had one paper in OR/MS.

3.4. Citation Statistics and Most-Cited Articles. By the end of 2018, OR/MS papers in the WoS database with at least one author from a European country had received 1,176,426 citations. We calculated the average number of citations per paper as 18.05. The average number of citations per paper for the articles published by U.S. researchers was 25.12. In comparing the two figures, someone might conclude that European publications had less impact than U.S. publications. Table 3 presents the average number of citations per paper for the top 15 publishing countries.

We also classified the OR/MS articles in the WoS database by the number of citations received. Thus, the articles that have received most attention by the scientific community have been identified (Table 4). Table 4 presents a list of the 20 most-cited articles from between 1980 and 2018 in OR/MS field in Europe. For each article, the table provides the name of the journal in which the article was published, the article's ranking, the total number of citations, the paper's title, the author(s)' name(s), the publication year, and the average number of citations per year.

The most-cited article is on a heuristic method for global optimization problems by R. Storn and K. Price in *Journal of Global Optimization* in 1997. The article received 9,057 citations so far. Then a study on asset stock accumulation comes with 3,215 citations by I. Dierickx and K. Cool in *Management Science* in 1989. Third rank is attained by a paper on communication networks by F. P. Kelly, Ak Maulloo, and D. K. H. Tan in the *Journal of the Operational Research Society* in 1998 with 2,689 citations. As seen in the table, four of the most-cited 20 papers appeared in *Management Science* and in the *European Journal of Operations Research* respectively.

3.5. Most Productive Institutions. Twenty institutions in Europe produced more than 500 papers during the years analyzed. The most productive institution in Europe in this field is the Centre National De La Recherche Scientifique, France with 2,492 papers (3.8% of the total). Other institutions with more than 1,000 papers are the Universite Paris Saclay Comue, France and Eindhoven University of Technology, Netherlands. Table 5 lists the top 20 institutions, their number of papers, and the percentage of the total. The results show that around one-fourth of the papers are published by only 20 institutions, 15 of which are located in only three countries: the United Kingdom, Netherlands, and France.

3.6. Collaboration Analysis. As part of the bibliometric analysis, we investigated the collaboration among authors and the collaboration among countries in the field of OR/MS studies in Europe. First, we analyzed how the average number of authors changed from 1980 through 2018. Then, we presented the most collaborated countries within Europe and non-European countries collaborating with European researchers.

In the analyzed papers, the average number of authors per article was 2.52. Figure 4 provides a graph showing the distribution of average number of authors per article over

TABLE 1: Most publishing 25 journals in OR/MS in Europe (1980–2018).

Rank	Journal name	Country/ Region	# of articles	% of total	H- index	Quartile	JCR 2016 impact factor
1	European Journal of Operational Research	Netherlands	7,973	12.2%	211	Q1	3.428
2	Expert Systems with Applications	United States	3,870	5.9%	145	Q1	3.768
3	International Journal of Production Research	United Kingdom	2,906	4.5%	107	Q1	2.623
4	International Journal of Production Economics	Netherlands	2,782	4.3%	141	Q1	4.407
5	Journal of the Operational Research Society	United Kingdom	2,581	3.9%	87	Q3	1.225
6	Reliability Engineering System Safety	Netherlands	2,258	3.5%	112	Q1	1.666
7	Journal of Optimization Theory and Applications	United States	2,131	3.3%	74	Q3	1.234
8	Systems & Control Letters	Netherlands	2,069	3.1%	117	Q1	2.656
9	Annals of Operations Research	Netherlands	2,011	3.1%	86	Q2	1.864
10	Computers & Operations Research	United Kingdom	2,008	3.1%	124	Q1	2.962
11	Safety Science	Netherlands	1,681	2.6%	81	Q2	2.835
12	International Journal of System Science	United Kingdom	1,588	2.4%	59	Q2	2.185
13	Mathematical Programming	Germany	1,392	2.1%	99	Q1	2.490
14	Operations Research Letters	Netherlands	1,123	1.7%	63	Q4	0.643
15	Management Science	United States	1,093	1.7%	209	Q1	2.822
16	Journal of Global Optimization	Netherlands	1,075	1.6%	70	Q2	1.407
17	OMEGA-International Journal of Management Science	United Kingdom	1,024	1.6%	108	Q1	4.311
18	International Journal of Technology Management	United Kingdom	1,020	1.6%	48	Q2	0.410
19	Technovation	United Kingdom	964	1.5%	102	Q1	2.010
20	Production Planning & Control	United Kingdom	930	1.4%	61	Q1	2.330
21	Transportation Research Part B: Methodological	United Kingdom	810	1.2%	107	Q1	3.110
22	Mathematics of Operations Research	United States	753	1.2%	67	Q1	1.270
23	Decision Support Systems	Netherlands	742	1.1%	115	Q1	3.565
24	International Journal of Computer Integrated Manufacturing	United Kingdom	731	1.1%	44	Q2	1.995
25	IEEE Networks	United States	715	1.1%	106	Q1	1.500

time. The average number of authors for the year 2018 was about 3.1, whereas in 1979, it was 1.45. The results show that collaboration among authors increased steadily over time. This implies that researchers in the field have been collaborating more and more through the years.

Table 6 provides detailed statistics relating to the number of authors per article. More than 34% of the articles were written by two authors, around 27% of the articles were written by three authors, and around 20% of the articles were single-author papers. The maximum number of authors per article was 22. Only 54 articles in the OR/MS field had 10 or more authors in Europe.

We also used data retrieved from the WoS database to show the number of different countries involved in collaborative research articles. In Table 7, first the number of countries whose researchers collaborated on an article was calculated, with the percentage of each listed. That is, 62.65% of the articles had authors from only one country, 28.54% of the articles had authors from two different countries, 7.20% of the articles had authors from three different countries, and so on.

We also analyzed the data to calculate the number of articles between (or among) collaborating countries/regions (Table 8) using the address field in the data retrieved to define collaborating countries/regions. The most collaboration occurred between British and Chinese authors with 482 articles. This is followed by Turkish and American authors with 450 articles. The United States was the most likely to collaborate with European countries in the field of OR/MS.

We also examined collaborations between European and non-European authors. Table 9 lists only non-European countries with more than 500 authors. The United States took first place with 6,227 articles (9.5%), followed by China (2,293 articles, 3.5%) and Canada (2,006 articles, 3.1%).

We also used collaboration data to depict the relationships between the countries of collaborating authors with VOSviewer, a bibliometric network visualization tool (VOSviewer Visualizing scientific landscapes) to create “Collaborated Countries/Regions Relationship Diagram,” as shown in Figure 5. In Figures 5 and 6, the size of the

TABLE 2: Most productive authors in OR/MS in Europe (1980–2018).

Sorted by number of papers				Sort by total citations				Institution	H-index	
Rank	Authors	Papers	Institutions	Rank	Author	Papers	Citations			Citation per paper
1	Zio, Enrico	154	Politecnico Milano	1	Van Wassenhove, Luk N.	122	9,681	79.35	Insead Business School	49
2	Van Wassenhove, Luk N.	122	Insead Business School	2	Storn, Rainer	1	9,057	9057	Siemens, Germany	1
3	Aven, Terje	116	Stavanger University	3	Price, K.	1	9,057	9057	Siemens, Germany	1
4	Puerto, Justo	111	University of Seville	4	Beasley, John E.	72	5,882	81.69	Brunel University	35
5	Speranza, M. Grazia	108	University of Brescia	5	Toth, Paolo	98	4,636	47.31	University of Bologna	39
6	Dolgui, Alexandre	101	Centre National De La Recherche Scientifique	6	Potts, Chris N.	80	4,248	53.10	University of Southampton	33
7	Dekker, Rommert	99	Erasmus University Rotterdam	7	Zio, Enrico	154	3,904	25.35	Politecnico Milano	34
8	Toth, Paolo	98	University of Bologna	8	Dekker, Rommert	99	3,703	37.40	Erasmus University Rotterdam	32
8	Woeginger, Gerhard J.	98	Rwth Aachen University	9	Pisinger, David	67	3,599	53.72	University of Copenhagen	29
10	Hartl, Richard F.	87	University of Vienna	10	Fischetti, Mateo	80	3,586	41.66	University of Padua	34
11	Fischetti, Mateo	86	University of Padua	11	Cool, Karel	2	3,484	1742	Insead Business School	2
12	Chu, Chengbin	85	Universite Paris Saclay	12	Dierickx, Ingemar	2	3,484	1742	Insead Business School	2
13	Bruneel, Herwig	83	Ghent University	13	Slowinski, Roman	58	3,029	52.22	Poznan University of Technology	29
14	Carrizosa, Emilio	82	Lancaster University	14	Kelly, FP	11	2,953	268.45	University of Cambridge	8
15	Potts, Chris N.	80	University of Southampton	15	Yang, Jian-Bo	66	2,892	43.82	University of Manchester	28
15	Escudero, Laureano F.	80	Universidad Rey Juan Carlos	16	Disney, Stephen M.	56	2,854	50.96	Cardiff University	27
17	Dallery, Yves	79	Universite Paris Saclay	17	Wolsey, Laurence A.	75	2,829	37.72	Catholic University of Louvain	30
18	Marti, Rafael	78	University of Vallencia	18	Kahraman, Cengiz	36	2,756	76.56	Istanbul Technical University	27
19	Boysen, Nils	77	Friedrich Schiller Univ Jena	19	Aven, Terje	116	2,751	23.72	Stavanger University	31
20	Kovalyov, Mikhail Y.	76	University of Siegen	20	Speranza, M. Grazia	108	2,640	24.44	University of Brescia	27

circle for each country/region represents the number of collaborative studies, and the thickness of links represents the number of studies between collaborating countries. The figures show that the top publishing countries in Europe have a large number of collaborations with the United States and that the United Kingdom has a relatively higher ratio of collaboration with China. Another result evident from the figure is that some pairs of countries (such as the United Kingdom and France or Germany and France, etc.)

have relatively higher numbers of collaborations. The figure also shows that European countries collaborated with non-European countries as well as they did with European countries.

VOSviewer also allowed us to highlight the strength of collaboration between one selected country and other countries by pointing to that selected country with the mouse. Figure 6 shows countries collaborating with British researchers. The thickness of links indicates that British

TABLE 3: Top publishing countries/regions in Europe-citation statistics (1980–2018).

Country/Region	Number of papers	Total number of citations	Citation per paper
England	11,801	224,415	19.02
France	8,670	152,380	17.58
Germany	7,404	130,028	17.56
Italy	6,758	116,354	17.22
Spain	6,147	98,771	16.07
Netherlands	5,813	110,473	19.00
Turkey	3,645	76,701	21.04
Belgium	2,836	70,460	24.84
Greece	2,036	36,737	18.04
Sweden	1,865	32,884	17.63
Poland	1,771	26,101	14.74
Portugal	1,768	31,532	17.83
Austria	1,544	26,113	16.91
Switzerland	1,481	32,200	21.74
Norway	1,472	27,610	18.76
Finland	1,462	28,393	19.42

TABLE 4: Most-cited articles in OR/MS in Europe (1980–2018).

Rank	Title	Authors	Journal	Publication year	Total citations	Average per year
1	Differential evolution-A simple and efficient heuristic for global optimization over continuous spaces	Storn, R; Price, K	<i>Journal of Global Optimization</i>	1997	9,057	411.68
2	Asset Stock Accumulation and Sustainability of Competitive Advantage	Dierickx, I; Cool, K	<i>Management Science</i>	1989	3,215	107.17
3	Rate control for communication networks: shadow prices, proportional fairness and stability	Kelly, FP; Maulloo, AK; Tan, DKH	<i>Journal of the Operational Research Society</i>	1998	2,689	128.05
4	A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm	Karaboga, Dervis; Basturk, Bahriye	<i>Journal of Global Optimization</i>	2007	2,313	192.75
5	Thermodynamical Approach to the Traveling Salesman Problem-An Efficient Simulation Algorithm	Cerny, V	<i>Journal of Optimization Theory and Applications</i>	1985	1,560	45.88
6	A Procedure for Ranking Efficient Units in Data Envelopment Analysis	Andersen, P; Petersen, NC	<i>Management Science</i>	1993	1,365	52.50
7	Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS	Opricovic, S; Tzeng, GH	<i>European Journal of Operational Research</i>	2004	1,226	81.73
8	Adapted Solution of a Backward Stochastic Differential Equation	Pardoux, E; Peng, SG	<i>System & Control Letters</i>	1990	1,092	37.66
9	Benchmarks for Basic Scheduling Problems	Taillard, E	<i>European Journal of Operational Research</i>	1993	1,053	40.50
10	Arcs of integration: an international study of supply chain strategies	Frohlich, MT; Westbrook, R	<i>Journal of Operations Management</i>	2001	962	53.44
11	OR-Library – Distributing Test Problems by Electronic Mail	Beasley, JE	<i>Journal of the Operational Research Society</i>	1990	957	33.00
12	In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition	Cassiman, B; Veugelers, R	<i>Management Science</i>	2006	925	71.15

TABLE 4: Continued.

Rank	Title	Authors	Journal	Publication year	Total citations	Average per year
13	An effective implementation of the Lin-Kernighan traveling salesman heuristic	Helsgaun, K	European Journal of Operational Research	2000	925	48.68
14	Smooth minimization of non-smooth functions	Nesterov, Y	Mathematical Programming	2005	883	63.07
15	Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators	Jansen, Justin J. P.; Van den Bosch, Frans A. J.; Volberda, Henk W.	Management Science	2006	880	67.69
16	AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models	Fournier, David A.; Skaug, Hans J.; Ancheta, Johnnoel; Ianelli, James; Magnusson, Arni; Maunder, Mark N.; Nielsen, Anders; Sibert, John	Optimization Methods & Software	2012	878	125.43
17	How to Select and How to Rank Projects–The Promethee Method	Brans, JP; Vincke, P; Mareschal, B	European Journal of Operational Research	1986	850	25.76
18	A new discrete-time robust stability conditions	de Oliveira, MC; Bernussou, J; Geromel, JC	System & Control Letters	1999	847	42.35
19	Linearization by Output Injection and Non-linear Observers	Krener, AJ; Isidori, A	System & Control Letters	1983	830	23.06
20	Robust Optimization of Large Scale Systems	Mulvey, JM; Vanderbei, RJ; Zeinos, SA	Operations Research	1995	826	34.42

TABLE 5: Most productive institutions OR/MS in Europe (1980–2018).

Institutions	Country/Region	Number of papers	% of total
Centre National De La recherche scientifique	France	2,492	3.8
Universite paris saclay comue	France	1,156	1.8
Eindhoven University of technology	Netherlands	1,125	1.7
University of london	United Kingdom	888	1.4
Erasmus University rotterdam	Netherlands	884	1.4
INRIA	France	821	1.3
Ku leuven	Belgium	721	1.1
Delft University of technology	Netherlands	717	1.1
Polytechnic University of milan	Italy	707	1.1
University of manchester	United Kingdom	702	1.1
University of southampton	United Kingdom	691	1.1
Imperial college london	United Kingdom	660	1.0
University of sevilla	Spain	649	1.0
University of Bologna	Italy	641	1.0
Universidade De lisboa	Portugal	610	0.9
Tilburg University	Netherlands	608	0.9
Universite paris saclay	France	604	0.9
University of warwick	United Kingdom	590	0.9
University of twente	Netherlands	577	0.8
Lancaster University	United Kingdom	557	0.8

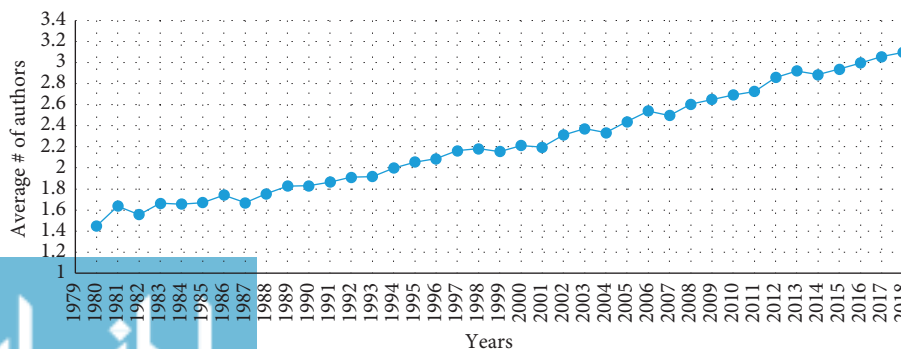


FIGURE 4: Number of authors per article.

TABLE 6: Total number of authors per article.

Number of authors	Total number of articles	Percentage of the total (%)
1	12,377	20.3
2	21,005	34.4
3	16,671	27.3
4	7,620	12.5
5	2,265	3.7
6	728	1.2
7	228	0.4
8	88	0.1
9	42	0.1
≥10	54	0.1

TABLE 7: Number of different countries collaborating on a given article.

# of different Country(ies)/Region(s) (in an article)	% of articles
1	62.65
2	28.54
3	7.20
4	1.34
5 or more	0.27

TABLE 8: Top collaborating countries/regions.

Collaborating countries/Regions	# of articles
United Kingdom, People’s Republic of China	482
Turkey, United States	450
France, United States	417
United Kingdom, United States	396
France, Italy	385
Germany, United States	343
Italy, United States	292
Netherlands, United States	281
France, Canada	265
Spain, United States	234
France, People’s Republic of China	182
United Kingdom, Germany	162
United Kingdom, People’s Republic of China, Hong Kong	143

TABLE 9: Number of articles written in collaboration with non-European countries.

Countries/Regions	Number of articles	% of articles
United States	6,227	9.5
People’s Republic of China	2,293	3.5
Canada	2,006	3.1
Australia	860	1.3
Brazil	673	1.0

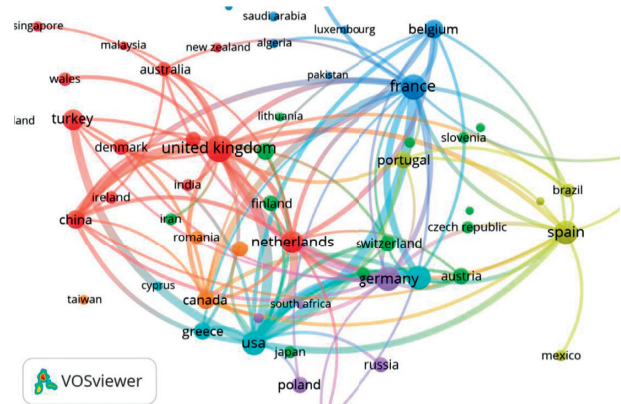


FIGURE 5: Collaboration relationships between countries/regions.

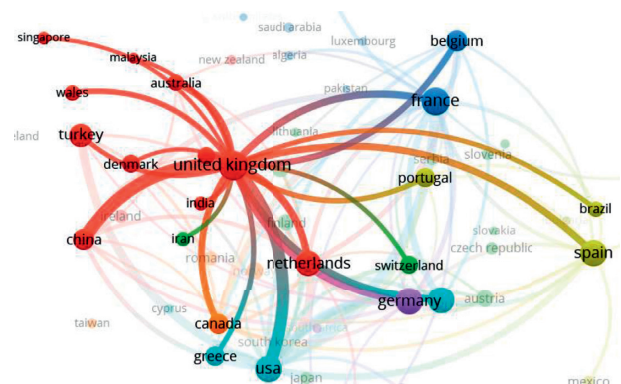


FIGURE 6: Collaborations of British authors.

authors collaborated most often with Chinese (482 articles) and American (396 articles) authors.

3.7. *Keyword Analysis.* The WoS database includes two different types of keywords: “Author Keywords” and “Keywords Plus.” Some articles discuss which of them is better (e.g., [13]). While “Keyword Plus” yielded more keywords, “Author Keywords” better explained the content of the article because the author(s) selected them specifically. This research analyzed and included “Author Keywords” from 1990 through 2018 in the resulting tables.

To do the keyword analysis, we first retrieved the author keywords from the WoS database and corrected spelling mistakes. Later, we changed some British spellings of words to American English, such as optimization and optimization. We deleted dashes or spaces that we thought unnecessary (e.g., “multiobjective” or “multiobjective” to “multiobjective”) and examined in detail keywords repeated more than five times. Then, we identified and merged keywords with the same or similar meanings, such as “MCDM” and “Multi Criteria Decision Making” or “AHP” and “Analytic

TABLE 10: Distribution of the most repeated keywords by year (between 1990 and 2018).

Keywords	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Freq.
Multiojective optimization	2	13	15	14	20	28	25	25	30	43	42	35	47	47	60	48	62	87	83	106	97	123	115	105	98	146	119	130	135	1900
Heuristics	3	19	13	18	26	31	44	33	57	42	36	29	56	55	50	60	61	85	77	81	71	78	83	84	70	90	88	82	65	1587
Scheduling	3	16	15	16	28	28	42	21	46	37	38	42	43	33	51	70	57	83	90	79	78	81	84	89	67	93	70	95	82	1577
Simulation	0	7	11	9	10	21	26	26	29	31	32	28	29	31	41	36	37	55	55	74	69	65	69	57	51	77	52	67	71	1166
Optimization	1	13	15	13	18	26	20	20	30	22	36	28	35	19	28	25	44	33	44	67	53	61	72	66	40	70	73	79	90	1141
Supply chain management	0	0	0	0	0	7	3	3	3	7	12	24	35	32	49	30	42	59	60	70	63	74	89	78	66	66	60	84	87	1103
Genetic algorithms	0	0	0	1	1	7	14	11	15	19	17	12	18	19	30	27	32	50	45	72	54	65	73	68	42	66	49	42	57	906
Data envelopment analysis	1	3	2	2	5	14	20	13	10	20	16	28	12	14	33	33	25	29	21	56	52	41	62	51	58	68	55	74	91	909
Integer Programming	2	6	16	6	8	15	9	10	29	14	15	22	25	15	30	15	39	38	36	44	44	50	56	32	47	55	69	51	79	877
Decision support systems	2	9	12	11	24	13	13	25	28	19	23	24	21	25	22	24	40	33	25	49	36	28	46	44	32	50	55	56	45	834
Combinatorial optimization	0	4	4	4	8	8	8	17	17	10	14	13	15	16	22	28	40	34	38	47	31	39	46	56	40	57	36	60	45	757
Dynamic programming	0	5	8	12	16	12	15	22	18	16	27	17	13	23	8	17	24	28	36	42	31	33	31	45	39	44	33	39	45	699
Linear programming	1	10	26	18	22	16	19	23	16	27	24	20	19	25	22	20	24	27	25	29	24	21	32	22	26	30	42	29	20	659
Optimal control	1	11	10	5	8	10	11	16	18	20	16	22	20	23	19	16	25	23	18	26	35	25	41	34	33	29	41	46	50	652
Branch and Bound	1	6	7	7	8	14	19	13	29	21	22	17	11	17	20	19	19	29	44	28	24	25	27	36	29	20	30	33	30	605
Inventory	0	3	7	4	4	7	18	13	14	24	16	18	8	16	14	26	33	32	26	28	19	27	28	45	34	30	29	40	35	598
Global optimization	0	6	3	15	18	9	11	18	14	16	20	17	15	14	18	21	19	24	26	40	34	19	28	35	23	25	33	36	34	591
Tabu Search	0	3	0	1	6	7	16	9	27	16	13	10	17	12	16	25	17	24	39	35	29	30	44	27	24	22	20	18	9	516
Stochastic programming	0	1	4	2	1	3	9	14	14	11	16	13	12	9	14	18	15	31	24	40	26	29	43	23	25	37	34	38	51	557
Metaheuristics	0	0	0	0	0	0	2	0	1	5	3	5	8	7	18	18	26	30	25	41	29	31	49	44	27	41	32	59	24	525

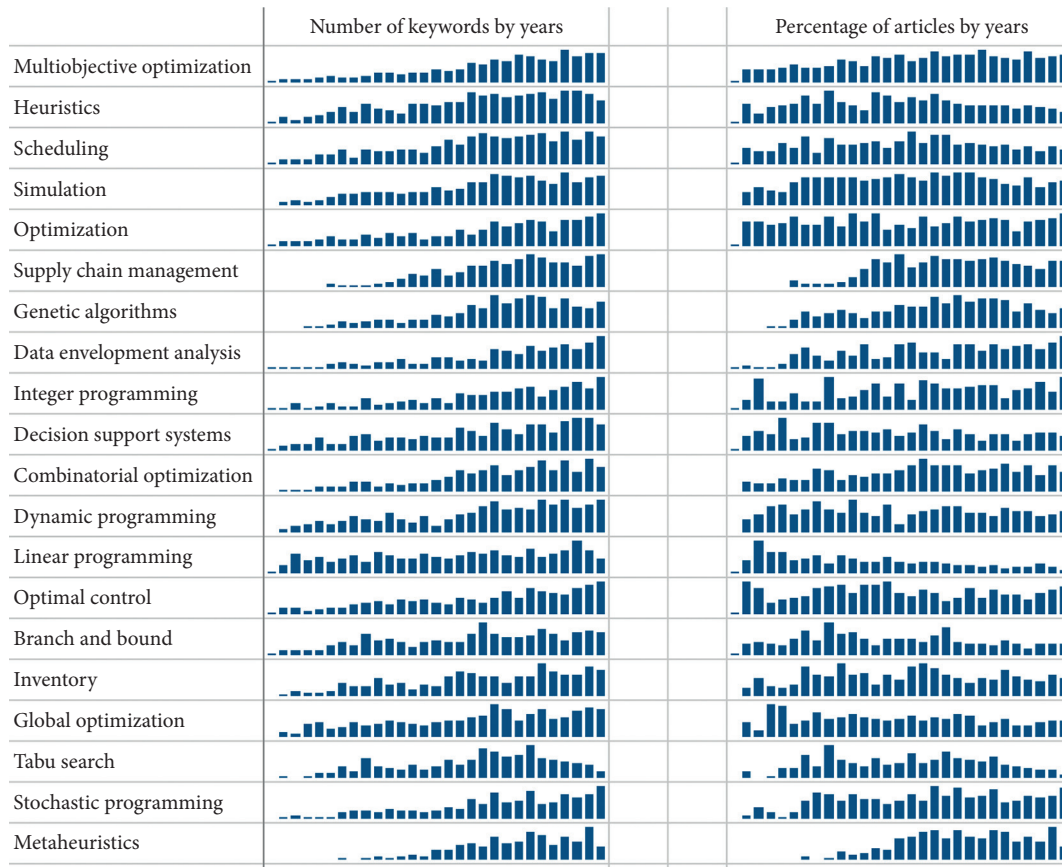


FIGURE 7: Mini column graphics of most repeated keywords.

Hierarchy Process.” In addition, we identified similar keywords with same the meaning, such as “Heuristic,” “Heuristic Algorithm,” “Heuristic Algorithms,” “Heuristic Method,” “Heuristic Methods,” “Heuristic Optimization,” “Heuristic Search,” and “Heuristics.” They were basically the same areas of study used by different articles, so we changed them all to Heuristics. In the analysis, we eliminated no keywords; we only examined them and changed, corrected, or merged them to maintain a common language among articles.

Table 10 depicts a list of the number of repetitions of the top 20 keywords, repeated 500 or more times between the years 1990 and 2018 (inclusive). The most repeated keyword is “Multiobjective Optimization” (1,900 times), followed by “Heuristics” (1,587 times) and “Scheduling” (1,577 times). The table also shows how the number of appearances of each keyword changed throughout the years analyzed.

We then generated mini column graphics based on numbers of keywords and on percentage of each keyword, calculated by dividing the number of keywords into the number of articles each year. Figure 7 shows these mini column graphics. The mini graphics show that the frequency of “Multiobjective Optimization” increased in interest over the years studied. Although the frequency increased slightly percentagewise, it did not increase as much as did the keyword frequency. Almost no interest existed for “Supply Chain Management” before 2000 or for “Metaheuristics”

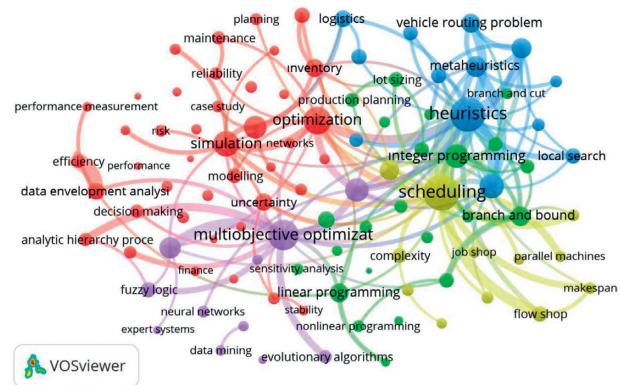


FIGURE 8: Keywords relationship diagram.

before 2004. Considering the number of keywords by years in number, we can conclude that no substantial change in the number of articles with the keyword “Linear Programming” existed. However, the trend for the percentages of articles through the years with the keyword “Linear Programming” decreased.

When we compare the most repeated keywords in our study and keywords in similar studies (e.g., [1, 9], we do not find much difference between the keywords in the studies in Europe and the studies worldwide or in Asia. That is, the European OR/MS studies have similar keywords and

has been done on OR/MS studies worldwide, this study is the first paper to focus on Europe, which publishes about 38% of the papers published worldwide in the analyzed subject. In conclusion, along with the complete overview of the studies, we also present some major and interesting results. Our analysis revealed that the ratio of OR/MS studies having at least one European author has steadily increased over the decades from 28.27% in the 1980 s, to 32.76% in the 1990 s, 39.68% in the 2000 s, and 41.29% in the 2010 s. Thus, we expect the number of articles in the field of OR/MS in Europe and their impact will continue to increase for the foreseeable future. In addition, thirteen out of the top 25 most publishing countries are European.

Approximately 65% of the analyzed articles were published in the top 25% of the journals in the field. The researchers mostly published articles in the *European Journal of Operational Research* (7,973; 12.2%), *Expert Systems with Applications* (3,870; 5.9%), the *International Journal of Production Research* (2,906, 4.5%), the *International Journal of Production Economics* (2,782, 4.3%), and the *Journal of the Operational Research Society* (2,581; 3.9%) were among the top five journals in which researchers published at the highest rates; 30.85% of the total publications appeared in those five top journals. The analysis also revealed that the preferences of European researchers differ from the non-European researchers. Researchers from European countries mainly preferred to publish in journals of European origin.

We calculated the average number of citations per paper as 18.05. Compared with the average number of U.S. citations in the same subject (25.12), we have concluded that the impact of European publications is less than the impact of U.S. publications. However, even in Europe, that ratio varied from author to author, from institution to institution, and, surprisingly, from country to country.

Our bibliometric review revealed that substantial portions of the studies were written as joint efforts with academicians working in other countries, either within Europe or outside Europe. The increasing number of average authors per article implies that the researchers in the field have been collaborating more and more through years. In the analyzed papers, the most frequent collaboration occurred between British and Chinese authors (482 articles), followed by Turkish and American authors with 450 articles. European authors collaborated the most with American authors (6,227 articles), followed by European authors collaborating with Chinese authors (2,293 articles). The collaboration analysis results also showed that European researchers collaborated with non-European countries as much as with European countries in the field of OR/MS.

Analysis on the most productive institutions revealed that 20 institutions produced more than 500 papers during the years under study. The results also show that one-fourth of the papers were published by only 20 institutions. Analysis of the papers showed that only a small portion of the countries, institutions, and even authors published a substantial portion of the papers in the field of OR/MS in Europe, as indicated by the Pareto rule.

The keyword analysis indicated that the three keywords that frequently appeared in 2000–2018 were “Multiobjective optimization,” “Heuristics,” and “Scheduling.” When we compared the most repeated keywords in our studies with keywords in similar studies, the results did not show much difference between the keywords in the European studies and those from other parts of the world. The results also support that, in academic life, some trendy subjects are heavily studied for a short period of time.

The bibliometric approach used in our study has one major limitation: it examined the OR/MS studies published only in OR/MS journals. Indeed, scholars do not necessarily publish their papers only in OR/MS journals indexed under the WoS. However, no practical way exists for identifying all OR/MS articles published in other journals or indexed by Scopus, ProQuest, or other indices.

Data Availability

The data used in the analysis are open to public who have access to Web of Science databases. We can also provide the data we gathered from WOS databases upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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