

**PUBLICATION PRODUCTIVITY OF MALAYSIAN
RESEARCHERS IN THE FIELD OF COMPUTER SCIENCE AND
INFORMATION TECHNOLOGY**

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ABSTRACT

Searches made in the CD-ROM databases, COMPENDEX (1987-1999), IEL (IEE/IEEE Electronic Library) (1988-1999) and INSPEC (1990-1998) revealed a total of 389 publications contributed by Malaysian researchers in the field of computer science and information technology. The trend in output indicates rapid growth that is expected to continue in future. A total of 458 unique Malaysian authors contributed to the 389 publications. Collaboration between two authors was the dominant authorship pattern. Single-authored or more than 3-authored works were rare. The active authors were affiliated to a few institutions, with the Universiti Teknologi Malaysia, Universiti Sains Malaysia and Universiti Malaya accounting for the highest number of publications, either in the form of journal articles or papers in conference proceedings. The most active research areas include simulation system, control engineering, computer-assisted instruction, programming techniques, expert systems, asynchronous transfer mode, image processing, software engineering and digital signal processing and applications.

Keywords: Publication productivity; Research output; Malaysia; Computer science; Information technology; Authorship pattern; Collaboration; Bibliometrics.

INTRODUCTION

Bibliometric measures have been widely used to measure the performance of the scientific community (Katz and Hicks, 1997). Measurements of productivity, size, recognition, impact and collaboration are derived from the most common product of research activity – the research paper. Size is measured by counting refereed scientific publications. Impact and recognition are measured by using citations to these papers. Collaboration is measured using information derived from institutional addresses listed on co-authored publications. Invariably, national and international scientific activities comprise: (a) size, consisting the number of

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published papers; (b) recognition, measured by citation of papers; (c) impact, measured by citations per paper; (d) collaboration, measured by the number of co-authored papers (Katz, 2000). The general belief is that the number of papers published by a group, institution or nation is a partial indicator of its size and productivity. Thus, to assess the productivity in a particular discipline, entails ascertaining the published output or publications produced in that discipline, which provides an indication of the research activity in that discipline. Publication data were obtained from lists of publication in the annual research reports of most universities, as well as those found in established indexes, bibliographies or databases.

Malaysia's output in science and technology (S & T) is ranked among the top 50 leading countries in the world. From 1984-1989, Malaysia ranked number 44 out of 48 leading countries with 0.05% share of the world's S & T publication output (*Second European Report..*, 1997, Table 2c.1). Malaysia's publication output increased to 0.07% for the years 1990-1995, and was ranked number 46 out of 50 leading countries. Malaysia's publication output achieved an average annual growth rate of 4% for 1980-1985, 5% for 1986-1989 and 7% for 1990-1995. Singapore was ahead of the other Asean countries, registering an average annual growth rate of 16% of the world publication output. Such studies, usually take into account only those publications that can be identified easily from international databases, and therefore, do not consider domestic contributions.

The total production of scientific publications by scientists and technologists in Malaysia has not been systematically recorded and collated. Each research or academic institution records the publications of its own resident scientists in one way or another. On the whole, it is difficult to get hold of such publications. Often the listings published, suffer a two-year publication lag, making it difficult to collect current research output information. As a result, the present study relied on publications listed in established international CD-ROM databases, focusing on those databases which indexed works published in the fields of computer science and information technology.

This paper is an extension of a previous paper (Gu and Zainab, 2000), which described the channels that Malaysian authors in computer science and information technology used to communicate their research findings. This paper will focus on the following:

- (a) The total number and spread of Malaysian publications in the fields of computer science and information technology found from selected international databases;

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- (b) The active Malaysian contributors;
- (c) The affiliation of the Malaysian authors; and
- (d) The subject areas researched upon.

The data for this study was taken from three CD-ROM databases, which cover a substantial proportion of refereed and established periodicals and conferences in the fields of computer science and information technology. The three databases include COMPENDEX (1987-1999), IEL (IEE/IEEE Electronic Library) (1988-1999) and INSPEC (1990-1998). All bibliographic records by Malaysian authors were collected and entered into a database. Data on the affiliation of the authors were obtained from the affiliation field in INSPEC and corporate source in COMPENDEX. Duplicate records found in any two of the three databases were identified and removed. In view of the variety in the citation style of authors' names, each author's name was checked, identified and unified manually. Non-Malaysian co-authors were ignored when analyzing the authorship pattern of published works. To identify the subject categorisation of published works, the classification scheme, *Malaysian Research and Development Classification System* (MRDCS) (1998), published by the Malaysian Science and Technology Information Centre (MASTIC), was used. To analyse present and future trends of publication output, the regression analysis was used. By using regression analysis, a trendline is extended in a chart forward or backwards beyond the actual data to show a trend, and a moving average is created to smooth out fluctuations in data pattern. The linear equation $y=mx + b$, where m is the slope and b is the intercept, calculates the least square fit for a trendline. A moving average is a sequence of averages computed from parts of a data series. The number of points in a moving average trendline equals the total number of points in the series minus the number specified for the period.

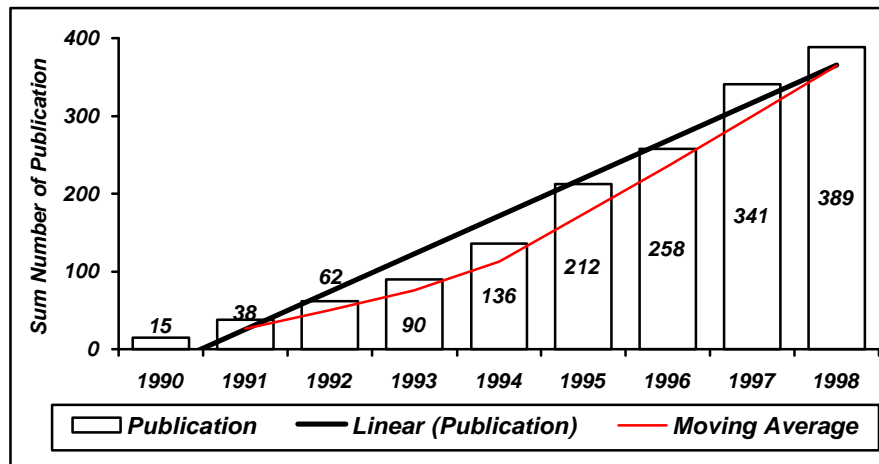
THE TOTAL AND SPREAD OF PUBLISHED WORKS

A total of 389 published Malaysian works were listed in the three CD-ROM databases between 1990 and 1998. Of these, 229 (58.9%) were conference papers, 159 (40.9%) were journal articles and 1 (0.2%) was a monograph chapter. Malaysian research publication productivity in computer science and information technology indicated two stages of development: an exploration period from 1990 and 1994 with 136 (35.0%) publications, followed by a period of rapid growth between 1995 and 1998 with 253 (65.0%) publications. The yearly average publication productivity was 43.2 during the 9-year period. The cumulative annual production is shown in Figure 1. The moving average line (period: 2) reveals two rough sections of linear curve with different slopes, 1991-1994 and 1994-1998.

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The second section displays a higher degree of oblique angle that indicates the rapid growth of publication during this period of time. The trendline ($y = 48.65x - 72.028$, $R^2 = 0.9637$) reveals a gently upward trend and further predicts that this trend would continue.

Figure 1: Chronological Cumulative Publication Productivity, 1990-1998



THE ACTIVE MALAYSIAN AUTHORS

A total of 458 unique Malaysian authors contributed to the 389 publications in computer science and information technology during the period from 1990 to 1998. Each author shared an average of 0.85 publications. Table 1 presents the publication productivity by unique author.

Table 1: Publication Productivity of Individual Author

Number of Authors (n=458)		Number of Publications (n=3389)		Cumulative Number of Authors	
2	0.4%	11	2.8%	2	0.4%
1	0.2%	10	2.6%	3	0.7%
1	0.2%	9	2.3%	4	0.9%
2	0.4%	8	2.0%	6	1.3%
3	0.7%	7	1.8%	9	2.0%
3	0.7%	6	1.5%	12	2.6%
10	2.2%	5	1.3%	22	4.8%
17	3.7%	4	1.0%	39	8.5%
29	6.3%	3	0.8%	68	14.8%
68	14.8%	2	0.5%	136	29.7%
322	70.3%	1	0.3%	458	100.0%

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More than one fourth (136 or 29.7%) of the 458 authors contributed two or more papers/articles, while an overwhelming number of researchers (322 or 70.3%) wrote only one paper. This indicates that the majority of Malaysian authors of research publication in the fields of computer science and information technology between the years 1990 and 1998, were one time authors.

Table 2 reveals the rank of authors' names in descending order of author groupings based on their productivity. Among the 458 Malaysian authors, Mashkuri Yaacob and Borhanuddin Mohd Ali, ranked equally as the top most productive authors. Each of them authored or co-authored 11 publications, in the nineties. Mazlan Abbas (ranked second) contributed 10 publications. S.M. Rezaul Hasan is ranked third with 9 publications. On an average, each of the four most active authors published one or more works per annum. Other authors who contributed between 5 and 8 publications each were Ishak Ismail and Shamsudin M. H. Amin (8), Abdullah Asuhaimi Mohd Zin, Sohail Ahmed, K. I Lo and Marzuki Khalid (7), Khalid Mohamed Nor, P. Raveendran and Rubiyah Yusof (6), H.T. Chuah, Hashim Shaibon, Hassan Basri, Ibrahim Khalil, M. H. Selamat, Mahmud Hasan, M.R. Mukerjee, Mohd. Ruddin Abd. Ghani and Ng Kang Siong (5). The number of authors who contributed one to three publications were 333, 68, 29, 17 and 10, respectively.

An analysis was made of the author's naming position pattern. Author placement practice varies widely, depending on the policies and tradition of the organization in which the research is undertaken. Subramanyam (1983) observed that it is not uncommon to find ten or more names for papers, which are based on extensive laboratory tests or field work. "The question of ordering the names of coauthors is highly complex and elusive, while it is generally true that the name of the principal investigator is almost always mentioned first.."(p.36). Zuckerman (1968) observed that names of coauthors were sometimes arranged alphabetically, except for the principal investigator's name, which was placed at the beginning or at the end. In this study, it is assumed that the position of the author's name is reflective of his role in the research publication, that is, the author named first is the main contributor to published works. Table 3 presents the position of author names (the numeral in front of brackets), as well as the number of times (the value between brackets) the author occupied a given position. P. Raveendran, Hassan Basri, N. A. Rahim and R. Nagarajan were respectively the first author of all their publications. The pattern is different for the most productive authors. Among his seven publications, Ahmed Sohail was the first author five times. Borhanuddin Mohd Ali was first author of only two and Mashkuri Yaacob led in four of their respective eleven publications.

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Table 2: Research Production by Individual Author

Group	Name	Number of Publication	Author Position Pattern
1	Cohort: 2		
	Mohd Ali, Borhanuddin Yaacob, Mashkuri	11 11	1(2) 2(7) 3(1) 4(1) 1(4) 2(4) 3(3)
2	Cohort: 1 Abbas, Mazlan	10	1(4) 2(3) 3(3)
3	Cohort: 1 Hasan, S. M. Rezaul	9	1(4) 2(5)
4	Cohort: 2		
	Amin, Shamsudin M. H. Ismail, Ishak	8 8	1(2) 2(4) 3(2) 1(1) 2(4) 3(3)
5	Cohort: 4		
	Ahmed, Sohail	7	1(5) 3(2)
	Khalid, Marzuki	7	1(2) 2(3) 3(2)
	Lo, K. L.	7	2(1) 4(5) 5(1)
Zin, Abdullah Asuhaimi Mohd	7	1(3) 2(2) 3(2)	
6	Cohort: 3		
	Mohamed-Nor, Khalid	6	1(2) 2(3) 3(1)
	Raveendran, P. Yusof, Rubiyah	6 6	1(6) 1(2) 3(4)
7	Cohort: 9		
	Abd. Ghani, Mohd. Ruddin	5	1(1) 2(3) 3(1)
	Basri, Hassan	5	1(5)
	Chuah, H.T.	5	1(2) 2(3)
	Hasan, Mahmud	5	2(4) 3(1)
	Khalil, Ibrahim	5	1(3) 2(1) 4(1)
	Mukerjee, Malay R.	5	1(1) 3(2) 4(2)
	Ng, Kang Siong	5	1(2) 2(3)
	Selamat, M. H.	5	1(4) 3(1)
Shaibon, Hashim	5	1(1) 2(2) 3(2)	
8	Cohort: 16		
	Abdullah, A. R.	4	1(1) 2(2) 5(1)
	Ahmad, Z. A.	4	2(4)
	Anuar, Zainol	4	1(3) 2(1)
	Darus, Zahari Mohamed	4	1(1) 2(3)
	Hashim, M. A.	4	2(4)
	Jegannathan, S.	4	1(2) 2(2)
	Kandiah, Sivasothy	4	1(3) 3(1)
	Lee, Hooi-Ling	4	1(1) 2(1) 3(1) 4(1)
	Moghavvemi, M.	4	1(3) 2(1)
	Mohamed, A.	4	1(3) 3(1)
	Mohamed, Mortaza	4	1(2) 2(2)
	Nagarajan, R.	4	1(4)
	Othman, Masuri	4	1(3) 2(1)
	Rahim, M. M.	4	2(2) 3(1) 4(1)
	Rahim, N. A.	4	1(4)
Sha'ameri, Ahmad Zuri	4	1(1) 2(3)	
9	Cohort: 34	3	
10	Cohort: 62	2	
11	Cohort: 333	1	

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Figure 2 illustrates the authorship pattern of the 389 publications. Most conference papers were multi-authored, with one paper published in 1995 qualifying as a mega-authored work (Sen, 1997), that is, authored by 10 co-authors.

Table 3 shows the chronological status of authorship patterns for the 9-year period studied. There was no significant difference among the mean of author per publication. The results indicate that the collaboration between two scientists was the dominant authorship pattern for research publications in the fields of computer science and information technology published between 1990-1998. Three-authored works was the second most frequent pattern. Papers with single author and those with more than three authors were not common.

Figure 2: Authorship Patterns

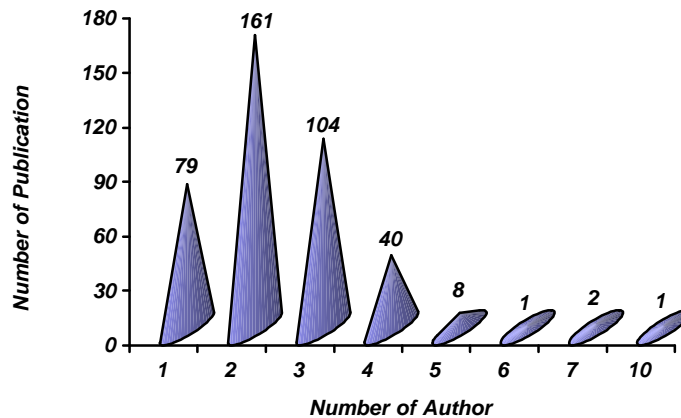


Table 3: Chronological Status of Authorship Patterns

Year	Number of Publication by Number of Author									Sum of Author	Mean of Author Per Publication
	1	2	3	4	5	6	7	10	Sum		
1990	4	8	2	1	-	-	-	-	15	30	2.0
1991	5	11	7	-	-	-	-	-	23	48	2.1
1992	5	9	7	2	-	1	-	-	24	58	2.4
1993	9	6	7	6	-	-	-	-	28	66	2.4
1994	6	21	12	5	1	-	1	-	46	116	2.5
1995	18	30	21	4	2	-	-	1	76	177	2.3
1996	11	22	9	4	-	-	-	-	46	98	2.1
1997	14	34	25	6	4	-	-	-	83	201	2.4
1998	5	21	10	10	1	-	1	-	48	129	2.7

The study of authorship pattern in a discipline helps to identify key researchers in the subject field, and indicates the collaborative activity among researchers involved in research. Sen and Gan (1990) proposed that the status of science and technology of a country, organization or subject field, is best understood through the study of personalities engaged in research and development. Analysing biodata elements reveal the research activity of scientists. Hence, the study of authorship relates to collaborative research activities, which is reflected by an increase in multi-authored papers and a decrease in single-authored publications.

THE AFFILIATION STATUS OF THE MALAYSIAN AUTHORS

The information about affiliation status was based on the institutional address of the first named author of the 389 publications. The first unique authors of the 389 publications were affiliated to 52 corporations in Malaysia, which covered three major sectors, namely, government agencies and research institutes (GRI), institutions of higher learning (IHL) and the private sector. There were authors affiliated to 15 GRI, 14 IHL, and 24 private sectors. Geographically, the 52 corporations are located in Kuala Lumpur (28) and eight other states; Selangor (8), Penang (6), Sarawak (3), Malacca and Perak (2) each, and Johor, Kedah and Kelantan (1), respectively. In order to facilitate statistical analysis, the two campuses of Universiti Teknologi Malaysia, one located in Kuala Lumpur and the other in Johor, were considered as one entity. Similarly, the three campuses of Universiti Sains Malaysia located in Penang, Perak and Kelantan was treated as one entity. In view of this, the total number of corporations is 49. Table 4 presents the publication productivity according to the authors' affiliation.

Table 4: Publication Productivity by Authors' Affiliation

Number of Institutions (n=50)		Number of Publications (n=396)		Cumulative Number of Institutions		Cumulative Number of Publications	
1	2%	79	19.9%	1	2%	79	19.9%
2	4%	71	17.9%	3	6%	221	55.8%
1	2%	43	10.9%	4	8%	264	66.7%
1	2%	37	9.3%	5	10%	301	76.0%
1	2%	18	4.5%	6	12%	319	80.6%
1	2%	9	2.3%	7	14%	328	82.8%
1	2%	7	1.8%	8	16%	335	84.6%
2	4%	6	1.5%	10	20%	347	87.6%
1	2%	3	0.8%	11	22%	350	88.4%
7	14%	2	0.5%	18	36%	364	91.9%
32	64%	1	0.3%	50	100%	396	100%

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Each institution contributes an average of 7.92 publications. A total of 18 institutions contributed 364 (91.9%) publications, while the remaining 32 institutions provided 32 (8.1%) publications. The results indicate that Malaysian research publications in the field of computer science and information technology come mainly from a few dominant institutions. Table 5 reveals the group ranking of institutions based on their publication productivity.

Table 5: Malaysian Research Production by Institutions

Group	Name	Number of Publication	Sum of Publication
1	Cohort: 1 Universiti Teknologi Malaysia	80	80
2	Cohort: 1 Universiti Sains Malaysia	73	153
3	Cohort: 1 Universiti Malaya	69	222
4	Cohort: 1 Universiti Putra Malaysia	38	260
5	Cohort: 1 Universiti Kebangsaan Malaysia	36	296
6	Cohort: 1 Institut Teknologi MARA	17	313
7	Cohort: 1 Intel Technology Sdn Bhd	9	322
8	Cohort: 1 Universiti Malaysia Sarawak	7	329
9	Cohort: 2 Esso Production Malaysia Inc Universiti Islam Antarabangsa Malaysia	6	341
10	Cohort: 1 Palm Oil Research Institute of Malaysia	3	344
11	Cohort: 7 Universiti Utara Malaysia Petronas Research & Scientific Services Sdn Bhd Malaysian Institute of Microelectronics System Malaysian Institute for Nuclear Technology Research Kuala Lumpur City Centre Andersen Consulting Advanced Micro Devices Export Sdn Bhd	2	358
12	Cohort: 31	1	389

The most productive institution is Universiti Teknologi Malaysia (UTM). It contributed about one fifth (80 papers or 19.9%) of the total number of publications from 1990 to 1998, with an average of 8.9 per annum. Universiti

Sains Malaysia (USM) ranks second with 73 (18.8%) publications, followed by Universiti Malaya (UM) with 69 (17.7%). The three universities produced more than half (57.1%) of the total number of publications. The research outputs of Universiti Putra Malaysia (UPM), Universiti Kebangsaan Malaysia (UKM) and Institut Teknologi MARA (ITM) were 38 (9.8%), 36 (9.3%) and 17 (4.4%), respectively. The six IHL mentioned above, contributed over 80.5% of publications. Other IHL were also among the top ten in producing the highest proportion of research publications. Universiti Malaysia Sarawak (UNIMAS) and Universiti Islam Antarabangsa Malaysia (UIAM) produced 7 (1.8%) and 6 publications, respectively. Among the 15 GRI, the majority contributed one publication, except for the Palm Oil Research Institute of Malaysia (PORIM) with 3 (0.8%), Malaysian Institute of Microelectronics System (MIMOS) and Malaysian Institute for Nuclear Technology Research (MINT) with 2 (0.5%) publications, respectively. In the private sector, Intel Technology Sdn Bhd (9 or 2.3%) and Esso Production Malaysia Inc (6 or 1.5%), ranked among the top ten most productive corporations. The results seem to indicate that Universiti Teknologi Malaysia, Universiti Malaya and Universiti Sains Malaysia played a decisive role in Malaysian computer science and information technology research. Table 6 shows the chronological distribution of production of the three universities from 1990 to 1998.

Table 6: Chronological Distribution of Publications of the Three Most Productive Institutions

Year	Number of Publication						Total
	Universiti Teknologi Malaysia		Universiti Malaya		Universiti Sains Malaysia		
1990	3	33.3%	6	66.7%	-	-	9
1991	10	66.7%	5	33.3%	-	-	15
1992	6	54.5%	3	27.3%	2	18.2%	11
1993	6	33.3%	6	33.4%	6	33.3%	18
1994	14	46.7%	7	23.3%	9	30.0%	30
1995	12	28.6%	15	35.7%	15	35.7%	42
1996	6	23.1%	4	15.4%	16	61.5%	26
1997	16	36.1%	11	25.0%	17	38.6%	44
1998	7	25.9%	12	44.5%	8	29.6%	27
Total	80	35.8%	69	32.1%	73	32.1%	222

Figure 3a illustrates the production of Universiti Teknologi Malaysia during 1990 to 1998. The moving average line (period: 2) illustrates an irregular trend

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throughout the whole decade. The trendline ($y = 0.6667x + 5.5556$, $R^2 = 0.1767$) indicates a roughly horizontal line. This indicates that the publication production from Universiti Teknologi Malaysia is plateauing. Universiti Sains Malaysia had no publication in 1990 and 1991. It picked up from 1992, and peaked to 17 in 1997. The trendline ($y = 2x - 1.8889$, $R^2 = 0.6614$) reveals that its publication contributions would continue to increase (Figure 3b). Publication from Universiti Malaya during 1990 to 1998, indicates irregularity. A trendline indicating a moderately upward tendency ($y = 0.8833x + 3.25$, $R^2 = 0.3547$) is demonstrated (Figure 3c).

Figure 3a: Publication Productivity of Universiti Teknologi Malaysia (1990-1998)

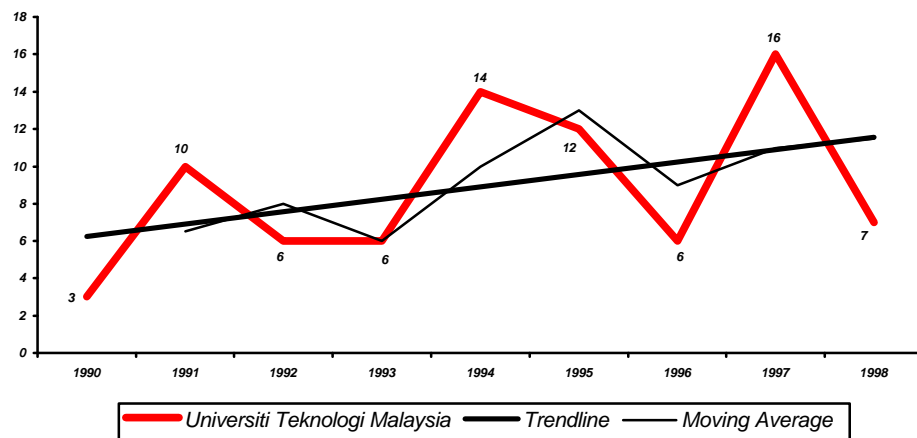


Figure 3b: Publication Productivity of Universiti Sains Malaysia (1990-1998)

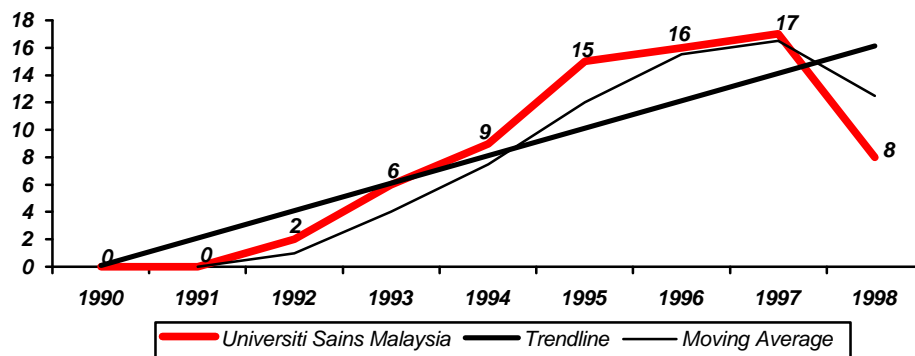
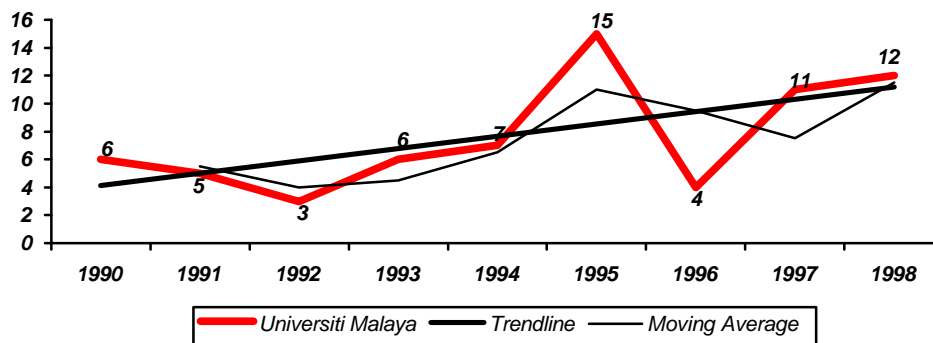


Figure 3c: Publication Productivity of Universiti Malaya (1990-1998)



THE SUBJECT AREAS OF RESEARCH

The 389 publications used in the study covered 39 fields of research. The fields of research follow those specified by *The Malaysian Research and Development Classification System (MRDCS)* (1998). The top subject areas that contributed 10 or more publications are software: simulation system (85), manufacturing and process technologies and engineering: control engineering (47), information systems: other information systems (45), educational technology: computer assisted instruction (CAI) (28), software: programming techniques (18), information systems: expert systems (14), communication: asynchronous transfer mode (ATM) (14), information systems: image processing (13), software: software engineering (11) and current information technology: digital signal processing and applications (11) (Table 7).

A list of publication productivity by institutions in a descending order of their research production in each subject area is given as an appendix. The findings indicate Universiti Teknologi Malaysia had achieved the highest number of publication in four subject areas; Manufacturing and process technologies and engineering: Control engineering, Educational technology: Computer Assisted Instruction (CAI), Current information technology: Digital signal processing and applications as well as Communication: Digital systems. Universiti Sains Malaysia (USM) is ahead in three fields, that is, Software: Programming techniques, Security system: Neutral network and Information systems: Computer graphics. USM also shared equal quantity of publications with Universiti Putra Malaysia in

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the field of Information systems: Parallel processing. Universiti Malaya (UM) played the leading role in subject fields of Software: Simulation system, Information systems: Image processing, Software: Software engineering, Software: Computer aided system, Information systems: Compression techniques and Communication: Antenna technology. UM also jointly dominated in the research publication output in Information systems: Artificial intelligence (AI) and Manufacturing and process technologies and engineering: CAD/CAM systems. Universiti Kebangsaan Malaysia and Universiti Putra Malaysia displayed successes in Information systems: Expert system, Current information technology: Knowledge base and Communication: Asynchronous Transfer Mode (ATM) respectively.

In general, Malaysian individual authors in the fields of computer science and information technology have varied areas of research interest. Few scientists dedicate themselves to a single subject area. This situation, as well as the widespread distribution of authors over subject areas, makes the attempt to ascertain the key authors in some subject areas, difficult.

Table 7: Malaysian Research Publications in Computer Science by Subjects

Group	Subjects	Number of Paper	Sum of Paper
1	Cohort: 1 F10503 Software: Simulation system	85	85
3	Cohort: 1 F10602 Manufacturing and process technologies and engineering: Control engineering	47	132
2	Cohort: 1 F10501 Information systems: Other information systems	45	177
4	Cohort: 1 F10604 Educational technology: Computer Assisted Instruction (CAI)	28	205
5	Cohort: 1 F10503 Software: Programming techniques	18	223
6	Cohort: 2 F10501 Information systems: Expert system F10505 Communication: Asynchronous Transfer Mode (ATM)	14	251
7	Cohort: 1 F10501 Information systems: Image processing	13	264
8	Cohort: 2 F10503 Software: Software engineering F10504 Current information technology: Digital signal processing & applications	11	286
9	Cohort: 1 F10503 Software: Computer aided system	9	295
10	Cohort: 1 F10506 Security system: Neutral network	8	303

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11	Cohort: 3 F10501 Information systems: Artificial intelligence (AI) F10505 Communication: Digital systems F10602 Manufacturing and process technologies and engineering: CAD/CAM systems	7	324
12	Cohort: 1 F10501 Information systems: Parallel processing	6	330
13	Cohort: 2 F10501 Information systems: Computer graphics F10503 Software: Computer languages	5	340
14	Cohort: 3 F10501 Information systems: Computer aided design (CAD) F10501 Information systems: Information systems management F10504 Current information technology: knowledge base	4	352
15	Cohort: 7 F10501 Information systems: Object oriented technology F10501 Information systems: Computer aided manufacturing F10502 Hardware: Integrated circuits F10502 Hardware: Processor design F10504 Current information technology: Man-machine interfacing F106023 Manufacturing and process technologies and engineering: Robotics & mechatronics F10604 Educational technology: Computer base training	3	373
16	Cohort: 5 F10501 Information systems: Interface design F10501 Information systems: Multimedia F10501 Information systems: Geographic information system (GIS) F10503 Software: Geographic information systems (GIS) F10505 Communication: Optical systems	2	383
17	Cohort: 6 F10501 Information systems: Compression techniques F10505 Communication: Audio/voice communication F10505 Communication: Antenna technology F10505 Communication: Software development F10506 Security system: Smart system F10602 Manufacturing and process technologies and engineering: Manufacturing technologies.	1	389

There were four authors who actively contributed publications in the field of Communication: Asynchronous Transfer Mode (ATM) (F10505) and they were Borhanuddin Mohd Ali and Ahmed Sohail (contributed 7 publications each), Mazlan Abbas (6 publications) and R. Mukerjee (4 articles/papers). In all, 156 authors contributed 85 publications in the subject of Software: Simulation system (F10503). The most active were: K. L. Lo who produced 5 conference papers in this field, followed by M. A. Hashim with 4 journal papers and Abdul Halim Mohd Yatim with 4 conference papers. Among the 89 authors who contributed 47 publications in the field of Manufacturing and process technologies and engineering: Control engineering (F10602), the most active were Rubiyah Yusof and Shamsudin M. H. Amin who provided 5 publications each, and Marzuki

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Khalid and Zainol Anuar who authored 4 publications each. The results indicate that most Malaysian publication contributions in computer science and information technology cover a wide variety of subject areas. This might be a reflection of the 'youthful' state of research in these areas in the country.

CONCLUSION

The results of this study indicate that Malaysian research has progressed remarkably well in some fields of computer science and information technology. This is indicated by the substantial publication output in fields such as simulation systems, computer control engineering, computer-assisted instructions, expert systems, asynchronous transfer mode, and image processing. The institutions of higher learning played a leading role in these areas of research. Also, in computer science and information technology, the research is highly collaborative in nature. This is indicated by the rarity of single-authored works and the predominance of two- or three-authored publications. Of the 389 publications in this study, eighty percent were joint-authored and only one-fifth was single-authored. This results is higher than that found for zoology literature by Vimala and Reddy (1997) who observed that 75% of works were co-authored. Melin (1997) suggested that the sole researcher was no longer the relevant producer of ideas and discoveries, and it was the team or an individual operating within a network that predominated. Bordon, Gomez, Fernandez, Zulueta and Mendez (1996) found a positive correlation between productivity and collaboration (international as well as domestic) at the author level. The increase in multi-authored works is not only an indication of active collaborative environment but also an indication of growing professionalism in the field of computer science and information technology. A number of studies have found a correlation between the nature and magnitude of collaboration and research productivity (Subramanyam, 1983). Pao (1980) found that highly collaborative authors were very productive. Narvaez-Berthelemot (1995) used an index developed to measure international collaboration and showed a positive increase in productivity of research for countries that indicated a high index in international collaboration.

The collaborative environment has nurtured an increasing number of productive academic research leaders. This is indicated by the predominance of productive authors from academic institutions of higher learning. The results also indicate that a small number of authors contributed to most of the published works. This is similar with the findings of most publication productivity studies that assert that half of all scientific papers in a field are contributed by a few highly productive authors, numbering approximately the square root of the total scientific authors in

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that discipline (Coile, 1977; Hargrove, 1980). Zhu, Meadows and Mason (1991) observed that productivity studies usually indicated skewed results and research excellence depended primarily on the publication activities of a limited number of researchers. Finally, the analysis of author's name position in co-authored works indicates very few productive authors' names lead in their joint publications. Further studies need to consider the changing roles of the research leaders from being directly involved in research to a supervisory position and whether this situation is productive in stimulating a dynamic research environment. The supervisory role may increase the opportunity for publications especially in the form of co-authored works and reflected in the changed position of the author's name in published works. The authorship pattern of the Malaysian authors indicate that more than 82% were one time publishers (322 out of 389), indicating a high "renewal rate" (the rate of new to leaving authors). The results indicate that the number of new authors entering into the pool of total publication within the period under study, is high. In a study of authors who published from 1981–1985, obtained from the Corporate Index files of the Institute for Scientific Information databases, Schubert and Glanzel (1991) grouped Malaysian scientific publications as those with an average renewal rate. In the present study, this is not indicated for authors publishing in the field of computer science and information technology as over 70% were one-time publishers.

It must be pointed out, however, that the results is only true for data collected from three CD-ROM-based databases and may reflect the "view from afar" as postulated by Schrum (1997), and does not accurately reflect the total productivity (international and domestic) of the total number of Malaysian researchers in the fields under study. Further study needs to incorporate both foreign and domestic data to verify the findings obtained.

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APPENDIX

(a) Research Publication by Subjects and Affiliations

F10501 Information systems: Artificial intelligence (AI) (7)Universiti Malaya (3)Universiti Teknologi Malaysia (3)Institut Teknologi MARA (1)

F10501 Information systems: Computer Aided Design (CAD) (4)Universiti Kebangsaan Malaysia (2)Universiti Sains Malaysia (2)

F10501 Information systems: Computer Aided Manufacturing (CAM) (3)Universiti Teknologi Malaysia (2)Universiti Sains Malaysia (1)

F10501 Information systems: Computer graphics (5)Universiti Sains Malaysia (3)Acad. Service Unit (1)Universiti Teknologi Malaysia (1)

F10501 Information systems: Expert system (15)Universiti Kebangsaan Malaysia (4)Universiti Teknologi Malaysia (3)Universiti Malaya (3)Universiti Putra Malaysia (2)Universiti Sains Malaysia (1)Institut Teknologi MARA (1)Intel Technology Sdn Bhd (1)

F10501 Information systems: Geographic Information System (GIS) (3)Malaysian Centre for Remote Sensing (1)Public Works Department Malaysia (1)Universiti Kebangsaan Malaysia (1)

F10501 Information systems: Image processing (11)Universiti Malaya (4)Universiti Teknologi Malaysia (2)Universiti Sains Malaysia (1)Universiti Putra Malaysia (1)TIME Automation & Management Services Sdn Bhd (1)Standards and Industrial Research Institute of Malaysia (1)Institut Teknologi MARA (1)

F10501 Information systems: Information systems management (5)Universiti Malaysia Sarawak (2)Honeywell Engineering Sdn Bhd (1)Universiti Putra Malaysia (1)Universiti Teknologi Malaysia (1)

F10501 Information systems: Interface design (2)Universiti Malaya (1)Universiti Teknologi Malaysia (1)

F10501 Information systems: Multimedia (2)Universiti Teknologi Malaysia (1)Universiti Putra Malaysia (1)

F10501 Information systems: Object Oriented Technology (3)Universiti Teknologi Malaysia (2)Universiti Malaya (1)

F10501 Information systems: Other information systems (48)Universiti Sains Malaysia (12)Universiti Malaya (8)Universiti Kebangsaan Malaysia (5)Institut Teknologi MARA (5)Universiti Teknologi Malaysia (4)Universiti Putra Malaysia (3)Esso Production Malaysia Inc (3)Intel Technology Sdn Bhd (2)Andersen Consulting (2)Prime Minister's Department (1)Nuclear Energy Unit, Kompleks PUSPATI (1)KTA-Global Engineering (1)Division of Medical Development, Ministry of Health (1)

F10501 Information systems: Parallel processing (6)Universiti Sains Malaysia (3)Universiti Putra Malaysia (3)

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- F105012 Information systems: Compression techniques (1)Universiti Malaya (1)
- F10502 Hardware: Integrated circuits (3)Universiti Sains Malaysia (3)
- F10502 Hardware: Processor design (3)Universiti Kebangsaan Malaysia (2)Universiti Malaya (1)
- F10503 Software: Computer aided system (9)Universiti Malaya (3)Universiti Islam Antarabangsa Malaysia (2)Universiti Kebangsaan Malaysia (2)Universiti Putra Malaysia (1)Universiti Teknologi Malaysia (1)
- F10503 Software: Computer languages (5)Universiti Sains Malaysia (2)Malaysian Institute of Microelectronics System (1)Palm Oil Research Institute of Malaysia (1)Universiti Putra Malaysia (1)
- F10503 Software: Geographic Information System (GIS) (2)Universiti Sains Malaysia (1)Universiti Kebangsaan Malaysia (1)
- F10503 Software: Programming techniques (18)Universiti Sains Malaysia (6)Universiti Malaya (5)Universiti Putra Malaysia (3)Universiti Teknologi Malaysia (1)Universiti Malaysia Sarawak (1)Universiti Kebangsaan Malaysia (1)Intel Technology Sdn Bhd (1)
- F10503 Software: Simulation system (89)Universiti Malaya (21)Universiti Sains Malaysia (18)Universiti Teknologi Malaysia (14)Universiti Kebangsaan Malaysia (6)Institut Teknologi MARA (6)Universiti Putra Malaysia (4)Intel Technology Sdn Bhd (4)Esso Production Malaysia Inc (3)Petronas Research & Scientific Services Sdn Bhd (2)Advanced Micro Devices Export Sdn Bhd (2)Universiti Telekom (1)Universiti Malaysia Sarawak (1)Tenaga Nasional Berhad (1)Rubber Research Institute of Malaysia (1)NCR Malaysia Sdn Bhd (1)Malaysian Institute for Nuclear Technology Research (MINT) (1)Malaysian Armed Forces Acad. (1)Environment Asia (1)Bayan Lepas Free Trade Zone (1)
- F10503 Software: Software engineering (11)Universiti Malaya (4)Universiti Putra Malaysia (3)Universiti Malaya (1)Universiti Sains Malaysia (1)Universiti Kebangsaan Malaysia (1)Analyst Workbench Consulting Sdn Bhd (1)
- F10504 Current information technology: Digital signal processing & applications (11)Universiti Teknologi Malaysia (5)Universiti Sains Malaysia (2)Universiti Kebangsaan Malaysia (2)Universiti Malaya (1)Intel Technology Sdn Bhd (1)
- F10504 Current information technology: Knowledge base (5)Universiti Kebangsaan Malaysia (3)Universiti Putra Malaysia (1)Universiti Sains Malaysia (1)
- F10504 Current information technology: Man-machine interfacing (4)Universiti Islam Antarabangsa Malaysia (1)Universiti Putra Malaysia (1)Universiti Sains Malaysia (1)Universiti Teknologi Malaysia (1)
- F10505 Communication: Asynchronous Transfer Mode (ATM) (14)Universiti Putra Malaysia (10)Universiti Teknologi Malaysia (2)
- F10505 Communication: Audio/voice communication (1)Institut Teknologi MARA (1)
- F10505 Communication: Digital systems (7)Universiti Teknologi Malaysia (5)IT Partners (1)Universiti Putra Malaysia (1)
- F10505 Communication: Optical systems (2)Institut Teknologi MARA (1)Universiti Sains Malaysia (1)
- F105051 Communication: Antenna technology (1)Universiti Malaya (1)
- F105057 Communication: Software development (1)Universiti Teknologi Malaysia (1)
- F10506 Security system: Neutral network (8)Universiti Sains Malaysia (5)Institut Teknologi MARA (1)Sarawak Electricity Supply Corp (1)Universiti Teknologi Malaysia (1)
- F10506 Security system: Smart system (1)Kuala Lumpur City Centre (1)
- F10602 Manufacturing and process technologies and engineering:CAD/CAM systems (7)Universiti Malaya (2)Universiti Sains Malaysia (2)Universiti Teknologi Malaysia (2)Universiti Kebangsaan Malaysia (1)

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F10602 Manufacturing and process technologies and engineering:Control engineering (47)Universiti Teknologi Malaysia (19)Universiti Malaya (9)Universiti Putra Malaysia (3)Universiti Kebangsaan Malaysia (3)Universiti Sains Malaysia (2)Palm Oil Research Institute of Malaysia (2)Scott Wilson Asia-Pacific (1)Motorola (M) Sdn Bhd (1)Motorola (1)Institut Teknologi MARA (1)Malaysian Institute for Nuclear Technology Research (MINT) (1)Lea-Elliott Transportation Consultants Sdn. Bhd. (1)Kvaerner Petrominco Engineering Sdn Bhd (1)Kuala Lumpur Universiti Malayapur City Centre (1)KDU Penang (1)

F106022 Manufacturing and process technologies and engineering: Manufacturing technologies (1)National Semiconductor (1)

F106023 Manufacturing and process technologies and engineering:Robotics & mechatronics (3)Universiti Teknologi Malaysia (2)Universiti Putra Malaysia (1)

F10604 Educational technology: Computer Assisted Instruction (CAI) (25)Universiti Teknologi Malaysia (5)Universiti Sains Malaysia (3)Universiti Putra Malaysia (3)Universiti Malaysia Sarawak (3)Universiti Kebangsaan Malaysia (3)Universiti Malaya (2)Universiti Islam Antarabangsa Malaysia (2)Universiti Malaya (1)Rason Systems (M) Sdn Bhd (1)National Institute of Education Management, Ministry of Education (1)British Council (1)

F10604 Educational technology: Computer base training (3)Malaysian Institute of Microelectronics System (1)Universiti Malaya (1)Medical Development Division, Ministry of Health (1)Universiti Islam Antarabangsa Malaysia (1)Ascom Timeplex F.E. Ltd (1).

(b) List of Authors who Contributed One to Three Publications

Cohort: 29 Frequency: 3

Abidi, Syed Sibte Raza
Ahmad, A.
Baharin, Iskandar B.
Bidin, Abdul Rahman
Darus, Zahari Mohamed
Deris, Safaai
Embong, Abdullah
Hamdan, Abdul-Razak
Hamid, Abd.R.A.
Hassan, A.Y.

Hu, Shze-Jer
Keng-Soon Soo
Koh, Hock-Lye
Madria, Sanjay Kumar
Moghavvemi, M.
Mohamed, Faisal A.
Mohd. Zain, A.A.
Muda, Zaniah
Osman, Johari H.S.
Othman, A.T.

Razak, Jarmin Ab
Seetharamu, K.N.
Subramanian, R.K.
Thulkarmine, A.S.
Tou, T.Y.
Yaacob, Sazali
Yasir, A.Q.
Yeoh, Teong-San
Yusoff, Mohammed

Cohort: 68 Frequency: 2

Abdullah, Omar Charles
Abdullah, S.K.S.
Abdullah, W.N.W.
Ahmad, Supian
Ahmed, Iftekhhar
Al-Zaydi, Mohammed Yassir
Aldebrez, Fareg Mohamed
Arichandran, K.
Awang, Mohd. Nasry
Bakar, A.
Barker, R.D.
Barsoum, N.N.
Chew, Poh Sin
Chik, Amran Nong
Chin, O.H.
Chui, Goh Chui
Daud, Mohammed
Fadzil, Ahmad M.H.
Farid, Mohammed Mehdi
Ghosh, Sumit

Hamouda, A.M.S.
Harun, Z.B.
Hasan, Masitah
Hashim, A.W.I.M.
Hashim, Khairuddin
Hashim, M.A.
Hassan, S.I.S.
Hew, W.P.
Hussin, Syed
Kapilevich, Boris
Kung, F.W.L.
Kwek, K.H.
Lee, Peter Chikeung
Lee, S.P.
Leow Soo Kar
Lian, Seng Teo
Lim, Poh-Eng
Loke, M.H.
Mohamad, D.
Mohamad, S.B.

Mustafa, M.M.
Nawayseh, Naser Kh.
Ohta, Hiroshi
Omar, Abdul Aziz
Ong, B.H.
Othman, N.
Ow, Siew Hock
Rajeswari, Mandava
Rashid, Abdul Halim Abdul
Rukonuzzaman, Md.
Saibon, H.
Said, H.B.
Salam, Md-Sayeed
Samat, Pathiah Abd
San, Ho Yoon
Sembok, Tengku M.T.
Singh, G.
Siowck-Lee Gan
Sulaiman, M.
Sulaiman, Shaharum

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Sureswaran, R.	Yatim, Baharudin	Zamulin, A.V.
Wong, S.V.	Yeok-Hwa Ngeow	Zubairi, Junaid Ahmed
Yahaya, Nor Adnan	Yusof, N.B.M.	

Cohort: 322 Frequency: 1

Abas, ZW	Azlin, Md	Hamdan, S.A.
Abdalla Ashraf Gasim Elsid	Baba, M.D.	Hamid, Aziz A.
Abdul Rahman, T.K	Baba, R.	Hamid, M.S.A.
Abdul Rashid, Abdul Halim	Baderon, mad Kamal	Hamid, Syed A.
Abdul Wahab, MB	Badri, M.	Hamsa, Abdul
Abdullah, Abdul Hanan	Badros, M.Z.	Hamzah, A.R.
Abdullah, M.H.	Bakar, Jaafar Haji ohamad	Hamzah, S.
Abdullah, M.Z.	Bakar, W.A.	Haque, Md. Enamul
Abdullah, Wan Ahmad Tajuddin	Bakar, Z.A.	Harba, M.I.A.
Abu Bakar, B.	Baker, R.A.	Haron, Che
Abu Bakar, H.	Bakti, N. A. K.	Harun, Mohd. Hanafiah
Abu Bakar, J.H.M.	Basir, S.	Hashim, H.
Abubakr, I.	Bhinder, F.S.	Hashim, M.S.J.
Adnan, Wan Azizun	Bin Samian, Y.	Hashim, R.
Agha, Syed Salim	Bin, Syed Nahar	Hashim, Y.
Agus, Arawati	Birch, A.P	Hassan, Che
Ahmad Fadzil, M.H.	Boashash, Boualem	Hassan, H.Md.
Ahmad, Fatimah	Boon Leong Law	Hassan, I.
Ahmad, H.B.	Buang, K.	Hassan, Mohd. Ezani Mat
Ahmad, Khrushid	Chan Gaik Tatt	Hong, Yeoh Eng
Ahmad, M.B.	Chan, Sei	Husain, F.
Ahmed, Feroz	Chang, L.H.T.	Hussain, H.
Ainon, Raja Noor	Chin, Chen Seong	Ibrahim, M.
Akhtar, Shahid	Ching Kah Hiang	Idris, Nik Rumzi Nik
Akram, Uzma	Chong, S.S.	Idrus, R.
Al-Amayreh, A.	Choong, C.Y.	Inayat-Hussain, Anis A.
Al-Hallaj, Said Mohd.	Chu, K.H.	Islam, M.N.
Al-Irhayim, Sulfyam	Chung, B.K.	Ismail, Abdul Samad
Al-Jumaily, Adel Ali S.	Chung, Chee Yee	Ismail, Hanafi
Al-Khateeb, Wajdi	Chye, Y.H.	Ismail, Mohd N.
Al-Zubaidy, S.	Dalimin, Mohd. Noh	Jafaar, Z.
Alam, Leha	Darus, Ahmad Bin	Jailani, N.
Alam, M.R.	Daud, A. R.	Jalil, N.A.
Alauddin, Mohd.	Devadass, V.	Jamaluddin, M.Y.
Ali, L.	Devarajan, G. V.	Jamaludin, M.A.
Ali, Md. Liakot	Ekiz, H.	Jumaat, Mohammad Zamin
Ali, N.H.M.	Elias, Mohd Rohani	Kadir, N.M.A.
Alif, N.H.M.	Eng Chin Peng	Kam, S.W.
Altaf-UL-Amin, Md.	Farsi, M.	Kamal, A.M.
Ang, W.T.	Ghanesh, Periasamy	Kannan, K.S.
Appalanaidu, U.B.	Ghani Kamaruddin, A.	Kashem, M.A.
Arshad, N.M.	Goh, Eric K.H.	Kasim, A.F. Bin
Asirvatham, D.	Goh, Keat-Choon	Kasimin, Hasmiah
Aw Yong, T. O.	Goh, Mark	Keen, Tham Chee
Aw, Kean-Hong	Gumel, A.B.	Khalil, Mohamed
Awang, Mariyamni	Habib, M.K.	Khan, Shahidul I.
Ayob, Mohb Sapihie	Hakim Juri, A.	Khessal, Nadir Ould
Aziz, A.Z.A.	Halim, N.	Krishnasamy, P.
Azli, N.A.	Halim, R.A.	Kumar, R.N.

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Kundan, Jayabalan
Kutlu, A.
Lau, Kwee Sing
Lau, T.W.
Le Lay, Tan
Lee Ling Ling
Lee, C. S.
Lee, K.Y.
Lee, L. H.
Lee, Tak C.
Lee, Y.K.
Liew, H-L.
Lim, Cheah Choon
Lim, Chee Peng
Lim, K.C.
Lim, Swee-Hong
Lin, Goh Mei
Liong, Tan Keh
Loh, K.F.
Low, F.
Lui, W.S.
Lye, Koh Hock
Mahamud, K.R.K.
Mahfudz, M.
Mahmood, N.N.
Mahmoud, M.
Mainal, M.R.
Majid, A.A.
Majid, H.A.
Maleque, M.A.
Mamat, M.R.
Manaf, Azizah Abdul
Marzuki, Khalid
Mat Zain, Ahmad Bazlee
Matharsha, K.
Mazumder, M.D.A.
Md Sharrif, Zainul Abidin
Mir Sadehgi, Bahram H.
Mohamad, B.
Mohamad bin Embong
Mohamed, S.
Mohd Nazim, M.
Mohd, S.
Mohd, Zainul Abidin
Mohd-Saman, M.Y.
Mohd., Dashuki
Mokhtar, W.M.B.
M.R.Bin Mainal
Muha, P. A.
Muhamad, Jasni
Mustafa, Adli
Mustafa, M.S.B.
Mustafa, M.W.
Mustain, A.H.
Nair, P.K.
Ngeow, C.L.
Ngo, D.C.L.
Nooh Abu Bakar
Noor, N.M.
Noormala, M.Y.
Nor, Sulaiman Mohd
Norlaili Mohd Noh
Nwesri, Abdusalam F.A.
Omar, A.M
Omar, J.
Ong, K.S.
Othman, Hasliza
Othman, Mohd. Yusof Hj.
Othman, W.A.M.
Po, Wong Kit
Rahman, A.G.A.
Rahman, Mizanur
Rahman, S.N.S.A.
Rahman, Samirah Abdul
Rahman, Syed A.
Rahman, Tharek Abd.
Rajesham, S.
Ramadass, S.
Ramani, Ashwani K.
Ramli, Abdul Rahman
Ramli, Yahaya
Rathemalar, M.
Rijal, Omar Mohd
Romli, A.B.
Rosli, Arman
Saad, M.
Sabirin, A.
Saia, A.
Said, A.M.
Said, Md
Sajed, K.A.
Salleh, Bin
Salleh, M.A.S.B.
Salleh, Shahrudin
Saman, Yazid
Saravanan, K.
Satti, Jahangir A.
Saw Kim Guan
Sawir, B.
Seelan, K.
Selamat, Samsuddin
Selvakennedy, S.
Semarak, Jalan
Sen Gupta, B.
Seong-Chong Toh
Shaaban, Z.
Shafie, S.
Shafiee, Shahimi
Shah, Azur
Shaharoun, A.M.
Shalaby, Hossam M.H.
Shariffadeen, T.M.A.
Shariffudin, R.S.
Shariffudin, Mohd Amin
Shehata, Farouk A.
Shum, Kok Hoong
Sidek, O.
Sing, Lau Buon
Soo, Fong-Seong
Sopian, Kamaruzzaman
Sreedharan, B.
Sudin, S.
Sulaiman, Shamsuddin
Syed-Mohamad, S.-M.
Taha, F.
Taib, Mohd Nor
Taib, Soib B.
Tajuddin, A.A.
Talib, A.Z.B. Haji
Tamimi, Abdul Rahman
Tan Chow Heang
Tan Geik Kew
Tang, C.H.
Tang, Ting-Nguon
Tasir, A.N.
Teh, Swee-Thian
Teng, Loo Yau
Tengku Shahdan, T.S.
Theong, Tan Shao
Tung, P.
Venkatalachan, A.
Wahiddin, M.R.B.
Wai, Kew Khak
Wai, Mui Kok
Wan Abdullah, W.A.T.
Wan Mahmood Bin Wan Abdul Majid Majid
We, Martin Tay Tiong
Wong, A.
Wong, K.L.
Wong, See Yong
Yaacob, Raja Abdullah
Yagasena, A.
Yap Chun Ming
Yap, T.C.
Yeo, A.
Yew, K.M.
Yew, L.T.
Yong, Lim Siew
Yow, S.K.
Yunus, J.
Yusof, A.M.
Yusof, Khairiyah Mohd

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Yusoff, Zulkalnain
Zahran, H.
Zaidah, R.
Zain, Ahmad Faizal Mohd

Zain, S.M.
Zainal, A.R.
Zakaria, A.
Zakaria, Mohamad

Zaki, A.
Zaman, H.B.
Zan, M.M