

## Fifty years of IISE Transactions: A bibliometric overview

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**Abstract:** *IISE Transactions, previously known as AIIE Transactions (1969-1982) and IIE Transactions (1983-2016), is a journal in the field of industrial and manufacturing engineering. It was established in 1969 and has gone through five decades by 2018. Therefore, motivated by its 50th anniversary, this study analyses the publications over the past fifty years and generates a bibliometric overview for the journal through performance analysis and science mapping. First, the performance analysis illustrates the characteristics and evolution of the journal with identifying the significant contributions of the leading authors, institutions, countries as well as the most cited articles. Then VOSviewer software is applied to science mapping, which creates bibliometric maps to visualise the collaboration relations, journal co-citation network and co-occurrence of high-frequency keywords. The results demonstrate the significant growth of the journal through time and its international diversity with publishing articles from all over the world.*

**Keyword:** *Bibliometrics, Network analysis, Science mapping, Co-citation, VOS viewer*

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### I. Introduction

IISE Transactions (IISE), previously known as AIIE Transaction (1969-1982) and IIE Transactions (1983-2016), is the flagship journal of the Institute of Industrial and Systems Engineers. Launched in 1969, the journal is published monthly with 12 issues per year and the publisher is Taylor & Francis. The journal consists of four focus issues: Design and Manufacturing, Operations Engineering and Analytics, Quality and Reliability Engineering, and Scheduling and Logistics. The journal encourages original high-quality articles to solve complicated engineering problems from assorted domains like service, public policy, health care, security, biotechnology and transportation. It also aims to facilitate the progress of engineering community by publishing papers covering new methodologies and state-of-the-art surveys motivated by practical problems that can guide engineering practice and research.

Bibliometrics aims to evaluate research performance to explore the characteristics of a certain field and reveal future research trends. Many kinds of topic categories have been studied under the bibliometric framework to show the development of a specific field, such as international facility location<sup>[13]</sup>, product upgradability<sup>[15]</sup>, process mining<sup>[12]</sup> and Augmented reality (AR) technology<sup>[2]</sup>, etc. Meanwhile, there are also many bibliometric studies for journals to present a general overview for readers. For instance, Laengle et al.<sup>[16]</sup> investigated all publications of European Journal of Operational Research from 1977 to 2016. Cancino et al.<sup>[3]</sup> analysed the evolution of Computers and Industrial Engineering for forty years, and others like Information Sciences<sup>[18,31]</sup>, Resources, Conservation and Recycling<sup>[7,11]</sup>, Sustainability<sup>[27]</sup>, International Journal of Computer Integrated Manufacturing<sup>[17]</sup>, and International Journal of Logistics Research and Applications<sup>[30]</sup>. In short, the influence of bibliometric almost radiates to all disciplines and boost the science development.

Therefore, inspired by IISE's 50th anniversary, the main purpose of this article is to provide a bibliometric overview of IISE for the past 50 years to (1) assess the productivity and influence of IISE; (2) identify the leading authors, institutions and countries, as well as how they are connected to each other; (3) reveal research emphasis and future trend. The rest of this paper is organized as follows. Section 2 introduces the bibliometric methods and data to be used for the analysis. Section 3 analyses the bibliometric results in terms of the publication and citation structure, author, institution and country analysis. Then section 4 visualises the bibliographic data via the software VOS viewer. Finally, section 5 is the conclusion with summarizing the main findings. Note that later in the article, when we mention IISE Transactions, it also refers to AIIE Transactions and IIE Transactions, not just the journal renamed "IISE Transactions" after 2016.

### II. Methodology and Data

Bibliometrics is a prevailing tool to quantitatively assess academic publications and construct structural images of a specific field<sup>[32]</sup>. There are two main methods for bibliometrics: performance analysis and science mapping. First, performance analysis is primarily about the assessment of the productivity and influence of the

journal, authors, institutions and countries, which is also perceived as evaluative bibliometrics. Therefore, the article uses a wide range of bibliometric indicators which are commonly recognised for describing and evaluating various facets of scientific performance<sup>[29]</sup>. For example, the total publications (TP) and total citations (TC) can represent an author’s productivity and influence in the research field. The h-index is defined by Hirsch<sup>[10]</sup> that  $h$  of an author papers have been cited at least  $h$  times each, which can measure both quantity and quality of an author’s output and reflect one’s scientific achievements. Citation threshold can identify authors and institutions whose influences have reached a certain level. These bibliometric indicators can highlight most of key characteristics and a general outline of bibliometric data.

Regarding the data source, Thomson Reuters’ Web of Science (WoS) and Elsevier’s Scopus both have significant superiority for bibliometric analysis<sup>[19]</sup>. Archambault et al.<sup>[1]</sup> have also demonstrated that there is an extremely high correlation ( $R^2 \approx 0.99$ ) between WoS and Scopus in terms of the number of papers, the number of citations received by countries as well as their ranks. Since we did not find all 50-year data of the journal on WoS, this article uses Scopus database to search and download the bibliographic data. Scopus, launched by Elsevier, is the largest abstract and citation database of peer-reviewed literature in the world. We searched documents with source title “AIIE Transactions” or “IIE Transactions” or “IISE Transactions” and the time span is 50 years from 1969 to 2018. The data was downloaded on 25 January 2019 and all statistical work was conducted between January and February 2019. There are 3803 documents in total and the number reduces to 3678 when limiting the document type to “article” and “review”. The citation information, bibliographical information, abstract and keywords, and other information are selected to export as CSV files. Up to 2018, the journal has received 81453 citations with 22.15 cites per paper. The h-index is 107, indicating that among these 3678 documents, 107 documents have received at least 107 citations. It should be noted that the bibliometric results may be biased depending on the database used<sup>[19]</sup>.

In addition to evaluative bibliometrics, descriptive bibliometrics should be emphasized as well, that is, science mapping<sup>[20]</sup>. In other words, science mapping is the second procedure in evaluative bibliometrics<sup>[21]</sup> to describe how specific disciplines, scientific domains, or research fields are conceptually, intellectually, and socially structured<sup>[5]</sup>. There are various software for it such as VOS viewer<sup>[28]</sup>, CiteSpace<sup>[4]</sup>, Sci<sup>2</sup> Tool<sup>[24]</sup> and BibExcel<sup>[22]</sup>. In this paper, we choose VOS viewer. It can analyse bibliographic data and create maps based on different analysis types including bibliographic coupling, citation, co-citation, co-authorship and co-occurrence. In a network, the nodes represent the unit of analysis like authors, institutions or countries, and different colours mean different clusters. The lines represent links between items such as collaboration or co-occurrence, and the line weight is decided by the link strength.

### III. Performance Analysis

#### 3.1 Publication and citation structure

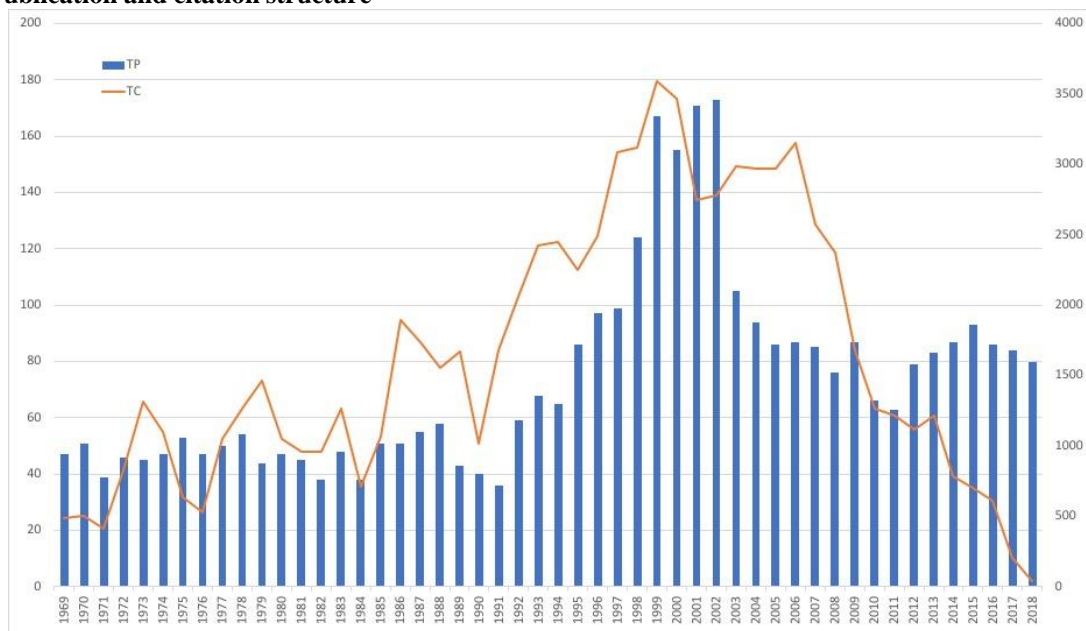


Figure 1: Annual number of publications and citations in IISE.

IISE Transactions launched its first issue in 1969 and Figure 1 visualizes the annual number of publications as well as citations in the journal over its lifetime. The blue bar represents total publications while the yellow line represents total citations with plotting this data series on the secondary axis. It is clear to see that

the journal grew stably during the first two decades while since 1995, the publications increased substantially. Especially at the turn of the millennium, the journal published over 150 papers per year and in 2002, the journal reached a new high of 173 papers. Afterwards, the average number of annual publications was around 80.

Now let's pay attention to the annual citation structure of the journal. In addition to the common indicators like total publications and total citations, the work also takes several specific citation thresholds into account to identify the number of those highly cited papers which was published in a given year. The results are presented in Table 1.

According to Scopus, the journal has received more than eighty thousand citations during these 50 years. From an overall perspective, the number of citations is increasing and gradually maintain the level above one thousand citations, although the papers published in the latest five years do not have so many citations, which need time to catch up. Specifically, 3.51% of the papers receive more than one hundred citations while around 50% of the papers are cited over ten times and 85.26% get at least one citation. The last column of Table 1 reports the annual h-index of the journal and among all publications, 107 documents have received at least 107 or more citations. In general, all these indicators reflect that IISE has been continuously improving itself and remaining a high quality.

**Table 1:** Annual citation structure of IISE.

Year	TP	TC	≥200	≥100	≥50	≥10	≥5	≥1	h
1969	47	486	0	0	3	13	23	38	12
1970	51	508	0	0	3	15	24	39	12
1971	39	409	0	0	2	11	18	27	10
1972	46	828	0	1	4	26	31	37	18
1973	45	1315	1	2	7	21	26	38	13
1974	47	1103	1	1	7	21	25	42	17
1975	53	633	0	0	4	17	26	41	13
1976	47	531	0	1	3	12	17	35	11
1977	50	1050	0	1	7	27	33	44	18
1978	54	1269	0	4	7	25	32	48	17
1979	44	1467	1	3	8	28	29	42	20
1980	47	1047	0	2	7	20	26	42	15
1981	45	955	0	1	6	24	31	36	16
1982	38	963	1	0	5	21	25	33	15
1983	48	1262	1	3	6	21	28	46	17
1984	38	710	0	0	4	17	24	34	15
1985	51	1067	0	2	5	22	33	48	16
1986	51	1892	2	2	8	26	37	48	17
1987	55	1740	0	2	11	34	44	54	24
1988	58	1557	0	6	10	27	39	50	18
1989	43	1668	0	4	14	29	37	41	23
1990	40	1015	1	2	6	21	31	38	16
1991	36	1682	2	5	12	23	27	34	19
1992	59	2057	2	4	11	37	43	54	22
1993	68	2420	2	3	13	44	57	63	26
1994	65	2448	4	7	11	39	51	64	22
1995	86	2246	2	3	8	46	60	84	24
1996	97	2490	0	3	14	69	82	93	31
1997	99	3082	0	5	18	77	85	95	33
1998	124	3116	0	5	19	74	93	107	34
1999	167	3590	1	5	23	74	93	109	37
2000	155	3469	0	10	22	76	86	107	34
2001	171	2743	0	3	14	70	86	109	33
2002	173	2780	0	1	22	73	83	100	32
2003	105	2985	1	7	18	64	76	91	30
2004	94	2970	0	7	17	69	83	92	33
2005	86	2966	1	6	15	61	74	84	31
2006	87	3153	1	6	16	66	75	86	31
2007	85	2573	1	6	12	61	77	84	27
2008	76	2375	1	3	10	57	67	76	28
2009	87	1675	0	1	6	53	76	87	24
2010	66	1268	0	0	5	40	55	65	20
2011	63	1215	0	1	4	39	50	63	21
2012	79	1115	0	0	1	46	61	78	19
2013	83	1219	0	0	4	45	63	78	21
2014	87	783	0	0	1	28	54	79	15
2015	93	701	0	0	0	21	55	88	13
2016	86	612	0	1	1	16	41	79	12
2017	84	205	0	0	0	3	14	62	6

2018	80	40	0	0	0	0	1	24	3
Total	3678	81453	26	129	434	1849	2407	3136	107
%	100%		0.71%	3.51%	11.80%	50.27%	65.44%	85.26%	

As for a publication, its citation frequency can reflect its academic influence and Table 2 lists the 20 most cited articles in the journal. The first half of these 20 papers receive 300 citations or more while the citations of the other half are also above 220 times. The paper entitled with “Economic production cycles with imperfect production processes” published by Rosenblatt and Lee<sup>[23]</sup> has been cited 775 times so far while simultaneously the paper “An EOQ model for items with Weibull distribution deterioration” by Covert and Philip<sup>[6]</sup> has 510 citations, indicating that they play prominent roles in the relative research fields. These two most cited papers have also given rise to the annual citation peak in 1973 and 1986 respectively, which can be seen from the orange line in Figure 1.

Furthermore, in order to evaluate and analyse the results comprehensively, we cannot look only at the total citation. We should also consider the publishing year from now and pay attention to the citations per year (C/Y). The article “Facility location under uncertainty: a review”<sup>[26]</sup> is cited 38.17 times per year and another one “Appointment scheduling in health care: Challenges and opportunities”<sup>[8]</sup> gets average 38.10 citations every year, which indicates that they are fairly influential in recent years, although their total citations are not the most. Meanwhile, these high cited articles are evenly distributed throughout the years from 1973 to 2008, which means the publications in this journal has retained a high quality and influence all the time.

**Table 2:** The 20 most cited articles in IISE according to Scopus.

R	TC	Title	Author(s)	Year	C/Y
1	775	Economic production cycles with imperfect production processes	Rosenblatt M.J., Lee H.L.	1986	24.22
2	510	An EOQ model for items with Weibull distribution deterioration	Covert R.P., Philip G.C.	1973	11.33
3	458	A review of multivariate control charts	Lowry C.A., Montgomery D.C.	1995	19.91
4	458	Facility location under uncertainty: A review	Snyder L.V.	2006	38.17
5	449	An algorithm for the computer control of a flexible manufacturing system	Kimemia J., Gershwin S.B.	1983	12.83
6	427	A Review of Production Planning and Scheduling Models in the Semiconductor Industry Part I: System Characteristics, Performance Evaluation and Production Planning	Uzsoy R., Lee C.-Y.	1992	16.42
7	412	Residual-life distributions from component degradation signals: A Bayesian approach	Gebraeel N.Z., Lawley M.A., Li R., Ryan J.K.	2005	31.69
8	381	Appointment scheduling in health care: Challenges and opportunities	Gupta D., Denton B.	2008	38.10
9	329	Travel-time models for automated storage/retrieval systems	Bozer Y.A., White J.A., Sr.	1994	13.71
10	323	On how to prioritize design requirements during the QFD planning process	Wasserman G.S.	1993	12.92
11	312	Strategies for robust multiresponse quality engineering	Pignatello J.J., Jr.	1993	12.48
12	292	Application of the similarity coefficient method in group technology	Seifoddini H., Wolfe P.M., Sr.	1986	9.13
13	291	A review of production planning and scheduling models in the semiconductor industry part h: Shop-floor control	Uzsoy R., Lee C.-Y., Martin-Vega L.A.	1994	12.13
14	280	Reliable preventive maintenance scheduling	Malik M.A.K.	1979	7.18
15	279	Determining the importance weights for the customer requirements in QFD using a fuzzy AHF with an extent analysis approach	Kwong C.K., Bai H.	2003	18.60
16	256	A review of integrated analysis of production-distribution systems	Sarmiento A.M., Nagi R.	1999	13.47
17	234	Design of automatic guided vehicle systems	Maxwell W.L.	1982	6.50
18	230	Controlling factor weights in data envelopment analysis	Roll Y., Cook W.D., Golany B.	1991	8.52
19	226	Robustness measures and robust scheduling for job shops	Leon V.J., Wu S.D., Storer R.H.	1994	9.42
20	220	An AHP framework for prioritizing customer requirements in QFD: An industrialized housing application	Armocost R.L., Companion P.J., Mullens M.A., Swart W.W.	1994	9.17

### 3.2 Author analysis

Besides from the authors in Table 2, there are many other authors contributing significantly to the journal. In total, there're 4327 authors contributing to the journal. In order to identify those outstanding contributors, Table 3 sorted the 20 most productive and influential authors with the ranking based on the total citations from most to least in case of a tie.

Jonathan F. Bard and Shiyu Zhou are both the most productive authors with 23 publications each, followed by Fugee Tsung with 22 papers. Meir J Rosenblatt and Chung Yee Lee also make great contribution to the journal with ranking fourth and fifth, respectively. As for h-index, David W. Coit and Wallace J. Hopp have

high h-index of 15, which suggests that their papers are relatively influential. Moreover, from a regional perspective, the authors' countries are not that diverse and authors from the USA have the highest presence, reaching 70%, while China and Canada only reaching 25% and 5% respectively.

**Table 3:** The 20 most productive and influential authors in IISE.

R	Author	Affiliation	Country	TP	TC	TC/TP	≥200	≥100	≥50	h
1	Bard, J.F.	University of Texas at Austin	USA	23	643	27.96	0	2	4	13
2	Zhou, S.	University of Wisconsin Madison	USA	23	383	16.65	0	1	1	10
3	Tsung, F.	Hong Kong University of Science and Technology	China	22	498	22.64	0	0	3	12
4	Rosenblatt, M.J.	Washington University in St. Louis	USA	20	1828	91.40	1	4	11	14
5	Lee, C.Y.	Hong Kong University of Science and Technology	China	20	1273	63.65	2	2	6	14
6	Tsui, K.L.	City University of Hong Kong	China	20	766	38.30	0	2	3	12
7	Wilson, J.R.	North Carolina State University	USA	20	374	18.70	0	0	1	12
8	Berman, O.	University of Toronto	Canada	19	475	25.00	0	1	3	10
9	Coit, D.W.	Rutgers, The State University of New Jersey	USA	18	1040	57.78	0	4	7	15
10	Hopp, W.J.	University of Michigan	USA	18	725	40.28	0	2	4	15
11	Meller, R.D.	University of Arkansas - Fayetteville	USA	18	610	33.89	0	1	5	14
12	Drezner, Z.	California State University-Fullerton	USA	18	341	18.94	0	0	2	9
13	Montgomery, D.C.	Arizona State University	USA	17	852	50.12	1	1	3	11
14	Kouvelis, P.	Washington University in St. Louis	USA	17	478	28.12	0	1	3	11
15	Yano, C.A.	UC Berkeley Haas School of Business	USA	17	466	27.41	0	0	3	10
16	Hodgson, T.J.	North Carolina State University	USA	17	349	20.53	0	0	2	10
17	Jin, J.	Stephen M. Ross School of Business	USA	16	313	19.56	0	0	1	10
18	Kuo, W.	City University of Hong Kong	China	16	257	16.06	0	0	0	10
19	McGinnis, L.F.	Georgia Institute of Technology	USA	15	537	35.80	0	2	4	10
20	Lau, H.S.	The University of Hong Kong	China	15	501	33.40	0	1	2	11

### 3.3 Institution analysis

There are 5244 institutions totally involved in contributing to the journal and Table 4 presents 20 leading institutions that published the highest number of papers in the journal with several indicators such as the cites per paper, the h-index, Academic Ranking of World Universities 2018 (ARWU) and Quacquarelli Symonds (QS) World University Ranking 2019. It is worth mentioning that the institution information in Table 4 is the affiliation of authors when they published their papers in the journal.

Georgia Institute of Technology (154), Purdue University (137), Texas A&M University (133), University of Michigan (125) as well as Virginia Polytechnic Institute and State University (103) are the top five productive institutions. They have already published more than one hundred papers so far in the journal and they are all located in the USA. Besides, Technion-Israel Institute of Technology and University of Texas at Austin rank only sixteenth and fourteenth while they are still influential with the highest cites per paper (43.85 and 34.26 respectively). Then seen from the location, among these 20 institutions, 16 are from North America, especially the USA, and America dominates the list with 15 institutions, accounting for 75%. By contrast, there is only one Canadian institution "McMaster University". On the other side, several Asian institutions are also active, like Hong Kong University of Science and Technology (90) and Tel Aviv University (88) in Israel, which follows top 5 closely in the sixth and seventh position. The other two Asian institutions, Technion-Israel Institute of Technology and National University of Singapore, have good performances as well.

**Table 4:** The 20 most productive and influential institutions.

R	Affiliation	Country	TP	TC	TC/TP	h	ARWU	QS
1	Georgia Institute of Technology	USA	154	4773	30.99	40	79	69
2	Purdue University	USA	137	3592	26.22	26	70	100
3	Texas A&M University	USA	133	2959	22.25	31	151-200	203
4	University of Michigan-Ann Arbor	USA	125	3126	25.01	34	27	20
5	Virginia Polytechnic Institute and State University	USA	103	2006	19.48	24	201-300	338
6	Hong Kong University of Science and Technology	China	90	1793	19.92	27	201-300	37
7	Tel Aviv University	Israel	88	1537	17.47	23	151-200	230
8	Pennsylvania State University	USA	78	1205	15.45	18	74	95
9	North Carolina State University	USA	78	1395	17.88	21	151-200	279
10	Rutgers, The State University of New Jersey	USA	75	2186	29.15	27	101-150	601-650
11	University of Florida	USA	73	1709	23.41	18	86	180
12	University of Wisconsin-Madison	USA	73	1716	23.51	23	28	53
13	Northwestern University	USA	71	1836	25.86	26	25	34
14	University of Texas at Austin	USA	70	2398	34.26	30	40	63
15	Arizona State University	USA	66	1654	25.06	23	101-150	212

16	Technion-Israel Institute of Technology	Israel	66	2894	43.85	24	77	247
17	National University of Singapore	Singapore	64	1218	19.03	22	85	11
18	McMaster University	Canada	56	1055	18.84	17	86	146
19	University of Arizona	USA	54	1647	30.50	23	101-150	246
20	University of California, Berkeley	USA	53	1250	23.58	23	5	27

### 3.4 Country analysis

In order to make the results of Table 4 clearer, let's consider them at the country level. Figure 2 visualises the geographical distribution of the ten leading countries and Figure 3 depicts the temporal evolution of each country's total publications. The complete data are given in Table A.1 of the appendix.

From a supranational perspective, North America makes the most conspicuous contributions with greater influence. On the other side of the earth, East Asia is also prominent while West Asia has good performance as well. Note that Figure 2 only contains the top 10 productive countries while there are 78 countries or territories in total that promote the development of the journal. The journal receives submissions from all over the world, although some regions such as South America and Africa do not publish so many articles like the regions mentioned before.

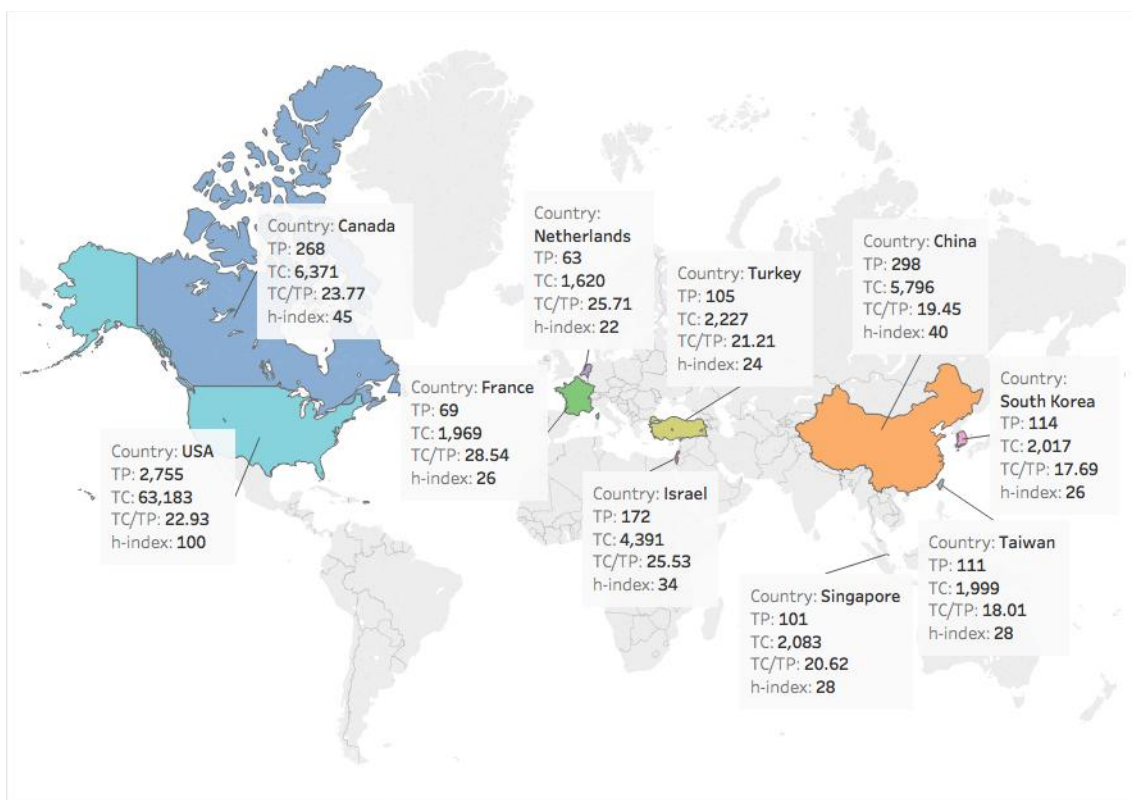


Figure 2: Geographical distribution of leading countries.

Then at the national level, there is no doubt that the USA is the most productive country all the time, since the journal initially was official publication of American Institute of Industrial Engineers. The journal published 47 articles in the first year 1969 and all the institutional affiliations of these 47 articles come from the USA. The increase of publications per decade is relatively steady as well. Meanwhile, China, Canada and Israel are not far behind. Similar to the USA, Canada's publications have been increasing at a constant rate. China did not publish many articles in the first thirty years while since 1999, the total publications have been shot up, which may be ascribed to the large increase of scientific research funds in recent decades<sup>[27]</sup>.

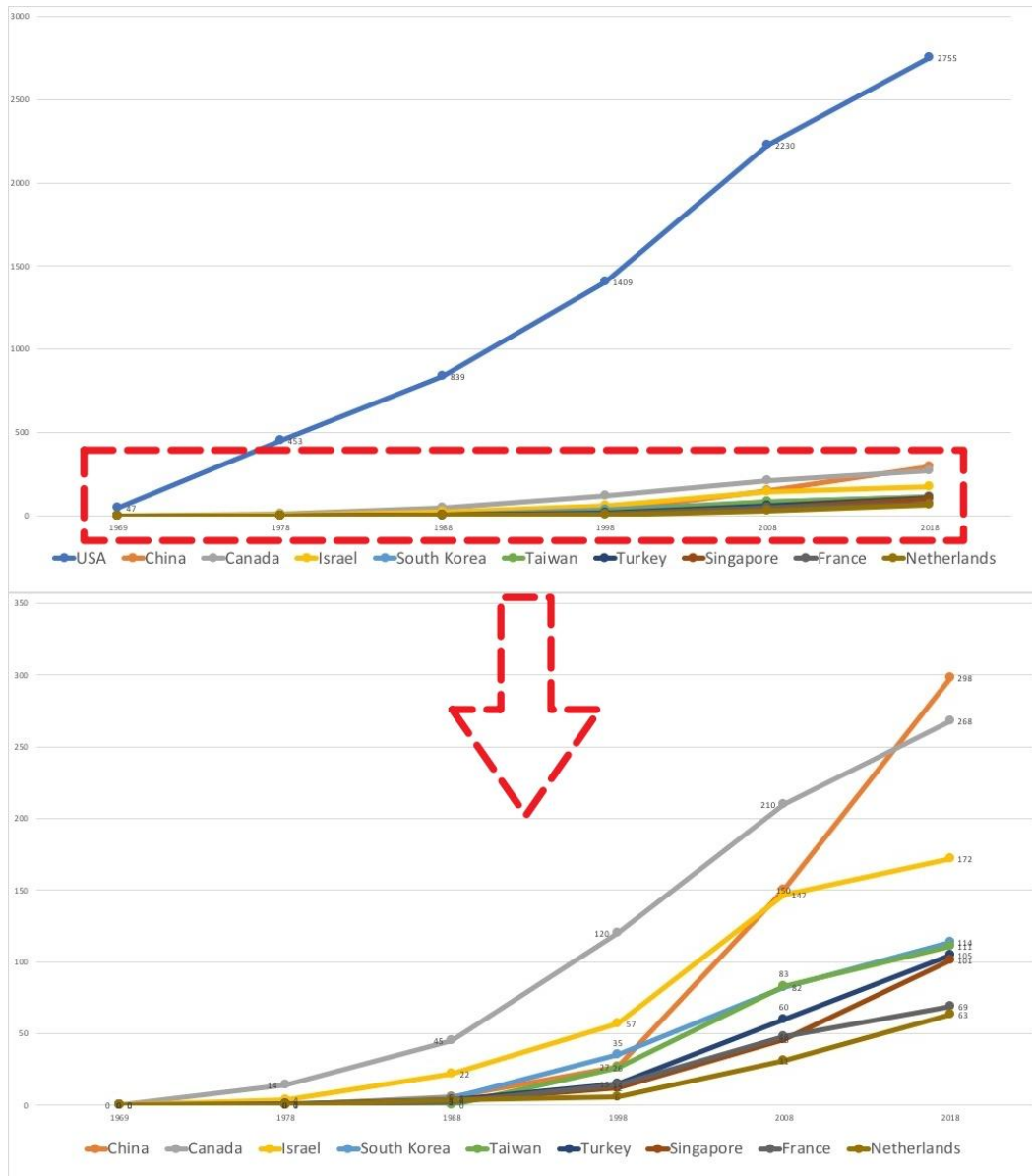


Figure 3: The growth trend of 10 most productive countries.

#### IV. Science Mapping

The previous section gives an informative overview of IISE through table data. In this section, in order to analyse the publication and citation structure thoroughly, we use VOS viewer software (version 1.6.10) to visualize the bibliographic connections between the leading sources.

##### 4.1 Bibliographic coupling

Bibliographic coupling occurs when two papers cite the same third paper and this single item of reference is defined as a unit of coupling between these two documents<sup>[14]</sup>. Therefore, bibliographic coupling of institutions aims to show how these institutions connect with each other. Figure 4 shows the bibliographic coupling of institutions with a threshold of five documents and one hundred connections. Citing the same articles means the research topics of two institutions are close and they are more likely to cooperate, thus it can be seen from colours that institutions from the same or surrounding countries are more likely to have similar research interests and study similar issues.





Figure 4: Bibliographic coupling of institutions that publish in IISE.

#### 4.2 Co-authorship

Co-authorship requires that two or more contributors intentionally make an utterance or work for which they take shared responsibility or credit<sup>[9]</sup>. Figure 5 is the co-authorship map of institutions which has the same threshold and connections as Figure 4, which makes the cooperative relationships between leading institutions clearer. Generally, institutions that are geographically close to each other have more collaborations. This conclusion is supplementary to the analysis of bibliographic coupling of institutions. Then to summarize these results at the country level, Figure 6 is the co-authorship map of countries with a threshold of five documents and thirty most representative connections. There is no doubt that the USA is the most leading country. It is way ahead of other countries in terms of total publications and citations. After the USA, China and Canada are neck to neck. There are also several European countries in the figure while the number of their publications is much lower than that of the North American and Asian countries. Regionally, countries from the same continent are more closely linked and may collaborate more.



Figure 5: Co-authorship of institutions that publish in IISE.



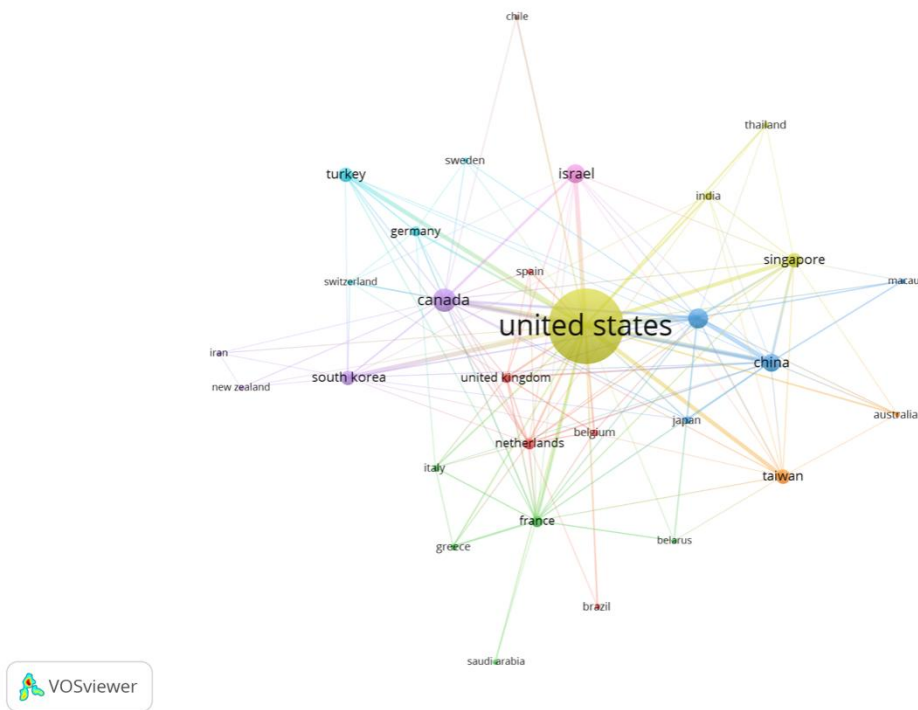


Figure 6: Co-authorship of countries publishing in IISE.

### 4.3 Co-citation

Co-citation is the frequency with which two items of earlier literature are cited together by the later literature, which differs significantly from bibliographic coupling<sup>[25]</sup>. Figure 7 presents the results with a minimum threshold of fifty citations and the one hundred most representative connections. Clearly, Management Science is the most cited journal followed by Operations Research. They have the strongest and broadest connection network. Besides, other journals including IIE Transactions itself (currently known as IISE Transactions), European Journal of Operational Research, International Journal of Production Research, Journal of Quality Technology, Technometrics, and IEEE Transactions on Reliability play an important role as well. It is worth noting that Figure 7 also illustrates that IISE is interdisciplinary. It does not only focus on industrial and manufacturing engineering but also involves other fields like operations research, management, computer science, statistics and marketing.

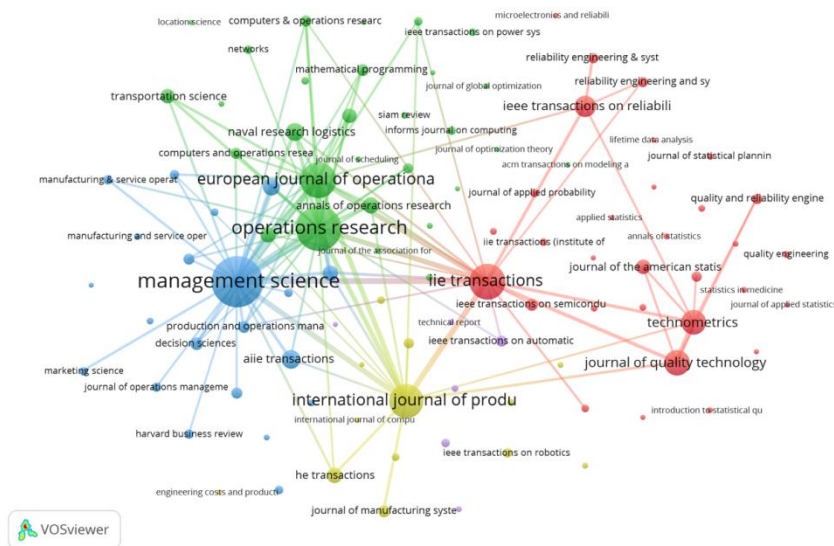
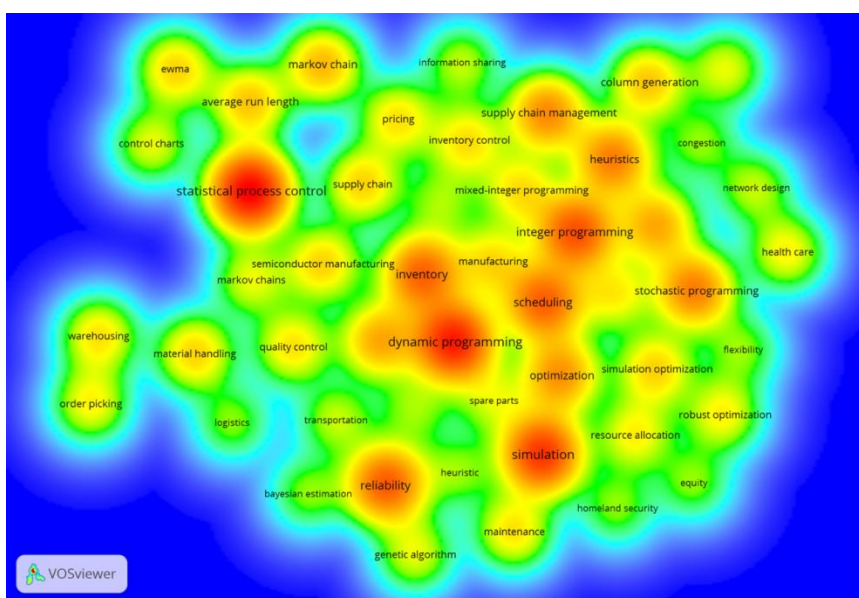


Figure 7: Co-citation of journals cited in IISE.

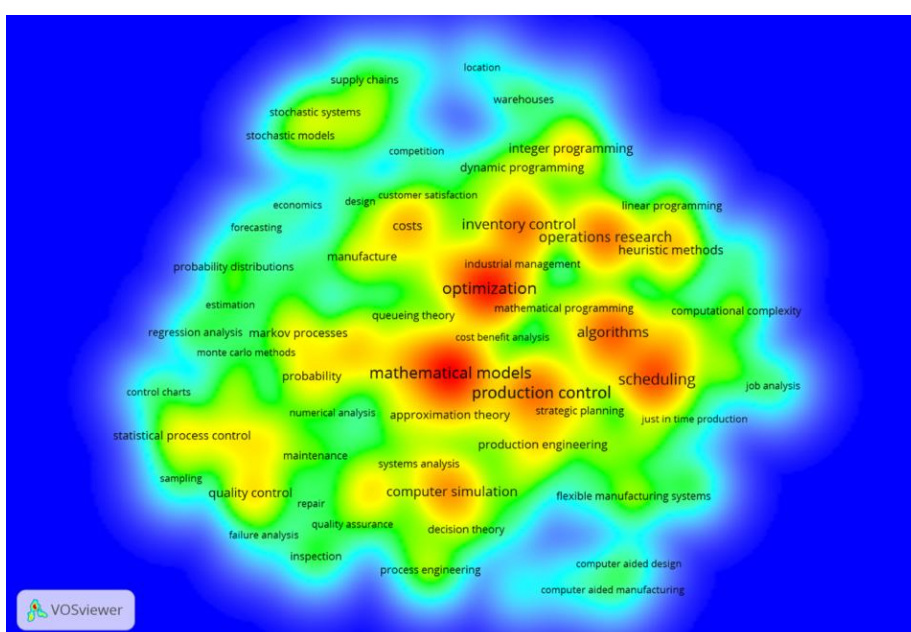
#### 4.4 Co-occurrence of keywords

Co-occurrence of keywords identifies the most frequent keywords to show the research field and conceptual structure of the journal. Let us analyse the author keywords. Author keywords, assigned to the document by the author, are standard terms selected from the title or text of the document to highlight the topic and core content of this document. Figure 8 visualises the co-occurrence of author keywords considering a threshold of five occurrences and the fifty greatest connections. As can be seen from Figure 8, “statistical process control”, “dynamic programming”, “simulation”, “integer programming” and “reliability” appear in the journal most frequently.

Since many authors did not add keywords to the articles in early stage, Scopus provides index keywords that is the controlled vocabulary terms assigned to the document. In order to identify the research field and trend of the journal and achieve a high precision of retrieval, let us analyse index keywords with a threshold of twenty occurrences and the one hundred connections (Figure 9). Apparently, index keywords like “mathematical models”, “optimization”, “scheduling”, “algorithms”, “production control”, “inventory control” and “operation research” have the highest occurrences, suggesting that the journal has a clear orientation to the fields of engineering and operations research. The keywords analysis can highlight the current research hotspots. It makes it easier and more convenient for new researchers to retrieve the information according to their interests.



**Figure 8:** Co-occurrence of author keywords in IISE.



**Figure 9:** Co-occurrence of index keywords in IISE.

## V. Conclusion

This article presents a retrospective review for IISE over the past 50 years from the bibliometric perspective. The performance analysis and science mapping are completed by analysing 3678 documents in the IISE (also AIIE and IIE) between 1969 to 2018 from Scopus database. To summarize the results, the most significant points are highlighted in the following conclusions.

For authors, IISE have attracted authors worldwide and there are most of them come from the USA. Among them, the most productive authors are Jonathan F. Bard from The University of Texas at Austin and Shiyu Zhou from University of Wisconsin-Madison. Meanwhile, Rosenblatt and Lee's article<sup>[23]</sup> have been cited the most (775 times) so far.

For institutions, most productive institutions are located in the USA and Georgia Institute of Technology takes the leading positions in terms of total publications and citations. Technion-Israel Institute of Technology and University of Texas at Austin are also influential with the highest cites per paper. Regionally, neighbouring institutions are more likely to have close research interests and study on similar topics, therefore the collaboration opportunities will be greater.

For countries, IISE receives submissions from all over the world. The USA is far ahead of other countries and it still maintains a steady and rapid growth in publications. China, Canada and Israel also contribute a lot to the journal.

IISE has a close citation relation with other top journals such as Management Science, European Journal of Operational Research, International Journal of Production Research and Journal of Quality Technology, which confirms that IISE covers broad and interdisciplinary fields.

For keywords, "statistical process control", "dynamic programming" and "integer programming" are the most frequent author keywords while simultaneously "mathematical models", "optimization", "algorithms" and "production control" are the high-frequency index keywords provided by Scopus. They not only represent the hot topics but also emphasises IISE's clear orientation to the fields of engineering and operations research.

There also exist some limitations in this study. For example, this study merely uses the data from Scopus while it may introduce some biases when performing comparative analyses<sup>[19]</sup>, so later downloading data from WoS or Google Scholar to make a comparison can be a good extension for this study. Furthermore, this study only focuses on the journal co-citation network instead of the comparison between IISE and other relevant journals, which should be explored in the future. Despite all that, this paper can be regarded as a snapshot of IISE, which benefits not only the readers who can find the related information according to their interests but also the researchers who intend to publish articles in IISE.

## Appendix

**Table A.1:** The 10 most productive countries in IISE.

R	Country	Publications within each decade				TP	TC	TC/TP	h	
		1969-1978	1979-1988	1989-1998	1999-2008					2009-2018
1	USA	453	386	570	821	525	2755	63183	22.93	100
2	China	0	6	21	123	148	298	5796	19.45	40
3	Canada	14	31	75	90	58	268	6371	23.77	45
4	Israel	4	18	35	90	25	172	4391	25.53	34
5	South Korea	0	5	30	47	32	114	2017	17.69	26
6	Taiwan	0	0	26	57	28	111	1999	18.01	28
7	Turkey	1	3	11	45	45	105	2227	21.21	24
8	Singapore	0	3	9	34	55	101	2083	20.62	28
9	France	0	2	12	34	21	69	1969	28.54	26
10	Netherlands	0	4	2	25	32	63	1620	25.71	22

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