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A Scientometric Analysis of Inventory Routing Problem Literature with Special Emphasis in Stochastic and Dynamic Version

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Abstract: *The popularity and rapid development of Inventory Routing Problem as an area of research has led to a huge amount of publications containing the achieved knowledge. Due to the interdisciplinary nature of inventory routing problems that include heuristics, operation research and management science, a scientometric study of the area should shed some light on the topic. Empirically studying the evolution of the research on this field will give a view about groups of researchers, their research productivity and impact, all that providing a better understanding of trends. While scientometric has a long tradition in many fields, we identify a lack of comprehensive studies in the areas of inventory routing. Based on bibliographic databases (Scopus and Web of Science), this study applies a scientometric method to empirically analyze the evolution and state of the Inventory Routing Problem research. We focus on analyzing variants of the problems where the inventory is revised periodically and the decision making is affected by the dynamic variation of the demand that is revealed as time goes by in the planning horizon. The results of this study provide a better understanding of patterns, trends and other important factors as a basis for directing research activities, sharing knowledge and collaborating in the operations research area. It also makes reference to the transversal areas such as the mathematics and computer science.*

Keywords: *Inventory Routing Problem, Scientometric Analysis, Stochastic and Dynamic Inventory Routing Problem, Operational Research, Inventory Management*

I. Introduction

The administration, control and inventory distribution is a topic of interest for the researchers for the last three decades [22]. A great number of documents are written every year proposing operational and tactical decisions on the supply chain, where the inventory and transportation are important to gain competitive advantages [45]. This problem is known as inventory routing problem, a classical optimization problem that puts together different knowledge areas. By considering the number of publications in the last ten years, we observe a continuous and incremental interest on this topic, it becomes more and more important to investigate the current state and evolution of Inventory Routing Problem (IRP). One manner to analyze this evolution is by means of the Scientometric study. According with [39], the Scientometric allows to quantize the studies as well as measuring and analyzing science activities. Also, the Scientometric studies facilitate the development and improvement of an academic discipline, serving as a vital basis for defining and debating future research agendas [25].

The identification of research areas has been a perennial theme in scientometric. A research area is defined as a set of documents or other biometrics units that define a research topic and associated group of research who share an interest in the topic [48]. Using an scientometric study, it is possible to find information about research activities in general, such as knowledge sharing, research quality, socio-organizational structures, influential countries, affiliations, authors, development of key topics, structural change, and economic impact of research that guide its work.

Due to complexity of IRP, its analyzing require two elements need to be taken into account. The first one consists of the versions of the problem that will involve the study and the second in which knowledge areas this versions are searching. The interest in this article is to analyze the versions of the problem that include Dynamic and Stochastic demand with revision of the inventory in period form. The study is focused on the subject areas related with operational research, social sciences and business science.

In the literature, a lack of scientometric studies in IRP and even more in the version that is proposed in this paper has been detected. However, there are review papers which will be take as a base to find the key factors for the analysis. Those articles contain a large number of references which are related and will be classified and analyzed. The most highlighting papers will be discussed below.In [43] the decision on factories location involved in IRP are considered. This study cited another 139 publications. The papers [41], [3] and [45] each cited 63, 125 and 49 documents respectively, they were emphasizing coordination mechanism in the supply

chain and inventory management and distribution. In [17] and [49], a review of trends in Maritime IRP is analyzed with 132 and 12 articles cited respectively. In [38] some applications of the soft computing in the supply chain are analyzed with 188 documents cited. The paper [33] analyzes strategies of efficient supply for logistics systems in the industry of perishable food, In this study, a dynamic and stochastic system was considered with the use of 35 references. In contrast, in this our work, we will be using more than 1000 bibliographic registers for the scientometric analysis and citing the 50 more highlighting documents.

The main objective of this study is to provide a more comprehensive view on the Inventory routing area, within a relevant time frame of the last ten years, in order to present empirical and relevant findings. We focus on analyzing the IRP where the inventory is revised periodically and the decision making is affected by the dynamic variation in the demand. Information about the demand is revealed as time goes by in the time horizon of planning. Therefore, in this paper we present a comprehensive scientometric study that empirically explores publications related to Inventory Rounting Problem covered by Elsevier's Scopus and Thompson's Web of Science databases from 2005 and 2014. We will be analyzing 934 in Scopus and 720 in Web of Science data bases.The remainder of the paper is organized as follows: Section II focuses on the methodology used for processing data. Section III is devoted to analyze publications patterns. Citations patterns are reviewed in Section IV. In Section V, the identification of groups of investigators are presented. The paper ends with conclusions, which emphasizes the current status, trends and patterns found for this field of study.

II. Methodology

The collection of relevant publications and citations establishes the foundation for a scientometric analysis of a specific research area. As indicated before, this study intends to cover a large part of peer-reviewed Inventory Routing Problem articles published in the last ten years, specifically; our focus is on documents related to the dynamic case for a periodically revised inventory. By this, we aim to obtain empirical evidence for supporting the metascientific findings of this scientometric study. In this section we describe our procedure regarding data collection and data processing and knowledge extraction.

2.1 Data Collection

The data was recollected by means of Elsevier's Scopus and Thomson's Reuters Web of Science databases. These databases were chosen for their relevance and reputation in the fields of physical and social sciences. We analyze each database separately to thereby complement and validate the results obtained. A search equation was created in order to cover a large part of publications in Inventory Routing Problem and in the specific topics that we want to deepen. The equation was formed by means of keywords chosen for their relevance regarding three key questions for the problem: a) how the inventory is controlled, b) how often the inventory is revised and c) how the information about the demand is reveled. These words in capital letter were written. For (a) two words INVENTORY and ROUTING were selected ; for (b) another two words POLICIES and PERIOD were selected, and for (c) only STOCHASTIC was selected. The equation was used for search query in the title, abstract and keywords for the documents contained in both bibliographic databases mentioned above.

The logical structure of this equation was (Inventory AND (Routing OR (Periodic AND (Policy OR Stochastic)))), thus, three sets of words were considered: a) Inventory -- Routing, b) Inventory -- periodic -- policy and c) inventory -- periodic -- stochastic. The union of the data collected by these sets formed the data base under study. The basic idea behind this specific equation is to get the documents related all the knowledge areas involved in the subject under study. The search equation was applied on several specific subject areas. Seven of them were chosen for each database due to their relevance in the field under study. Three of them were common for both databases: mathematics, computer science and engineering, but the others vary according to the categorization that each database had. In general, subject areas related with operational research, social sciences and business science were included.

Table 1: Number of publications per database and year

Data Source	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Scopus	50	50	59	99	95	116	95	101	125	144	934
WoS	44	54	45	70	76	70	67	84	98	112	720

For the period of time from the year 2005 to 2014, the search query found 934 publications by Elsevier's Scopus and 720 by Thomson-Reuters's Web of Science (see Table 1). A trend line of number publications per database and year can be observed in Fig. 1, where we can speak of a growing number of publications and increasing interest by the researchers. It is important to note that although the information obtained has some similar registers, the work with each database independently, instead of be redundant was complementary.

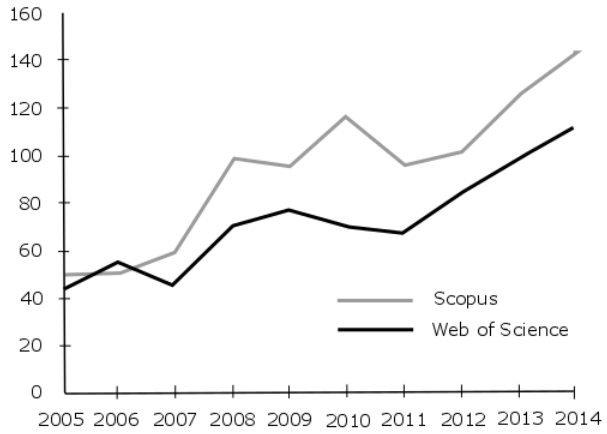

Figure 1: Trend line of number publications per database and year

2.2 Data Processing and Knowledge Extraction

We used several attributes to analyze frequency, productivity, quality and impact of the research into of the extensive information registers that were obtained. Below, we described briefly, the methods that we have used in the data processing to obtain trends and patterns, to highlight documents and researchers groups in specific topic among other relevant information.The data processing begins with the form in which the registries of the data base are counted according to attributes that are analyzed. In most of the cases a simply counting was sufficient, for these cases, a measure of frequency that coincides with the criteria under analysis was obtained and denoted with f. Also, for many other attributes it was worthy to calculate the relative frequency denoted with fr. These metrics could be used for the complete time horizon, namely ten years, or could be presented per year.

For measuring the productivity and according with [25] in their review of the literature, two could be of the methods to measure research productivity for the authors: straight count of the number of publications denoted by SCM and author position in the author list, denoted by APM. The SCM as its name indicates assigns a score equal for each authors who his registered in the publication. APM instead, assigns a higher score to the first author and the score decreases as the author reaches the last position. We have used only these methods, because consider that they both preserve properly the concepts we want to analyze.

The impact that one publication generates in the research community is a measure of its quality. We measure this impact counting the number of citations received by the publication jointly with the longevity of the publication. Thus, we used the metric Normalized Citation Impact Index (NCII) not only for this purpose but also to analyze the quality of the research through the impact on new publications. We have used a NCII weighted denoted NCIIW. This metric consists of using the metric that counts the number of citations that one author has received by each publication depending on the author position, namely metric APM, and then, joining it by the metric NCII. Others metrics used were: Number of citation in Google Scholar (GS); SJR a measure of scientific influence of scholarly journals that accounts for both the number of citations received by a journal and the importance or prestige of the journals where such citations come from; SNIP measures contextual citation impact by weighting citations based on the total number of citations in a subject field; the impact factor (IF) and the impact factor of the last 5 years (IF5).To ensure the accuracy of the results, the generated outputs are validated by manual proof-reading activities, this way inconsistencies can be identified. This semi-automatic process guarantees the quality of the results of the study.

III. Analysis per number of publications

In order to obtain patterns in the subject under study, the fields of information databases by the number of publications were analyzed. For this purpose we used specific perspectives such as academic disciplines, author distributions, forms of publication and publications by authors.

3.1 Academic Disciplines

The general structure and development of the Inventory Routing Problem research can be observed through of the academic disciplines involved (see Table 2 and Table 3). At first, the average of publications percentage for a time horizon of ten years, we can state that in the part five of average of number of publications by year can be classified into at least one of the following three academic disciplines: Decision science, Engineering and Operation research and management science. Secondly, the first transversal areas that contributed in the research in area under study are the Computer Science and Mathematics; this demonstrates

their importance of the problem formulation and the techniques of solution. Notably, no more than 6% of the publications included specific areas such as: Social science, Automation, Transportation, Economic, Econometric and finance.

Table 2. Percentage of documents that were generated in each subject area per year on Scopus database

Subject	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Av
Area	%	%	%	%	%	%	%	%	%	%	%
Decisions Sciences	29.76	26.44	21.10	26.80	25.60	21.82	24.63	23.70	26.27	22.58	24.87
Engineering	17.86	32.18	27.52	19.59	19.81	24.55	20.20	24.17	23.92	26.45	23.62
Computer Science	8.33	5.75	8.26	18.04	23.67	20.45	19.21	21.33	15.29	15.81	15.61
Mathematics	14.29	12.64	15.60	10.82	11.59	15.00	12.81	15.64	16.08	10.97	13.54
Business, management and Accounting	9.52	9.20	11.01	10.31	13.04	10.45	16.26	11.37	12.94	16.13	12.02
Scocial sciences	9.52	9.20	14.68	9.79	2.42	3.18	1.97	2.37	1.18	3.55	5.79
Economics, Econometric and Finance	10.71	4.60	1.83	4.64	3.86	4.55	4.93	1.42	4.31	4.52	4.54

Tabla 3. Percentage of documents that were generated in each subject area per year on Web of Science database

Subject	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Av
Area	%	%	%	%	%	%	%	%	%	%	%
Operations Research and Management Science	36.14	37.50	47.62	43.57	38.26	44.17	42.40	40.00	43.86	42.36	41.59
Engineering	16.87	20.19	15.48	22.86	20.13	15.83	25.60	18.67	25.15	22.66	20.34
Business and Economics	20.48	22.12	22.62	20.71	16.78	19.17	12.00	17.33	14.04	16.75	18.20
Computer Science	15.66	14.42	5.95	7.86	16.78	10.83	12.80	14.67	9.36	8.87	11.72
Mathematics	6.02	2.88	3.57	1.43	3.36	5.00	2.40	2.67	1.17	3.45	3.19
Automation and Control Systems	3.61	2.88	1.19	2.14	4.03	3.33	1.60	4.67	4.09	1.97	2.95
Transportation	1.20	0.00	3.57	1.43	0.67	1.67	3.20	2.00	2.34	3.94	2.00

3.2 Forms of the publication

The articles were the most common type of document analyzed in both databases. In average, the were about 61% of documents per year in the Scopus database, whereas in Web of Science they were about 75%. This difference for the number of articles is compensated with the number of documents that are a result of the participation in conferences like articles, conference review and proceedings with about 30% and 20% respectively. These results can be observed in the Tables 4 and 5.

Table 4. Percentage of documents classified by type in Scopus database

Document	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Av
Type	%	%	%	%	%	%	%	%	%	%	%
Article	42.00	70.00	69.49	61.62	63.16	58.62	48.42	65.35	65.60	58.33	60.26
Conference Paper	36.00	24.00	27.12	34.34	29.47	34.48	37.89	16.83	25.60	19.44	28.52
Review	8.00	4.00	1.69	1.01	2.11	3.45	8.42	14.85	4.00	3.47	5.10
Conference Review	4.00	0.00	0.00	3.03	5.26	2.59	1.05	2.97	3.20	5.56	2.77
Article in Press	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	13.19	1.48
Book Chapter	6.00	2.00	0.00	0.00	0.00	0.86	2.11	0.00	0.00	0.00	1.10
Book	2.00	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.41
Short Survey	0.00	0.00	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Note	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20

Table 5. Percentage of documents classified by type in Web of Science database

Document	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Av
Type	%	%	%	%	%	%	%	%	%	%	%
Article	54.55	57.41	88.89	61.43	76.32	88.57	68.66	89.29	85.71	85.71	75.65
Proceedings Paper	29.55	22.22	8.89	25.71	19.74	7.14	16.42	4.76	4.08	5.36	14.39
Article; Proceedings Paper	13.64	20.37	0.00	10.00	1.32	0.00	11.94	1.19	5.10	4.46	6.80
Review	2.27	0.00	2.22	2.86	2.63	4.29	2.99	4.76	4.08	3.57	2.97
Editorial Material	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.89	0.19

Table 6, shows a list of journals and the related number of publications. Only taking into account the European Journal of Operational Research and International Journal of production economics, the sum of their participation in the two databases is about 15% in Scopus and 23% in Web of Science. IRP being an optimization problem, there are journals of transversal areas to operational research area as is the computer science. This is in particular evident in the database Web of Science with journals as Computer & Operations research and Computers & Industrial Engineering. Also, this is showed, in Table 7 where the five most important conferences appear. Besides finding specialized conferences for industrial engineering, it appears also a conference related the industrial engineering with the computer science area (International Conference on Computers and Industrial Engineering) that shows the relevance of computers science area for IRP.

Tabla6. Ranking of publications per journal

Scopus Database				Web of Science Database			
Rank	Journal	f	fr(%)	Rank	Journal	f	fr(%)
1	European Journal of Operational Research	73	7.79	1	European Journal of Operational Research	89	12.36
2	International Journal of Production Economics	64	6.83	2	International Journal of Production Economics	78	10.83
3	Journal of Optimization Theory and Applications	37	3.95	3	International Journal of Production Research	39	5.42
4	Flexible Services and Manufacturing Journal	30	3.20	4	Operations Research	34	4.72
5	Discrete Dynamics in Nature and Society	28	2.99	5	Computers and Operations Research	30	4.17
6	Socio-Economic Planning Sciences	20	2.13	6	Computers and Industrial Engineering	24	3.33
7	Transportation Science	17	1.81	7	Naval Research Logistics	20	2.78
7	Operations Research and Computer Science Interfaces Series	17	1.81	8	Journal of the Operational Research Society	16	2.22

Table 7. Ranking of publications per conferences

	Scopus		WoS	
Conference Name	f	fr(%)	f	fr(%)
Annual Conference and Expo of the Institute of Industrial Engineers	21	8.24	--	--
International Symposium on Inventories	--	--	19	13.38
International Conference on Computers and Industrial Engineering	17	6.67	--	--
International Conference on Industrial Engineering and Engineering Management	12	4.71	16	11.27
Winter Simulation Conference	10	3.92	--	--

3.3 Publications by Authors

In Tables 8 and 9, the authors with the highest number of publications and the position that every of these authors has in the publication list of authors are presented. In these tables, the number of publications per each author and their position is considered as first, second, third, fourth or fifth coauthor. Afterwards, we use two different metrics to show their production: i) the Straight Count Method (SCM), assigned the same punctuation to all publications reported, in this case of 1, by each author are added and the results are shown in a column with the same name. ii) this second method applies Author Position Method (APM) in which a different punctuation is given for every position, being the first position the one with the highest punctuation and successively descending this punctuation for the next positions until every punctuation is calculated for every author. Taking into account that the highest number of authors gathered article in the sample is 8, the maximum punctuation is this number. For each author, their punctuations are multiplied by the number of publications respectively and then the total obtained. The results are in the corresponding column for both tables ordered in decreasing order of total punctuation by author.

For scientometic study, the most prominent researchers are Ignaciuk przemystaw, Bartoszewicz Andrzej and Laporte Gilbert. The first two researchers linked the research areas of computer science and operations research, this is evident in their research topics for the first one are logistic systems and supply chain management, congestion control in data transmission networks, networked control systems, dynamical optimization and robust control and for the second one are sliding mode control and congestion control in communication networks. Regarding Laporte Gilbert in his expertize as reported by HEC Montreal are in Combinatorial optimization, Transportation and Operational research. Also, according with Google scholar other areas off his interest are distribution management and mathematical programming.

Table 8. Top sixteen authors by APM metric in Scopus

Rank	Author	1st	2nd	3rd	4th	5th	SCM	*APM
1	Ignaciuk Przemystaw	15	--	--	--	--	15	120
2	Bartoszewicz Andrzej	--	16	--	--	--	16	112
3	Laporte Gilbert	--	8	8	--	1	17	108

4	Aghezzaf El-Houssaine	3	9	1	--	--	13	93
5	Chen Haoxun	1	5	8	--	--	14	91
6	Li Jianxiang	8	1	2	--	--	11	83
6	Christiansen Marielle	3	4	3	1	1	12	79
7	Chu Feng	--	7	4	1	--	12	78
8	Zhou Sean X.	4	5	1	--	--	10	73
9	Chao Xiuli	5	3	2	--	--	10	73
10	Coelho Leandro C.	9	--	--	--	--	9	72
11	Cordeau Jean-Francois	1	8	--	1	--	10	69
12	Bertazzi Luca	5	3	1	--	--	9	67
13	Savelsbergh Martin W. P.	2	2	3	3	--	10	63
13	Zhang Jiang	5	2	1	--	--	8	60
13	Wang Li	4	4	--	--	--	8	60
14	Louly Mohamed-Aly Ould	5	2	--	1	--	8	59
15	Cannella Salvatore	5	2	--	--	--	7	54
16	Song Jin-Hwa	2	3	1	1	1	8	52
16	Chen Yuerong	3	4	--	--	--	7	52

IV. Analysis per citations received

Bearing in mind that the number of citations shows how often the publication is referenced by other publications, in this sections we will be analyzing the impact of the citations and its patterns. For that, the number of citations received was analyzed for the time frame. The total number of citations obtained for the sample was 5724 in Scopus and 4996 in Web of Science with a mean of publication citations of 6.11 and 6.94 respectively.

4.1 Citations by document type

The reviews most cited were [43] and [41]. In the first one, a complete review of strategies in the design of supply chain networks focuses in facility location was presented. Also, reviewed the optimization methods for solving facility location problems in a supply chain context and included practical applications of location models in SCM. And the second one, a review of coordination mechanisms of supply chain systems in a framework that is based on supply chain decision structure and nature of demand was presented. This framework highlighted the behavioral aspects and information need in the coordination of a supply chain. In Table 10, the most important reviews are showed.

Table 9. Top sixteen authors by APM metric in Web of Science

Rank	Author	1st	2nd	3rd	4th	5th	SCM	*APM
1	Laporte Gilbert	--	7	8	--	1	16	101
2	Zhou Sean X.	5	5	1	--	--	11	81
3	Chao Xiuli	4	3	4	--	--	11	77
4	Coelho Leandro C.	9	--	--	--	--	9	72
5	Bertazzi Luca	5	3	1	--	--	9	67
6	Aghezzaf El-Houssaine	3	5	1	--	--	9	65
6	Christiansen Marielle	2	4	2	1	1	10	65
7	Savelsbergh Martin W. P.	2	1	3	3	--	9	56
8	Cordeau Jean-Francois	--	7	--	1	--	8	54
9	Song Jin-Hwa	2	3	1	1	1	8	52
10	Louly Mohamed-Aly Ould	4	2	--	1	--	7	51
11	Chen Youhua (Frank)	2	4	1	--	--	7	50
12	Archetti Claudia	6	--	--	--	--	6	48
13	Speranza Maria Grazia	--	2	2	4	--	8	46
13	Huh Woonghee Tim	4	2	--	--	--	6	46
13	Chew Ek Peng	4	2	--	--	--	6	46
14	Chu Feng	--	4	2	1	--	7	45
15	Kiesmueller Gudrun P.	2	4	--	--	--	6	44
16	Janakiraman Ganesh	--	5	1	--	--	6	41
16	Cardos Manuel	2	1	3	--	--	6	41

Table 10. Top five review papers by NCII metric in the both database

		Scopus				Web of Science			
Year	Review	Rank	NCII	f	FG	Rank	NCII	f	FG
2009	Facility location and supply chain management: A review	--	--	--	--	1	44.67	268	752
2007	Coordination mechanisms of supply chain systems	--	--	--	--	2	16.38	131	332
2010	Industrial aspects and literature survey: Combined inventory management and routing	1	17.00	85	185	3	14.40	72	185

2013	Ship routing and scheduling in the new millennium	2	9.50	19	74	4	7.50	15	74
2010	A review of soft computing applications in supply chain management	--	--	--	--	5	5.80	29	70
2007	Inventory routing problems: A logistical overview	3	8.00	64	143	--	--	--	--
2013	A maritime inventory routing problem: Practical approach	4	6.50	13	47	--	--	--	--
2012	LQ optimal sliding-mode supply policy for periodic-review perishable inventory systems	5	5.00	15	20	--	--	--	--

The articles, specially the most cited ones, offer approximations to the boundaries of knowledge of every subject. For this reason, being the most published type of document and being among the most cited ones, we created a ranking of articles in descending order of metric NCII for each database in Table 11 and Table 12. The two articles most cited in Scopus were [44] and [22]. In the first one, it was develop a stochastic programming model to select the storage locations of medical supplies and required inventory levels for each type of medical supply. In the second one, a comprehensive review of literature in IRP is presented. It is based on categorize IRP with respect to their structural variants and with respect to the availability of information on customer demand. Regarding to Web of Science, the reviews most cited were [13] and [51]. In the first one, an integrated scheduling model of production and distribution operations by applications in the computer and food catering service industries were studied. The problem consisted in to find a joint schedule of production and distribution such that an objective function that takes into account both customer service level and total distribution cost is optimized. The second one aims to find the best truck docking or scheduling sequence for both inbound and outbound trucks to minimize total operation time when a temporary storage buffer to hold items temporarily is located at the shipping dock were found. Also, the product assignment to trucks and the docking sequences of the inbound and outbound trucks are all determined simultaneously.

Table 11. Top ten by NCII metric in Scopus database

Rank	Year	Article	*NCII	f	FG
1	2010	Stochastic optimization of medical supply location and distribution in disaster management	18.20	91	184
2	2014	Thirty years of inventory routing	12.00	12	73
3	2007	Incorporating inventory and routing costs in strategic location models	11.50	92	191
4	2005	Distribution network design: New problems and related models	11.10	111	238
5	2006	Vehicle routing scheduling for cross-docking in the supply chain	8.67	78	157
6	2010	Incorporating location, routing and inventory decisions in supply chain network design	8.40	42	91
7	2009	Inventory inaccuracy in retail stores due to theft: An analysis of the benefits of RFID	7.83	47	78
8	2012	The inventory-routing problem with transshipment	7.67	23	56
8	2012	On the Bullwhip Avoidance Phase: The Synchronized Supply Chain	7.67	23	33
9	2009	Vehicle routing with cross-docking	7.33	44	106
10	2010	LQ optimal sliding mode supply policy for periodic review inventory systems	7.20	36	45
*the data with the same NCII score, also obtained the same rank position}					

4.2 Citations by Journals}

With the aim of identifying the most specialized journals in IRP document publications, two tables (see Tables 13 and 14) with the most cited journals was created for each database. The results show that the journals obtained appear with high impact factor usually in Q1 quartile for the ranking of publications classified by topics.

Table 12. Top ten by NCII of the best articles in Web of Science database

Rank	Year	Article	*NCII	f	FG
1	2005	Integrated scheduling of production and distribution operations	11.60	116	267
2	2008	Scheduling of inbound and outbound trucks in cross docking systems with temporary storage	10.00	70	200
3	2010	Stochastic optimization of medical supply location and distribution in disaster management	9.40	47	184
3	2010	Quality. safety and sustainability in food distribution	9.40	47	112
4	2014	Thirty Years of Inventory Routing	9.00	9	73
5	2005	Distribution network design: New problems and related models	8.60	86	238
6	2007	Incorporating inventory and routing costs in strategic location models	8.38	67	191
7	2013	The exact solution of several classes of inventory routing problems	6.50	13	44
7	2013	A maritime inventory routing problem: Practical approach	6.50	13	47
8	2007	Inventory routing problems: a logistical overview	6.25	50	143
9	2012	The inventory routing problem with transshipment	6.00	18	56
9	2009	Vehicle routing with cross docking	6.00	36	106
9	2012	Consistency in multi vehicle inventory routing	6.00	18	41
9	2007	A branch and cut algorithm for a vendor managed inventory routing problem	6.00	48	116
10	2010	A Branch and Price Method for a Liquefied Natural Gas Inventory Routing Problem	5.40	27	64
*the data with the same NCII score. also obtained the same rank position					

Table 13. Journal citations in Scopus Database with seven metrics

Rank	Journal name	f	n	fr	SJR	SNIP	IF	IF5
1	European Journal of Operational Research	1112	73	15.23	2.60	2.50	1.84	2.63
2	International Journal of Production Economics	677	64	10.58	2.39	3.20	2.08	2.59
3	Computers and Operations Research	373	28	13.32	2.97	3.03	1.72	2.34
4	Operations Research	371	37	10.03	3.45	1.93	1.50	2.50
5	Transportation Science	246	14	17.57	3.14	2.93	2.29	2.91
6	Journal of the Operational Research Society	188	11	17.09	1.39	1.23	0.91	1.27
7	Computers and Industrial Engineering	186	20	9.30	1.72	2.38	1.69	2.38
8	International Journal of Production Research	154	30	5.13	1.33	1.73	1.32	1.25
9	Manufacturing and Service Operations Management	131	13	10.08	2.64	1.58	1.45	2.69
10	Naval Research Logistics	105	17	6.18	1.13	0.74	1.04	1.24

4.3 The most cited authors

The number of citations every author receives is important to detect those authors that most contribute to the growth of the specific subject area. To give an impartial indicator of the most important authors according to the number of citations received, the metric NCII is used again, adapting it as an individual productivity measure. Thus, we calculate the weighted metric NCII according as we have naming NCIIW. In this case the punctuation's authors are multiplied by the value of NCII instead that theirs number of publications.

Tabla14. Journal citations in Web of Science Database with seven metrics

Rank	Journal name	f	n	fr	SJR	SNIP	IF	IF5
1	European Journal of Operational Research	1356	89	15.24	2.60	2.50	1.84	2.63
2	International Journal of Production Economics	518	78	6.64	2.39	3.20	2.08	2.59
3	Computers and Operations Research	358	30	11.93	2.97	3.03	1.72	2.34
4	Operations Research	311	34	9.15	3.45	1.93	1.50	2.50
5	Management Science	199	8	24.88	3.65	3.10	1.73	3.30
6	Transportation Science	198	14	14.14	3.14	2.93	2.29	2.91
7	International Journal of Production Research	186	39	4.77	1.33	1.73	1.32	1.25
8	Journal of the Operational Research Society	176	16	11.00	1.39	1.23	0.91	1.27
9	Computers and Industrial Engineering	165	24	6.88	1.72	2.38	1.69	2.38
10	Manufacturing and Service Operations Management	106	14	7.57	2.64	1.58	1.45	2.69

In Table 15 shows the top twenty best authors for each database. The table includes the rank, author, the weighted metric NCIIW, the number of citations f and the number of publications n and relative frequency fr.

Table 15. Top twenty cited authors by fur metrics

Scopus						Web of Science					
Rank	Author	NCIIW	f	n	fr	Rank	Author	NCIIW	f	n	fr
1	Laporte Gilbert	428.08	253	17	14.88	1	Teresa Melo	376.00	275	2	137.50
2	Christiansen Marielle	331.27	199	12	16.58	2	Laporte Gilbert	366.00	214	16	13.38
3	Coelho Leandro C.	310.67	75	9	8.33	3	Nickel Stefan	329.00	275	2	137.50
4	Cordeau Jean-Francois	279.33	108	10	10.80	4	Saldanha-da-Gama F.	282.00	275	2	137.50
5	Ignaciuk Przemystaw	221.07	108	15	7.20	5	Coelho Leandro C.	276.00	69	9	7.67
6	Bartoszewicz Andrzej	193.43	108	16	6.75	6	Christiansen Marielle	266.53	161	10	16.10
7	Bertazzi Luca	189.34	126	9	14.00	7	Cordeau Jean-Francois	244.67	94	8	11.75
8	Andersson Henrik	175.33	109	5	21.80	8	Bertazzi Luca	174.12	132	9	14.67
9	Song Jin-Hwa	165.71	112	8	14.00	9	Song Jin-Hwa	153.46	100	8	12.50
10	Savelsbergh Martin	158.24	143	10	14.30	10	Archetti Claudia	150.00	88	6	14.67
11	Cannella Salvatore	155.68	87	7	12.43	11	Andersson Henrik	139.53	90	5	18.00
12	Ciancimino Elena	151.53	87	6	14.50	12	Li Xiuhui	131.00	131	1	131.00
13	Mete Huseyin Onur	145.60	91	1	91.00	13	Speranza Maria Grazia	125.85	127	8	15.88
14	Lokketangen Arne	135.60	142	5	28.40	14	Savelsbergh Martin	123.06	105	9	11.67
15	Archetti Claudia	131.00	86	5	17.20	15	Lokketangen Arne	120.93	124	6	20.67
16	Zhou Sean X.	130.47	67	10	6.70	16	Wang Qinan	118.63	132	2	66.00
17	Zabinsky Zelda B.	127.40	91	1	91.00	17	Zhou Sean X.	116.40	61	11	5.55
18	Moin Noor Hasnah	125.75	96	5	19.20	18	Chao Xiuli	103.02	61	11	5.55
19	Kjetil Fagerholt	125.50	61	6	10.17	19	Fagerholt Kjetil	101.75	49	6	8.17
20	Aghezzaf El-Houssaine	124.32	114	13	8.77	20	Hoff Arild	100.80	72	1	72.00

V. Analysis per citations received

In this section we identified groups of the researchers that we considered important by their contributions. We assumed that the best groups also have the best researchers. For this reason the main factor in the selection of the groups are the best researchers as well as the connections that they have with other researchers and the number of the documents that they generated. The results obtained are showed in the summarized in the Fig. 2 and 3.

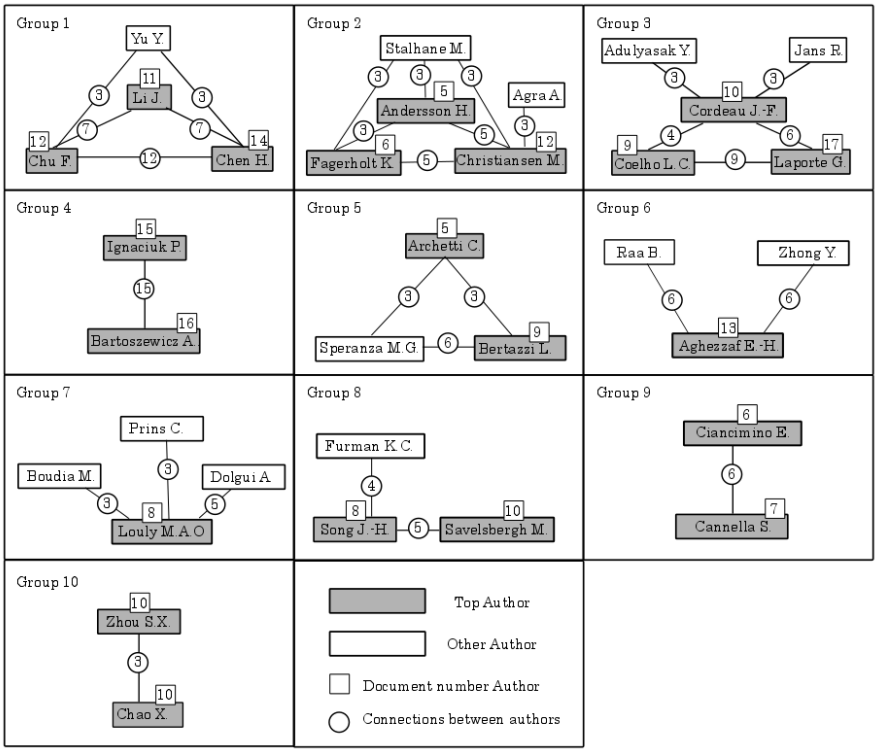

Figure 2: Groups of Researchers in Scopus Database. The groups 11, 12 and 13 were not highlighted

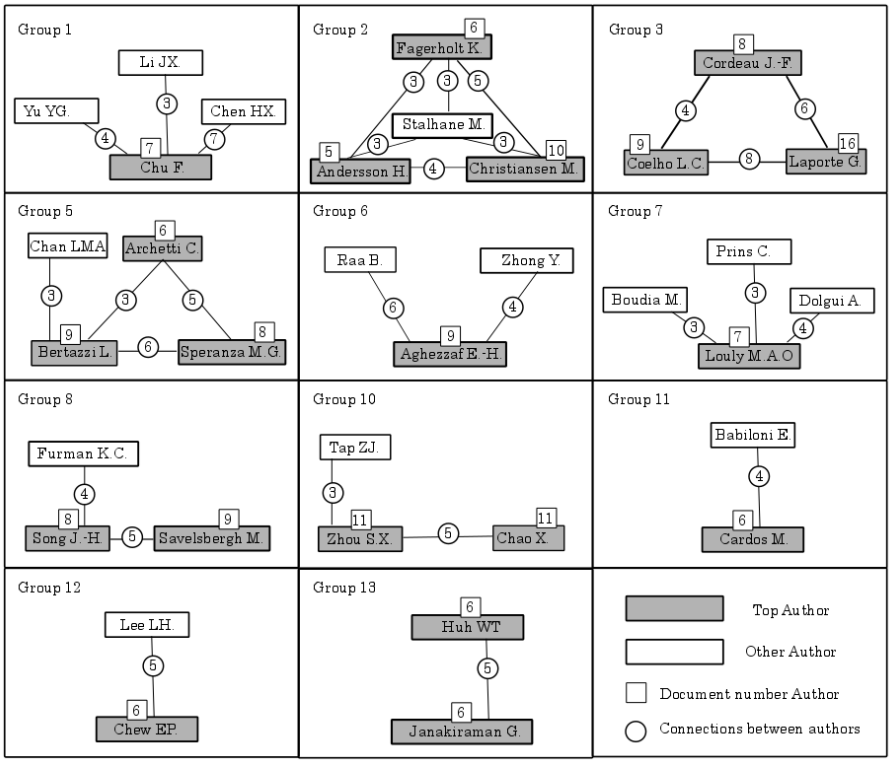

Figure 3: Groups of Researchers in Web of Science Database. The groups 4 and 9 were not highlighted

Based on the research groups, the topics of interest of each group were identified and highlighted according with the publications of the most impact. Below, the information obtained is summarized. The groups of investigators identified in the two databases are:

- Group 1: group with Chinese researches that involves severals institutions School of Management, University of Science and Technology of China, Department of Automatic Control, Beijing Institute of Technology, Rotterdam School of Management, Erasmus University Rotterdam, School of Management, Lanzhou University, Industrial Systems Optimization Laboratory, Charles Delaunay Institute of Technology of Troyes and Laboratoire IBISC, Université d'Evry. Their research interests include Performance evaluation of distribution strategies for the inventory routing problem [40], inventory routing problems with split delivery and stochastic demand study [12], also it is common that uses the Lagrangian relaxation method [52]. The most prominent researchers in this group are Feng Chu, Jianxiang Li, Haoxun Chen and YU Yugang.
- Group 2: composed by Researchers Chisteansen, Andersson, Fagerholt and Lokketangen among others. The contributions of this group are generally affiliated to Norwegian University of Science and Technology, Department of Industrial Economics and Technology Management: this group specializes in Maritime IRP problems or MIRP [3] and [16], also have worked Rolling horizon heuristics for solved problems of optimization [47].
- Group 3: In this group, Coelho, Cordeau and Laporte were identified as the most outstanding researchers. This group of researchers based in Canada that involves the following institutions: HEC Montreal, Department of Logistics and Operations Management, CIRRELT and Laval University. We highlight of this group contributions on issues of heuristics for IRP in special Branch-and-cut [20] and [1], IRP with transshipments [21] and [23].
- Group 4: Przemyslaw Ignaciuka and Andrzej Bartoszewiczb. They form a group of researchers based in Poland in the Institute of Technical and Institute of Automatic Control of the University of Lodz. The most notable contributions of this group are related to applications of sliding-mode control and discrete-time dynamical optimization in inventory [30], [31], [32], [33], [34], [35] and [36].
- Group 5: In this group we found researchers of the Brescia University such as Bertazzi, Archetti and Speranza. This group specializes in foundations of IRP in special contributions in the formulation of problems [5], contributions in Stochastic IRP with stock-out [7] and the Branch-and-cut heuristic [4].
- Group 6: El-Houssaine Aghezzaf, Birger Raa and Yiqing Zhong form a group of researchers based in Belgium in department of Industrial Management at Ghent University. The most notable contributions of this group are related with cyclical distribution plan and designing distribution patterns for long-term inventory routing [2] and [46].
- Group 7: Alexandre Dolgui, Mohamed-Aly Louly and Christian Prins affiliated to University of Technology of Troyes in Charles Delaunay Institute. Their research interests include applications of combinatorial optimization to transportation and supply chain, production planning and stochastic models for inventory control [8] and [42].
- Group 8: Savelsberg, Song Jin-Hwa, Doerner and Furman of an Interagency group that involves the institutions of University of Newcastle, School of Mathematical and Physical Sciences, Australia, Georgia Tech and ExxonMobil Research and Engineering Company. This group specializes in the maritime IRP problem or MIRP [49], stochastic inventory routing problem with direct deliveries [37], the heuristics branch-price-cut [26] and Variable neighborhood search [24].
- Group 9: Salvatore Cannella, and Elena Ciancimino affiliated to faculty of engineering in the University of Palermo and Italian National Research Council (CNR). The most notable contributions of this group are related with increasing levels of shared information [9] and analysis of bullwhip effect in multi-echelon supply chain [18] and [19].
- Group 10: Zhou, SX and Chao, XL conforms a group that involves severals institutions such as Department of Systems Engineering and Engineering Management The Chinese University of Hong Kong, Department of Industrial and Operations Engineering, University of Michigan. This group specializes in Stochastic inventory system [11], Finite ordering capacity [12], Optimal pricing decision and reverse logistic [54].
- Group 11: A group of the Universidad Politécnica de Madrid constituted by Manuel Cardos and Eugenia Babiloni. The most important contributions of this group is to propose exact and approximate calculation of the cycle service level in periodic review inventory policies [10] and [6].
- Group 12: E.P Chew and L.H. Lee are a group of researchers is the department of industrial and system engineering. National University of Singapore. They analyze of the impact of the random lead time in the supply chain [14] and also study the dynamic rationing problem for multiple demand classes with Poisson demands [29] and [15].
- Group 13: Ganesh Janakiraman, Woonghee Tim Huh and Bijvank in Unites States group that include the institutions Department of Industrial Engineering and Operations Research, Columbia University, Stern

School of Business, New York University. Their research interests focus on inventory theory where one of his interest topics is the (s, S) policy [27] and [28].

VI. Conclusion

By detecting the lack of scientometrics studies in the subject of IRP, in this paper, a study of this type is presented that include special emphasis in the version stochastic, dynamic and the revision periodic of the inventory. For this propose, one search equation in which were chosen the keywords as well as subject areas the more interest for the IRP was used. 934 y 720 registers of the Scopus and Web of Science databases were considered for the study. The analysis focuses in number of publications, number of citations and detection of the groups of researchers. For the data processing, metrics to measure of productivity and quality was used such as SCM, APM and NCII. A new metric we have called NCIIW that uses the criteria of the APM and NCII metric was used for the identification of the prominent authors. This metric allowed relating the number of citations and the longevity of the publications with the author position. The best outstanding publications were identified and these were cited and referenced in this paper such as reviews, articles and conferences articles. Also, the journals and the conferences more used for the researcher to publish their results were highlighted. Based on the information of prominent authors, their connection with other authors and number of the documents that generated, were identified the groups of researchers and the topics of expertise for each one. Finally, a journey through all tables in the paper allows know the state of the research in the subject of IRP in the special topic of version stochastic, dynamic and the revision periodic of the inventory with its trends and patterns.

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