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Forty years of Computers & Industrial Engineering: A bibliometric analysis

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ABSTRACT

Computers & Industrial Engineering (CIE) is a leading international journal in the field of industrial engineering, whose first issue was published in 1976. Motivated by its 40th anniversary in 2016, this study aims to develop a bibliometric analysis of the publications of the journal between 1976 and 2015. The objective is to identify the leading trends of the journal in terms of impact, topics, universities and countries. In doing so, the work uses the Web of Science Core Collection database to analyze the bibliometric data. Additionally, the work also uses the visualization of similarities (VOS) viewer software to map graphically the bibliographic material. The graphical analysis uses bibliographic coupling, co-citation, citation, co-authorship and co-occurrence of keywords. This paper also offers an editorial perspective of the journal's policy, editorial process, and performance progress.

1. Introduction

Computers & Industrial Engineering (CIE) is one of the leading journals in the field of industrial engineering. Dr. Hamed K. Eldin, the founding editor, published the first issue in 1976. The publisher of the journal was Pergamon press, which was later acquired by Elsevier. In 1998, Mohamed Dessouky from the University of Southern California, USA, became editor-in-chief after Eldin passed away unexpectedly in December 1997. Today, the journal is very well recognized in the scientific community. In the 2016 Journal Citation Reports of Thomson & Reuters Web of Science, CIE had an impact factor of 2.623 and was ranked in the 9th position out of 44 journals in the Web of Science category of Engineering, Industrial. The journal also appears in the Web of Science category of Computer Science, Interdisciplinary Applications in the 28th position out of 105 journals.

In 2016, the journal celebrated its 40th anniversary. This milestone stimulated an interest in conducting a general bibliometric analysis of the principal trends that have occurred in the journal during this period. The study analyzes the productivity and influence of the journal and shows the leading topics, authors, institutions and countries. For doing so, the work uses the Web of Science (WoS) Core Collection database to collect and analyze the bibliographic material. Moreover, the paper also uses the visualization of similarities (VOS) viewer software (Van Eck & Waltman, 2010) to map graphically the bibliographic data. For developing the mapping analysis, the work uses bibliographic coupling (Kessler, 1963), co-citation (Small, 1973), citation, co-authorship and co-occurrence of keywords. Note that Uys, Schutte, and Van Zyl (2011) developed a textual analysis perspective of CIE. However, still nobody has developed a general bibliometric overview of the journal.

In the literature, it is very common to develop some special activities when the journal reaches a significant anniversary including the organization of an editorial (Barley, 2016; Shugan, 2006), a review (Van Fleet et al., 2006) or a special issue (Meyer & Winer, 2014). Particularly, it is very interesting to develop a bibliometric overview of the journal because it gives some general and historical results that permit to develop a retrospective evaluation (Schwert, 1993). Many studies have already been developed a long time ago (Heck & Bremser, 1986). However, in recent years it is becoming very popular and practical, due to the strong technological development of computers and internet over the last years. For example, García-Merino, Pereira-do-Carmo, and Santos-Álvarez (2006) developed a bibliometric analysis of the first twenty-five years of Technovation, Biemans, Griffin, and Moenaert (2007) of the first twenty years of Journal of Product Innovation Management and Dereli, Durmusoglu, Delibas, and Avlanmaz (2011) of the papers published in Total Quality Management & Business

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Excellence between 1995 and 2008. Merigó, Mas-Tur, Roig-Tierno, and Ribeiro-Soriano (2015a) developed a bibliometric overview of the Journal of Business Research between 1973 and 2014 and Cobo, Martínez, Gutiérrez-Salcedo, Fujita, and Herrera-Viedma (2015) for the first twenty-five years of Knowledge-Based Systems. Recently, motivated by the thirtieth anniversary, Merigó, Blanco-Mesa, Gil-Lafuente, and Yager (2017) presented an overview of the International Journal of Intelligent Systems and Valenzuela, Merigó, Johnston, Nicolás, and Jaramillo (2017) of the Journal of Business & Industrial Marketing. Finally, note that nowadays, there are many studies published in this direction and probably in the future (Laengle et al., 2017).

This paper first presents an editorial perspective of journal's history, policy, editorial process and performance. Section 3 briefly describes the bibliometric methods used throughout the paper. Section 4 presents the bibliometric results of the WoS Core Collection and Section 5 develops a graphical analysis of the bibliographic material. Section 6 gives a short description of the main findings and conclusions of the paper.

2. Editorial perspective

From the first year of its publication, 1976, Computers & Industrial Engineering sponsored the first of a series of conferences labeled "International Conference on Computers & Industrial Engineering (ICC&IE)", which continued without interruption until today. From the beginning, the journal followed a rigorous double-blind review process. The publication offered one volume of 4 issues in this first year. In subsequent years it expanded to contain 2 volumes of 4 issues each a year. It contained a good number of special issues dedicated to topics of current interest. However, it also offered special issues containing selected papers from the proceedings of the ICC&IE, which were not reviewed. This practice was discontinued in the early 2000s since it shed a doubt on the rigor of reviewed papers. At about the same time, the journal sought to enhance the rigor and quality of the published papers by appointing area editors specialized in the areas which they are handling.

Table 1
CIE submission rejection statistics.

Year	CAIE submission rejection statistics Submissions						
	TS	DR	% DR	ER	% ER	TR	% TR
2006	533	54	10.13%	96	18.01%	150	28.14%
2007	688	130	18.90%	287	41.72%	417	60.61%
2008	734	245	33.38%	301	41.01%	546	74.39%
2009	850	183	21.53%	258	30.35%	441	51.88%
2010	971	216	22.25%	319	32.85%	535	55.10%
2011	1.089	273	25.07%	382	35.08%	655	60.15%
2012	1.126	301	26.73%	347	30.82%	648	57.55%
2013	1.147	354	30.86%	432	37.66%	786	68.53%
2014	1.255	478	38.09%	430	34.26%	908	72.35%
2015	1.663	603	36.26%	559	33.61%	1.162	69.87%
2016	1.805	656	36.34%	701	38.84%	1.357	75.18%
Total	11.861	3.493	29.45%	4.112	34.67%	7.605	64.12%

Abbreviations: TS = All submissions made in the year; DR = Desk rejections returned by editors without entering the editorial process; %DR = Percentage of desk rejections to total submissions; ER = Editorial rejections rejected by editors after editorial reviews; %ER = Percentage of editorial rejections to total submissions; TR = Total rejections; %TR = Percentage of total rejections to total submissions.

Table 2
Computers & Industrial Engineering key indicators.

Year	TC	JIF	IF-SC	5Y-IF	CiteScore[a]
1997	397	0.117	0.096	N/A	N/A
1998	447	0.105	0.076	N/A	N/A
1999	467	0.093	0.063	N/A	N/A
2000	540	0.128	0.128	N/A	N/A
2001	656	0.391	0.372	N/A	N/A
2002	735	0.270	0.260	N/A	N/A
2003	909	0.413	0.391	N/A	N/A
2004	906	0.632	0.557	N/A	N/A
2005	960	0.347	0.300	N/A	N/A
2006	1.487	0.650	0.566	N/A	N/A
2007	1.538	0.554	0.505	1.058	N/A
2008	2.389	1.057	0.973	1.637	N/A
2009	3.161	1.491	1.215	2.055	N/A
2010	3.179	1.543	1.265	1.823	N/A
2011	3.499	1.589	1.293	1.872	2.92
2012	4.135	1.516	1.248	2.028	2.78
2013	5.060	1.690	1.369	2.382	2.81
2014	5.700	1.783	1.553	2.412	2.80
2015	6.359	2.086	1.674	2.517	3.13
2016	8.227	2.623	2.128	2.859	3.41

Abbreviations: TC = Total citations; JIF = 2-year impact factor; IF-SC = Journal impact factor without journal self-cites; 5Y-IF = 5-year impact factor.
[a] CiteScore measures the average citations received per document published in this title. CiteScore values are based on citation counts in a given year to documents published in three previous calendar years, divided by the number of documents in these three previous years.

To relieve the burden on area editors and reviewers, both the publisher, Elsevier, and the Editorial Office (consisting of the editor-in-chief and the associate editor, currently Yasser Dessouky of San Jose State University, California, USA) developed a policy for screening articles before they are sent through the editorial process. The publisher introduced a procedure called "Technical Screening", which examined submissions for adherence to publication policy and guidelines and for the use of the English language. Papers which pass the test are forwarded to the editorial office; otherwise, they are sent back to the author if the violations are minor or rejected if they are significant. Another concern for the publisher and the editors is Plagiarism. To guard against it Elsevier runs submissions through CrossCheck to find any significant overlap with the contents of existing publications, and reports to the editors any overlaps or duplications. At the editorial office's end papers are screened again and returned to the author with a Return letter if they fail to meet any of the following criteria:

- The topic being within the journal's scope (Return Topic).
- Following a rigorous scientific method (Return Methodology).
- Making a significant contribution to the literature (Return Contribution).
- Making a presentation in good style and language (Return Presentation).

All these are lumped under Desk Rejections, as shown in Table 1, "CIE Editorial Statistics". In addition, the Editorial Office looks at the results of CrossCheck provided by the publisher and decides if the overlap warrants rejection of the submission, returning the article to the author to remove unnecessary overlap, or just rejecting it.

Papers which are not rejected for any of the reasons outlined above are sent through the editorial process. After being reviewed a manuscript is either accepted, accepted with minor modifications, returned to the author for major changes, or rejected. The desk rejection and the editorial rejection rates are shown in Table 1.

At the beginning of 2006 the journal went online, using a system called, "Elsevier Editorial System (EES)". All papers had to be submitted to EES, and the full editorial process is handled through it. This encouraged an upsurge in submissions, and with it the rejection rates, as reflected in Table 1. Nevertheless, the number of accepted papers increased drastically, prompting the publisher to increase the number of issues to 12 per year starting with Volume 64 in January 2013, with still 4 issues per volume. In 2014

Table 3
Annual citation structure of CIE.

Year	TP	TC	≥100	≥50	≥20	≥10	≥5	≥1
1976	6	11	0	0	0	0	1	3
1977	18	3	0	0	0	0	0	3
1978	21	76	0	0	2	2	4	12
1979	22	36	0	0	0	2	2	10
1980	27	17	0	0	0	0	1	8
1981	25	34	0	0	0	0	2	11
1982	24	97	0	0	1	3	5	15
1983	29	65	0	0	1	1	3	17
1984	22	86	0	0	1	3	6	14
1985	38	201	0	1	3	7	7	28
1986	162	274	0	0	2	7	19	70
1987	123	186	0	0	2	5	8	49
1988	123	562	1	1	4	13	33	66
1989	170	532	0	1	5	11	26	100
1990	180	758	0	2	7	18	51	123
1991	167	758	0	3	9	24	38	99
1992	169	1015	1	3	13	30	45	115
1993	197	944	0	2	9	28	53	130
1994	201	1033	0	1	13	34	60	145
1995	207	1635	1	5	20	45	88	160
1996	290	3073	5	11	38	74	115	225
1997	283	2576	1	8	38	87	128	231
1998	221	2275	1	10	27	70	117	182
1999	184	2937	3	13	36	68	101	159
2000	31	594	0	4	10	14	25	30
2001	69	1325	1	4	25	39	51	68
2002	110	2793	2	17	45	64	83	106
2003	81	1729	2	8	29	53	62	79
2004	93	1996	3	12	28	54	72	89
2005	87	2195	2	8	38	59	72	85
2006	99	2032	3	11	28	59	80	96
2007	93	1759	1	7	29	54	78	92
2008	139	2802	3	13	47	88	116	135
2009	310	5259	3	19	82	177	253	303
2010	201	3188	1	12	52	110	165	193
2011	229	2336	1	5	30	85	154	216
2012	226	2074	0	3	21	71	144	210
2013	285	1771	0	0	12	58	145	262
2014	238	906	0	0	2	17	68	207
2015	338	520	0	0	0	3	23	205
Total	5538	52463	35	184	709	1537	2504	4351
%	100.00%		0.63%	3.32%	12.80%	27.75%	45.21%	78.57%

Abbreviations: TP and TC = Total papers and citations; ≥100, ≥50, ≥20, ≥10, ≥5, ≥1 = Number of papers with equal or more than 100, 50, 20, 10, 5 and 1 citations; IF = Impact Factor of the Journal Citation Reports.

the publisher dispensed with multiple issues per volume and restricted them to one, starting with Volume 67.

More recently, Elsevier introduced an option for authors according to which their accepted papers would be put in open access where readers are not charged for downloading. Authors are levied a certain fee for this option.

Table 2, CIE Key Performance Indicators, shows the progress of the journal from 1997 to 2016. It shows the steady improvement in its (2-year) impact factor and its 5-year impact factor. Of particular interest is the standing on CiteScore which measures the average citations received per document published in this title. CiteScore values are based on citation counts in a given year to documents

Table 4
The 50 most cited documents in CIE.

R	TC	Title	Author/s	Year	C/Y
1	415	Issues in environmentally conscious manufacturing and product recovery: a survey	Gungor, A; Gupta, SM	1999	24.41
2	281	Supply chain modeling: past, present and future	Min, H; Zhou, GG	2002	20.07
3	249	An effective hybrid optimization approach for multi-objective flexible job-shop scheduling problems	Xia, WJ; Wu, ZM	2005	22.64
4	243	Product planning in quality function deployment using a combined analytic network process and goal programming approach	Karsak, EE; Sozer, S; Alptekin, SE	2003	18.69
5	236	A tutorial survey of job-shop scheduling problems using genetic algorithms. 1. Representation	Cheng, RW; Gen, M; Tsujimura, Y	1996	11.80
6	228	Multi-objective genetic algorithm and its applications to flowshop scheduling	Murata, T; Ishibuchi, H; Tanaka, H	1996	11.40
7	201	Genetic algorithms for flowshop scheduling problems	Murata, T; Ishibuchi, H; Tanaka, H	1996	10.05
8	170	Hybrid flow shop scheduling: A survey	Linn, R; Zhang, W	1999	10.00
9	170	Single facility scheduling with nonlinear processing times	Gupta, JND; Gupta, SK	1988	6.07
10	167	A fuzzy goal programming approach for vendor selection problem in a supply chain	Kumar, M; Vrat, P; Shankar, R	2004	13.92
11	165	Cell formation in group technology: Review, evaluation and directions for future research	Selim, HM; Askin, RG; Vakharia, AJ	1998	9.17
12	155	Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach	Ravi, V; Shankar, R; Tiwari, MK	2005	14.09
13	140	A tutorial survey of job-shop scheduling problems using genetic algorithms, part II: hybrid genetic search strategies	Cheng, RW; Gen, M; Tsujimura, Y	1999	8.24
14	140	Evolutionary algorithms for constrained engineering problems	Michalewicz, Z; Dasgupta, D; Leriche, RG; Schoenauer, M	1996	7.00
15	136	A Genetic algorithm approach to the machine component grouping problem with multiple objectives	Venugopal, V; Narendran, TT	1992	5.67
16	129	A review of optimization techniques in metal cutting processes	Mukherjee, I; Ray, PK	2006	12.90
17	127	An effective hybrid particle swarm optimization algorithm for multi-objective flexible job-shop scheduling problem	Zhang, GH; Shao, XY; Li, PG; Gao, L	2009	18.14
18	126	Design for manufacture and design for 'X': concepts, applications, and perspectives	Kuo, TC; Huang, SH; Zhang, HC	2001	8,40
19	123	A survey of scheduling with deterministic machine availability constraints	Ma, Y; Chu, CB; Zuo, CR	2010	20.50
20	122	A hybrid particle swarm optimization for job shop scheduling problem	Sha, DY; Hsu, CY	2006	12.20
21	119	Analyzing the design and management of biomass-to-biorefinery supply chain	Eksioglu, SD; Acharya, A; Leightley, LE; Arora, S	2009	17.00
22	119	The use of grey relational analysis in solving multiple attribute decision-making problems	Kuo, Y; Yang, T; Huang, GW	2008	14.88
23	119	Study on multi-stage logistic chain network: a spanning tree-based genetic algorithm approach	Syarif, A; Yun, Y; Gen, M	2002	8.50
24	117	A genetic algorithm approach for multi-objective optimization of supply chain networks	Altiparmak, F; Gen, M; Lin, L; Paksoy, T	2006	11.70
25	115	The vehicle routing problem: A taxonomic review	Eksioglu, B; Vural, AV; Reisman, A	2009	16.43
26	114	Evolving dispatching rules using genetic programming for solving multi-objective flexible job-shop problems	Tay, JC; Ho, NB	2008	14.25
27	112	Penalty guided genetic search for reliability design optimization	Coit, DW; Smith, AE	1996	5.60
28	108	A hybrid genetic algorithm for the job shop scheduling problems	Park, BJ; Choi, HR; Kim, HS	2003	8.31
29	107	Performance measurement of supply chain management: A balanced scorecard approach	Bhagwat, R; Sharma, MK	2007	11.89
30	107	Evaluation of the number of rehandles in container yards	Kim, KH	1997	5.63
31	107	The use of data envelopment analysis for technology selection	Khouja, M	1995	5.10
32	103	Decision-making with distance measures and induced aggregation operators	Merigo, JM; Casanovas, M	2011	20.60
33	102	An evolutionary algorithm for manufacturing cell formation	Goncalves, JF; Resende, MGC	2004	8.50
34	102	Application of fuzzy multi-objective linear programming to aggregate production planning	Wang, RC; Liang, TF	2004	8.50
35	101	Some scheduling problems with deteriorating jobs and learning effects	Cheng, TCE; Wu, CC; Lee, WC	2008	12.63
36	97	Fuzzy decision making with immediate probabilities	Merigo, JM	2010	16.17
37	97	A discrete differential evolution algorithm for the permutation flowshop scheduling problem	Pan, QK; Tasgetiren, MF; Liang, YC	2008	12.13
38	96	Collaborative networked organizations - Concepts and practice in manufacturing enterprises	Camarinha-Matos, LM; Afsarmanesh, H; Galeano, N; Molina, A	2009	13.71
39	93	Optimal manufacturing batch size with rework process at a single-stage production system	Jamal, AMM; Sarker, BR; Mondal, S	2004	7.75
40	93	Genetic algorithm for non-linear mixed integer programming problems and its applications	Yokota, T; Gen, M; Li, YX	1996	4.65
41	92	Linear programming in disassembly/clustering sequence generation	Lambert, AJD	1999	5.41
42	91	Production-distribution planning in supply chain considering capacity constraints	Lee, YH; Kim, SH	2002	6.50
43	91	Reengineering of design and manufacturing processes	Kusiak, A; Larson, TN; Wang, JR	1994	4.14
44	90	An optimal ordering and recovery policy for reusable items	Koh, SG; Hwang, H; Sohn, KI; Ko, CS	2002	6.43
45	89	Economic production lot size model for deteriorating items with partial back-ordering	Wee, HM	1993	3.87
46	88	QFD Optimizer: A novice friendly quality function deployment decision support system for optimizing product designs	Moskowitz, H; Kim, kJ	1997	4.63
47	87	Coordinating a two-level supply chain with delay in payments and profit sharing	Jaber, MY; Osman, IH	2006	8.70
48	87	Advanced planning and scheduling with outsourcing in manufacturing supply chain	Lee, YH; Jeong, CS; Moon, C	2002	6.21
49	87	Backpropagation pattern recognizers for (X)over-bar control charts: Methodology and performance	Hwarng, HB; Hubele, NF	1993	3.78
50	86	Single linkage versus average linkage clustering in machine cells formation applications	Seifoddini, HK	1989	3.19

Abbreviations available in Table 3 except for: R = Rank; C/Y = Citations per year.

Table 5
Most cited documents in CIE publications.

R	Year	Cited reference	Type	Citations	TLS
1	1989	Goldberg DE, Genetic Algorithms	B	146	101
2	1980	Saaty TL, Analytic Hierarchy Process	B	103	36
3	1975	Holland JH, Adaptation in Natural and Artificial Systems	B	99	83
4	1979	Garey MR, Computers Intractability	B	98	52
5	1983	Kirkpatrick S, Science, v220, p671	A	79	55
6	1965	Zadeh LA, Inform Control, v8, p338	A	75	42
7	1979	Graham RL, Ann Discrete Math, p287	A	72	58
8	1974	Baker KR, Intro Sequencing and Scheduling	B	71	48
9	1997	Gen M, Genetic Algorithms	B	67	45
10	1978	Charnes A, Eur J Oper Res, v2, p429	A	65	49
11	1954	Johnson S, Nav Res Log, v1, p61	A	62	49
12	1983	Nawaz M, Omega-Int J Manage Sci, v11, p91	A	55	48
13	1980	King JR, Int J Prod Res, v18, p213	A	54	51
14	1982	King JR, Int J Prod Res, v20, p117	A	54	49
15	1972	McAuley J, Production Eng, v51/2, p53	A	53	51
16	2000	Gen M, Genetic Algorithms	B	47	39
17	1976	Garey MR, Mathematics of Operations Research, v1, p117	A	46	42
18	1995	Kennedy J, IEEE Int Conf Neural Networks Proc, vols. 1–6, p1942	C	44	27
19	1995	Pinedo M, Scheduling: Theory, Algorithms, and Systems	B	43	36
20	1967	Conway R., Theory of Scheduling	B	43	33
21	2002	Deb K, IEEE T Evolut Comput, v6, p182	A	38	21
22	1958	Wagner HM, Manage Sci, v5, p89	A	37	9
23	1991	Law A, Simulation Modeling and Analysis	B	36	9
24	1987	Kusiak A, Int J Prod Res, v25, p561	A	35	34
25	1963	Hadley G, Analysis of Inventory Systems	B	35	5
26	2008	Biskup D, Eur J Oper Res, v188, p315	A	34	33
27	1986	Seifoddini H, IIE Trans, v18, p271	A	34	32
28	1988	Yager RR, IEEE T Syst Man Cyb, v18, p183	A	34	15
29	1988	Choobineh F, Int J Prod Res, v26, p1161	A	33	32
30	1989	Glover F, ORSA Journal on Computing, v1, p190	A	33	31

Abbreviations: A = Article; B = Book; C = Conference proceedings; TLS = Total Link Strength.

Table 6
Citing articles of CIE: Journals.

R	Journal	76–80	81–85	86–90	91–95	96–00	01–05	06–10	11–15	TP
1	Computers Industrial Engineering	15	48	253	378	437	503	834	530	2998
2	Int J Production Research	6	33	170	362	687	582	545	264	2649
3	Int J Advanced Manufacturing Tech	2	15	99	228	512	409	469	125	1859
4	European J Operational Res	20	38	107	211	338	242	301	178	1435
5	Expert Systems with Applications	–	2	29	75	214	287	380	136	1123
6	Int J Production Econ	5	15	45	132	236	275	281	116	1105
7	Computers Operations Res	2	16	62	92	199	184	206	94	855
8	Applied Mathematical Modelling	3	4	11	28	52	86	242	103	529
9	Mathematical Problems in Engineering	–	–	15	15	53	56	191	161	491
10	Applied Soft Computing	–	–	3	20	72	100	180	122	497
11	J The Operational Research Society	2	21	52	63	107	50	81	42	418
12	J Intelligent Manufacturing	–	6	28	72	130	104	102	31	473
13	Int J Computer Integrated Manufacturing	–	4	46	65	104	103	85	21	428
14	Production Planning Control	1	14	36	56	79	66	62	22	336
15	Information Sciences	–	–	4	17	51	51	116	68	307
16	Applied Mathematics and Computation	–	2	7	34	68	51	107	39	308
17	Omega Int J Management Science	5	13	29	29	55	41	67	43	282
18	IIE Transactions	9	14	43	56	60	30	25	9	246
19	Int J Systems Science	1	9	19	39	48	41	80	31	268
20	Annals Operations Res	2	8	11	35	39	40	65	32	232
21	Proc Inst Mechanical Engin Part B	–	2	13	36	77	46	52	11	237
22	J Manufacturing Systems	2	–	14	29	55	58	90	48	296
23	Computers in Industry	1	4	32	45	53	34	45	18	232
24	Transportation Research Part E	1	1	2	5	35	25	74	72	215
25	Reliability Engineering System Safety	–	1	5	15	60	24	29	65	199
26	J Intelligent Fuzzy Syst	–	–	2	9	14	30	71	82	208
27	Int J Industrial Engineering	1	–	16	22	59	44	29	10	181
28	J Cleaner Production	–	–	1	4	43	27	72	33	180
29	Robotics and Computer Integrated Manufacturing	–	3	6	42	78	36	17	4	186
30	Quality and Reliability Engineering Int	–	2	2	20	37	41	39	39	180

Abbreviations available in Tables 3 and 4 except: 76–80, 81–85, 86–90, 91–95, 96–00, 01–05, 06–10, 11–15 = Number of papers published in CIE in the five-year period considered.

published in three previous calendar years, divided by the number of documents in these three previous years. The score of CIE is 3.41, which puts it in the 11th ranking among 265 engineering journals.

3. Bibliometric methods

Bibliometrics is the research field of library and information sciences that studies the bibliographic material by using quantitative methods (Broadus, 1987; Pritchard, 1969). Over the years, bibliometrics has become very popular for classifying bibliography and developing representative summaries of the leading results. Some decades ago, it took a lot of time to classify the data because the process to collect the information was manual (Ding, Rousseau, & Wolfram, 2014; Garfield, 1955). However, today it is very easy to analyze this data thanks to the strong improvement of computers and internet during the last years (Merigó, Gil-Lafuente, & Yager, 2015b).

In the literature, there are many bibliometric studies of a wide variety of issues including topics (Emrouznejad & Marra, 2014; Yu, 2015), journals (Thongpapanl, 2012), universities (Linton, 2004), and countries (Bonilla, Merigó, & Torres-Abad, 2015). For example, Podsakoff, MacKenzie, Podsakoff, and Bachrach (2008) presented a general bibliometric analysis of leading management authors and institutions over a quarter of century, Coupé (2003) in economic research, and Blanco-Mesa, Merigó, and Gil-Lafuente (2017) and Yu, Li, Merigó, and Fang (2016) in decision making. There are also several bibliometric studies about engineering topics including software engineering (Garousi & Fernandes, 2016; Garousi & Ruhe, 2013), chemical engineering (Fu, Long, & Ho, 2014), engineering nanomaterials (Wang, Yang, Yang, Long, & Li, 2014), engineering education (Borrego & Bernhard, 2011), decision making and ecological engineering (Zhang, Wang, Hu, & Ho, 2010).

Bibliometric indicators are very useful for representing the bibliographic material. The aim of the indicator is to provide a representative and informative perspective of the data. There are many open questions regarding which is the optimal indicator to represent the information (Podsakoff et al., 2008). Since there is no consensus on the optimal approach, this study presents several indicators usually regarded as the most popular ones. By doing so, the article aims to be informative but showing different results of the same variable so each reader can understand the data according to its particular interests and at the same time detect strengths and opportunities. Among others, the study uses the total number of papers and citations in order to measure productivity and influence, the cites per paper and the *h*-index (Alonso, Cabrerizo, Herrera-Viedma, & Herrera, 2009; Hirsch, 2005). Additionally, the study also uses citation thresholds that measure the number of documents above a number of citations, and some general indicators used by other research institutions such as the university rankings and the number of documents per person.

The bibliometric data of the study comes from the WoS Core Collection database. The search process uses the keyword "Computers & Industrial Engineering" and was carried out between August and November 2016. The study considers all the documents published in the journal up to 31 December 2015. The search obtains 5760 documents, which reduces to 5538 if only considering articles, reviews, letters and notes. Currently, the journal has 52,463 citations coming from other sources available in WoS Core Collection which makes a cites per paper ratio of 9.47. The *h*-index is 77. That is, of the 5538 documents, 77 documents have 77 citations or more. At the same time, there are not 78 documents with 78 citations.

To obtain a more general view of the results, the work also develops a graphical analysis of the bibliographic material by using the VOS viewer software (Van Eck & Waltman, 2010). This software collects the data and generates maps based on bibliographic coupling, co-authorship, citation, co-citation and co-occurrence of keywords (Merigó, Cancino, Coronado, & Urbano, 2016). Recall that bibliographic coupling (Kessler, 1963) occurs when two documents cite the same third article. Co-citation (Small, 1973) measures the

Table 7
Citing articles of CIE: Authors, universities and countries.

R	Author	TP	University	TP	Country	TP
1	Tavakkoli-Moghaddam R	141	Islamic Azad U	488	PR China	5589
2	Cheng TCE	108	U Tehran	464	USA	4653
3	Chan FTS	99	Hong Kong Polytechnic U	432	Taiwan	3139
4	Lin YK	91	Indian Institute Technology	381	Iran	1931
5	Wu CC	88	Shanghai Jiao Tong U	325	UK	1452
6	Tiwari MK	85	National Taiwan U Science Technology	320	India	1394
7	Zandieh M	82	Amirkabir U Technology	301	Turkey	1346
8	Ghomi SMTF	79	CNRS France	296	Canada	1127
9	Wee HM	77	National Chiao Tung U	275	South Korea	1054
10	Azadeh A	76	Feng Chia U	269	France	896
11	Jolai F	71	Iran U Science Technology	265	Spain	877
12	Wang JB	70	Tsinghua U	258	Germany	637
13	Niaki STA	68	Huazhong U Science Technology	253	Italy	634
14	Lee WC	65	National Cheng Kung U	243	Australia	490
15	Merigo JM	65	National U Singapore	234	Japan	467
16	Gen M	64	Northeastern U China	223	Singapore	452
17	Jaber MY	64	City U Hong Kong	213	Brazil	419
18	Dolgui A	61	U Hong Kong	189	Malaysia	389
19	Chen T	59	National Tsing Hua U	189	Netherlands	358
20	Levitin G	58	Chung Yuan Christian U	186	Greece	284
21	Pan QK	58	Nanyang Tech U Singapore	183	Belgium	263
22	Wang L	56	Xi An Jiaotong U	180	Portugal	231
23	Baykasoglu A	53	Sharif U Technology	174	Poland	224
24	Gupta SM	53	U Montreal	173	Saudi Arabia	213
25	Huang GQ	51	Southeast U China	172	Israel	201
26	Gao L	50	Dalian U Technology	170	Mexico	198
27	Xu JP	50	KAIST – S. Korea	168	Thailand	180
28	Kahraman C	49	Gazi U	165	Sweden	138
29	Xu ZS	49	Penn State U	161	Denmark	126
30	Chen HY	48	National Central U	150	Chile	121

Abbreviations available in Tables 3 and 4.

most cited documents and appears when two documents receive a citation from the same third work. Co-authorship measures the degree of co-authors between the most productive sources. Citation analysis focuses on the degree of citations between two variables. Co-occurrence of author keywords shows the most common keywords that usually appear below the abstract and the network connections visualizes the keywords that appear more frequently in the same papers. Finally, note that in the literature there is a wide range of software for carrying out mapping studies of the bibliographic data (Cobo, Lopez-Herrera, Herrera-Viedma, & Herrera, 2011).

4. Results

4.1. Publication and citation structure of CIE

CIE published its first issue in 1976 although the first volume with four issues appeared in 1977. In order to analyze the publications and citations of CIE, Table 3 presents the annual number of papers published in the journal and the total number of citations received by these papers up to November 2016. Additionally, Table 3 also presents several citation thresholds in order to identify highly cited papers and those that at least have received one or five citations.

Until 1985, the journal published a small number of papers per year. In 1986 it started growing significantly publishing more than one hundred papers every year. During the beginning of the new millennium, the number decreased significantly and started growing again in 2008. From 2009, the journal has been publishing more than two hundred documents per year with a top of 338 papers in 2015. Note that 0.6% of the papers receive more than one hundred citations and 3.3% more than fifty. 45% of the documents have more than five citations and 78% get at least one citation. The last column of Table 3 shows the impact factor of the journal. Observe that it only presents the electronic version of the impact factor that is available from 1997. The first years is very low because at that time

Table 8
The most productive and influential institutions in CIE.

R	Institution	Country	TP	TC	H	C/P	≥50	≥25	≥5	ARWU	QS	Top 50
1	U Central Florida	USA	103	363	10	3.5	0	1	3	401–500	701+	–
2	Ashikaga Inst Technol	Japan	84	1662	22	20	3	6	22	–	–	4
3	KAIST	S. Korea	83	715	15	8.6	0	1	11	201–300	46	–
4	U Louisville	USA	81	946	15	12	1	3	9	–	–	1
5	Indian Institute Technology	India	66	1274	17	19	4	5	15	–	–	4
6	Texas AM U College Station	USA	62	304	10	4.9	0	0	3	101–150	160	–
7	North Carolina AT State U	USA	60	193	6	3.2	0	0	2	201–300	277	–
8	Purdue U	USA	58	544	13	9.4	0	2	9	63	92	1
9	Islamic Azad U	Iran	58	170	4	2.9	0	1	9	–	–	–
10	Ohio U	USA	57	294	10	5.2	0	0	1	–	701+	–
11	Virginia Polytech Inst State U	USA	57	226	9	4	0	0	1	301–400	361	–
12	Hong Kong Polytechnic U	China	56	797	15	14	1	5	12	301–400	111	–
13	Penn State U	USA	55	405	12	7.4	0	1	4	77	95	1
14	Arizona State U	USA	54	588	13	11	0	3	9	101–150	222	–
15	U Puerto Rico	P. Rico	51	249	10	4.9	0	0	4	–	701+	–
16	National Taiwan U Sci Tech	Taiwan	49	564	12	12	1	3	8	–	243	–
17	National Chiao Tung U	Taiwan	47	618	14	13	1	2	9	401–500	174	–
18	City U Hong Kong	China	45	580	12	13	0	3	7	201–300	55	–
19	U Oklahoma Norman	USA	45	207	8	4.6	0	0	1	–	461–470	–
20	National Cheng Kung U	Taiwan	44	654	15	15	1	2	11	401–500	241	–
21	Oregon State U	USA	44	175	8	4	0	0	2	151–200	461–470	–
22	Pusan National U	S. Korea	42	646	14	15	1	2	13	401–500	451–460	1
23	Louisiana State U	USA	42	357	11	8.5	0	1	4	301–400	651–700	–
24	U South Florida	USA	41	163	8	4	0	0	1	201–300	491–500	–
25	Western Michigan U	USA	40	115	6	2.9	0	0	1	–	–	–
26	National U Singapore	Singapore	39	638	12	16	0	5	9	83	12	–
27	U Florida	USA	39	351	8	9	1	1	3	90	185	1
28	Tsinghua U	China	38	559	13	15	0	3	12	58	24	–
29	Chung Yuan Christian U	Taiwan	38	382	11	10	0	0	7	–	–	–
30	National Tsing Hua U	Taiwan	38	293	10	7.7	0	0	5	301–400	151	–
31	Feng Chia U	Taiwan	37	609	13	16	1	4	9	–	–	–
32	U Hong Kong	China	37	342	10	9.2	0	0	4	–	–	–
33	U Miami	USA	37	167	6	4.5	0	0	1	151–200	252	–
34	Wichita State U	USA	37	138	7	3.7	0	0	1	–	–	–
35	Pusan National U Hospital	S. Korea	36	637	14	18	1	2	13	401–500	451–460	1
36	Iowa State U	USA	36	210	8	5.8	0	1	1	201–300	421–430	–
37	U Michigan	USA	35	416	12	12	0	2	5	23	23	–
38	Missouri U Science Technology	USA	35	143	7	4.1	0	0	0	–	501–550	–
39	U Arkansas Fayetteville	USA	34	208	8	6.1	0	1	4	–	701+	–
40	U Southern Mississippi	USA	34	34	3	1	0	0	0	–	–	–
41	Seoul National U	S. Korea	33	390	10	12	0	3	3	101–150	35	–
42	U Quebec	Canada	33	360	11	11	0	1	6	301–400	501–550	–
43	Clemson U	USA	33	294	9	8.9	0	1	3	–	701+	–
44	U Tehran	Iran	32	431	14	13	0	1	5	301–400	551–600	–
45	Florida International U	USA	32	358	8	11	1	1	4	401–500	–	–
46	Xi An Jiaotong U	China	32	344	9	11	0	2	6	151–200	318	–
47	Oklahoma State U Stillwater	USA	32	207	7	6.5	0	1	3	401–500	701+	–
48	Iran U Science Technology	Iran	31	311	9	10	0	0	5	–	491–500	–
49	Texas Tech U	USA	31	277	8	8.9	1	1	3	401–500	–	1
50	Northeastern U	USA	30	935	12	31	1	6	7	201–300	361	–

Abbreviations are in Tables 3 and 4 except: H = *h*-index; C/P = Cites per paper; ≥25 = Number of documents with equal or more than 25 citations; ARWU and QS = Ranking in the general ARWU and QS university rankings; Top 50 = Papers among the fifty most cited published in CIE.

the average impact factor was much lower than today. The main reason is the growth of the WoS database that now includes many more journals and documents generating more citations to all the journals, especially, those with the highest quality.

Next, let us consider the most cited papers published in the journal. For doing so, Table 4 presents a list with the fifty most cited papers of all-time in the journal. Observe that in the case of a tie in the number of citations, the youngest paper appears first.

The most cited paper is from 1999 by Askiner Gungor and Surendra M. Gupta and has more than four hundred citations. Mitsuo Gen has six papers in the list and Tadahiko Murata, Hisao Ischibuchi and Hideo Tanaka co-authored two papers that are currently among the ten most cited papers in the journal.

Another interesting issue to consider is the most cited documents by papers published in CIE. In order to do so, the work uses the VOS viewer (Van Eck & Waltman, 2010) and generates the results for the co-citation of documents where the ranking appears according to the most cited documents. Table 5 shows the thirty most cited documents.

The first four positions go for four books. The first book in the ranking is written by David E. Goldberg about Genetic Algorithms. The Top 30 contains eighteen articles, eleven books and one conference proceeding document.

A further interesting issue is to analyze who is citing CIE. For doing so, Table 6 presents the thirty journals with the highest number of citing articles to CIE. Note that a citing article is a document that cites CIE. However, inside the article the only requirement is to cite at least once the journal although it may cite several times the same journal.

CIE itself leads the ranking which is quite obvious because it is very common for a journal to cite itself. Note that in 1996–2000 and 2001–2005 the journal that gave more citations to CIE was the International Journal of Production Research. Most of the journals connect with engineering, computer science or operations research.

Next, let us consider the citing articles from the point of view of authors, universities and countries in order to identify the places that are significantly productive and more influenced by CIE. Table 7 presents the Top 30.

The Islamic Azad University is the leading citing university of CIE. Note that the list is very diverse from universities all over the world, particularly from Asia. This also occurs at the country level where China obtains the first position over the USA. Additionally, Taiwan and Iran get the third and fourth position, respectively, and India, Turkey and South Korea appear in the Top 10.

Table 9
Most productive institutions in CIE throughout time.

	1976–1980			1981–1985			1986–1990			1991–1995		
R	University	TP	TC	University	TP	TC	University	TP	TC	University	TP	TC
1	Oklahoma State U SW	9	1	Texas A M U Coll St	9	31	U Central Florida	47	127	U Louisville	40	237
2	Texas A M U Coll St	6	6	Purdue U	9	29	Penn State U	25	76	Ashikaga Inst Tech	33	313
3	Purdue U	5	11	Auburn U	9	15	U Louisville	18	66	U Central Florida	29	44
4	U Florida	4	33	Virginia Tech Inst St U	7	13	Virginia Tech Inst St U	17	43	Arizona State U	24	252
5	Auburn U	4	3	U Central Florida	7	3	U South Florida	17	42	North Carolina At St U	23	57
6	Virginia Tech Inst St U	4	2	Penn State U	5	10	Texas A M U Coll St	16	80	Oregon State U	22	62
7	IBM	4	1	Louisiana State U	5	7	Western Michigan U	16	34	U Oklahoma Norman	20	97
8	U Dayton	4	0	Texas Tech U	4	67	Iowa State U	16	34	Ohio U	19	90
9	U Central Florida	2	10	U Southern California	4	40	Cleveland State U	16	25	Western Michigan U	19	59
10	Stanford U	2	2	U Windsor	4	36	U Miami	16	18	Missouri U Sci Tech	18	91
11	Lehigh U	2	2	U Florida	4	18	U Florida	15	34	Virginia Tech Inst St U	16	38
12	Wichita State U	2	1	Wichita State U	3	13	U Southern Mississippi	15	7	Wichita State U	16	32
13	U Wisconsin Madison	2	1	U Cincinnati	3	9	Ohio U	14	5	Purdue U	14	147
14	U Southern California	2	1	U Minnesota Twin Cities	3	6	Wichita State U	12	32	Tennessee Tech U	13	116
15	U Notre Dame	2	1	George Washington U	3	4	North Carolina At St U	12	31	Texas A M U Coll St	13	82
16	U Moncton	2	1	U South Florida	3	0	Oklahoma St U Sw	12	26	KAIST	13	60
17	U Houston	2	1	Arizona State U	2	54	U Missouri Columbia	12	14	Alfred U	13	13
18	Clemson U	2	0	U Hong Kong	2	45	Florida Atlantic U	12	0	U Ottawa	12	65
19	Asian Inst Tech	2	0	Florida Inst Tech	2	8	U Oklahoma Norman	11	37	U Louisiana Lafayette	12	13
20	US Dep Defense	2	0	Iowa State U	2	5	Drexel U	11	33	Louisiana State U	11	73
	1996–2000			2001–2005			2006–2010			2011–2015		
1	Ashikaga Inst Tech	40	1016	Chung Yuan C U	10	174	Hong Kong Tech U	20	442	Islamic Azad U	41	212
2	KAIST	35	374	Swinburne U Tech	9	119	Nat Cheng Kung U	18	372	Hong Kong Tech U	29	264
3	U Puerto Rico Mayaguez	34	167	Hanyang U	8	439	Islamic Azad U	16	356	CNRS France	29	157
4	Pusan National U	17	443	Indian Inst Tech	8	438	Feng Chia U	15	404	Indian Inst Tech	27	178
5	Hong Kong U Sci Tech	15	320	KAIST	8	154	Chung Yuan C U	15	143	Nat Taiwan U Sci Tech	25	123
6	Seoul National U	15	120	Arizona State U	7	118	Nat Taiwan U Sci Tech	14	271	U Tehran	20	147
7	North Carolina At St U	15	20	Chinese Acad Sci	7	102	Waseda U	13	477	Iran U Sci Tech	20	105
8	U Southern Mississippi	15	17	U Quebec	7	79	National Chiao Tung U	13	224	Feng Chia U	19	196
9	Northeastern U	14	855	Ashikaga Inst Tech	6	321	Yonsei U	13	206	National Tsing Hua U	18	91
10	U Quebec	14	145	National U Singapore	6	106	Northeastern U China	12	286	National Chiao Tung U	17	108
11	U Michigan	13	144	Sultan Qaboos U	6	96	CNRS France	12	259	Xi An Jiaotong U	16	78
12	SUNY Binghamton	12	50	City U Hong Kong	6	84	City U Hong Kong	12	141	Tsinghua U	15	107
13	City U Hong Kong	11	272	U Louisville	5	387	Indian Inst Tech	11	285	Shanghai Jt U	15	96
14	Louisiana State U	11	100	Tsinghua U	5	197	Iran U Sci Tech	11	206	Sharif U Tech	15	61
15	Florida International U	11	99	Nat Chiao Tung U	5	157	Tsinghua U	11	178	Ryerson U	15	55
16	U Central Florida	11	85	Louisiana State U	5	151	Amirkabir U Tech	11	165	National Cheng Kung U	14	81
17	Indian Inst Tech	10	165	Nat Cheng Kung U	5	116	Gazi U	10	330	Beihang U	14	74
18	Pohang U Sci Tech	10	137	Nanyang Tech U	5	110	Ryerson U	10	266	Shanghai Maritime U	14	43
19	U Louisville	10	82	Orta Dogu Teknik U	5	84	U Tehran	10	250	National Central U	13	64
20	Oregon State U	10	40	Concordia U Canada	5	83	KAIST	10	99	City U Hong Kong	13	64

Abbreviations are available in the previous tables.

Table 10
Temporal evolution of the publications classified by countries.

		Total				1976–80		1981–85		1986–90		1991–95		1996–00		2001–05		2006–10		2011–15				
R	Country	TP	TC	H	C/P	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	P/Po	C/Po	T50
1	USA	2444	15938	49	6.52	85	127	116	368	673	2049	654	3314	437	4405	136	2854	133	1929	210	892	7.54	49.17	17
2	PR China	643	8099	41	12.60	–	–	2	45	5	8	23	106	85	1092	43	1358	159	3423	317	2067	0.47	5.86	8
3	Taiwan	492	6299	36	12.80	–	–	–	–	3	10	37	313	39	588	53	1155	171	3070	189	1163	21.03	269.24	6
4	South Korea	422	4985	34	11.81	–	–	–	–	12	47	55	344	143	1569	54	1487	90	1258	68	280	8.36	98.71	6
5	Canada	261	2260	23	8.66	5	8	7	39	30	122	48	456	56	494	25	289	32	582	58	270	7.19	62.28	1
6	Japan	259	3458	29	13.35	–	–	–	–	7	14	100	502	88	1725	20	534	29	578	15	105	2.05	27.37	7
7	Iran	188	1890	21	10.05	–	–	–	–	–	–	–	–	1	–	5	39	51	1015	131	836	2.35	23.61	–
8	Turkey	168	2444	28	14.55	–	–	–	–	1	1	4	33	15	180	14	508	55	1253	79	469	2.11	30.70	2
9	India	156	2028	23	13.00	–	–	–	–	8	37	11	208	13	187	14	516	39	705	71	375	0.12	1.53	5
10	UK	135	1692	24	12.53	2	15	2	2	3	17	9	53	34	304	19	497	28	463	38	341	2.07	25.99	–
11	France	127	1325	18	10.43	–	–	–	–	–	–	3	16	14	293	9	136	30	551	71	329	1.96	20.49	2
12	Spain	67	904	17	13.49	–	–	–	–	1	–	–	–	2	–	9	183	18	377	37	344	1.45	19.62	2
13	Singapore	62	1078	17	17.39	–	–	2	3	2	3	2	92	13	201	11	216	16	394	16	169	10.88	189.24	2
14	Australia	62	938	18	15.13	–	–	–	–	–	–	6	155	12	135	19	338	7	135	18	175	2.55	38.59	–
15	Germany	62	642	15	10.35	–	–	1	4	–	–	2	–	11	192	7	181	2	21	39	244	0.77	7.96	–
16	Brazil	61	379	11	6.21	–	–	–	–	–	–	1	1	15	73	5	80	10	109	30	116	0.29	1.81	–
17	Italy	57	535	12	9.39	–	–	–	–	1	2	3	3	7	84	4	31	15	302	27	113	0.95	8.95	–
18	Saudi Arabia	55	393	11	7.15	–	–	2	5	4	–	10	84	5	26	8	95	5	60	21	123	1.71	12.22	–
19	Egypt	44	487	9	11.07	1	–	3	6	6	7	1	–	20	258	2	55	5	136	6	25	0.47	5.22	1
20	Thailand	43	502	12	11.67	2	–	3	16	1	2	2	12	4	65	5	134	11	176	15	97	0.63	7.37	–
21	Israel	39	537	12	13.77	–	–	4	30	5	44	7	116	7	156	5	96	3	63	8	32	4.76	65.55	–
22	Malaysia	38	351	10	9.24	–	–	–	–	1	–	–	–	1	6	4	58	7	68	25	219	1.24	11.41	–
23	Poland	30	474	13	15.80	1	1	–	–	–	–	1	6	5	187	2	28	13	205	8	47	0.78	12.28	1
24	Belgium	30	351	9	11.70	–	–	–	–	–	–	–	–	3	18	2	109	10	163	15	61	2.64	30.87	–
25	Portugal	28	562	10	20.07	–	–	–	–	–	–	–	–	4	11	6	234	8	231	10	86	2.72	54.54	2
26	Tunisia	26	215	8	8.27	–	–	–	–	–	–	–	–	2	3	1	15	7	135	16	62	2.29	18.90	–
27	Mexico	25	314	7	12.56	–	–	–	–	–	–	–	–	8	9	1	1	7	282	9	22	0.19	2.44	1
28	Netherlands	23	718	12	31.22	–	–	–	–	–	–	–	–	5	222	5	259	7	217	6	20	1.35	42.29	2
29	Greece	20	138	8	6.90	–	–	–	–	–	–	–	–	2	15	3	34	4	48	11	41	1.83	12.64	–
30	Kuwait	19	126	8	6.63	–	–	1	–	3	10	–	–	9	48	3	49	1	11	2	8	4.74	31.44	–
31	U Arab Emirates	17	144	8	8.47	–	–	–	–	–	–	–	–	1	1	2	37	2	16	12	90	1.83	15.54	–
32	Ireland	16	158	7	9.88	–	–	–	–	–	–	–	–	2	22	1	8	2	8	11	120	3.39	33.52	–
33	South Africa	14	52	5	3.71	–	–	–	–	2	4	3	11	5	16	–	–	1	6	3	15	0.25	0.95	–
34	Lebanon	13	236	7	18.15	–	–	–	–	–	–	–	–	1	–	4	83	4	139	4	14	2.17	39.41	1
35	Sweden	13	108	7	8.31	–	–	–	–	–	–	–	–	–	–	1	26	3	28	9	54	1.32	10.96	–
36	Argentina	12	38	3	3.17	–	–	–	–	–	–	–	–	6	15	–	–	2	15	4	8	0.27	0.87	–
37	Oman	9	194	4	21.56	–	–	–	–	–	–	–	–	–	–	6	96	1	97	2	1	1.93	41.68	1
38	Belarus	9	62	6	6.89	–	–	–	–	–	–	–	–	–	–	2	14	1	21	6	27	0.95	6.54	–
39	Denmark	9	36	4	4.00	–	–	1	–	–	–	–	–	1	2	–	–	1	6	6	28	1.58	6.33	–
40	Finland	9	18	2	2.11	–	–	–	–	1	5	4	10	1	2	–	–	1	1	2	–	1.63	3.44	–

Abbreviations available in previous tables except: P/Po and C/Po = Papers and cites per million inhabitants.

4.2. Leading institutions and countries of CIE

Many institutions from all over the world publish in CIE. To identify the most productive ones, Table 8 presents the institutions with the highest number of papers published in the journal. In the case of tie, the ranking is by number of citations. Additionally, Table 8 also presents several other indicators including the cites per paper, the *h*-index and citation thresholds.

The University of Central Florida is the most productive institution although Ashikaga Institute of Technology is the most influential one according to the number of citations. Most of the leading universities in CIE are among the Top 500 of the general university rankings. However, not many are at the Top 100 with the exception of Purdue University, Penn State University, National University of Singapore, Tsinghua University and the University of Michigan. Half of the universities are from the USA. In order to analyze the results throughout time, Table 9 presents the results.

During the first years of the journal, US institutions had more influence in the journal. However, the last years have seen a strong emergence of Asian institutions publishing in CIE and today they are clearly the leaders of the journal.

To get a more general perspective of the results, let us look into the publications at the country level. Table 10 presents the fifty most productive countries in the journal.

The USA is the most productive country in the journal and the most influential one followed by China. However, if normalizing the results per capita, then, the most productive and influential countries are Taiwan and Singapore. By looking into the results throughout time, it is clear that at the beginning the USA was the most influential country in the journal although recently it has been losing influence in favour of China and other Asian countries. However, the journal is very diverse with countries from all over the world publishing in CIE.

5. Graphical analysis of CIE with VOS viewer

The previous section provides some general results regarding the leading variables in CIE. However, it is also interesting to see the bibliographic material mapped from a general point of view in order to identify the leading publication and citation connections in terms of bibliographic coupling, co-citation, citation, co-authorship and co-occurrence of keywords. For doing so, the work uses the VOS viewer software (Van Eck & Waltman, 2010). First, let us look into co-citation of journals of documents published in CIE. Recall that co-citation of journals occur when two documents from two different journals receive a citation from the same document from a third journal. The graph visualizes the two journals that have received the citation and they have one co-citation link. Fig. 1 presents the results with a threshold of one hundred citations and the one hundred most representative co-citation connections.

The European Journal of Operational Research is the most cited journal and has the broadest network. CIE itself and International Journal of Production Research are also highly cited. Most of the journals are from operations research, engineering and computer science.

In order to analyze the results of Fig. 1, Table 11 presents the fifty most cited journals by documents published in CIE. The table also shows the results in five-year periods in order to see the evolution of the influence of each journal.

Another interesting issue to consider is bibliographic coupling of institutions. Note that here the graph shows the institutional affiliation of the authors that publish in CIE. Fig. 2 shows the data with a threshold of ten documents and one hundred bibliographic coupling connections.

The results are similar to Table 8. The difference is that here the graph visualizes how each of the leading institution is connected to

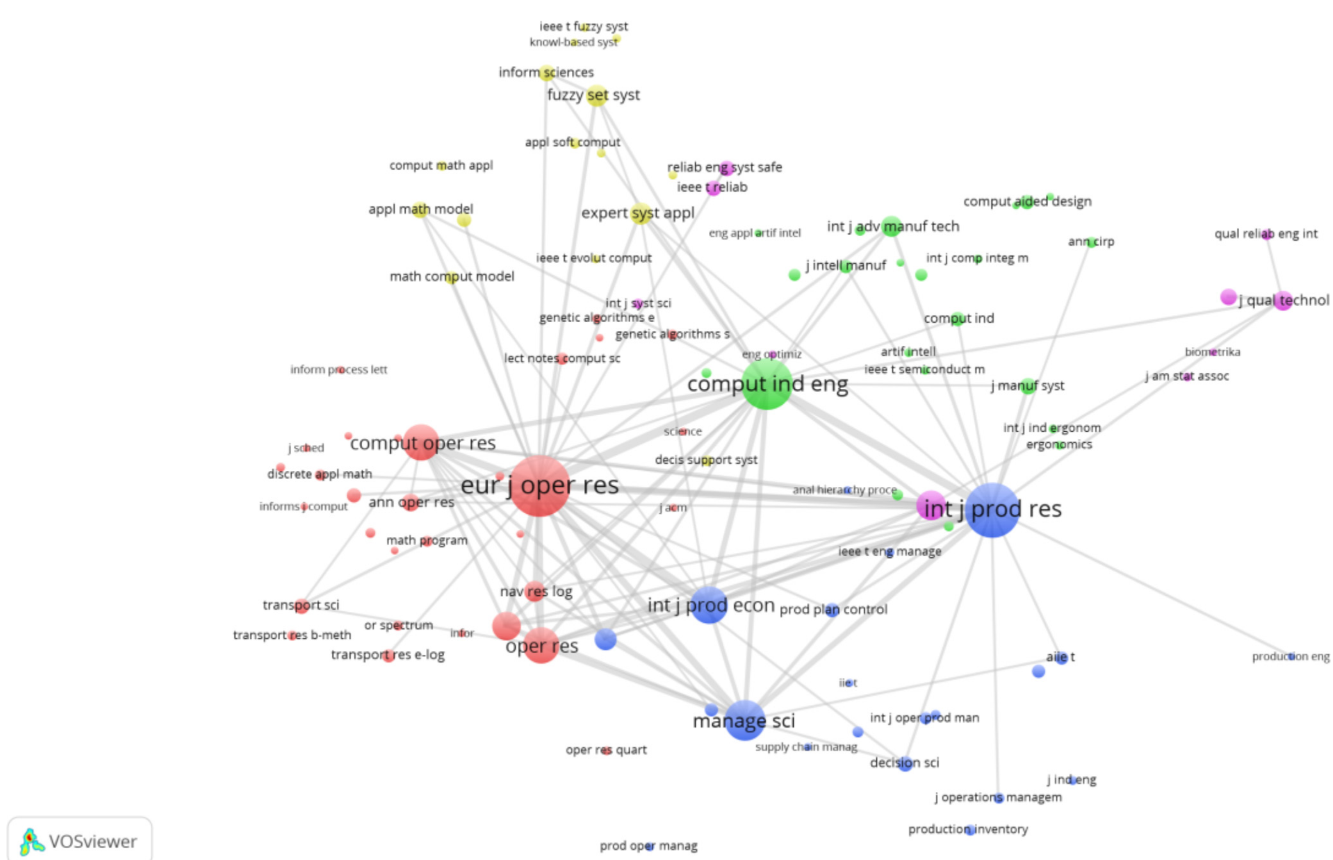

Fig. 1. Co-citation of journals cited in CIE.

Table 11
Most cited journals in CIE.

		Global		2010–2015		2000–2009		1990–1999		1976–1989	
R	Journal	Cit	CLS	Cit	CLS	Cit	CLS	Cit	CLS	Cit	CLS
1	Eur J Oper Res	6602	5249.34	4477	3672.52	1674	1344.75	424	354.11	27	25.86
2	Int J Prod Res	5106	3618.00	1892	1545.89	1585	1111.39	1397	915.59	232	162.05
3	Comput Ind Eng	4571	3792.93	3053	2626.90	946	811.05	493	401.99	79	67.22
4	Manage Sci	2892	2383.62	1249	1109.24	705	599.32	670	531.36	268	205.44
5	Int J Prod Econ	2430	2088.26	1793	1557.23	578	518.88	59	53.13	–	–
6	Oper Res	2244	1924.09	956	881.94	613	544.57	475	389.98	200	152.98
7	Comput Oper Res	2238	2006.21	1573	1426.83	516	473.87	130	115.85	19	15.53
8	IIE Trans	1498	1379.58	703	659.66	473	434.50	284	262.64	38	33.64
9	J Oper Res Soc	1400	1256.60	774	722.86	400	360.26	192	160.96	34	27.02
10	Fuzzy Set Syst	888	682.55	515	440.44	313	219.51	52	43.00	8	7.58
11	Expert Syst Appl	852	759.75	790	726.45	56	48.11	6	5.71	–	–
12	Omega-Int J Manage S	852	811.96	524	503.29	218	210.91	92	86.95	18	16.20
13	Nav Res Log	795	722.63	382	359.95	227	208.82	158	139.22	28	23.95
14	Int J Adv Manuf Tech	743	685.29	545	510.63	185	171.54	13	11.71	–	–
15	J Qual Technol	732	496.68	376	299.39	178	120.96	132	81.69	46	31.56
16	Ann Oper Res	565	549.79	394	384.40	133	129.83	34	33.55	4	4.00
17	Inform Sciences	513	459.75	401	369.66	94	84.35	15	14.68	3	2.67
18	J Manuf Syst	487	435.72	113	110.07	110	103.27	234	195.98	30	26.10
19	Appl Math Model	473	441.28	426	403.95	37	35.41	10	9.50	–	–
20	Technometrics	463	358.38	212	184.17	138	103.30	85	65.75	28	22.62
21	Decision Sci	455	415.39	143	138.46	147	137.08	134	119.82	31	25.08
22	Transport Sci	436	379.33	315	285.52	95	77.29	20	18.00	6	3.83
23	IEEE T Reliab	435	295.60	234	191.91	105	69.52	86	40.28	10	7.79
24	Reliab Eng Syst Safe	405	318.88	331	265.17	71	60.83	3	3.00	–	–
25	Prod Plan Control	391	375.37	211	204.64	150	144.53	26	24.46	4	3.00
26	Oper Res Lett	370	350.56	253	243.78	96	92.36	21	21.00	–	–
27	Comput Ind	358	324.45	144	135.14	115	105.97	91	80.59	8	7.91
28	Appl Math Comput	357	339.26	303	291.48	52	50.09	2	2.00	–	–
29	Comput Aided Design	349	201.97	107	65.69	140	79.23	98	59.52	4	3.65
30	AIIE T	326	285.76	34	33.81	41	40.54	133	119.78	118	103.62
31	J Intell Manuf	323	306.61	199	192.22	100	94.30	24	21.89	–	–
32	Interfaces	302	272.32	105	103.40	78	74.01	87	75.63	32	22.85
33	Ind Eng	299	195.65	15	15.00	22	21.44	117	91.37	145	98.94
34	Math Comput Model	298	287.41	223	219.39	59	57.12	16	15.34	–	–
35	Transport Res E-Log	294	264.89	260	238.01	34	32.05	–	–	–	–
36	IEEE T Syst Man Cyb	288	237.20	71	70.10	68	66.95	127	101.76	22	14.26
37	Lect Notes Comput Sc	263	241.48	190	182.63	67	59.37	6	6.00	–	–
38	Int J Oper Prod Man	248	226.32	150	140.13	84	74.91	11	10.99	3	3.00
39	Robot Cim-Int Manuf	247	220.05	148	130.78	81	77.37	18	18.00	–	–
40	Discrete Appl Math	242	231.53	161	156.00	74	69.89	7	6.90	–	–
41	Qual Reliab Eng Int	241	211.96	195	175.06	44	41.43	2	2.00	–	–
42	Appl Soft Comput	235	225.78	223	216.41	12	11.98	–	–	–	–
43	Production Inventory	235	172.25	23	22.85	49	46.24	85	73.89	78	37.83
44	Decis Support Syst	224	205.92	153	148.30	52	45.07	15	12.54	4	4.00
45	Ann Cirp	216	151.21	12	11.81	62	50.83	114	84.70	28	12.71
46	J Oper Manag	215	197.87	149	139.90	57	54.34	9	8.74	–	–
47	Math Program	213	192.68	112	107.61	41	38.39	38	32.53	22	17.57
48	IEEE T Robotic Autom	208	157.03	64	59.55	86	67.63	58	39.51	–	–
49	Commun ACM	207	146.21	20	19.82	54	43.89	83	62.32	50	37.68
50	Comput Chem Eng	201	158.98	131	118.19	48	35.09	22	15.97	–	–

Abbreviations: R = rank; Cit = Total citations in CIE; CLS = Co-citation links.

the other ones. Note that a general trend that occurs both in CIE and in other journals (Merigó et al., 2017) is that universities from the same country tend to work on closer topics than with institutions from other countries. Observe that this is in part due to co-authorship because here the co-authoring institutions are citing literally the same bibliographic material increasing their similarities. In order to understand better the results generated with a co-authorship analysis, Fig. 3 presents the bibliographic connections with a threshold of ten documents and one hundred connections.

The results are quite similar to Fig. 2. The size of the circles is equal because they also consider the number of documents published. The network has some differences although the national connection is more evident here.

Additionally, let us also look into the citations between institutions. Here, the network visualizes the universities that cite each other more. Note that the citations represent the sum between the citations that university *A* gives to *B* and vice versa. Fig. 4 presents the results.

The results are again consistent with those of Figs. 2 and 3 although here the national perspective is less significant. It is worth noting that CIE is a very diverse journal with universities from all over the world publishing in the journal.

A further interesting issue to consider is the country affiliation of the institutions of Figs. 2–4. By doing so, the figure summarizes the regions that publish more in the journal. Fig. 5 presents bibliographic coupling of countries that publish in CIE with a threshold of five documents and the fifty most representative bibliographic coupling connections.

The USA is the most productive country followed by China, Taiwan and South Korea. The results are in accordance with the data of Table 10.

Finally, let us analyze the most common keywords used by authors below the abstract to characterize their papers. In order

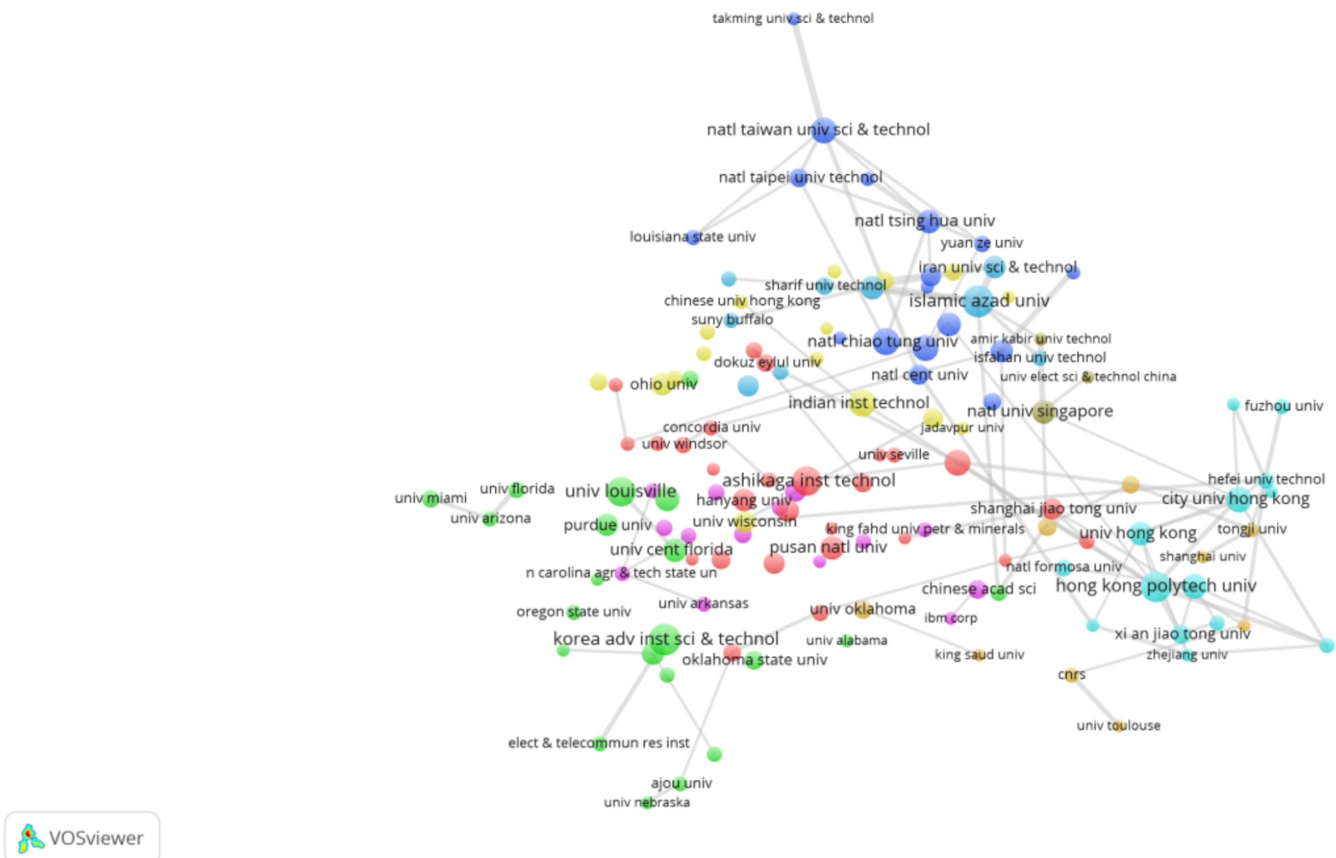

Fig. 2. Bibliographic coupling of institutions that publish in CIE.

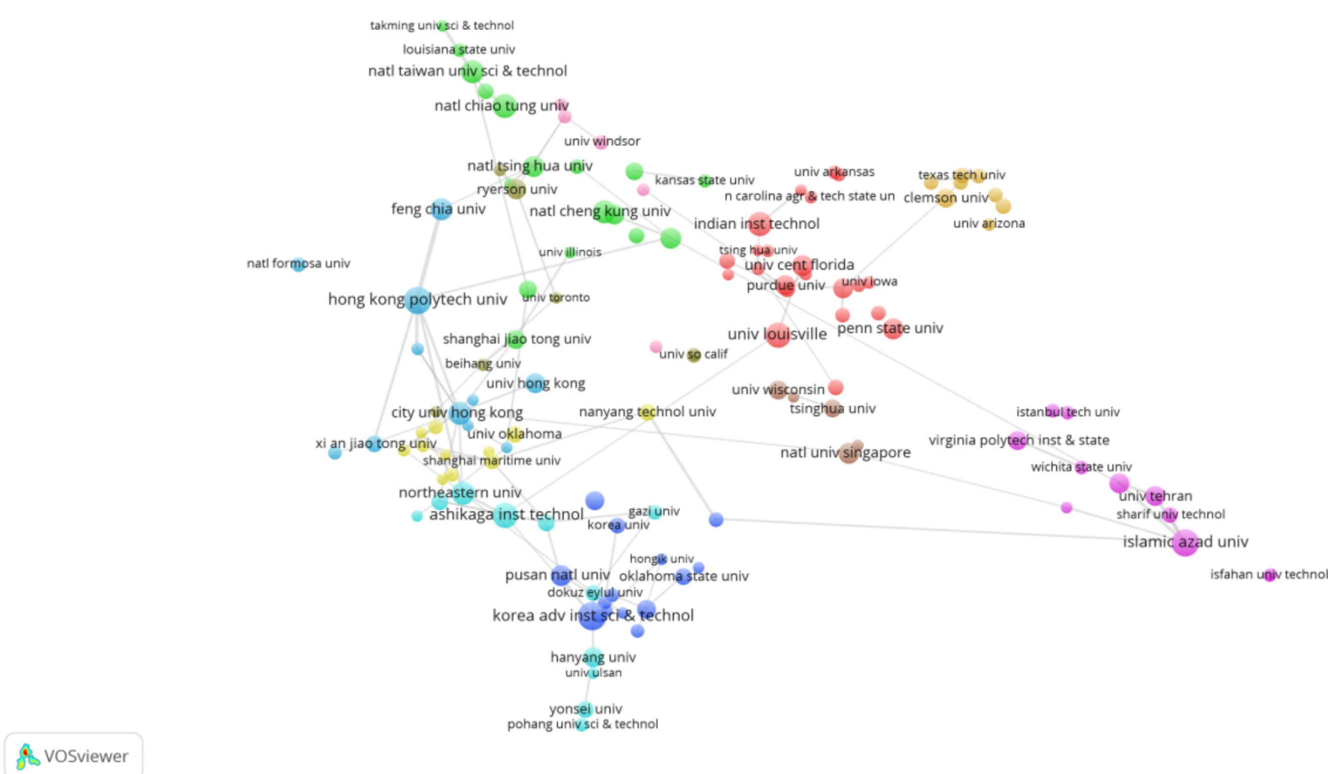

Fig. 3. Co-authorship of institutions that publish in CIE.

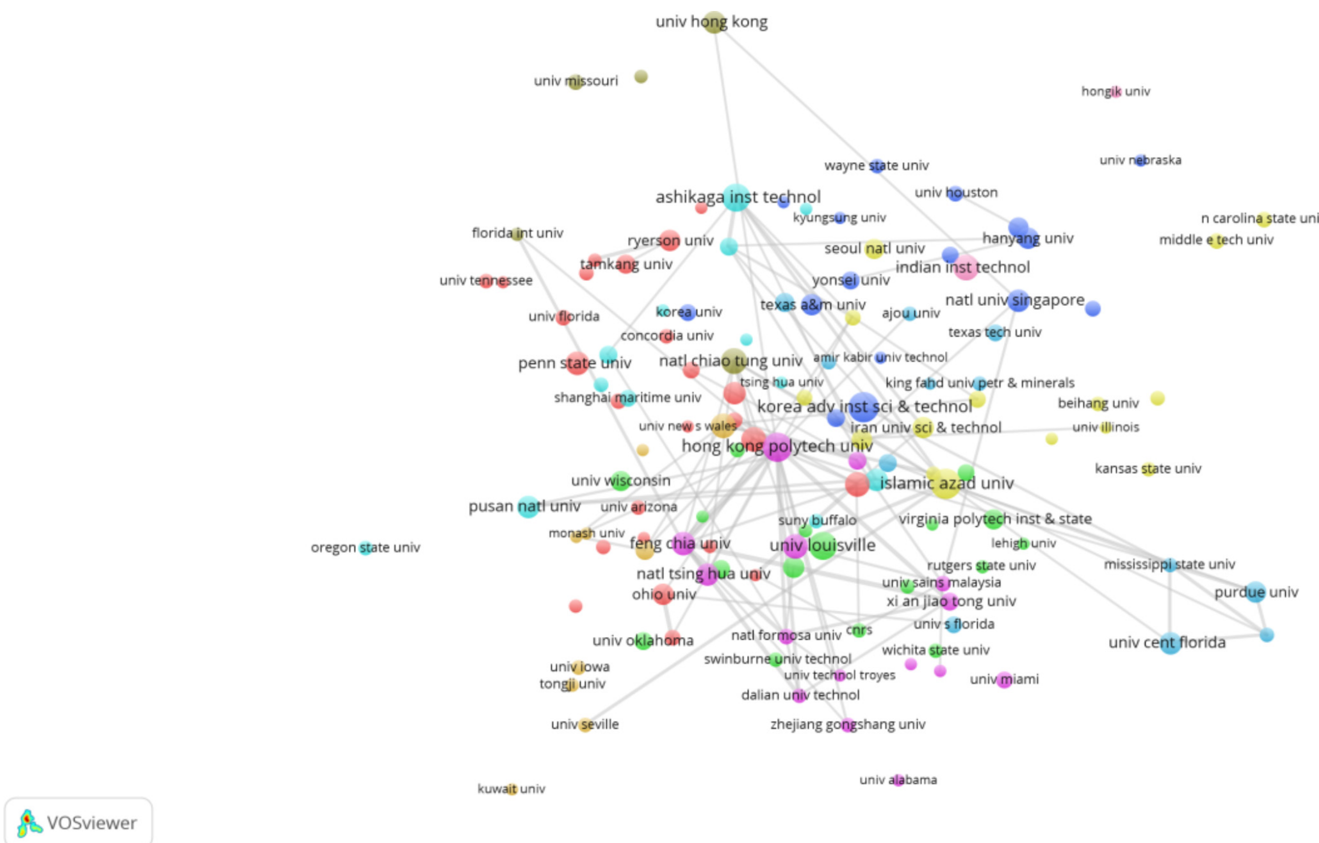

Fig. 4. Citation analysis of institutions publishing in CIE.

to do so, the work develops a co-occurrence of author keywords visualization with VOS viewer software. Fig. 6 presents the results considering a threshold of ten occurrences and the one hundred most frequent co-occurrences. Note that in the case of a tie in the number occurrences, the keywords appear in alphabetical order.

Genetic algorithms, scheduling and simulation are the most common keywords used in the journal. The journal shows a clear orientation to engineering, operations research and computational intelligence. In order to see more specifically the leading author keywords appearing in the journal, Table 12 presents a list of the Top 30 keywords of all-time and of the periods 1990–1999, 2000–2009 and 2010–2015.

Scheduling is the most common keyword although if unifying genetic algorithm with genetic algorithms, these keywords become the most common ones. The results are in accordance with Fig. 6. The main advantage of Table 12 is that it specifically identifies the Top 30 while the figure only provides a general representation of the leading keywords. Fig. 6 may omit the names of some keywords although it represents graphically how they connect between them.

6. Conclusions

In 2016, CIE has celebrated its fortieth anniversary. Motivated by this event, this study presents a bibliometric overview of the leading trends that have occurred in the journal during this period of time. The study uses the WoS Core Collection and analyses all the publications of the journal between 1976 and 2015. The results show the strong growth of CIE throughout time being today one of the leading journals in computer science and industrial engineering.

The study presents the leading institutions and countries of the journal. The USA is the most productive and influential country in CIE although his influence has been decreasing throughout time and today China is publishing more documents yearly in CIE. The University of Central Florida is the most productive university although the most influential institution is Ashikaga Institute of Technology. It is also worth noting the results of Taiwan that is the most productive and influential country when normalizing per capita and currently stands in the third position in absolute terms.

In order to deepen into the results the work also develops a graphical and mapping analysis of the bibliographic material by using VOS viewer software. The study considers co-citation, bibliographic coupling, citation, co-authorship and co-occurrence of author keywords. The results are consistent with the results of the tables. However, the main advantage of the graphical analysis is the representation of the connections between the variables that indicates similar profiles inside the publications of CIE.

Note that the work provides a general overview of the publication and citation structure of CIE by using a wide range of indicators including the total number of papers and citations, the *h*-index, the cites per paper and several citation thresholds. By doing so, the work aims to be informative representing the data under different perspectives so each reader can understand the data according to his interests and priorities. The main reason for this, is that today there is no single indicator that everybody agrees as the optimal indicator for measuring research. Therefore, the alternative is to represent the available information in a complete way and considering different perspectives. Future research should make improvements in this direction in order to find general indicators for measuring academic research.

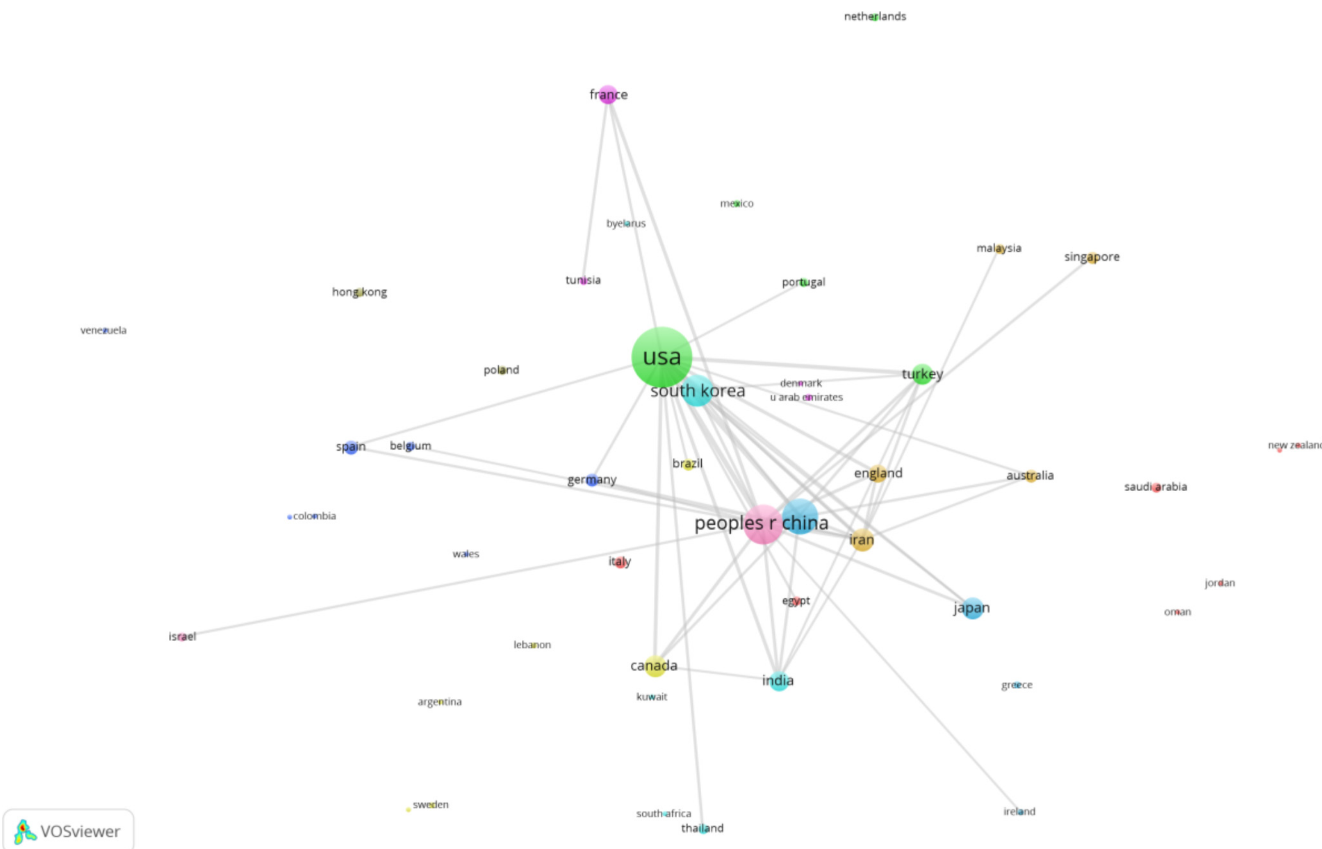

Fig. 5. Bibliographic coupling of countries that publish in CIE.

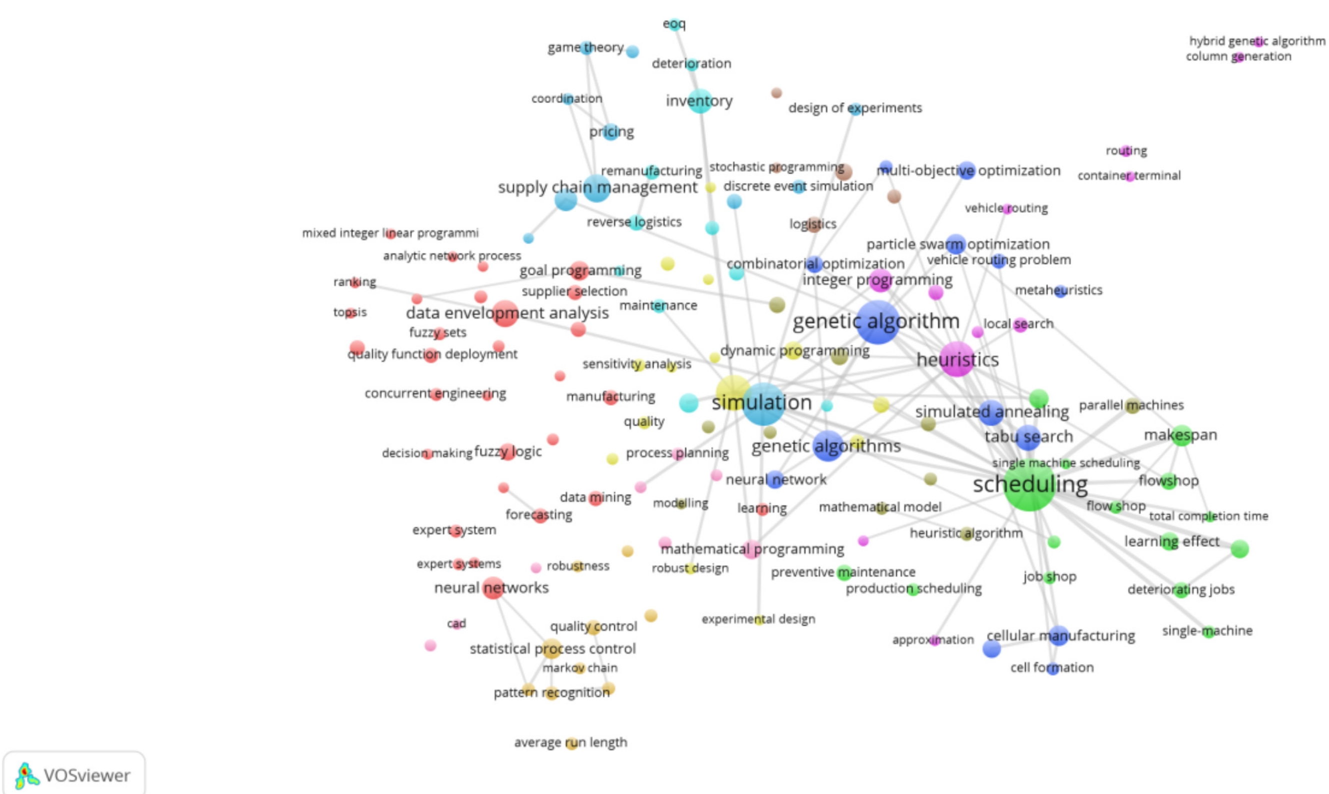

Fig. 6. Co-occurrence of author keywords of documents published in CIE.

Table 12
Most common author keyword occurrences in CIE.

	Global			2010–2015			2000–2009			1990–1999		
R	Keywords	Oc	Co	Keywords	Oc	Co	Keywords	Oc	Co	Keywords	Oc	Co
1	Scheduling	233	190	Scheduling	121	95	Scheduling	76	65	Simulation	60	34
2	Genetic algorithm	164	83	Genetic algorithm	68	35	Genetic algorithm	74	39	Scheduling	36	22
3	Simulation	156	96	Optimization	51	34	Heuristics	52	44	Optimization	29	25
4	Heuristics	110	91	Simulation	50	32	Simulation	45	25	Genetic algorithms	24	11
5	Optimization	108	81	Data envelopment analysis	49	25	Genetic algorithms	37	20	Genetic algorithm	23	11
6	Genetic algorithms	82	47	Heuristics	42	32	Optimization	28	20	Neural networks	22	9
7	Supply chain management	66	35	Supply chain management	39	26	Supply chain management	26	12	Heuristics	16	11
8	Data envelopment analysis	64	29	Inventory	34	23	Tabu search	26	22	Simulated annealing	15	11
9	Tabu search	59	49	Supply chain	33	21	Cellular manufacturing	21	16	Expert system	13	8
10	Simulated annealing	58	41	Integer programming	26	20	Simulated annealing	20	15	Reliability	13	5
11	Inventory	55	32	Multi-objective optimization	25	17	Inventory	18	8	Expert systems	12	4
12	Integer programming	50	38	Tabu search	25	18	Neural networks	18	11	Fuzzy logic	11	5
13	Supply chain	46	25	Particle swarm optimization	24	14	Integer programming	17	10	Group technology	11	2
14	Neural networks	45	20	Simulated annealing	23	12	Makespan	15	15	Statistical process control	11	6
15	Makespan	41	35	Genetic algorithms	21	13	Data envelopment analysis	14	4	Cellular manufacturing	10	4
16	Statistical process control	38	22	Dynamic programming	19	13	Single machine	14	11	Concurrent engineering	10	6
17	Particle swarm optimization	37	26	Learning effect	19	16	Data mining	13	4	Decision support systems	9	4
18	Cellular manufacturing	36	25	Makespan	19	14	Flowshop	13	12	Neural network	9	3
19	Heuristic	34	23	Statistical process control	18	12	Goal programming	13	5	Quality	9	7
20	Reliability	34	17	Pricing	17	14	Heuristic	13	9	Mathematical programming	8	5
21	Goal programming	33	21	Resource allocation	17	16	Neural network	13	9	Tabu search	8	6
22	Mathematical programming	33	20	Goal programming	16	10	Particle swarm optimization	13	10	Artificial intelligence	7	6
23	Dynamic programming	30	21	Reverse logistics	16	13	Supply chain	13	6	Forecasting	7	3
24	Neural network	30	19	Supplier selection	16	10	Group technology	12	11	Heuristic	7	5
25	Group technology	29	16	Facility location	15	10	Artificial neural networks	11	5	Integer programming	7	6
26	Learning effect	29	24	Group decision making	15	5	Flow shop	11	11	JIT	7	3
27	Single machine	29	25	Preventive maintenance	15	13	Flexible manufacturing systems	10	5	Makespan	7	6
28	Multi-objective optimization	28	18	Reliability	15	9	Learning effect	10	8	Manufacturing	7	5
29	Facility location	26	16	Single machine	15	15	Mathematical programming	10	8	Production management	7	1
30	Fuzzy logic	26	13	Combinatorial optimization	14	11	Production planning	10	6	Productivity	7	4
31	Production planning	26	17	Deteriorating jobs	14	14	Sequencing	10	10	Quality control	7	4
32	Combinatorial optimization	25	20	Heuristic	14	9	Cell formation	9	8	AHP	6	0
33	Flowshop	25	23	Logistics	14	10	Quality function deployment	9	6	Business process reengineering	6	3
34	Pricing	25	20	Mathematical programming	14	10	Reverse engineering	9	1	CAD	6	2
35	Logistics	24	20	Parallel machines	14	10	Statistical process control	9	5	Education	6	3
36	Parallel machines	24	20	Local search	13	11	Combinatorial optimization	8	6	Facility location	6	3
37	Preventive maintenance	23	13	Inventory management	12	9	Deteriorating jobs	8	8	Information systems	6	2
38	Deteriorating jobs	22	22	Linear programming	12	9	Discrete event simulation	8	1	Internet	6	4
39	Linear programming	22	12	Mixed integer programming	12	8	Fuzzy sets	8	7	Modeling	6	6
40	Resource allocation	22	17	Transportation	12	9	Lot sizing	8	6	Product design	6	2

Abbreviations: R = Rank; Oc = Author keyword occurrences; Co = Author keyword co-occurrences links.

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