BIBLIOMETRIC OVERVIEW OF OPERATIONS RESEARCH/ MANAGEMENT SCIENCE RESEARCH IN ASIA

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This paper evaluates the distribution of papers published by Asian authors in Operations Research and Management Science (OR/MS) journals from 1968 to 2006. The impact of OR/MS research in Asia is compared with that of the United States and the World, and research trends are highlighted through an analysis of keywords. From 1968 to 2006, 89,293 papers were published in 60 OR/MS journals. Of these, 41.4% came from USA and 16.6% came from seven Asian countries/regions. The contribution of different countries/regions is as follows: Japan 3.7%, Taiwan 3.2%, India 2.3%, Hong Kong 2.2%, South Korea 2.1%, People's Republic of China (PRC) 1.9%, and Singapore 1.2%. Among all the articles analyzed, 20% have a single author, and 9% have more than three authors; additionally, 22 papers have been cited more than 100 times and 29% have never been cited. Most articles originating in Japan, Taiwan, India, South Korea, PRC, and Singapore are produced in collaboration with local scholars, followed by authors from the United States. Hong Kong is a notable exception, 73% of articles from Hong Kong are produced in cooperation with the PRC, followed by local scholars. The five most productive institutions are as follows: The Indian Institute of Technology, the Korea Advanced Institute of Science and Technology, the National University of Singapore, The Hong Kong Polytechnic University, and the National Chiao-Tung University (Taiwan).

Keywords: Operations research; management science; bibliometric analysis.

1. Introduction

Research in the fields of Operations Research and Management Science (OR/MS) has profoundly influenced the development of industry and the national economy. The survey conducted by Chen and Wei (2002) shows that OR/MS has been acknowledged by Taiwanese companies as an efficient managerial tool for economic

development, with future usage likely to increase exponentially. Ranyard (1995) described the unique developmental path of OR in the UK, which originated with scientists assisting war-time operations, only to later transfer to industry in the immediate postwar years, where they have successfully solved the problems associated with most business functions.

Japan formed a unique refined industry based on learning about quality management after World War II, eventually prompting American researchers to consider why they could not match such achievements. Throughout the 1960s, and indeed up until the 1990s, Hong Kong, Singapore, South Korea, and Taiwan reached miraculous economic milestones by not only leading Asia in industrialization and technology, but also cultivating several unparalleled industries. Therefore, they are acclaimed as the Four Asian Tigers. These five economies share several common features. First, they are deeply nurtured by Chinese culture, where individuals are diligent and thrifty, with a concomitant emphasis on education that is conducive to economic development. Second, the complementary characteristic has to do with the widespread traumatic experience of war among the population, a phenomenon that has nurtured personal qualities of resilience and aggression, which have subsequently become harnessed to industrialization. Third, a factor is the political condition of relative stability, and in this context one might consider the formative influence of authoritarian politics in the initial phase of economic development. This legacy remains relevant in the sense that government policies are consistent and sustainable, with the attendant stability drawing foreign capital and technology as a stimulus to economic development. Fourth, the factor acknowledges how exogenous value systems can play a constructive role by connecting with the West technologically and institutionally. Fifth, a factor recognizes that these countries do not have vast lands and population, and are therefore export-oriented economies, in more endogenous terms. Contextualizing each of these constitutive elements makes an appreciable difference in situating present and future trends. This leads in turn to discussion of why the focus of attention at the turn of the 21st century is "Chindia", (i.e. China and India), both of which are assured of a promising future in terms of economic development. Given their abundant labor supply, they appear set to become the main manufacturing and service providers in the world. Indeed, these combined advantages will most likely transform "Chindia" into world economic superpowers in the near future.

Therefore, this study applies bibliometric analysis to analyze the international academic publications of OR/MS scholars in seven countries/regions in Asia, namely Hong Kong, India, Japan, People's Republic of China (PRC), Singapore, South Korea and Taiwan. Many OR/MS researchers from Asian countries/regions return to their home countries to teach or provide service after receiving doctoral education in the West. International publication has become an important indicator of academic performance, and so the researchers from these Asian countries/regions tend to share their research results with scholars in the same field through international publications.

The value of publications is commonly rated by the rank of the journals in the Journal Citation Report (JCR) (Lenhard *et al.*, 2006), which is published annually in two editions, science and social science, by The Thomson Corporation. JCR Science Edition includes data from over 5,900 journals in science and technology and ranks the journals by the impact factor (IF). The impact factor is a measure of the frequency with which the “average article” in a journal has been cited in a particular year or period. The annual *JCR* impact factor is a ratio of citations to recent citable items published. Thus, the impact factor of a journal is calculated by dividing the number of current year citations to the source items published in that journal during the previous two years (Garfield, 1994). Since this factor is an easily available means to quantify the value of scientific work, it is fast becoming widely adopted in the academic world.

The ISI Web of Science (WOS) includes information not only on the frequency of citations expressed by the IF, but also on the authors’ origin, document type and the keywords of the individual articles. The present study uses this database further to explore these bibliometric indicators in order to measure the distribution of papers published by authors from these seven promising Asian countries/regions in OR/MS journals from 1968 to 2006.

2. Method

JCR Science Edition has Operations Research & Management Science as a subject category. The 2006 edition has 60 journals (Appendix, listed alphabetically). This study searched the WOS database based on these 60 journals, and found that the WOS documents can be traced back to 1956. The 60 journals in the OR/MS discipline published 89,293 papers from 1968 to 2006. Of these, American authors published 36,929 papers. In Asia, Japan is the country with both the earliest and the highest number of publications, with two appearing in 1968 (Miyasawa, 1968; Senju and Toyoda, 1968) and totaling 3,342. India also had a paper published in the same year (Erlenkotter and Manne, 1968). The first papers in Taiwan and Hong Kong both appeared in 1975. Taiwan has a total of 2,896 papers, second only to Japan in Asia, including three in 1975 (Chen and Hsiao, 1975; Shih and Chu, 1975; Wu and Shih, 1975). Hong Kong had two papers published in the same year (Chan, 1975a, 1975b). A Singaporean scholar published a book review in *Interfaces* in 1976 (Langham, 1976); South Korea had its first article published in 1978 (Lee, 1978), and the first article from a PRC scholar appeared in 1981 (Zheng, 1981). Therefore, the data collection criteria for publications stand as follows: at least one author had to be affiliated with one of the seven Asian countries/regions and the paper had to be published between 1968 and 2006.

Many publications had multiple authors. We adopted an inclusive approach to counting, which was better able to evaluate author productivity. Each institution that appears in the author list receives one credit for an article. When articles are authored by collaborating institutions from multiple countries, each country receives

one count for its participation, irrespective of the number of its collaborating institutions. For example, Taiwan and Singapore would each receive one credit for an article coauthored by one Taiwanese institution and two Singaporean institutions. Thus, the number of credits for an article is subject to variation, depending on the number of institutional authors and the number of countries represented among the collaborating institutions. When institutions collaborate, a single article is counted more than once.

The resident population (expressed in millions of inhabitants) was retrieved for each country from the *CIA World Factbook*.

3. Results

The 2006 edition of JCR OR/MS category includes 60 journals, of which 13 have an impact factor above 1 (2.516–1.036); *Production and Operations Management* and *Journal of Operations Management* have an impact factor above 2. If analyzed by region of publication, 35 (58%) of the 60 OR/MS journals are from Europe; 22 (37%) are from the United States and Canada. The seven Asian countries/regions have three journals (two from Singapore and one from Japan), thereby confirming that this discipline originated from Europe (Kirby, 2003). If simply analyzed by country, publication centers on America, the UK and the Netherlands. America has 21 journals, which is the largest number, followed by the UK with 17, the Netherlands with 14, and Germany with three. Singapore publishes two titles, while Canada, France, Japan and Switzerland are responsible for one journal each.

Analysis conducted by subject category reveals that 16 of the 60 OR/MS journals, such as *Management Science*, *Journal of Operations Management*, and *Operations Research*, belong to the single discipline of OR/MS. Twenty-two journals belong simultaneously to two disciplines, and 21 journals belong to three disciplines. *International Journal of Information Technology & Decision Making* belongs to four subject categories. The discipline with most overlap is Industrial Engineering: 11 journals belong to OR/MS and Industrial Engineering at the same time; the one with the second most overlap is the discipline of Applied Mathematics, with ten journals crossing over into this discipline, and nine journals overlap with Manufacturing Engineering.

3.1. Number of papers

The number of academic papers published is an important indicator in scientific research. From 1968 to 2006, 14,816 papers were published by the seven Asian OR/MS researchers (Table 1). The leading countries were Japan (22.6% of papers), Taiwan (19.5%) and India (13.6%). These figures can be usefully compared with the 36,929 papers published in the same period in the United States. Seven Asian countries/regions account for 16.6% of all OR/MS literature during the same period, in contrast to the 41.4% produced by the United States. In the first decade (1968–1976), the United States published 2,572 OR/MS papers which are 14 times as many

Table 1. Scientific production of the seven Asian countries/regions, the USA, and the World (1968–2006).

Country/ region	Number of papers					Percent Asia					Percent World				
	Total	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV
Hong Kong	1,921	3	41	252	1,625	13.0%	0.0%	0.3%	1.7%	11.0%	2.2%	0.0%	0.0%	0.3%	1.8%
India	2,019	71	370	690	888	13.6%	0.5%	2.5%	4.7%	6.0%	2.3%	0.1%	0.4%	0.8%	1.0%
Japan	3,342	105	638	1083	1,516	22.6%	0.7%	4.3%	7.3%	10.2%	3.7%	0.1%	0.7%	1.2%	1.7%
People's R China	1,730	0	60	390	1,280	11.7%	0.0%	0.4%	2.6%	8.6%	1.9%	0.0%	0.1%	0.4%	1.4%
Singapore	1,068	1	34	269	764	7.2%	0.0%	0.2%	1.8%	5.2%	1.2%	0.0%	0.0%	0.3%	0.9%
South Korea	1,839	0	65	450	1,324	12.4%	0.0%	0.4%	3.0%	8.9%	2.1%	0.0%	0.1%	0.5%	1.5%
Taiwan	2,896	3	82	731	2,080	19.5%	0.0%	0.6%	4.9%	14.0%	3.2%	0.0%	0.1%	0.8%	2.3%
Total (Asia 7)	14,816	183	1,290	3,865	9,477	100.0%	1.2%	8.7%	26.1%	64.0%	16.6%	0.2%	1.4%	4.3%	10.6%
USA	36,929	2,572	7,532	12,612	14,213						41.4%	2.9%	8.4%	14.1%	15.9%
World	89,293	4,147	16,830	27,670	40,646						100.0%	4.6%	18.8%	31.0%	45.5%

I: 1968–1976, II: 1977–1986, III: 1987–1996, IV: 1997–2006.

as that of the seven Asian countries/regions. However, this difference progressively reduced during the following decade to 1.5 times in the fourth decade (1997–2006). The number of OR/MS papers published in the different Asian countries/regions as compared to the total number of papers published in Asia changed slightly in the four decades examined, increasing in Taiwan, Hong Kong and Japan. Taiwan published 14% more papers in the fourth decade than in the first decade. Hong Kong's output increased by 11% during the same period, while Japan's increased by 10%. The OR/MS output of all seven Asian countries/regions increased during the period examined.

Since the first OR/MS article appeared in Japan in 1968, its output has always been much higher than that from the other six Asian countries/regions (with the exception of 1975, when it was exceeded by India). The greatest number of papers from Japan was 199 in 1999, thereafter recording a sharp decline. For example, only 132 papers were published from Japan in 2006. The situation in India is similar to Japan. After the first OR/MS article appeared in 1968, its number of articles followed Japan closely, and has fluctuated since 1993. The number of articles exceeded 100 only in 1997, 2005 (103 papers) and 2006 (137 papers). Taiwan experienced the fastest growth in literature among the seven Asian countries/regions, having published three articles in 1975, and being second only to Japan in 1993. Taiwan eventually exceeded Japan in the year 2000, and then took the lead along the way. Taiwan produced 323 articles in 2005, making it the only Asian country with over 300 articles in a year. Another fast growing country is PRC. Since the first OR/MS article from PRC appeared in 1981, output has increased steadily over the years. It had over 100 articles in 1999, increasing to 250 in 2006. Exponential growth in Hong Kong became discernible from 1998.

The number of papers published in the international OR/MS journals by the scholars from the seven Asian countries/regions, show steady growth rates overall. Figure 1 indicates the largest number of papers came from Japan, with Taiwan and India following closely. The number of papers from Taiwan surpassed that from India, and followed that of Japan in 2000. The difference between the numbers of papers from Taiwan and Japan had become smaller in 2006. The number of papers, and the growth trend, in Hong Kong and South Korea are both very similar. PRC was late in starting to produce papers, but grew very fast, while Singapore has the smallest number of papers and the slowest growth pace.

The ratio of number of papers to country population in millions of inhabitants was 13.5 globally, 122.6 in the US, and 5.6 in the seven Asian countries/regions. In Asia, Hong Kong ranked first (275.2), followed by Singapore (234.7), Taiwan (126.7), South Korea (37.5), Japan (26.2), India (1.8), and PRC (1.3).

3.2. *Quality of papers*

International Journal of Systems Science published the most papers by researchers from the seven Asian countries/regions, ranked 53 by JCR 2006 OR/MS category

Fig. 1. Cumulated distribution of OR/MS papers in seven Asian countries/regions.

(1,779 papers, 12.41%), followed by *International Journal of Production Research*, ranked 22 (1,179, 8.22%), and *European Journal of Operational Research*, ranked 16 (1,158, 9.55%). These three journals published over 1,000 papers by Asian scholars. Only one journal in OR/MS category, *Military Operations Research*, did not publish papers by scholars from the seven Asian countries/regions. Table 2 shows the ten most active journals, that is, those with the most papers published by researchers from the seven Asian countries/regions. This table presents the number of papers, percentage of total documents, the position of the journal in JCR OR/MS category, 2006 impact factor and the JCR category of journals. Only one journal listed in Table 2 has an IF value greater than 1, namely *International Journal of Production Economics*.

It is clear from Table 3 that Japan (2.1%) ranks first, followed by Hong Kong (1.67%) and Taiwan (1.43%), in terms of the number of papers published in the top ten IF-ranked OR/MS journals. Among the seven Asian countries/regions, Singapore had the highest percentage of paper published in top ten journals, ranked

Table 2. Ten most active journals containing most papers by the scholars from the seven Asian countries/regions (1968–2006).

Rank	Journal	Papers	Percentage	2006 Rank	2006 IF	Country	Subject category
1	<i>International Journal of Systems Science</i>	1779	12.41	53	0.343	GB	OR/MS+2
2	<i>International Journal of Production Research</i>	1179	8.22	22	0.799	GB	OR/MS+2
3	<i>European Journal of Operational Research</i>	1158	8.08	16	0.918	NL	OR/MS
4	<i>Journal of the Operations Research Society of Japan</i>	833	5.81	55	0.292	JP	OR/MS
5	<i>Journal of Optimization Theory and Applications</i>	709	4.95	31	0.633	USA	OR/MS+1
6	<i>Expert Systems with Applications</i>	547	3.82	14	0.957	USA	OR/MS+2
7	<i>Computers & Operations Research</i>	529	3.69	17	0.893	GB	OR/MS+2
8	<i>Reliability Engineering & System Safety</i>	507	3.54	15	0.92	GB	OR/MS+1
9	<i>Journal of the Operational Research Society</i>	488	3.40	33	0.597	GB	OR/MS
10	<i>International Journal of Production Economics</i>	484	3.38	10	1.183	NL	OR/MS+2
Total		8213	57.29	60			

by JCR 2006 OR/MS category by IF, accounting for the total number of papers of that country, which was about 18%. Singapore was followed by Hong Kong with 15.7%, Japan with 11.4%, PRC and South Korea were about 10%, India with 9.2%, and finally Taiwan with 8.9%. (Table 3).

The top-tier journals known by OR/MS scholars are *Management Science*, *Operations Research*, *INFORMS Journal on Computing*, *Production and Operations Management*, and *Journal of Operations Management*. To investigate further the publication patterns of researchers from seven Asian countries/regions in the top-tier OR/MS journals, Singapore also had with the highest percentage of paper publication accounting for the total number of papers of that country, which was 6.5% (69 papers), Hong Kong followed with 5%, South Korea with 3.4%, India with 2.7%, Japan with 2.1%, PRC with 1.4%, and Taiwan with 1.1%.

The percentage of papers published by scholars from the seven Asian countries/regions in the bottom ranked ten journals (JCR position 51-60) was the lowest in PRC at only 5.5% of the overall total of papers produced in OR/MS literature. It was followed by Taiwan with 6.3%, Hong Kong with 6.5%, Singapore and South Korea with 8.6%, India with 11%, and Japan with 27.7% (926 papers). The high percentage from Japan was because of the papers published in the 55th-ranked *Journal of the Operations Research Society of Japan*.

Table 3. Paper presentations in OR/MS top ten journals by scholars from the seven Asian countries/regions (1968-2006).

Rank	Journals	Year	World	Asia 7	HK	IN	JP	PRC	SG	SK	TW
1	<i>Production and Operations Management</i>	1999	267	21 ^a	9	2	2	1	5	1	1
2	<i>Journal of Operations Management</i>	1999	281	7.87 ^b	3.37	0.75	0.75	0.37	1.87	0.37	0.37
3	<i>Transportation Research Part B-Methodological</i>	1979	1078	12	6	0	0	1	1	2	2
4	<i>Management Science</i>	1968	4207	4.27	2.14	2	37	0.36	0.36	0.71	0.71
5	<i>Systems & Control Letters</i>	1981	2756	166	69	2	37	11	7	13	27
6	<i>Journal of Quality Technology</i>	1977	1130	15.40	6.40	0.19	3.43	1.02%	0.65	1.21	2.50
7	<i>Transportation Science</i>	1980	892	187	46	17	30	6	34	38	16
8	<i>Operations Research</i>	1968	4902	4.44	1.09	0.40	0.71	0.14	0.81	0.90	0.38
9	<i>OR Spectrum</i>	2002	147	456	42	37	135	109	59	13	61
10	<i>International Journal of Production Economics</i>	1991	2420	16.55	1.52	1.34	4.90	3.96	2.14	0.47	2.21
Total of OR/MS top ten journals			18080	98	10	14	5	8	20	19	22
Total of OR/MS 60 Journals			89293	8.67	0.88	1.24	0.44	0.71	1.77	1.68	1.95
				44	12	3	9	3	1	5	11
				4.93	1.35	0.34	1.01	0.34	0.11	0.56	1.23
				170	35	33	36	10	27	18	11
				3.47	0.71	0.67	0.73	0.20	0.55	0.37	0.22
				28	3	0	2	3	6	13	1
				19.05	2.04	1.36	1.36	2.04	4.08	8.84	0.68
				500	70	78	124	23	33	65	107
				20.66	2.89	3.22	5.12	0.95	1.36	2.69	4.42
				1682	302	186	380	175	193	187	259
				9.30	1.67	1.03	2.10	0.97	1.07	1.03	1.43
				14337	1921	2019	3342	1730	1068	1839	2896
					15.72	9.21	11.37	10.12	18.07	10.17	8.94

Note: ^aNumber of documents, ^bpercentage.

3.3. *Type of document*

The document types identified by the WOS database were analyzed. The most common was Journal Article, contributing about 96% of the total in Asia and 85% globally (Table 4). The second most common document type is Note, followed by Editorial material, Review, Book Review and Letter. Japan has the most types of document (12) in the seven Asian countries/regions, followed by Hong Kong and India, while PRC and Taiwan have the fewest. The document type with the largest number of documents is Note, with 59 and 42 published by Indian and Japanese scholars respectively. Hong Kong is the region with the most Review literature (18), followed by India (16) and Taiwan (12). Hong Kong also has the greatest number of Editorial materials, followed by Japan.

3.4. *Most productive institution*

The seven Asian countries/regions have 32 institutions, which published over 100 papers. The papers from India, Singapore, and South Korea tend to come from one single research institution. For instance, the institution with the most papers in Singapore is National University of Singapore (NUS) which produced 671 papers. Its closest competitor, Nanyang Technological University, was only able to match half this productive output (308), while Singapore Management University settled into third place with only 29 papers. Distinctive as these results may be, it is also instructive to consider the situation in India, not least because it is even more centralized than Singapore. The institution with the most papers is Indian Institute of Technology which has 704 papers, the largest number in Asia. The second place is Indian Institute of Management which has only 151 papers. The Indian Institutes of Technology (IITs) are a group of seven autonomous engineering and technology-oriented institutes of higher education established by the Government of India, but the statistical ramifications of this fact tend to be somewhat distorted by the methodology adopted by the Web of Science. The problems stem from how "INDIAN INST TECHNOL" is referenced as an institutional umbrella term to index the sum total of publications produced by the IITs. The most dispersed institutional distribution of papers can be found in PRC, where many institutions contend with one another. The institution with the highest tally is the Chinese Academy of Sciences which has 264 papers. Second place is occupied by Tsinghua University (161 papers). Shanghai Jiao Tong University comes in behind, with 82 papers. Table 5 presents the top twenty institutions.

Hong Kong and Taiwan each have five of the top 20 institutions with over 150 papers published. Japan has four, while India and Singapore have two respectively. PRC and South Korea each have one such institution. The distribution of research institutions in Hong Kong and Taiwan is more even. Hong Kong papers are mainly from five institutions: The Hong Kong Polytechnic University (472 papers), the Hong Kong University of Science and Technology (374 papers), the City University of Hong Kong (369 papers), the Chinese University of Hong Kong (357 papers)

Table 5. Most productive institutions (1968–2006).

Rank	Institutions	Papers	Country
1	Indian Inst Technol	704	IN
2	Korea Adv Inst Sci & Technol	700	SK
3	Natl Univ Singapore	671	SG
4	The Hong Kong Polytech Univ	483	HK
5	Natl Chiao Tung Univ	407	TW
6	City Univ Hong Kong	382	HK
7	Hong Kong Univ Sci & Technol	378	HK
8	Kyoto Univ	364	HK
9	Chinese Univ Hong Kong	361	JP
10	Natl Cheng Kung Univ	325	TW
11	Tokyo Inst Technol	317	JP
12	Univ Hong Kong	311	HK
13	Nanyang Technol Univ	308	SG
14	Natl Tsing Hua Univ	279	TW
15	Chinese Acad Sci	264	PRC
16	Natl Taiwan Univ Sci & Technol	247	TW
17	Univ Tsukuba	236	JP
18	Osaka Univ	213	JP
19	Natl Taiwan Univ	172	TW
20	Tsinghua Univ	161	PRC

and the University of Hong Kong (307 papers). The institutions with the greatest amount of literature in Taiwan are National Chiao-Tung University (ranking number 5), National Cheng Kung University, National Tsing-Hua University, National Taiwan University of Science and Technology, and National Taiwan University.

3.5. *Most productive authors*

Singapore is the country with the most authors of one paper only, accounting for 67% of the total, followed by Hong Kong and India (63%), while Taiwan has the fewest (58%). Taiwan has the greatest percentage of authors with over ten papers published (4%), followed by 3.8% from Hong Kong and South Korea (Table 6).

The author with the most papers published in OR/MS journals in the seven Asian countries/regions is TCE Cheng from the Logistics Department of The Hong Kong Polytechnic University, having published a total of 133 papers. The author ranked second is Masao Fukushima from Kyoto University Graduate School Informatics (84 papers), XQ Yang from the Department of Applied Mathematics of The Hong Kong Polytechnic University attained third position (67 papers). Hirsch (2005) proposed the h -index, a new metric for characterizing the scientific output of a piece of research, which is defined as follows: “A scientist has index h if h of his or her Np papers have at least h citations each and the other $(Np - h)$ papers have $\leq h$ citations each”, where Np = total number of papers. Table 7 ranks the active Asian academics by the total items published and the total citations (times cited). Since some of the authors moved or returned to Asia after spending the earlier part of

Table 6. Breakdown of scientific production by number of papers (1968–2006).

No. of Papers	Hong Kong		India		Japan		PRC		Singapore		South Korea		Taiwan	
	Authors	%	Authors	%	Authors	%	Authors	%	Authors	%	Authors	%	Authors	%
1	1176	62.62	1248	62.97	1629	61.49	1629	61.49	811	67.08	1036	60.30	1399	58.00
2	293	15.60	316	15.94	421	15.89	421	15.89	173	14.31	264	15.37	414	17.16
3	124	6.60	147	7.42	147	5.55	147	5.55	81	6.70	156	9.08	166	6.88
4	64	3.41	85	4.29	112	4.23	112	4.23	40	3.31	70	4.07	129	5.35
5	45	2.40	49	2.47	73	2.76	73	2.76	27	2.23	51	2.97	73	3.03
6	33	1.76	30	1.51	61	2.30	61	2.30	11	0.91	21	1.22	36	1.49
7	25	1.33	16	0.81	34	1.28	34	1.28	16	1.32	16	0.93	31	1.29
8	13	0.69	18	0.91	26	0.98	26	0.98	8	0.66	18	1.05	27	1.12
9	18	0.96	11	0.55	24	0.91	24	0.91	3	0.25	10	0.58	15	0.62
10	15	0.80	8	0.40	24	0.91	24	0.91	4	0.33	10	0.58	24	1.00
10 ↑	72	3.83	54	2.72	98	3.70	98	3.70	35	2.89	66	3.84	98	4.06
No. Authors	1878		1982		2649		2649		1209		1718		2412	
No. Papers	1921		2019		3342		1730		1068		1839		2896	

Table 7. Most productive authors in OR/MS (1968–2006).

Rank	Sort by Papers			Sort by Total Citations									
	Papers	Author	Country	Citations	Author	Country	Papers	Citations per Paper	<i>h</i> -Index	Overall Papers	Overall Citations	Citations per Paper	Overall <i>h</i> -Index
1	133	Cheng, TCE	HK	1066	Kojima, M	JP	54	19.04	18	58	1070	18.45	18
2	84	Fukushima, M	JP	890	Fukushima, M	JP	84	10.6	15	95	898	9.45	15
3	67	Yang, XQ	HK	786	Mizuno, S	JP	35	22.46	13	36	791	21.97	13
4	64	Teo, KL	HK	749	Cheng, TCE	HK	133	5.76	13	199	1477	7.42	19
5	61	Ibaraki, T	JP	662	Rajendran, C	IN	49	13.24	16	50	665	13.30	16
6	56	Kim, YD	SK	653	Yang, H	HK	51	11.07	15	52	604	11.62	15
7	55	Ohta, H	JP	635	Ibaraki, T	JP	61	10.08	14	72	648	9	14
8	55	Xie, M	SG	614	Kim, YD	SK	56	10.77	15	63	620	9.84	15
9	54	Kojima, M	JP	552	Lee, CY	HK	44	12.55	13	86	1461	16.99	18
10	54	Kim, SH	SK	545	Konno, H	JP	46	11.6	13	55	590	10.73	14
11	54	Kim, S	SK	484	Wang, SY	PRC	50	10.52	14	63	176	2.79	7
12	51	Yang, H	HK	400	Yao, JC	TW	37	10.26	12	50	403	8.06	12
13	50	Wang, SY	PRC	364	Fujishige, S	JP	41	8.27	11	45	364	8.09	11
14	49	Rajendran, C	IN	360	Kim, SH	SK	54	6.55	11	56	368	6.57	11
15	49	Hwang, H	SK	348	Hwang, H	SK	49	6.96	11	51	349	6.84	11
16	48	Sung, CS	SK	341	Nakagawa, T	JP	29	12.18	11	42	419	9.98	12
17	47	Ishii, H	JP	317	Chaudhuri, KS	IN	27	11.74	12	29	317	10.93	12
18	47	Yamamoto, Y	JP	311	Pearn, WL	TW	45	6.91	8	57	369	6.47	10
19	46	Konno, H	JP	307	Park, KS	SK	34	8.77	12	37	311	8.41	12
20	45	Pearn, WL	TW	282	Chen, GY	PRC	26	10.85	9	26	283	10.88	9
45	45	Mak, KL	HK	236	Sueyoshi, T	JP	29	8.74	10	50	519	10.38	12
45	45	Lai, KK	PRC	198	Li, D	HK	36	5.21	10	58	270	4.66	10
				197	Nee, AYC	SG	28	6.79	10	32	198	6.19	10

their academic and research careers in countries outside Asia, to give a fuller picture on the most active and influential OR/MS researchers from Asia, their overall number of publications, overall number of citations, and overall *h*-indices, regardless of their institutional affiliations, are presented as supplementary information in Table 7.

3.6. Co-author analysis

Papers from Hong Kong have the greatest number of co-authors, with 4,936 authors for the 1,921 papers. That is, Hong Kong has 2.57 authors per paper on average. The next largest number of co-authors is from Singapore, with 2,644 authors for 1,068 papers (i.e. 2.48 authors per paper on average). The smallest number of co-authors is in Japan, with 3,343 papers contributed by 7,112 authors, amounting to 2.13 authors per paper on average. The 2,896 papers published in Taiwan are the contributions of 6,376 authors, which equates to 2.2 authors per paper on average. Overall, the most common collaboration is between two authors publishing OR/MS papers in the seven Asian countries/regions. India accounts for 52%, followed by Taiwan and South Korea 47%. The second common cooperation is among three authors, of which Singapore accounts for about 35%, followed by Hong Kong with 34%.

The country with the most single-author papers is Japan, approximately 31% of papers. PRC is the next with about 21%. South Korea has the fewest single authors, with slightly less than 11%, while Hong Kong only accounts for about 12%.

The largest number of co-authors for a paper is 16, originated from PRC. It was co-written by five American authors and 11 PRC authors (Kuby *et al.*, 1995). One paper in Japan has ten authors, and four papers with nine authors. Of the latter group, two are from Japan, and one each is from Singapore and Taiwan. The greatest number of authors for a single paper in Taiwan is nine, which included seven American authors, in addition to another two from Japan and Taiwan (Adams *et al.*, 1996).

On the whole, it is clear that most papers published in the OR/MS journals generally involve only one to three authors. Of such papers, India accounts for nearly 95%; Taiwan (93%); Japan (92%); PRC and South Korea (each 89%); Singapore 87%; Hong Kong (slightly less than 85%). Table 8 provides a more complete analysis.

The number of authors collaborating with researchers from different countries serves as a significant indicator of the globalization of that discipline. Table 9 indicates that the scholars from India, Japan, PRC, Singapore, South Korea and Taiwan, prefer to work with domestic scholars, and the percentage can reach 100%. Other than domestic scholars, the six countries exhibit a marked preference for scholars from the United States. South Korea has the highest percentage in terms of co-authorship, where 21% of papers were produced in cooperation with American scholars, followed by Hong Kong, PRC, Singapore and Taiwan. The country with

Table 8. Breakdown of scientific production by number of authors (1968–2006).

No. of Authors	HK	IN	JP	PRC	SG	SK	TW
1	223 11.61%	364 18.03%	1,040 31.11%	370 21.39%	191 17.88%	199 10.82%	602 20.79%
2	746 38.83%	1045 51.76%	1,217 36.40%	678 39.19%	366 34.27%	869 47.25%	1,366 47.17%
3	658 34.25%	503 24.91%	821 24.56%	478 27.63%	370 34.64%	572 31.10%	726 25.07%
4	239 12.44%	87 4.31%	199 5.95%	161 9.31%	108 10.11%	148 8.05%	162 5.59%
5	43 2.24%	16 0.79%	41 1.23%	34 1.97%	25 2.33%	39 2.12%	30 1.04%
6 or more	12 0.63%	4 0.20%	25 0.75%	9 0.52%	8 0.75%	12 0.65%	10 0.35%
Total	4936	4416	7112	4041	2644	4514	6376
No. Papers	1921	2,019	3,343	1730	1,068	1,839	2,896
Average	2.57	2.19	2.13	2.34	2.48	2.45	2.20

the second largest degree of cooperation varies by country: India, PRC and South Korea scholars are content to work with Canadian scholars

More than 70% of Hong Kong scholars work with PRC scholars to publish their papers, with fellow Hong Kong scholars serving as a secondary reserve of intellectual capital. Additionally, Hong Kong scholars network with scholars from Canada, the United Kingdom, Singapore, Australia and Taiwan. Overall, international cooperation is the most active in Hong Kong and then Singapore.

Which scholars typically publish papers together is another important issue. Of the seven Asian countries/regions studied, PRC has the highest percentage of single papers authored by different pairs of collaboration (87%), followed by South Korea and Taiwan (each approximately 80%). Hong Kong has the lowest percentage, 70%. The greatest number of collaborating pairs of authors producing over ten papers is seven from Japan, followed by five from Hong Kong, two from Singapore, and one each from India and Taiwan.

Table 10 indicates that OR/MS research in PRC is diversified and contentious, inasmuch as a clear research network currently remains at an emergent developmental stage. India has the greatest number of co-author papers among the seven Asian countries/regions. The collaboration network between India and PRC can accordingly undergo further comparison through network analysis. Figure 2 demonstrates that Indian authors who co-publish over three papers have very strong networks, and are likewise inclined to write and publish more papers together (the thickness of lines represents the number of papers, thus highlighting the network ties). In contrast, the collaborative networks among PRC authors are more dispersed in the absence of a clear research network, leading to fewer jointly authored papers being published.

Table 9. List of the countries of co-author (1968–2006).

Hong Kong		India		Japan		People's R China		Singapore		South Korea		Taiwan	
PRC	73.09%	IN	100%	JP	99.97%	PRC	100%	SG	99.91%	SK	100%	TW	100%
HK	30.14%	USA	8.47%	USA	6.97%	USA	15.95%	USA	17.04%	USA	20.66%	USA	14.09%
USA	19.16%	CA	5.20%	PRC	2.72%	CA	5.84%	PRC	9.93%	GB	1.52%	PRC	1.80%
CA	6.61%	PRC	1.14%	CA	1.56%	GB	4.34%	AU	4.68%	CA	1.36%	AU	0.83%
GB	4.79%	DE	1.09%	DE	0.93%	JP	4.22%	CA	3.93%	JP	1.31%	CA	0.73%
Total	1921		2019		3342		1730		1068		1839		2896

Table 10. Number of papers published by collaboration pairs in seven Asian countries/regions (1968–2006).

No. of Papers	HK	IN	No. of Pairs				
			JP	PRC	SG	SK	TW
1	532	372	468	491	426	666	482
	69.63%	78.81%	77.74%	87.06%	75.94%	80.73%	79.02%
2	123	62	77	53	94	112	76
	16.10%	13.14%	12.79%	9.40%	16.76%	13.58%	12.46%
3	51	14	23	6	22	27	33
	6.68%	2.97%	3.82%	1.06%	3.92%	3.27%	5.41%
4	16	10	10	10	8	12	10
	2.09%	2.12%	1.66%	1.77%	1.43%	1.45%	1.64%
5	15	6	5	1	6	7	3
	1.96%	1.27%	0.83%	0.18%	1.07%	0.85%	0.49
6†	27	8	19	3	5	1	6
	3.53%	1.69%	3.16%	0.53%	0.89%	0.12%	0.98%
Unique Pairs	764	472	602	564	561	825	610

3.7. *Most cited authors*

Nineteen papers published by authors from the seven Asian countries/regions are cited over 100 times. These comprise seven from Japan, which is the largest number, four from India, three from Taiwan, two from PRC and Singapore respectively, and one from Hong Kong. The most cited paper from South Korea has only been cited 89 times.

The most cited paper is the collaboration between E Pardoux from Shandong University and SG Peng from Fudan University, which has been cited 226 times. The second most cited paper is co-written by KY Tam from the Hong Kong University of Science and Technology and MY Kiang from Arizona State University (cited 189 times). The paper co-produced by SS Keerthi from the Indian Institute of Science, and EG Gilbert from Aerospace Engineering Department of Michigan University in America, has been cited 175 times, earning it a respectable third place in the collaborative citation ranking (Table 11).

3.8. *Research topics analysis*

This paper analyzes the keywords listed by the author to analyze differences among the research interests of OR/MS scholars in the seven Asian countries/regions. Each author might choose different types of words when listing key words. Most scholars use plural forms such as “fuzzy sets” and “fuzzy sets theory”, while few settle for singular forms, such as “fuzzy set”, “fuzzy set theory”. Some employ full names, such as “data envelopment analysis”, while others resort to its acronym “DEA”, with both acronym and full name, as “DEA (data envelopment analysis)” or “data envelopment analysis (DEA)”, making recurrent appearances in the literature as well. Naturally differences also occur in spelling, i.e. “data envelop analysis” is also

Indian

People's R China

Fig. 2. Author collaboration networks of India and People's R China.

Table 11. The most cited papers (1968–2006).

Rank	Time Cited	Self-Cited	Country	
1	226	28	PRC	(Pardoux and Peng, 1990)
2	189	3	HK	(Tam and Kiang, 1992)
3	175	2	IN	(Keerthi and Gilbert, 1988)
4	171	12	JP	(Fukushima, 1992)
5	162	33	JP	(Pearn, Kotz, and Johnson, 1992)
6	160	57	TW	(Kojima, Mizuno, and Yoshise, 1989)
7	157	0	IN	(Sugimori, Kusunoki, Cho, and Uchikawa, 1977)
8	155	0	JP	(Chandrasekharan and Rajagopalan, 1987)
9	154	2	JP	(Chen, Drezner, Ryan and Simchi-Levi, 2000)
10	148	12	IN	(Furuta, 1990)

Table 12. Top 20 keywords (1968–2006).

Rank	Keywords	Frequency
1	inventory	329
2	scheduling	290
3	genetic algorithm	242
4	heuristics	233
5	optimization	220
6	dynamic programming	158
7	simulation	145
8	neural networks	138
9	data envelopment analysis	137
10	linear programming	126
11	supply chain management	125
12	reliability	120
13	global optimization	118
14	branch and bound	99
15	global convergence	99
16	integer programming	97
17	data mining	93
18	analytic hierarchy process	87
19	fuzzy sets	83
20	simulated annealing	82

used. Hence it is prudent to make allowance for different types of keywords when analyzing them.

Table 12 lists the top 20 keywords used by OR/MS scholars in the seven Asian countries/regions. The most widely studied research topics in the seven Asian countries/regions include inventory, scheduling, genetic algorithm, heuristics and optimization. The research topics unique to Taiwanese scholars are fuzzy sets, data mining, reliability, and data envelopment analysis. Further analysis of the keywords among papers from Taiwan, Hong Kong, and PRC reveals that the research topics of PRC scholars are the most dispersed, and the key words are the most definite. The research interests of Taiwan and Hong Kong scholars are similar. The most popular research topic in Taiwan is inventory, which ranks number five in Hong Kong. However, only 12 PRC papers use a keyword relating to this topic. Taiwan

and Hong Kong have the most papers discussing dynamic planning, while PRC has the most papers on linear programming.

4. Conclusion

This paper considers only journals quoted by ISI as OR/MS journals. The analytical approach employed herein has some limitations, and does not cover all the OR/MS publications from 1968 to 2006. Indeed, OR/MS scholars do not necessarily publish their papers in OR/MS journals, but can submit their results to journals of other fields that specifically address their areas of interest. The process of identifying OR/MS papers in other journals is complicated and too impractical to be broached in this study. New methods are worth developing that could perform a series of related functions. Particularly noteworthy in this regard is the identification of an author's scientific background, in tandem with the matching of keywords, names of the authors and Institutions of provenance, all of which will greatly enrich future understanding of the scientific performance of OR/MS scholars in Asia.

In conclusion, the present study offers a fairly complete and reliable overview of OR/MS research in Asian in the years between 1968 and 2006. In the seven Asian countries/regions under review here, the OR/MS research is active and productive, and accounts for 16.6% of all the OR/MS fields. In a highly competitive world, to precisely know its position in comparison with its competitors can be utilized to identify the strategies to improve the property of allocation of resources and therefore to upgrade the quality of its research.

Appendix. 60 Journals listed under the subject category of OR/MS in JCR 2006 version.

Journal Title	Rank by IF	Impact Factor	Articles	Issues/ Year	Country/ Territory	Subject categories
<i>Annals of Operations Research</i>	34	0.589	129	8	Netherlands	1
<i>Applied Stochastic Models in Business and Industry</i>	47	0.443	40	4	England	3
<i>Asia-Pacific Journal of Operational Research</i>	51	0.375	31	4	Singapore	1
<i>Computers & Operations Research</i>	17	0.893	183	14	England	3
<i>Computational Optimization and Applications</i>	21	0.8	51	9	United States	2
<i>Concurrent Engineering-Research and Applications</i>	36	0.569	29	4	England	3
<i>Decision Support Systems</i>	11	1.16	156	11	Netherlands	3
<i>Discrete Event Dynamic Systems-Theory and Applications</i>	13	1.036	19	4	United States	3

Appendix. (Continued)

Journal Title	Rank by IF	Impact Factor	Articles	Issues/ Year	Country/ Territory	Subject categories
<i>Engineering Optimization</i>	39	0.557	57	6	England	2
<i>European Journal of Operational Research</i>	16	0.918	651	24	Netherlands	1
<i>Expert Systems with Applications</i>	14	0.957	162	8	United States	3
<i>IIE Transactions</i>	30	0.637	86	12	United States	2
<i>INFOR</i>	59	0.095	10	4	Canada	2
<i>Informis Journal on Computing</i>	18	0.865	40	4	United States	2
<i>International Journal of Computer Integrated Manufacturing</i>	50	0.383	69	6	England	3
<i>International Journal of Flexible Manufacturing Systems</i>	46	0.448	3	4	United States	2
<i>International Journal of Information Technology & Decision Making</i>	19	0.818	46	4	Singapore	4
<i>International Journal of Production Economics</i>	10	1.183	217	18	Netherlands	3
<i>International Journal of Production Research</i>	22	0.799	270	18	England	3
<i>International Journal of Systems Science</i>	53	0.343	98	12	England	3
<i>International Journal of Technology Management</i>	57	0.233	84	8	Switzerland	2
<i>Interfaces</i>	54	0.338	44	6	United States	1
<i>Journal of Global Optimization</i>	37	0.568	100	8	Netherlands	2
<i>Journal of Industrial and Management Optimization</i>	42	0.488	21	4	United States	3
<i>Journal of Manufacturing Systems</i>	58	0.15		6	United States	3
<i>Journal of Operations Management</i>	2	2.042	49	6	Netherlands	1
<i>Journal of the Operational Research Society</i>	33	0.597	139	12	England	1
<i>Journal of the Operations Research Society of Japan</i>	55	0.292	17	4	Japan	1
<i>Journal of Optimization Theory and Applications</i>	31	0.633	123	12	United States	2
<i>Journal of Quality Technology</i>	6	1.411	23	4	United States	3
<i>Journal of Scheduling Management Science</i>	20	0.811	29	6	Netherlands	2
	4	1.687	141	12	United States	1
<i>Mathematical Methods of Operations Research</i>	49	0.388	65	6	Germany	2

Appendix. (Continued)

Journal Title	Rank by IF	Impact Factor	Articles	Issues/ Year	Country/ Territory	Subject categories
<i>Mathematics of Operations Research</i>	23	0.785	36	4	United States	2
<i>Mathematical Programming</i>	12	1.117	91	12	Germany	3
<i>Military Operations Research</i>	60	0.08	15	4	United States	1
<i>Naval Research Logistics</i>	52	0.362	59	8	United States	1
<i>Networks & Spatial Economics</i>	43	0.486	19	4	Netherlands	2
<i>Networks</i>	44	0.485	45	7	United States	2
<i>Omega-International Journal of Management Science</i>	28	0.663	52	6	England	1
<i>Operations Research</i>	8	1.234	82	6	United States	1
<i>Operations Research Letters</i>	24	0.767	94	10	Netherlands	1
<i>Optimal Control Applications & Methods</i>	32	0.6	18	6	England	3
<i>Optimization and Engineering</i>	25	0.73	25	4	United States	3
<i>Optimization Methods & Software</i>	38	0.563	56	4	England	3
<i>Optimization</i>	41	0.5	39	6	England	2
<i>OR Spectrum</i>	9	1.224	32	4	Germany	1
<i>Probability in the Engineering and Informational Sciences</i>	45	0.462	39	4	United States	3
<i>Production and Operations Management</i>	1	2.516	39	4	United States	2
<i>Production Planning & Control</i>	48	0.438	65	8	England	3
<i>Quality and Reliability Engineering International</i>	40	0.508	68	6	England	2
<i>Queueing Systems</i>	27	0.689	56	12	Netherlands	2
<i>RAIRO-Operations Research</i>	56	0.286	16	4	France	1
<i>Reliability Engineering & System Safety</i>	15	0.92	147	12	England	2
<i>Safety Science</i>	26	0.725	57	9	Netherlands	2
<i>Systems & Control Letters</i>	5	1.683	125	15	Netherlands	2
<i>Technovation</i>	35	0.582	123	12	Netherlands	2
<i>Transportation Research Part B-Methodological</i>	3	1.761	52	10	England	3
<i>Transportation Research Part E-Logistics and Transportation Review</i>	29	0.643	27	6	England	3
<i>Transportation Science</i>	7	1.27	38	4	United States	2

References

- Adams, J, R Bajcsy, J Kosecka, V Kumar, M Mintz and R Mandelbaum (1996). Cooperative material handling by human and robotic agents: Module development and system synthesis. *Expert Systems with Applications*, 11(2), 89–97.
- Chan, WL (1975a). Saddle-point characterization of a class of optimal signal detectors. *International Journal of Systems Science*, 6(12), 1179–1184.
- Chan, WL (1975b). Stackelberg strategy for linear quadratic partial-differential games. *International Journal of Systems Science*, 6(5), 433–441.
- Chandrasekharan, MP and R Rajagopalan (1986). An ideal seed non-hierarchical clustering-algorithm for cellular manufacturing. *International Journal of Production Research*, 24(2), 451–464.
- Chandrasekharan, MP and R Rajagopalan (1987). Zodiac: An algorithm for concurrent formation of part-families and machine-cells. *International Journal of Production Research*, 25(6), 835–850.
- Chen, CF and CH Hsiao (1975). State-space approach to Walsh series solution of linear-systems. *International Journal of Systems Science*, 6(9), 833–858.
- Chen, F, Z Drezner, JK Ryan and D Simchi-Levi (2000). Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information. *Management Science*, 46(3), 436–443.
- Chen, SP and TS Wei (2002). The practice of operational research in Taiwan. *Journal of the Operational Research Society*, 53(12), 1330–1337.
- Erlenkotter, D and AS Manne (1968). Capacity expansion for Indias nitrogenous fertilizer industry. *Management Science*, 14(10), B553–B572.
- Fukushima, M (1992). Equivalent differentiable optimization problems and descent methods for asymmetric variational inequality problems. *Mathematical Programming*, 53(1), 99–110.
- Furuta, K (1990). Sliding mode control of a discrete system. *Systems & Control Letters*, 14(2), 145–152.
- Garfield, E (1994). The Thomson Scientific impact factor. *Current Contents*, Retrieved November 15, 2007, from <http://scientific.thomson.com/free/essays/journalcitationreports/impactfactor/>
- Hirsch, JE (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46), 16569–16572.
- Keerthi, SS and EG Gilbert (1988). Optimal infinite-horizon feedback laws for a general-class of constrained discrete-time-systems — stability and moving-horizon approximations. *Journal of Optimization Theory and Applications*, 57(2), 265–293.
- Kirby, MW (2003). *Operational Research in War and Peace: The British Experience from the 1930s to 1970*. London: Imperial College Press.
- Kojima, M, S Mizuno and A Yoshise (1989). A polynomial-time algorithm for a class of linear complementarity-problems. *Mathematical Programming*, 44(1), 1–26.
- Kuby, M, QG Shi, T Watanatada, XF Sun, ZJ Xie and W Cao (1995). Planning China coal and electricity delivery system. *Interfaces*, 25(1), 41–68.
- Langham, MR (1976). *Adaptive Economic-Models*. Day, RH and T Groves. *Interfaces*, 7(1), 115–119.
- Lee, SD (1978). Study of differences and characteristics between nations, in measured values of human-body and working area. *International Journal of Production Research*, 16(4), 335–347.
- Lenhard, MS, TRC Johnson, I Himsl, N Ditsch, S Rueckert and K Friese (2006). Obstetrical and gynecological writing and publishing in Europe. *European Journal of Obstetrics Gynecology and Reproductive Biology*, 129(2), 119–123.

- Miyasawa, K (1968). Information structures in Stochastic programming problems. *Management Science*, 14(5), 275–291.
- Pardoux, E and SG Peng (1990). Adapted solution of a backward stochastic differential-equation. *Systems & Control Letters*, 14(1), 55–61.
- Pearn, WL, S Kotz and NL Johnson (1992). Distributional and inferential properties of process capability indexes. *Journal of Quality Technology*, 24(4), 216–231.
- Ranyard, JC (1995). Supporting real decisions: A review of OR practice in the UK. *European Journal of Operational Research*, 87(3), 474–482.
- Senju, S and Y Toyoda (1968). Approach to linear programming with 0-1 variables. *Management Science*, 15(4), B196–B207.
- Shih, YP and CK Chu (1975). Optimal feedback-control of a class of linear distributed systems. *Journal of Optimization Theory and Applications*, 16(3–4), 327–338.
- Sugimori, Y, K Kusunoki, F Cho and S Uchikawa (1977). Toyota production system and Kanban system materialization of just-in-time and respect-for-human system. *International Journal of Production Research*, 15(6), 553–564.
- Tam, KY and MY Kiang (1992). Managerial applications of neural networks — The case of bank failure predictions. *Management Science*, 38(7), 926–947.
- Wu, WT and YP Shih (1975). Approximation of irrational transfer-function $\exp(-\text{square-root } s)$ by Ritz method. *International Journal of Systems Science*, 6(2), 175–180.
- Zheng, YP (1981). Some basic algebraic relations in the order-reduction of large-scale systems by aggregation. *Optimal Control Applications & Methods*, 2(1), 75–79.

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