

Visualizing the knowledge domain of Operations Research and Management Science in Africa: a bibliometric analysis

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Abstract

The bibliometric analysis is the employment of quantitative tools to study a literature review of scientific domain. As a field, the Operations Research and Management Science has become a well-established area of study and practice in both developed and developing countries. The main objective of this study is to provide an objective global view of the application of Operations Research and Management Science in Africa and to identify the major research lines that constitute the intellectual structure of the discipline. Therefore, this paper affords a bibliometric review of Operations Research and Management Science works published by African authors by analyzing bibliographic records downloaded through the Web of Science for the period from 1988 to 2018.

Keywords: bibliometrics, co-citation analysis, intellectual structure.

I. INTRODUCTION

For many decades, the Operational Research and Management Science (OR-MS), the science of the optimum solutions as it was defined by The Institute for Operations Research and Management Sciences (INFORMS), has certainly become a well-established domain of study and practice. It has been used to solve real-world issues and to ameliorate the decision-making. In addition, the OR-MS has contributed in increasing the productivity and profitability of several organizations in the whole world and thus improving the efficiency of the economy in various countries. This made the OR-MS as the one of career fields developing rapidly for US college graduates [1]. Furthermore, this discipline has seen a noteworthy development in the scientific community and become a strand of work for a lot of professional societies. Indeed, it was presented as a topic for important conferences. For instance, we can mention The International Federation of Operational Research Societies (IFORS), an

organization integrating different national operations research societies of over 45 countries from three geographical regions that are: America, Europe and Asia Pacific. Another important event was the foundation of regional associations such as the African Federation of Operations Research Societies (AFROS) that cover a whole continent. This AFROS integrates African operations research societies such as the Institute for Operations Research of Nigeria (INFORN), The Operations Research Society of South Africa (ORSSA), Operational Practice in Africa (ORPA) and the Tunisian Operational Research Societies (TORS). As there is a notable amount of interest in the potential for applying OR-MS in African countries, AFROS has as goal to favor the augmentation in the use of OR-MS as a practical tool for several issues in Africa.

In the literature, several publications have appeared reviewing the employment of OR-MS field using two different methods. The first one is based on the classic qualitative survey. A literature review of the researchers' participation in OR-MS field was

generated in [1] for sixty years of experiences, however, this practice was described in only developing countries by [3] and in South Africa particularly by [4]. Chopra [5] has provided an overview of the past accomplishments of the OR-MS and the prospects ahead for five decades. Similar, other classic overviews were generated dealing with a lot of fundamental subjects of OR-MS discipline in EJOR[6], OR[7], JORS[8] and many other journals. In addition to the studies using this classic subjective survey to review the application of OR-MS, there are others quantitative overview that have been undertaken on several OR-MS topic using statistical and bibliometric analysis. Reisman & Kirschnick [9] have reviewed the evolution of the OR-MS by analyzing the contents of three journals in the US, Management Science, Operations Research and Interfaces. Kao [10] has surveyed 56 OR-MS journals while focusing on the intervention of the different countries in the production of the OR-MS studies. However, Chang & Hsieh [11] have chosen to analyze the state of OR-MS in only one region, continent of Asia. Author studies have chosen to stress other issues than the countries and journals encompassing the analysis of the institutions participating to the INFORMS practice literature [12] and the journal citations behavior in OR-MS [13-14].

To the best of our knowledge, very few publications are available in the literature that address the practice of OR-MG in Africa, including the study of Smith [15] that has provided a systematic bibliography for west Africa usage of OR-MS and Stewart [16] that has revealed some challenges to the practice of OR-MS in South Africa. However, none of these papers have created a systematic bibliography for all countries in Africa while indicating the major research trends of the discipline.

Therefore, this paper is an attempt at presenting a bibliometric overview of OR-MS practice in Africa in order to generate a global objective view of the field. In addition, we endeavor to evaluate the distribution of documents published by African authors and to investigate the theoretical foundations and core cited documents that constitute the intellectual structure of this knowledge domain. This paper analyzes bibliographic records gathered through the Web of Science (WOS) from 1988 to 2018 using some bibliometric approaches.

II. MATERIALS AND METHODOLOGY

Differing from the methods of narrative survey, this work adopts bibliometric analysis in order to perform a quantitative literature review. White and McCain [17] have indicated that bibliometric is "the quantitative study of literatures as they are reflected in bibliographies". This bibliometric has two main uses: the performance analysis to assess the research papers performance of individuals and institutions and the science mapping for revealing the intellectual structure of a scientific field [18].

Analyzing research works required the extraction of the data from the Web of Sciences Core Collection (WoSCC). This leading WoSCC database is a source of high quality and multidisciplinary research information [19]. It is available online through the Thomson Reuters produced by the Institute for Scientific Information. With the intention of assessing the scientific advance of the OR-MS knowledge domain in all Africa countries, we choose to use "Operations Research & Management Science" as "SU: Research Area" and a total of 54 African countries as "CU: Country/Region" keywords for our search query for timespan "all years". As this WoSCC data-base contains research works starting from 1990, therefore, this 1990 is considered as the starting date for the OR-MS literature. The dataset last updated on March 08, 2018. The retrieved results were classified by document types, including "ARTICLE (1838)", "PROCEEDINGS PAPERS (1230)", and "REVIEW (24)."

Thus, these bibliographic records are the preferred unit in bibliometric studies using two software packages: The bibliometrix R-package (<http://www.bibliometrix.org>) written in the R language, an open-source environment, and provides a set of tools for performing bibliometric analysis. The second software package is the Citespace, a free available java application developed by Chen [20], and used for the science mapping.

III. RESULTS AND DISCUSSION

Derived from WoS, the pool of 2991 OR-MS source documents had received a total of 62244 references, 8510 keywords, 331 source journals and 18273 Times

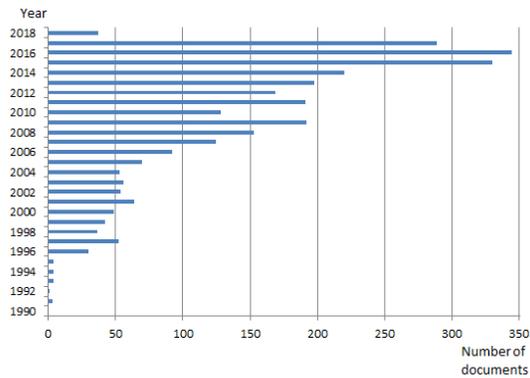


Figure 1: OR-MS research works Indexed in WOS (1990-2018)

cited (without self-citation) during 1990-2018. This broad set of researches proves that the OR-MS field has reaching an advanced phase of development and practice in Africa especially between 2011 and 2017. Figure 1 depicts the number of documents published over time where the highest number (345) of research works was in 2016.

Presenting some of the African authors that have made fundamental contributions to the development of this field is one of this study’s objectives. According to the information found in WoS, 4949 authors showing interest in this domain. The table 1 lists the top ten prolific authors classified in terms of the number of papers published in OR-MS literature. As authors list shows, the majority of them are from South Africa and Tunisia. In terms of authorship patterns, 186 authors have individually created research documents and 4763 authors have collaborated in generated research works. This indicates that collaboration in OR-MS is clearly remarkable with 1.84 collaboration index.

Numerous African institutions showing research interest in the OR-MS field. Revealing the most productive universities required the analysis of the institution-based distribution of the research works. The table 2 presents the distribution of top ten most active universities classified by the total number of documents. These leading universities published 1143 papers that contributed to 18.16 % of the total documents. This table shows also the dominance of South Africa and Tunisian universities making them as the most active and productive countries in OR-MS field. South Africa participates to the OR-MS research production with a total of 587, followed by Tunisia (432) and Algeria (291) (table 3).

Rank	Author	ND
1	Chabchoub H	33
2	Mbohwa C	31
3	Pretorius L	31
4	Chelbi A	25
5	Benrejeb M	18
6	Stewart TJ	18
7	Jarboui B	16
8	Aissani D	16
9	Pretorius JHC	16
10	Loukil T	16

ND: the number of total published documents.

Table 1: Top ten active authors

Identify the intellectual sub-fields that typify the

Rank	Author	ND
1	University of Pretoria	273
2	University of Sfax	146
3	University of Cape Town	139
4	University of Witwatersrand	135
5	Cairo University	131
6	University of Johannesburg	113
7	University of Tunis	101
8	Obafemi Awolowo University	78
9	University of Stellenbosch	71
10	University of Alexandria	69

Table 2: Top ten active universities

OR-MS subject is on the basis of the Co-Citation Analysis that indicate the relationship that reflects a semantic similarity between cited documents. Presenting and visualizing the document co-citation network of OR-MS literature is developed by means of CiteSpace (figure 2). This network consists of 728 reference nodes and 3215 co-citation links. Each link colors is correlated with each time slice, in other word, the year in which the co-citation link was first made: the blue and violet (1990-2000) links represent early citations , red-violet and orange link represents a co-citation relationship occurring in the period of (2001-2012) and the most recent co-citation relationships are visualized as yellow links (2013-2018).

Four focal points could be concluded from figure 2. First, nodes with bigger size are indicating that the document was cited more frequently. Second, nodes with many rings with different colors rep-

Rank	Author	ND
1	South Africa	587
2	Tunisia	432
3	Algeria	291
4	Egypt	269
5	Morocco	259
6	Nigeria	119
7	Ghana	15
8	Ethiopia	14
9	Libiya	9
10	Nambia	8

Table 3: Top ten active countries

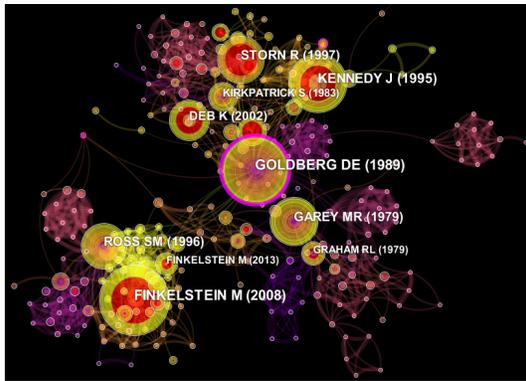


Figure 2: The document co-citation network

resent when the documents citations were actually made. The more rings are thick, the more the document receive citations in a particular year. Third, some rings are purple, indicating that the node has a relatively high Betweenness Centrality in the network. The Betweenness Centrality is an indicator of a node considering the number of shortest links from all nodes to all others and which pass through this node [21]. The more the value of Betweenness Centrality is high, the more the node has influence on the transfer of information through the network [22]. The final point is about the nodes with red rings denoting a Citation Burst in a particular year, meaning the citation frequency of a research work that suddenly increased during some certain time slices. Generally, the Citation Bursts detect the significant developments of research strands in a field. The document with the strongest Citation Burst for the OR-MS literature network is of Finkelstein M (2008). Its Burst lasted for 6 years from 2012 to 2018 with Burst strength of 9.212. It is also interesting to note that Zadeh LA (1978) has the second strongest

Citation Burst (7.878) in the period of 2007 to 2010. After revealing the most dominant and influential documents, we need then to explore research lines and emerging trends in the body of OR-MS knowledge that will be clustered into different non-overlapping groups. This process of grouping the data elements of the field generated 83 clusters. The modularity Q of 0.9041 is relatively high, which means that the network is reasonably divided into loosely coupled clusters. The silhouette score of 0.6081 suggests that the homogeneity of these clusters is acceptable on average. Only the labels of the most 5 largest clusters are shown in the figure 3. These labels are proportional to the size of the clusters.

Table 4 describes the 5 largest clusters: the label, the size, the average year of publication (mean cite year) and the silhouette of each community. It also indicates the most interesting members of each cluster in term of the citation frequency criteria that counts how many times a reference was cited by other source documents, the Betweenness Centrality and the PageRank which is a link analysis algorithm used to calculate the node quality ranking. The values of the silhouettes for these 5 clusters are greater than 0.5, suggesting robust and significant results, in other word, the cluster members are consistent and coherent.

The largest cluster, “Computational complexity” (#0),

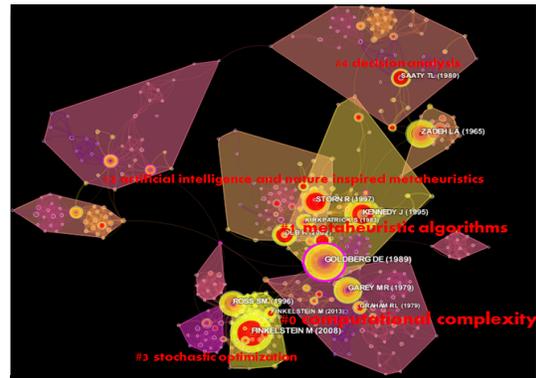


Figure 3: The clustering view of the document co-citation network)

consists of 67 members. 1989 is the average year of publication in this community. This makes it as an old cluster of the set. Its high silhouette value (0.939) indicates a high homogeneity between cluster nodes. As a branch of theoretical computer science, the computational complexity is the complexity of a problem

Cluster ID	Label	Size	Silhouette	Mean year	Most interesting members				
					Reference	Citation frequency	Page Rank	Burst Citation	Centrality
0	Computational complexity	67	0.981	1989	Garey MR 1979	36	2.53	-	0.06
					Graham RL 1979	17	1.77	5.26	0.03
1	Metaheuristic algorithms	59	0.931	1995	Goldberg DE 1989	50	6.30	-	0.43
					GKennedy J 1995	44	3.06	4.83	0.05
					Deb K 2002	30	1.60	5.88	0.01
2	Artificial intelligence and nature inspired metaheuristics	58	0.926	1994	Storn R 1997	35	2.86	5.03	0.04
					Kirkpatrick S 1983	21	2.60	-	0.04
					Ali MM 2004	9	1.95	4.76	-
3	Stochastic optimization	53	0.872	2000	Finkelton M 2008	53	3.03	9.21	0.07
					Ross M 1996	34	3.09	-	0.03
					Finkelston M 2013	16	1.60	6.79	0.02
4	Decision analysis	51	0.97	1990	Saatly TL 2002	24	2.20	5.18	0.08
					Belton V 2002	10	2.36	-	0.02
					Shafer GA 1976	10	1.01	4.25	0.04

Table 4: : Top five largest clusters

in terms of algorithms that solve it, in other word, the classification of the computational problems basing to their difficulty to be solved. Garey MR Book (1979) is considered as the most cited reference in this cluster and has the highest PageRank value too. This book covers the basis theory of NP completeness and emphasizes the most useful concepts and techniques for applying this theory to the NP and NP-hard complexity classes. The second most cited reference is the book of Graham RL (1979). The citation frequency of this node sharply increased during 2013-2015 with 4.708 as a Citation Burst strength. In this book (p 278-326), the author has emphasized the computational complexity theory while he has reviewed the state of some deterministic sequencing and scheduling problems as the single and parallel machine scheduling problems and open shop, flow shop and job shop scheduling problems.

The second largest cluster is labeled “*Metaheuristics algorithms*” (#1) and contains 59 members. The average year of publication in this community is 1995 and the silhouette value is 0.931 indicating a better data clustering. The goal of metaheuristic is to find near optimal solution for NP-hard problems. These Metaheuristics algorithms are divided into population-based search methods as genetic algorithm and trajectory methods as the tabu search algorithm. The most active node of this cluster are of Goldberg DE (1989), Kennedy J (1995) and Deb K (2002). In the first book the author has discussed some computer techniques and mathematical tools that allow the application of the genetic algorithm, an evolutionary optimization method, in any scientific field easier. This node has the highest Between-

ness Centrality value (0.43) of all the network and connects three large groups of nodes (#0, #2 and #3) within itself between. It can be then seen as a bridge extending from earlier to more recent ideas. The second leading paper of Kennedy J describes the concept of the particle swarm methodology in order to improve the continuous nonlinear function. The last active book generates a non-dominated sorting-based MOEA (MultiObjective Evolutionary Algorithm) called NSGA-II (Non-dominated Sorting Genetic Algorithm II). Deb K has tested this novel method on some problems in order to observe its perfect performance.

“*Artificial intelligence and nature inspired methheuristics*” (#2) is the third largest cluster of the network with a total of 58 reference nodes. The major cluster members describe the relationship between the nature and the artificial intelligence and how these natures inspired methheuristics algorithms effect on artificial and complex systems. The first leading node of this community is a the publication of Storn R (1997) that has the highest value of both Page Rank and Citation Burst of the cluster. The author has employed the differential evolution strategy as one of the evolutionary algorithms in order to minimize the non-differentiable continuous space-functions and then optimize certain system properties by suitably choosing the system parameters. The second most interesting document is the research work of Kirkpatrick S (1983). Kirkpatrick S has applied simulated annealing algorithm that is inspired by the process of annealing in metallurgy in his study. The analogy of statistical mechanics with such annealing in solids provides new information and generates a

framework for optimizing the properties of several complex systems. The third active study is an article of Ali MM (2004). The searcher has generated an introductory analysis of the role of genetic algorithm in studies of artificial and complex adaptive system in order to modify the traditional views of mathematical genetics. This cluster is consider as a milestone of the OR-MS field seeing that it contains five nodes with strong citation bursts values (Storn R (1997) : 5.026, Ali MM (2004) : 4.757, Holland JH (1975) : 4.654, Mladenovic N (1997) : 4.038 and Solomon MM (1987) : 4.038).

The fourth largest community is labeled “*Stochastic optimization*” (#3) and contains 53 references. The mean cite year is 2000 making this cluster as the new one compared to the set. Stochastic optimization is a development under uncertainty, in other word; the variables are described by probability distribution. Stochastic optimization algorithms could be considered as “industry standard” methods solving challenging optimization problems under uncertain environment [23]. Finkelsten M (2008) book is the most influential and leading node in this cluster seeing that it has the highest value of both Citation Burst and citation frequency of the whole network. The author has discussed the failure rate (the hazard rate) modeling in a random environment and on repairable systems while considering the variable failure rate as a crucial probabilistic characteristic for reliability, survival and risk analysis and demography disciplines. The second most cited node is the research work of Ross SM (1996). The searcher has provided an introduction to stochastic optimization, and brought together a set of applications, exercises and problems about the probabilistic optimization and has introduced a new chapter on Poisson approximations and Poisson random variables. Finkelsten M (2013) book, as the third active node, has the second Citation Burst value. The author has focused on the reliability modeling in unified stochastic framework while presenting numerous practical examples that illustrate recent theoretical findings of the authors. This cluster is also considered as a second milestone of OR-MS knowledge domain. It encompasses six nodes with strong citation bursts. The last cluster is “*Decision analyses*” (#4). This cluster contains 51 references nodes. This cluster focuses on the analysis of complex decisions under random or uncertain environments using mathematical techniques that may aid the decision makers to make the best decision. The most active study of this community is the research work of Saatly TL (1980) that

is cited 24 times and possesses the highest Burst Citation value of the group. The author has described the AHP technique as efficient technique for dealing with complex decision-making and checking the consistency of the decision maker’s evaluations, thus reducing the bias in the decision making process. The two other leading nodes are of Belton V (2002) and Shafer G (1976) that have attracted an extraordinary degree of attention from their cluster seeing that they present both a high Citation Burst values. The Belton provides readers with sufficient awareness of the underlying philosophies and theories while emphasizing the development of an integrated view of MCDA (multiple criteria decision making) seeing that this domain has developed swiftly. The last study of Shafer is an overview of the Mathematical Foundations Applications and Computational Aspect of theory of evidence. As a natural method, the evidence theory has emerged in different domains such as statistical inference, diagnostics, and risk and decision analysis while generating convincing results.

IV. CONCLUSION AND PERSPECTIVES

The relevance of OR-MS has drawn the attention of African operational researchers. This field has become a practical tool for several issues in Africa. This present paper generated a quantitative literature and a global objective vision on the OR-MS research area and its development in all Africa countries. In addition, this study specified the potential research streams and the emerging trends of this knowledge domain.

The bibliographical methods and visualization techniques were integrated to evaluate the distribution of documents published by African authors and to examine and visualize the theoretical foundations and core cited documents in network literature. The bibliographic data of our study was gathered through the (WOS) from 1990 to 2018. Five major strands of research with this field were recognized. The finding result of a quantitative review is explicative, substantiated and exhaustive seeing that it uses different inquiry techniques such as surveys and experimental design and generate statistical data after being assembled on predetermined tools [24]. In addition, this research work help researches students and particular those who are new to a field to quickly understand the field’s structure and examine the intellectual foundations of a network. Thus, the obtained results allow

discovering new research directions. Although we produce a network research on OR-MS according on bibliographic information founded in WoS, this database cover research documents only from 1990. For this reason, the number of references for this discipline is limited. The same thing was for the number of citation received by the set of OR-MS document in WoS. The older published papers are more favored to be selected into the core set than the newly published documents.

Despite these limitations, however, the present study is a first attempt to incorporate bibliometric method for quantitative data analysis in order to bring to light the network literature of the OR-MS practice in all Africans countries.

From the perspective of the research method applied in this paper, different other research lines and sub-fields within the OR-MS domain that haven't yet investigated should be discussed. Also, additional researches might keep citations up to date and periodically renovate our results in order to produce a longitudinal assessment of the changes. Last, other bibliometric approaches and tools that could be applied to generate and analyze the literature network of the OR-MS area are suggested for future analysis.

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