Citation Reports. For reasonable comparison, the two year average AIF values were considered. It was found that the order of the subject categories with regard to the JIF value corresponded very well to that of the AIF value as shown earlier.

Table 1. General meaning and examples in sub-position for citation consideration

Citation position	General meaning	Examples (Exact citations from the citing articles)
Citations in Introduction		
• As a general reference	The cited work was cited in the citing article to support general statements that were already known amongst researchers in that field.	"*Research activities are mainly directed towards* the optimization of process efficiency in terms of effluent quality, membrane types, plant configurations and operational practices [1, 2]." (Water Research 38 (2004) 1799-1808)
		"In fact, ternary composites based on particulate filler filled or fiber reinforced thermoplastic/elastomer blends have increased dramatically in *popularity over recent years* [11-13]." (Polymer 42 (2001) 6557-6563)
• One of many cited articles	The cited work was cited as one of many cited articles in the citing article.	"There have been *numerous studies* including those by Gajadhar et al. [28], Luton et al. [131], Gagnon et al. [132], Sogin and Silberman [133], Dolezel et al. [134], Kakuda et al. [135], and Barta et al. [27] using the nuclear encoded ssrRNA gene for phylogenetic analyses of apicomplexan genera." (International Journal for Parasitology 30 (2000) 1053-1070)
		"*More than 20 research papers* reporting the cytotoxicity of artemisinin family were recently published.[2-21]" (Bioorganic & Medicinal Chemistry 11 (2003) 977-984)
• Detailed by the citing article	The experimental conditions, results and the significant findings of the cited work were mentioned and explained in great detail in the citing article.	"Srivastava et al. (2003) *analyzed the* utility planning, environmental and economic effects of an integrated power sector development at the national level. *The study shows that* the integrated development and operation of the power system at the national level would reduce the total cost, total capacity addition and emissions and improve system reliability." (Energy Policy 32 (2004) 1737-1751)
		"*The recent description* of the crystal-structure of *P. falciparum* DHFR in a ternary complex with NADPH and WR99210 [20] provided and excellent template for model building and was used here as a basis for comparing the *dhfr* sequence of *B. bovis* with those of other apicomplexans and for studying the potential effects of the observed amino acid substation." (Molecular & Biochemical Parasitology 133 (2004) 209-219)
• Referred as the pioneer in the field	The cited paper was referred to as the first contribution to particular research finding.	"*A preliminary result* of the backscattering studies was included elsewhere [7]. This study provides an evaluation of the relative merits of these approaches for compositional elucidation of thin films containing nearby elements." (Thin Solid Films 388 (2001) 195-200)
		"*A single study, by* Reinprayoon et al., on the influence of Implanon on the duration of lactation, milk composition, and infant growth and health has been published [24]." (Contraception 65 (2002) 39-46)

Table 1. (cont.)

Citation position	General meaning	Examples (Exact citations from the citing articles)
Citations in Experimental		
• Raw materials	The citing article aimed to use the raw material(s) as referred to in the cited article.	"*Applying* these methods, *composite materials* such as Nylon hybrids [121-123], epoxy resin materials [124-, 125], or in situ poly (MMA) [126], and poly (caprolactone) [127] polymerized systems have been produced with ion-exchanged clays." (Progress in Polymer Science 28 (2003) 83-114)
		"Double-blind comparative studies are also *available versus* chloroquine *from* India and Mefloquine from Thailand (LOOAREESUWAN *et al.*, 1999)." (Transactions of The Royal Society of Tropical Medicine and Hygiene 94 (2000) 419-424)
• Processes, techniques & test methods	The citing article aimed to use the same or similar techniques, processes, and test methods that were used in the cited article.	"*Compound 4*. Colorless amorphous powder, CD (λ_{max}) (c = 0.001, MeOH) $\Delta\varepsilon$ -29.4 (210); FABMS (negative-ion mode) m/z: 387.15 [M - H]$^-$. The NMR data of compound 4 were *identical to the published data of* phlomuroside (Kanchanapoom et al., 2001)" (Life Sciences 75 (2004) 753-763)
		"The analytical procedure was a *modification of the method described by* Tanabe et al. (2000). Briefly, 10 g of well homogenized tissues were mixed with anhydrous Na_2SO_4 until the homogenate was free-flowing." (Marine Pollution Bulletin 48 (2004) 795-805)
• Mathematical models & calculations	The citing article referred to the mathematical models and calculation methods used in the cited article.	"Defining for orthotropic bimaterial the *generalized* Dundurs's *constants α and β as* (Poonsawat et al., 2001; Ting, 1996)" (International Journal of solids and Structures 40 (2003) 6839-6857)
		"Instead of searching for equivalence transformations using the direct form of change of variables, a new generalization of the Lie infinitesimal criterion that will *simplify the calculation of* the infinitesimal generators will be adopted (see [16])." (Journal of Physics A: Mathematical and General 37 (2004) 3835-3846)
• Processing and test conditions	The citing article had used the same or similar processing and test conditions (such as test temperature, speed, moisture content, %humidity, ect) that were mentioned in the cited article.	"With these parameters, InAs islands with an average height of 11 nm and a narrow size distribution are obtained [18]." (Physica E 23 (2004) 384-389)
		"DEN 1-4 pre-membrane (*prM*) and envelope (*E*) genes inserted into non-structural portion of yellow fever 17D vaccine. Single dose of tetravalent chimera raised 100% neutralizing antibodies in monkeys [3]. Phase 1 trial planned for 2002." (Vaccine 20 (2002) 3043-3046)

Table 1. (cont.)

Citation position	General meaning	Examples (Exact citations from the citing articles)
Citations in Result & Discussion		
• Supported by the citing article	The results in the citing article had a similar tendency to those obtained in the cited article (qualitatively).	"In the particular, the PMMA/Clay nanocomposites by sonication processing at low frequency are very different from that pure PMMA. These behaviors of nanocomposites are characteristic of a pseudo-solid-like response of the material. The *same observation was reported by* nanocomposites of eq. Poly(propylene) [7], Poly amide-12 [8]." (Materials Science & Engineering C 24 (2004) 285-288)
		"The results of metal concentrations found in beer samples were very well consistent with those obtained recently [19-21] and related to the analysis of beers of different type and origin. In the cited work, beers were characterized according to their mineral contents by ICP-MS [20], FI-FAAS [21], and ICP-AES [19]. However, in the last case, only the elements present at levels above the detection limits of the method applied were determined." (Analytica Chimica Acta 502 (2004) 83-90
• Disagreed by the citing article	The results in the citing article had an opposite tendency to those obtained in the cited article (qualitatively).	"*In contrast, other studies did not find any relationship* between duration of DRM and HIV transmission [7-11, 19], but these observations were limited to cases where antiretroviral therapy was during labor." (International Journal of Gynecology and Obstetrics 82 (2003), 17-23)
		"Also it has been found that ω_0 is affected by the active current tracking errors α_2 and α_3, but ω_0/Q is not affected by any active current tracking errors of the three CCCIIs, *unlike the previous work* [1, 3]." (IEE Proceedings – Circuits, Devices and Systems 151 No. 4 (2004) 273-277)
• Compared with the citing article	The results obtained in the cited article were compared with those found in the citing article (quantitative comparison).	"This result *is comparable to* the reported retention (R = 0.89) for a 17 mM NaCl solution [11]." (Chemical Engineering & Technology 26 No.11 (2003) 1166-1168)
		"These sterically hindered neutral ferrocene derivatives are therefore much *less* effective anion binding hosts *than those previously reported* by Beer et al. [15]." (Polyhedron 22 (2003) 763-768)
• Discussion referred to:	The discussion given in the cited article was mentioned in the citing article.	"Regarding the aforementioned deactivation of the enzyme activities following successive incorporations by the procedure A, we have investigated a second route of platinum incorporation (procedure B) which avoids successive changes of solutions and thus may be more favorable for the enzyme stability. *Such an incorporation procedure*, which involves ionic exchange and metal electroprecipitation in the same solution, *has been successfully used by* Arjsiriwat and collaborators [12] for the inclusion of rhodium in polypyrrole GOx films." (Talanta 55 (2001) 1005-1013)
		"*Two recent modeling studies have suggested that* it is the flexibility of the WR99210 molecule that allows it to retain effectiveness even against enzymes that are highly resistant to the more rigid pyrimethamine and cycloguanil [43, 44]." (Molecular & Biochemical Parasitology 113 (2001) 139-150)

Table 1. (cont.)

Citation position	General meaning	Examples (Exact citations from the citing articles)
Citations in Conclusion		
• Normal citations	The citing and cited articles had similar conclusions.	"The ANN ability to mimic stream flow observations without needing a mathematical description of the hydrogical processes has now been thoroughly documented (e.g. Campolo et al. 1999; .....Coulibaly et al., 2000, 2001a), making ANNs serious contenders in R-R forecasting." (Environmental Modeling & software 19 (2004) 357-368)
		"Moreover, adequate response to malaria epidemics is often delayed and has resulted in high mortality in countries such as Burundi, Ethiopia, Somalia, and Kenya (M Coosemans, personal communication).[38, 39] The current AIDS pandemic has also had a major effect on health staff, contributing to the shortage of qualified health personnel,...." (The Lancet 3 (2003) 99-102)

Table 2. Average Article Impact Factors (AIF) of Thai researchers in SCI database from 1998 to 2002 in comparison with the most recent Journal Impact Factors (JIF)

	Year	Subject category			
		Clinical Medicine	Chemistry	Material Sciences	Engineering
Article number	2002	523	267	47	220
	2001	469	212	43	174
	2000	453	164	37	138
	1999	362	119	26	130
	1998	413	103	17	121
Time cited*	2002	1343	454	56	197
	2001	1475	705	78	259
	2000	2523	697	119	298
	1999	2805	648	91	339
	1998	2915	563	36	313
Yearly Article Impact Factor (AIF)	2002	2.568	1.700	1.191	0.895
	2001	3.145	3.325	1.814	1.489
	2000	5.570	4.250	3.215	2.159
	1999	7.749	5.445	3.50	2.608
	1998	7.058	5.466	2.118	2.587
AIF 5year		5.218	4.037	2.368	1.948
AIF 2 year		2.856	2.512	1.502	1.192
JIF**		1.790	1.643	0.748	0.667

*As of 30 September 2003

**JIF obtained by averaging the 2003 impact factors of all journal titles within the four subject categories in the JCR.

Table 3. Position Impact Factor (PIF) values of Thai researchers in the SCI database from 1998 to 2002

Subject category	No. of citing articles used (A)	Total position times cited (B)	PIF value (B/A)
Clinical Medicine	300	454	1.512
Chemistry	300	422	1.406
Material Sciences	300	407	1.355
Engineering	300	384	1.281

Table 3 shows the number of position times cited of articles authored by Thai researchers in 1,200 articles of non-Thai researchers for the Clinical Medicine, Chemistry, Material Sciences, and Engineering categories, the results being reported in PIF values. It should be noted that the position times cited, in this case, means the number of citation positions of cited articles in citing articles. It can be seen that the PIF values for all subject categories were greater than unity. This means that each article produced by Thai researchers was cited more than once in a citing article. Clinical Medicine was found to have the highest PIF value, while the second and third positions were Chemistry and Material Sciences, respectively. Engineering exhibited the lowest PIF value. The sequence of PIF values for these four subject categories corresponded well to that of JIF and AIF values. The explanation for this could be given in connection with the citation behavior of researchers in each subject category as discussed earlier.

Qualitative evaluation: Citation behaviors for different subject fields

Figure 1 shows the percentage of the total number of times articles authored by Thai researchers were cited in four subject categories with respect to the citation position in the selected citing articles. It can be seen that most citations occurred in the Introduction and Results & Discussion sections. Citations in the Introduction section were relatively high in the Material Sciences and Engineering categories. The most citations of Thai articles in non-Thai articles in Clinical Medicine occurred in the Results & Discussion section. In addition, the differences in percentage total number of times cited between the Introduction and the Results & Discussion sections were large for Material Sciences and Engineering as compared with those for Clinical Medicine and Chemistry. This suggests that the experimental results obtained in later works for Material Sciences and Engineering categories were not greatly dependent on those in early works. Having a large fraction of references in the Introduction is not unusual as most journal articles require authors to review previous works and their relation to the authors' work. Experience has shown that the trend and characteristics of the published results in Material Sciences and Engineering are quite independent among published papers in these subject fields, the experimental results of articles published in these two subject fields varying as a result of type, grade and manufacturer of raw materials, material nature (e.g., time dependency), processing technique and conditions, as well as testing

conditions. In Clinical Medicine and Chemistry, the experimental results are more specific, the environmental conditions having minor effects on the results. As a consequence, writing a paper in Clinical Medicine and Chemistry does require more substantial early works in the Results & Discussion for comparisons. The high citations in both Introduction and Results & Discussion sections may be one of the reasons explaining why the average impact factors for journals listed in the Clinical Medicine and Chemistry categories are higher than those in the Material Sciences and Engineering categories as mentioned earlier.

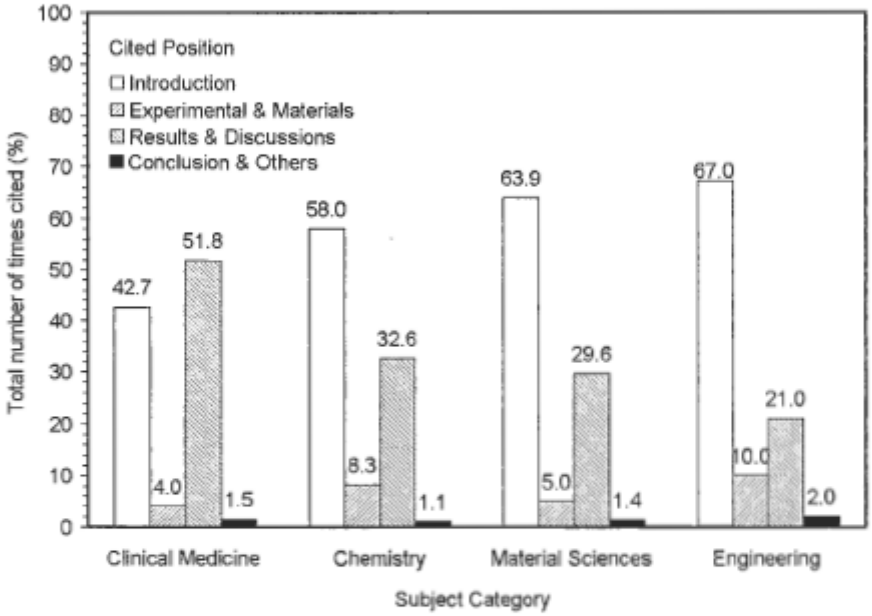

Figure 1. Number of times cited, and positions of articles by Thai researchers in SCI database during 1998–2002

Figures 2–5 show the percentage citation counts with respect to sub-positions in the citing articles for Clinical Medicine, Chemistry, Material Sciences and Engineering, respectively. It is reasonable to say that citations in the Results & Discussion part are comparatively more significant than those in the Introduction part. It can be seen from Figure 2 that non-Thai researchers in Clinical Medicine generally used Discussion from articles of Thai-researchers for the discussion of their work. They also referred to Thai articles as "one of the many cited references" in the Introduction section. This citation behavior in Clinical Medicine seemed to be opposite to that of the others. Most citations

in Chemistry, Material Sciences and Engineering occurred in the Introduction section and were used as general references ("As a general reference" or "One of many cited articles").

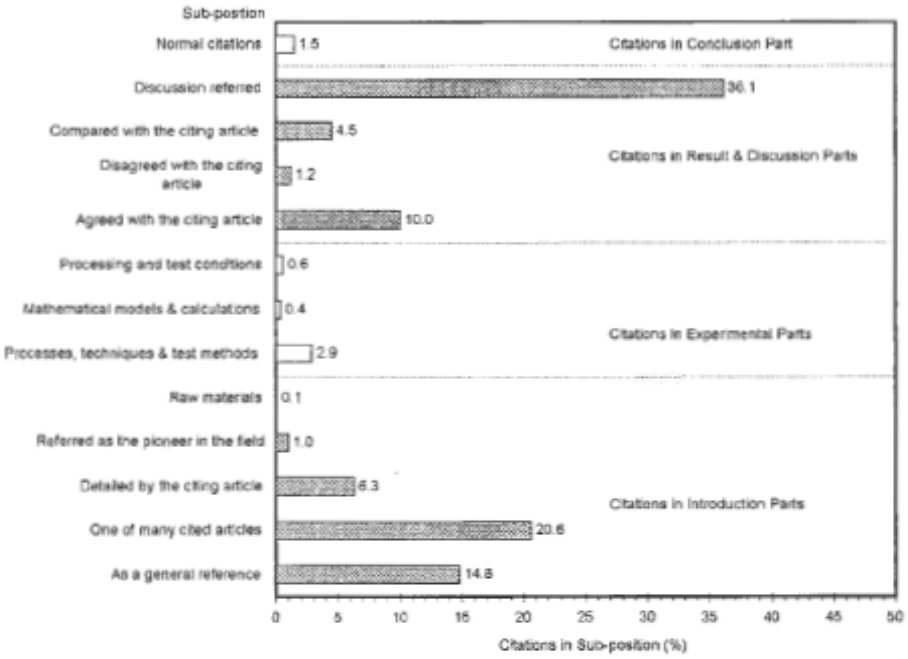

Figure 2. Citation counts in sub-positions of articles in Clinical Medicine category

Based on the results in Figures 2–5, the following interpretations are drawn and implicitly reflect *the characteristics and scientific qualities of the researches performed by Thai scholars* at international level based on publications in four subject categories of interest, within the scope of the results and designed conditions in this work.

- Most publications (scientific qualities) of Thai researchers in Clinical Medicine had a relatively high benefit to the research community in discussing the results of their work. The publications of Thai scholars contributing as "the pioneer in the field" was at only 1.0%. A very low amount of contributions in new experimental techniques, calculations, and test conditions were invented by Thai-researchers.
- Most publications (scientific qualities) of Thai researchers in Chemistry were used as one of many cited articles. The publications of Thai researchers contributing as "the pioneer in the field" was at only 1.5%.

Very minor contributions in new experimental techniques, calculations, and test conditions were invented by Thai-chemists.

- Publications (scientific qualities) of Thai researchers in Material Sciences contributed mostly in use as supporting general statements in the Introduction section. The contribution as "the pioneer in the field" was very low, this being calculated to 0.4%. Relatively minor contributions in new Material Sciences, mathematical models and calculations, and test conditions were offered by Thai-material scientists.
- Publications (scientific qualities) of Thai engineers are most referred to as one of many cited articles. The contribution as "the pioneer in the field" was the least as compared to the other subject categories, this being 0.2%. Among contributions in the Experimental section, 5.1% of the publication works contributed to new mathematical models and calculations.

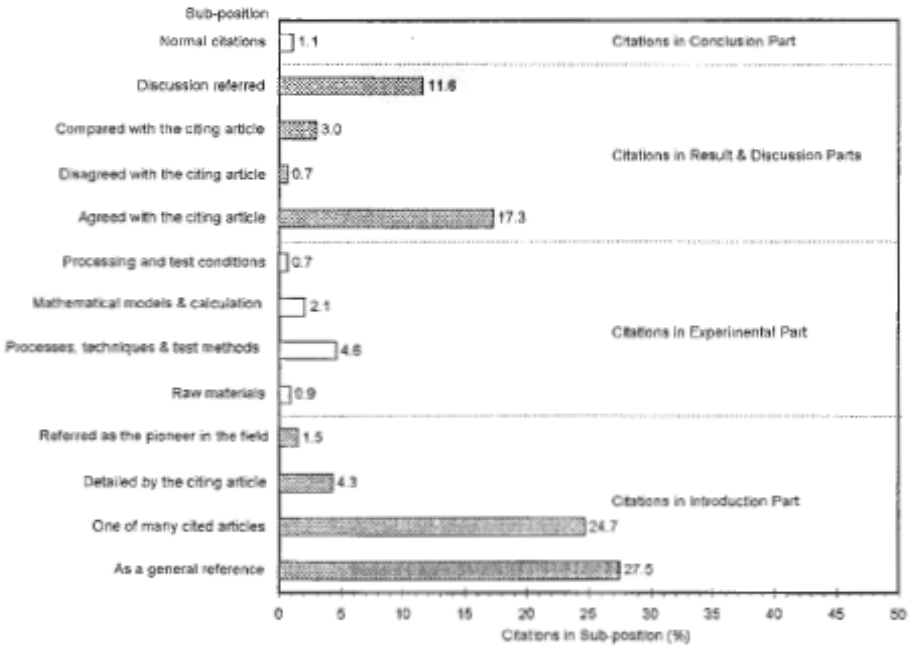

Figure 3. Citation counts in sub-positions of articles in Chemistry category

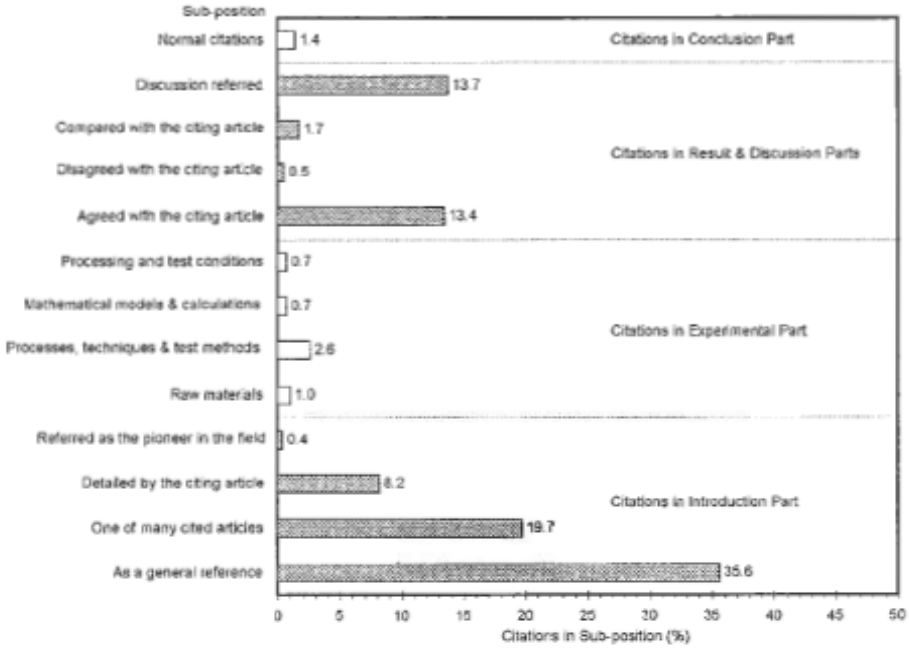

Figure 4. Citation counts in sub-positions of articles in Material Sciences category

In addition, the results obtained in this work (as a case study of Thailand) could be a useful example for evaluating the research performance through scientific quality by considering citation counts, citation position, and the contents and significance levels of the citations. The results could be interpreted differently if other subject categories or cited articles from other countries were studied. Besides, the citation patterns might change over time if the citation quality of research works was evaluated with respect to positions and significance levels (meaning of the citation contents) of the cited articles in citing articles. The results in this work have, at least, reported the current status of scientific quality and research performance, which had not yet been evaluated and discussed elsewhere, with respect to international publications in the SCI database. Further studies of this work can be carried out by considering the citation quality (by considering the citation contents and citation positions) for different subject categories, subfields within a subject category, and countries.

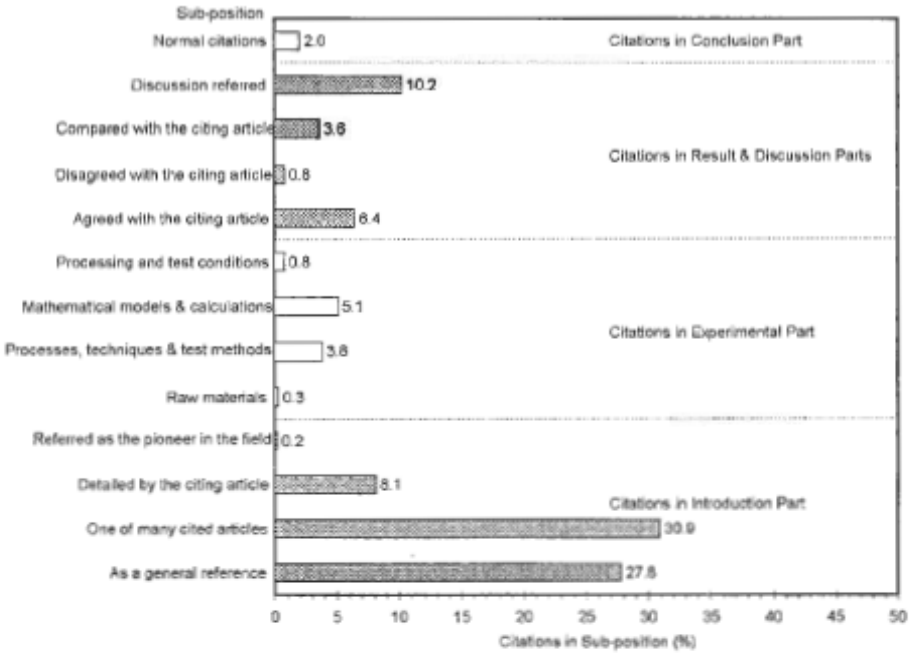

Figure 5. Citation counts in sub-positions of articles in Engineering category

Conclusion

For quantitative evaluation, the results suggested that the highest article number and number of times cited were given by Thai researchers in Clinical Medicine, the lowest being for Material Sciences. When considering the article impact factors (AIF), Clinical Medicine had the highest value, while Engineering exhibited the lowest. The differences in the AIF values were probably associated with the citation behaviors of researchers and the journal impact factors in each subject field, research on the basic and life sciences (Clinical Medicine and Chemistry) being more likely to be cited as compared to articles with applied or industrial applications. Each article produced by Thai researchers was found to be cited more than once in a citing article, this being the most likely for Clinical Medicine. For qualitative assessment, most articles from Thai scholars were cited in Introduction and Results & Discussion sections of the citing articles from non-Thai researchers. Citations in the Introduction section were relatively high in Material Sciences and Engineering categories. Most citations in Clinical

Medicine occurred in the Results & Discussion section. Non-Thai researchers in Clinical Medicine preferred to use Discussion from Thai articles for discussion of their work. Most citations in Chemistry, Material Sciences and Engineering were referred to as general references. Under the scope of this work, less than 1.5% of research works from Thai scholars was regarded as "the pioneer" to the research community.

*

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An Evaluation of Research Performance for Different Subject Categories using Impact Factor Point Average (IFPA) Index: Thailand Case Study. (2005) ***Scientometrics***, 65(3): 293-305 (IF = 1.738)

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An evaluation of research performance for different subject categories using Impact Factor Point Average (IFPA) index: Thailand case study

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The research performance of Thai researchers in various subject categories was evaluated using a new mathematical index entitled "Impact Factor Point Average" (IFPA), by considering the number of published papers in journals listed in the Science Citation Index (SCI) database held by the Institute for Scientific Information (ISI) for the years 1998-2002, and the results compared with the direct publication number (PN) and publication credit (PC) methods. The results suggested that the PN and PC indicators cannot be used for comparison between fields or countries because of the strong field-dependence. The IFPA index, based on a normalization of differences in impact factors, rankings, and number of journal titles in different subject categories, was found to be simple and could be used with equality for accurate assessment of the quality of research work in different subject categories. The results of research performance were found to be dependent on the method used for the evaluations. All evaluation methods indicated that Clinical Medicine was ranked first in terms of the research performance of Thai scholars listed in the SCI database, but exhibited the lowest improvement of performance. Chemistry was shown to be the most improved subject category.

Introduction

It is generally accepted that articles published in high impact factor journals should be of high quality, although it has been realized that a journal's high impact factor may not necessarily result from citations of all the articles in the journal, but may in fact come from a small number of articles in that journal being cited frequently.[1] However, a number of works[2–6] have addressed the restrictions of using ISI impact factors in evaluating the quality of research works and researchers, the details being obtained elsewhere. One of the limitations of using impact factors is that differences in subject categories or disciplines cause unfairness in assessing quality and efficiency of

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researchers and research institutions. This is because the journal impact factors of journals in each subject category are different because of different specific tendencies in making references,[2, 7] the speed of change and discovery in different subject categories[4] and the different quantities of journals in each subject category.

In spite of the limitations of using ISI impact factors, many research works have attempted to utilize and modify the journal impact factors to evaluate the research quality and performance of researchers in different subject categories.[6, 8-13] The Thailand Research Fund[8] has issued a new simplified index called Publication Credit (PC) which has been used to periodically examine the quality of individual research work. The PC results from the multiples of a journal's impact factor (JIF) and the number of research articles (n) published in that journal. Vinkler[9] used a new indicator called "Specific Impact Factor Contribution" (SIC) for equalizing the difference in the Garfield impact factors of journals. The SIC was related to the citation share of a respective team (or journal) in the total citations of the teams (or journals) evaluated to its share in publications. It has been realized that the normalized Garfield impact factors and the normalized SIC values are identical measures within any selected set of journals. A so-called Journal to Field Impact Score (JFIS) was presented by van Leeuwen and Moed[10] as an alternative journal impact measure. The JFIS is field-normalized and is mostly based on citation windows of four to five years or even more. The length of the selected publication window can in principle be set for each subject category. The Disciplinary Impact Factor (DIF) was introduced to overcome the subject bias of citation measures. The DIF was based on the average number of times a journal was cited in a given sub-field alone rather than across the complete set of the Science Citation Index.[11] Ramirez et al.[12] proposed a renormalized impact factor (F_r) based on the dimensionless ideas in the Engineering field. The F_r index allowed a direct comparison among journals in different categories. It was suggested by the authors that the F_r index was a useful tool for a global evaluation when comparing scientific works from multidisciplinary research institutions.

Recent work by Sombatsompop and Markpin[13] introduced a new mathematical index entitled "Impact Factor Point Average" (IFPA) for assessment of the quality of individual research work in different subject categories. The index was established based on a normalization of differences in impact factors, rankings, and number of journal titles in different subject categories. The proposed index was found to be simple and enabled the ISI impact factors to be used with equality. However, further work and more data are required in order to determine the most effective conditions (including limitations that may occur) for its measure. This present article was aimed to extend the previous work[13] by making use of the IFPA index to evaluate the research performance of Thai researchers in various subject categories during a specified period of time. Twenty-two subject categories from the ISI Essential Science Indicators were selected and the retrieved data were obtained for 1998 to 2002 for this study.

Experimental work

Data retrieval

Twenty-two subject categories as listed in the ISI Essential Science Indicators were selected and considered. All papers by Thai scholars published in the journals listed in the twenty-two subject categories during the past five years (from 1998 to 2002) were retrieved. Only original and review articles authored by Thai researchers were used in this study. The categorization of the articles of interest was based on the journals in which they were published, this already being indicated in the ISI Essential Science Indicators. The numbers of articles and journals used for this study are listed in Table 1.

Table 1. Numbers of articles and journals published by Thai researchers during 1998–2002

Subject categories	Number of articles					Number of journals				
	1998	1999	2000	2001	2002	1998	1999	2000	2001	2002
Agricultural Sciences	67	75	88	109	133	50	54	62	61	67
Animal Science	114	90	108	137	99	66	59	73	64	64
Biology & Biochemistry	60	55	93	93	113	41	38	54	59	69
Chemistry	103	118	164	212	267	62	77	86	103	113
Clinical Medicine	413	362	453	469	523	202	206	244	239	291
Computer Science	15	16	18	44	37	12	15	18	32	37
Economics & Business	2	0	5	8	5	2	0	4	4	4
Engineering	121	130	138	174	220	113	103	109	156	182
Environment/Ecology	41	44	57	78	83	36	37	47	41	54
Geosciences	17	18	39	51	46	15	18	29	28	34
Immunology	105	123	132	150	167	40	49	50	53	61
Material Sciences	17	26	37	43	47	14	17	25	28	32
Mathematics	7	13	18	10	24	7	13	13	9	18
Microbiology	96	137	145	146	192	59	66	83	74	97
Multidisciplinary	4	2	7	2	8	3	2	4	2	3
Neuroscience & Behavior	24	33	18	18	41	17	25	16	14	41
Pharmacology & Toxicology	80	82	79	99	105	42	42	39	45	39
Physics	56	52	62	99	111	43	43	47	49	59
Plant Science	64	57	54	72	98	23	30	18	19	33
Psychology/Psychiatry	5	9	9	9	9	5	6	3	4	7
Social Sciences, General	0	2	4	3	2	0	2	3	2	2
Space Science	0	1	0	0	8	0	1	0	0	7

The retrieved data for the calculations were:

1. Impact factor of the journal (Year 2003)
2. Average impact factor of all journals in each subject category
3. Ranking of the journal's impact factor in each subject category
4. Numbers of journal titles in each subject category
5. Number of research articles published in each subject category

Design of index calculations

Three methods were used to evaluate the research performance of Thai researchers in different subject categories by considering papers published by Thai scholars listed in the Science Citation Index (SCI) database during 1998–2002.

- Method#1 - Publication Number (PN): The PN value for each subject category [referred to as $PN_{(subject\ category)}$] is directly a total number of articles published by Thai scholars in journals in the same category. This method takes no account of the impact factors of the journals in which the works have been published.
- Method#2 – Publication Credit (PC): This method is derived from the multiples of a journal's impact factor (JIF) and the number of research articles (n) published in that journal. The PC value for each subject category [referred to as $PC_{(subject\ category)}$] is the sum of the publication credit for each journal [$PC_{(journal)}$] within the same category as shown in Equations 1 and 2.

$$PC_{(Journal)} = I_J \times n \quad (1)$$

$$PC_{(Subject\,Category)} = \sum PC_{(Journal)} \quad (2)$$

where I_J is the impact factor of the journal in which the research article is published, and n is the number of research articles published in the journal.

- Method#3 – Impact Factor Point Average (IFPA): The index is based on a normalization of differences in impact factors, rankings, and number of journal titles in different subject categories. This proposed index has been proven effective and accurate in our previous investigation[13] for fairly evaluating the quality of research works in different subject categories. The mathematical formula of the IFPA for each journal [referred to as $IFPA_{(journal)}$] can be calculated using Equation 3, whereas that for each subject category [referred to as $IFPA_{(subject\ category)}$] is shown in Equation 4. It should be noted that the criterion used for the IFPA index is a consideration of both *quality* and *quantity* of research works by which the difference of

impact factors and subject category has carefully been normalized. The source of, and detailed information on the IFPA index can be obtained in previous work.[13]

$$IFPA_{(Journal)} = \left[\left[\frac{I_J}{I_A}\right]\right]\left[\left[1 - \frac{R}{N+1}\right]\right]. [n] \quad (3)$$

$$IFPA_{(Subject\ Category)} = \sum IFPA_{(Journal)} \quad (4)$$

where I_J is the impact factor of the journal in which the article is published, I_A is the average impact factor of all journals in a subject category, R is the ranking of the journal's impact factor in the same subject category, N is the number of journal titles in the same subject category, and n is the number of research articles published in each journal in the same subject category.

It is worthy to note that from Equation 3, the first monomial $[I_J / I_A]$ on the right is used to normalize the difference in impact factors of the journals in each subject category, and indicates the specific quality of the journal by the journal impact factor value, compared to the quality as a whole of other journals in the same subject category. The second monomial [1-(R/N+1)] is used to normalize the difference in the number of journals in each subject category and represents the specific quality of the journal by ranking the impact factors of the journal, compared to the quality as a whole of other journals in the same subject category. Finally, the third monomial [n] indicates the specific quality of researchers or research institutions, by viewing the quantity of research articles published in the journal.

Data analysis

It should be noted that the main objective in this work was to use the IFPA index to evaluate the research performance of Thai researchers in different subject categories, as a case study, with regard to publications listed in the SCI database during 1998–2002. The experimental results from the PN and PC methods were considered solely for pinpointing the main limitations of using impact factors in evaluating research work across different subject categories. The analysis of the experimental data reported in this work was conducted in two different aspects, one to make qualitative comparisons of the results obtained from the PN, PC and IFPA methods by considering a ranking change of the subject category of each calculation method, and the other to determine the most improved subject categories by considering the changes in indexes calculated in each method over the five specified years (1998–2002).

Results and discussion

Overall assessment of research performance

Figure 1 shows values of the PN index, which directly refers to the number of published papers produced by Thai researchers in various subject categories for the selected year of 2002. Clinical Medicine was found to have the highest PN value. The second and third positions were Chemistry and Engineering, respectively. Figure 2 shows values of the PC index for different subject categories for the year 2002. It can be seen that the order of the subject categories with regard to the evaluation value was different from that shown in Figure 1. For the PC index, Clinical Medicine was still ranked first while Immunology and Microbiology took over the second and third places, respectively. Chemistry and Engineering ranked by the PC index now went down to the forth and sixth positions, respectively. The position changes of Chemistry and Engineering, and Immunology and Microbiology were caused by the differences in the impact factors. According to the *Journal Citation Reports* (2003), the average impact factors of Chemistry, Engineering, Immunology and Microbiology were calculated to 1.643, 0.667, 2.505 and 2.948, respectively.

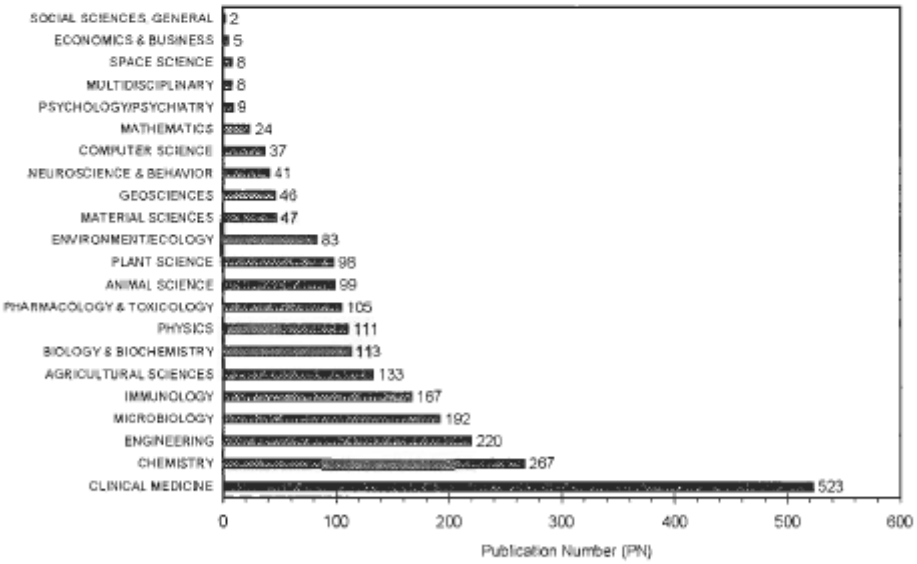

Figure 1. Values of Publication Number (PN) & subject categories in year 2002

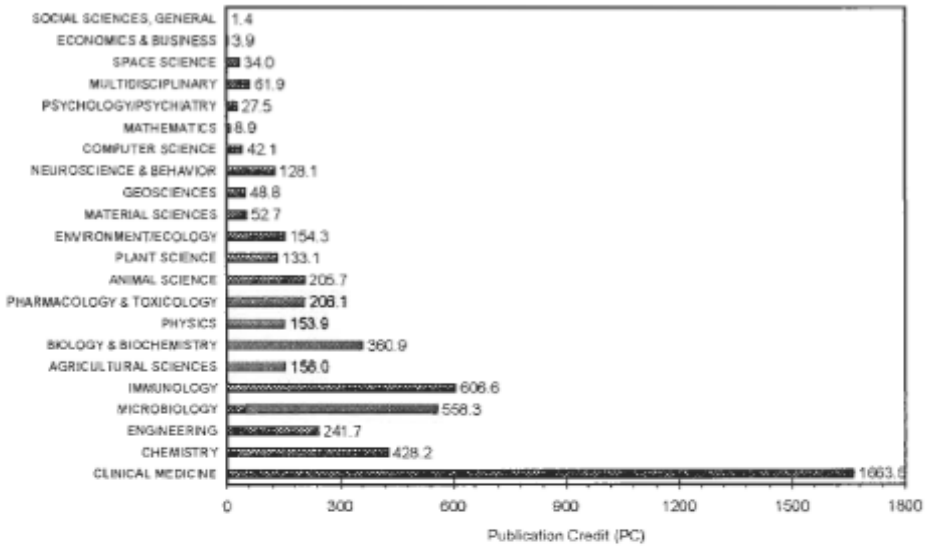

Figure 2. Values of Publication Credit (PN) & subject categories in year 2002

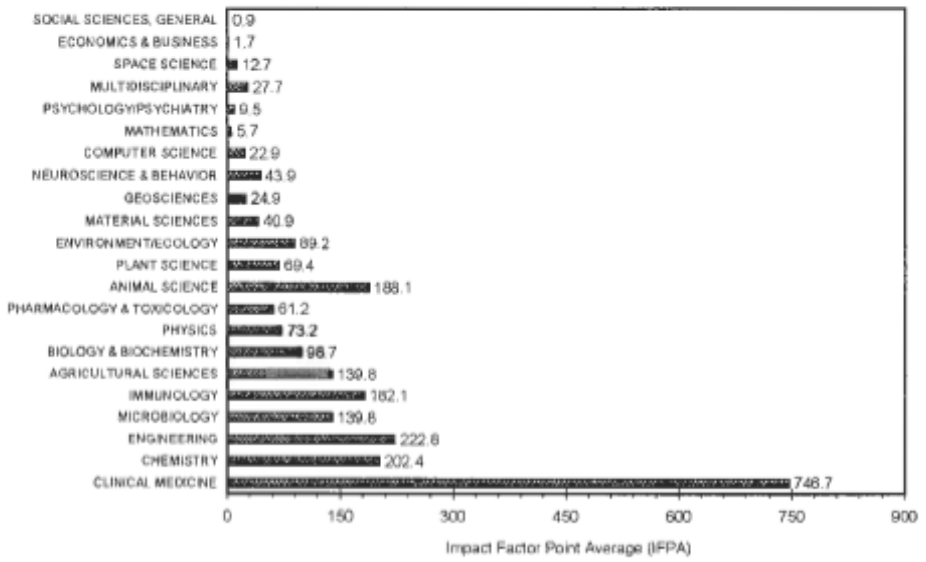

Figure 3. Values of Impact Factor Point Average (IFPA) & subject categories in year 2002

Figure 3 shows values of the IFPA index for evaluation of research performance of Thai scholars in different subject categories for the year 2002. Clinical Medicine was still the first, and far removed from the other subject fields. This suggested that Thailand has a relatively high research performance in Clinical Medicine as compared to other subject fields. It was interesting to note that the second and third places were now allocated to Engineering and Chemistry, respectively, and Animal Science gained the forth position. It can be clearly seen that when normalizing the impact factors and the ranking of the journals within subject field, different evaluation results were found. These variables clearly explain the differences in the results obtained from PN, PC and IFPA methods. Taking all the above results into account, it can be said that the results of research performance were greatly dependent on the evaluation methods used.

For practical purposes, it should be noted that when one assesses the research performance of researchers and research institutions one must consider both quantitative and qualitative performances. The evaluation by the PN method only indicates the quantitative evaluation, and by introducing the impact factor value the qualitative measure is taken into account, as noted by the PC index. However, it is widely known that the journal impact factors cannot be used with equality when considering different subject categories.[4,9,13] Therefore, the evaluations of research performance by the PN and PC methods may have contained some unfairness and inaccuracy. This has then come to the advantage of the IFPA index which could perform more accurate evaluations of the research performance across subject categories as a result of the effective normalization of the journal impact factors, ranking of the journals of interest, and number of journal titles.

Improvement level of research publication

In this work, an improvement of the research performance of Thai researchers was assessed by considering the changes in the three indexes of each subject category over the five specified years. Only the top ten subject categories sorted by each evaluation index (PN, PC or IFPA) were selected for determining the most improved subject categories, the bottom twelve subject fields exhibiting insignificant changes of improvement (thus, the results are not shown). Figures 4, 5 and 6 show the values of PN, PC and IFPA indexes for the selected ten subject categories from 1998 to 2002, respectively. It can be seen that the values of the three indexes generally increased with time (from 1998 to 2002), this being the case for all subject categories. However, the level of improvement for each subject category was not the same.

In order to determine the most improved subject category even more clearly, the values across the different calculation methods would need to be compared. However, this was not possible because the values had come from different calculations and the starting point for each subject category was not the same. In order to achieve such a

comparison, a data normalization technique is required which could divide the index values of all years by those of year 1998 within the same category. The normalization results of PN, PC and IFPA indexes for all subject categories are shown in Figures 7–9, respectively. It can be seen that after the normalization, all the data from each subject category had the same starting point and it was then made it fair to make a comparison across the various categories. It was interpreted that the greater the slope of the changes in the normalized values during the five years, the greater the improvement of the research performance. If so, Chemistry was indicated by the three indexes as the most improved subject category for Thai researchers among the twenty-two subject categories during 1998-2002, although it was ranked the 2nd, 4th, and 3rd by the PN, PC and IFPA indexes, respectively. It was also surprising that Clinical Medicine exhibited the lowest improvement in research performance as its values remained the same for the time period of interest. In this work, it was stated earlier that the IFPA method was considered to be the most accurate and fair technique to evaluate research performance across different subject fields. When considering the results in Figure 9, it can be observed that Biology & Biochemistry, Engineering and Microbiology are ranked the 2nd, 3rd and 4th, respectively, with regard to the subject category improvements.

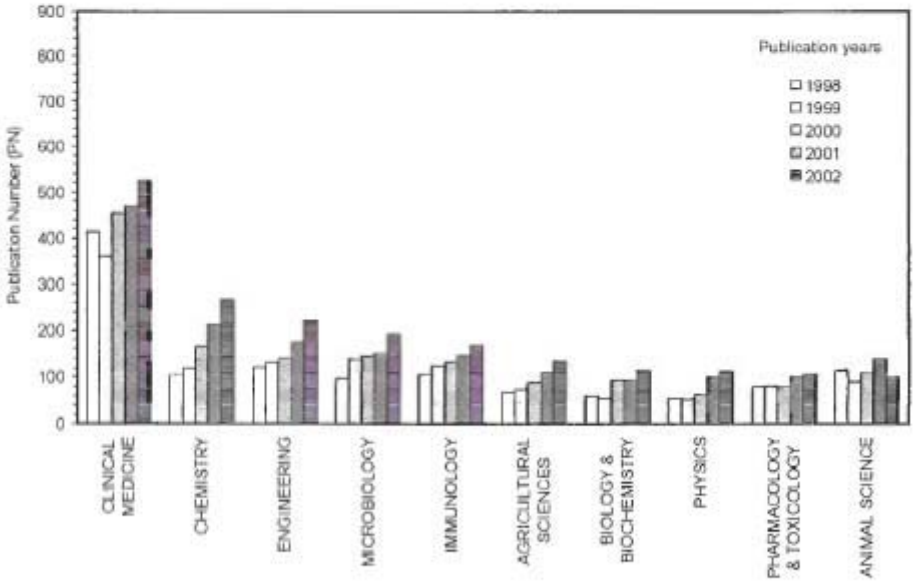

Figure 4. The values of PN index for ten selected subject categories during 1998–2002

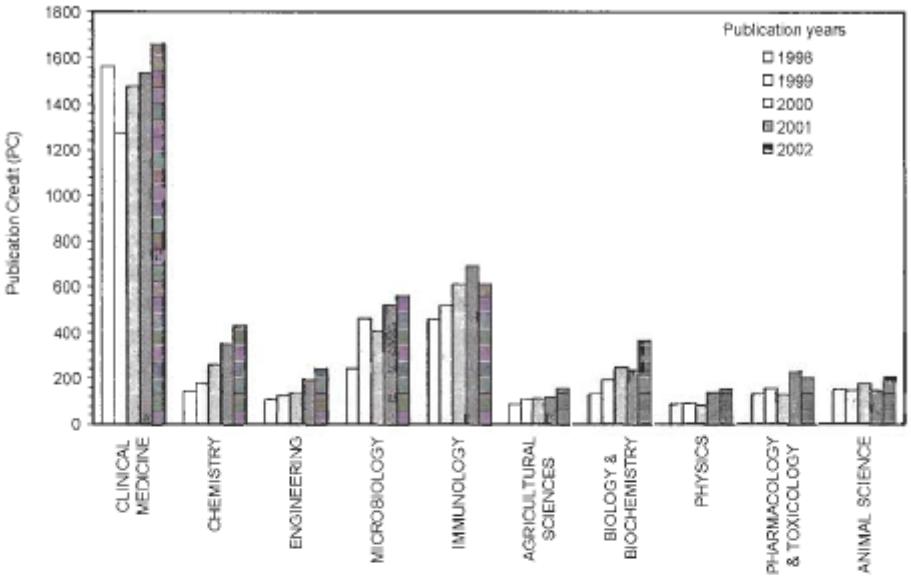

Figure 5. The values of PC index for ten selected subject categories during 1998–2002

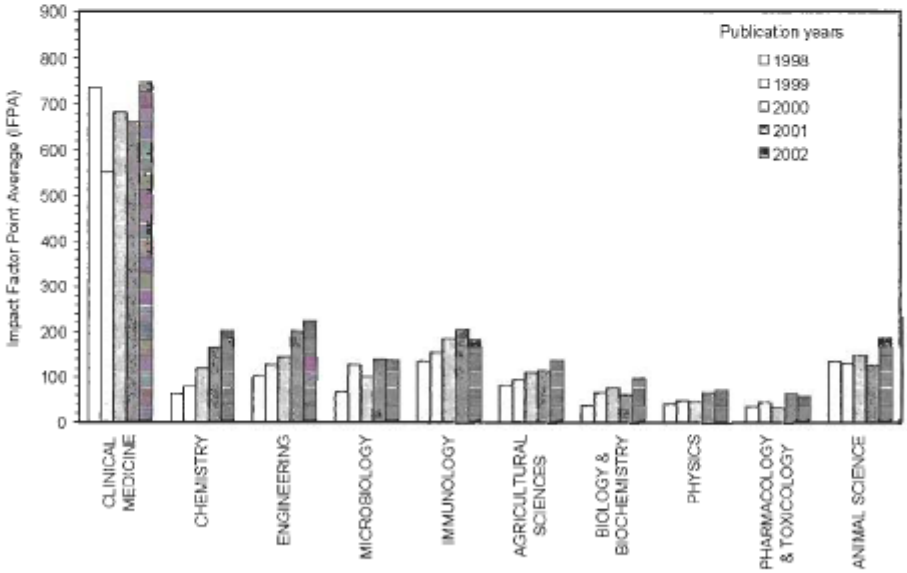

Figure 6. The values of IFPA index for ten selected subject categories during 1998–2002

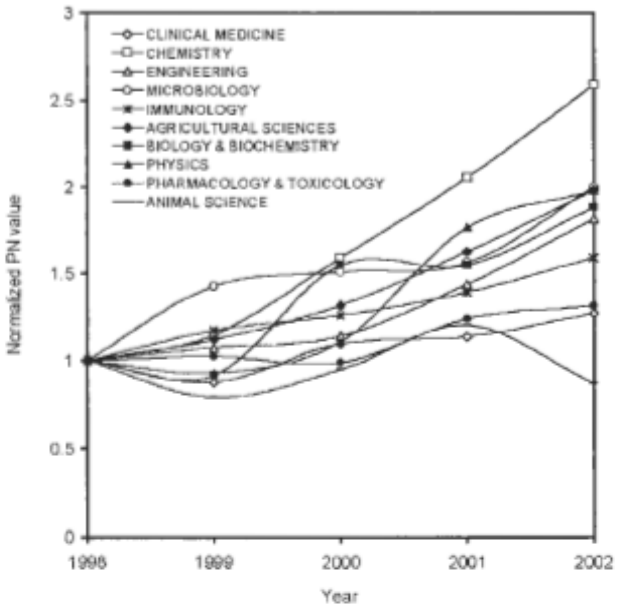

Figure 7. The normalized PN index for ten selected subject categories during 1998–2002

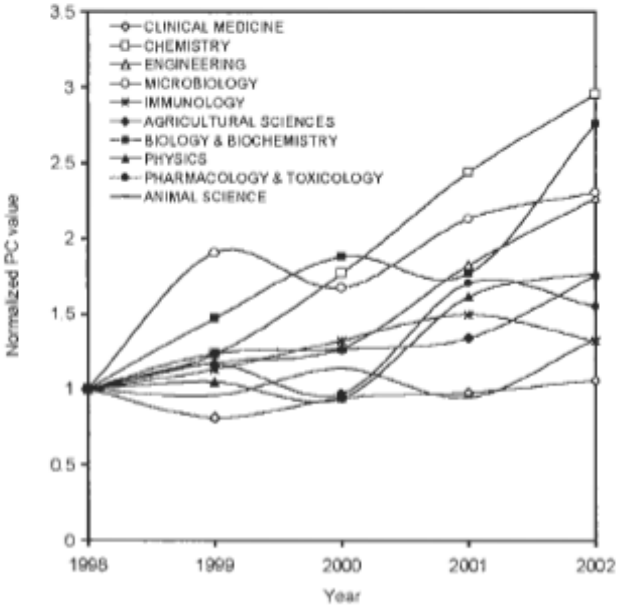

Figure 8. The normalized PC index for ten selected subject categories during 1998–2002

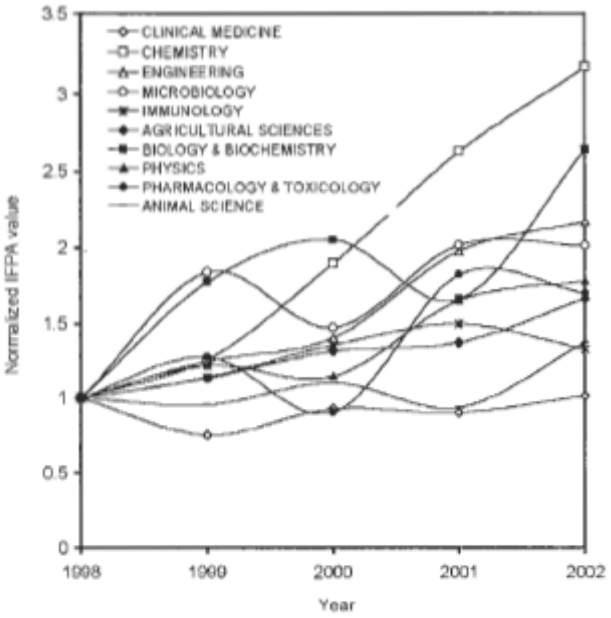

Figure 9. The normalized IFPA index for ten selected subject categories during 1998–2002

In summary, according to the results in Figures 1–9, one must realize that the results of the research performance were very much dependent on the method used. The right evaluation method can give correct information to any persons who are involved in making decisions on research and development policies in their countries. The results obtained in this work could be of benefit to researchers, research funding agencies, and research policy makers, and have at least reported the current status of research performance in Thailand, which had not yet been evaluated and discussed through the use of international information (like the SCI database). Further studies of the IFPA method can be carried out by considering the research performance for different subfields within a subject category (such as various subfields in Engineering), despite the many limitations and problems derived from using the journal impact factors. Alternatively, the IFPA method could be used to measure the capacity, efficiency and research performance of researchers and research institutions in different countries, including their comparisons.

Conclusion

It was found that PN and PC indicators cannot be used for comparison between fields or countries because of the strong field-dependence. The Impact Factor Point Average (IFPA) index was found to be able to be used with equality, as compared to the PN and PC indexes, for assessing the research performance of Thai researchers in various subject categories during the five years from 1998 to 2002. All the evaluation methods indicated that Clinical Medicine was ranked in the first position in terms of the research performance of Thai scholars in the SCI database, but exhibited the lowest improvement in performance. Chemistry was shown to be the most improved subject category. It was found that the results of research performance were dependent on the method used for the evaluations.

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Making an Equality of ISI Impact Factors for Different Subject Fields. (2005) *Journal of the American Society for Information Science and Technology*, 56(7): 676-683 (IF = 1.583)

Making an Equality of ISI Impact Factors for Different Subject Fields

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The journal impact factors, published by the Institute for Scientific Information (ISI; Philadelphia, PA), are widely known and are used to evaluate overall journal quality and the quality of the papers published therein. However, when making comparisons between subject fields, the work of individual scientists and their research institutions as reflected in their articles' ISI impact factors can become meaningless. This inequality will remain as long as ISI impact factors are employed as an instrument to assess the quality of international research. Here we propose a new mathematical index entitled *Impact Factor Point Average* (IFPA) for assessment of the quality of individual research work in different subject fields. The index is established based on a normalization of differences in impact factors, rankings, and number of journal titles in different subject fields. The proposed index is simple and enables the ISI impact factors to be used with equality, especially when evaluating the quality of research work in different subject fields.

ISI Impact Factors

It is surprising that in many countries the impact factors of academic journals (collected by the Institute for Scientific Information; ISI, Philadelphia, PA) have been used to the measure capacity, efficiency, and quality of researchers and research institutions, despite the many limitations and problems derived from using such factors (Adam, 2002; Bordons, Fernandez, & Gomez, 2002; Glanzel & Moed, 2002). Furthermore, many journal publishers have objected and complained about errors causing journal's impact factors to be lower than they actually should be (Correspondence: Errors in citation analysis, 2002). However, there have been no complaints from publishers of research journals when impact factors have been valued higher than they should have been.

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The criteria used to assess the quality of research proposals and research works are based on the belief that the articles published in high impact factor journals should be of high quality although it has been realized that a journal's high impact factor may not result from citations of all the articles in the journal, but may, in fact, come from a small number of articles in that journal being cited frequently (Colquhoun, 2003). It is also generally accepted that the quality of a research article, which is examined by a strong peer-review system (by experts and editors) reflects the quality of the journal in which it is published. However, it has been found that some editors do not function as reviewers, but merely as 'messengers' between authors and reviewers (Michell, 2003). The criteria used for calculating ISI impact factors include periods or number of years calculated, referential quality, types of articles published in a journal, numbers of articles published each year, and specific features of each journal or subject category. Earlier research works (Adam, 2002; Bordons et al., 2002; Colquhoun, 2003; Glanzel & Moed, 2002; Pudovkin & Garfield, 2002) have shown the limitations of using ISI impact factors in evaluating the quality of research papers, researchers, and research institutions. Therefore, to avoid repetition of information and research findings, we will not discuss in detail the restrictions of using impact factors.

Effects of Impact Factors in Thailand and Some Other Countries

The Thailand Research Fund (TRF) is one of the research funding organizations that provide research grants in Thailand and is well known among Thai and foreign researchers. The TRF uses impact factors as a criterion to consider and measure the quality of researchers and research works, for example:

1. Providing research grants to researchers: The TRF considers the quality of research proposals (basic research) by checking impact factors of research journals in which the researcher expects his research article to be published.

2. Awarding high quality researchers: The TRF allots research awards annually to researchers whose research articles have been published in research journals having high impact factors and having been referred to most by others (self-reference is not included).
3. The TRF has issued a new simplified index called Publication Credit (PC), which is used to periodically examine the quality of individual research work. The PC results from the multiples of a journal's impact factor and the numbers of research articles published in that journal (Equation 1).

$$PC = I * n \quad (1)$$

where I is the impact factor of the journal in which the research article is published; n is number of research articles published in the journal.

In addition, the Foundation for the Promotion of Science and Technology under the Patronage of His Majesty the King (FSTK) annually presents the Outstanding Scientist Award and Young Scientist Award. One of the qualification requirements for the awards is having research articles published in high impact factor journals.

Besides Thailand, many other countries use the ISI impact factors as an index for the quality of research works, researchers, and research institutions. In Finland impact factors are utilized as a part of the country's law. Impact factors are legally used in the determination of the allotment research funding, e.g., for a researcher to be further financially supported, the journals his articles appear in should have an impact factor of greater than 2. Similarly in Germany and Italy, impact factors are used as a criterion for providing research grants and in promoting an individual's position. The evaluation was based on calculating *the average impact factor* of the journals in which researcher's articles have appeared for each year. In Hungary, the *Specific Impact Factor Contribution* (SIC) was introduced to be used equally with the ISI impact factors in the assessment of the publications of the Hungarian Academy of Sciences (Vinkler, 2002). The SIC index involved the citation share of a respective team (or journal) in the total citations of the teams (or journals) evaluated to its share in publication. It was found that the normalized IF and the normalized SIC gave identical measures within any selected set of journals. In the Netherlands, the so-called *Journal to Field Impact Score* (JFIS) was presented as an alternative journal impact measure (van Leeuwen & Moed, 2002). The JFIS is field-normalized and is mostly based on citation windows of 4 to 5 years or even more. The length of the selected publication window can, in principle, be set for each subject field. The studies suggested that several indicators rather than one were needed in any specific decision-making process. Disciplinary Impact Factor (DIF) was introduced to overcome the subject bias of citation measure, which was based on the average number of times a journal was cited in a given subfield alone rather than across the entire set of disciplines of the Science Citation Index (Hirst, 1978). In Spain and in Thailand, impact factors are used more as criteria in the allotment of research grants and awards to individuals rather than to institutions. The assessment is based on the journal's impact factors and the numbers of researchers' articles published in those journals. According to Garfield (2001), impact factors would be more reliable if the were related to an individual's research; this could be computed from the numbers of times an individual's research article is referred to by others per number of research articles published. This is in accordance with Seglen's view (Seglen, 1997), stating that using research journal's impact factors to evaluate individuals was quite unfair. In writing a research article one unavoidably needs to refer to other research papers, consequently impact factors occurred.

An Injustice of ISI Impact Factors

Using ISI impact factors in evaluating research works published in the journals has both positive and negative points. One of the good points of using impact factors is that they could stimulate researchers to produce higher quality research work that would be accepted in a high impact-factor journal. However, a negative aspect is that a good researcher and his work could be viewed poorly if his research paper were published in a journal, which had a low impact factor. *This negative judgment occurs when the impact factors of journals in different subject fields are compared universally.* It is the differences in subject fields or subject categories that causes unfairness in the assessment of quality and worth of researchers and research institutions when impact factors are used in that assessment. Because of the different specific tendencies of researchers in making references (Abt & Garfield, 2002; Adam, 2002) and the speed of change and discovery in different subject categories (Bordons, 2002), the journal impact factors of each subject field, as a result, become different. For example, Life Science journals have average impact factors in the range of 2.5–3.0, whereas the impact factors of Engineering and Mathematics journals are about 0.5–1.0 on average. Moreover, the difference in the number of journals and the number of papers published in each subject field are other factors that greatly affect the impact factors. There is a great need to address the issue of fairness in relation to the use of ISI impact factors as an instrument to assess the quality of research work worldwide.

Equalization of the ISI Impact Factors

Our purpose here is to reduce the above-mentioned injustice. To minimize the inaccuracy and unfairness of using journal impact factors in evaluating and comparing the quality of researchers and research institutions in different subject fields, we propose a new and simple mathematical formula (index). The criterion used in this formula is the consideration of both quality and quantity of research works by which the difference of impact factors and subject category has carefully been normalized. The proposed mathematical

TABLE 1. Calculations and values of the IFPA and PC indices for different subject fields.

Category (no. of journals)	Group	Journal titles	2002 Impact factor	Average impact factors in category	Ranking	IFPA	PC
Neurosciences (197)	A	PSYCHOPHARMACOLOGY	3.275	2.766	49	0.891	3.275
	B	INT J PSYCHOPHYSIOL	2.055	2.766	96	0.383	2.055
	C	J NEUROCYTOL	0.993	2.766	146	0.094	0.993
	D	CONFIN CEPHALALGICA	0.035	2.766	193	0.0003	0.035
Pharmacology & Pharmacy (188)	A	MICROB DRUG RESIST	2.565	2.296	46	0.845	2.565
	B	CHIRALITY	1.575	2.296	92	0.352	1.575
	C	ADV THER	0.828	2.296	139	0.095	0.828
	D	BIOPHARM-APPL T BIO	0.113	2.296	184	0.0013	0.113
Medicine, General & Internal (107)	A	MED J AUSTRALIA	1.673	1.880	26	0.676	1.673
	B	CLEV CLIN J MED	0.722	1.880	54	0.192	0.722
	C	J FORMOS MED ASSOC	0.400	1.880	79	0.057	0.400
	D	MED SPORT	0.055	1.880	106	0.0005	0.055
Physics, Multidisciplinary (68)	A	RIV NUOVO CIMENTO	1.565	1.733	17	0.681	1.565
	B	WAVE MOTION	0.840	1.733	34	0.246	0.840
	C	AUST J PHYS	0.385	1.733	51	0.058	0.385
	D	PTB-MITT	0.050	1.733	67	0.001	0.050
Chemistry, Multidisciplinary (119)	A	J PORPHYR PHTHALOCYA	1.421	1.557	30	0.685	1.421
	B	MATCH-COMMUN MATH CO	0.758	1.557	59	0.248	0.758
	C	J SERB CHEM SOC	0.361	1.557	89	0.060	0.361
	D	DOKL CHEM	0.077	1.557	117	0.001	0.077
Plant Sciences (135)	A	PLANT SCI	1.556	1.444	34	0.808	1.556
	B	J PLANT NUTR SOIL SC	0.914	1.444	68	0.316	0.914
	C	J HATTORI BOT LAB	0.434	1.444	101	0.077	0.434
	D	BANGLADESH J BOTANY	0.047	1.444	134	0.0005	0.047
Biology (62)	A	J RADIAT RES	1.934	1.435	15	1.027	1.934
	B	ANN HUM BIOL	0.896	1.435	31	0.317	0.896
	C	FOLIA BIOL-KRAKOW	0.441	1.435	46	0.083	0.441
	D	PERIOD BIOL	0.094	1.435	60	0.003	0.094
Environmental Sciences (132)	A	J AIR WASTE MANAGE	1.496	1.062	33	1.059	1.496
	B	ARCH ENVIRON HEALTH	0.853	1.062	66	0.405	0.853
	C	WATER AIR SOIL POLL	0.526	1.062	98	0.130	0.526
	D	J ENVIRON SCI HEAL C	0.048	1.062	130	0.0010	0.048
Polymer Science (74)	A	COLLOID POLYM SCI	1.182	0.994	18	0.903	1.182
	B	KAUT GUMMI KUNSTST	0.725	0.994	37	0.369	0.725
	C	POLYM POLYM COMPOS	0.387	0.994	55	0.104	0.387
	D	MOD PLAST	0.041	0.994	72	0.002	0.041
Education, Scientific Disciplines (16)	A	TEACH LEARN MED	0.797	0.560	4	1.088	0.797
	B	IEEE T EDUC	0.454	0.560	8	0.429	0.454
	C	INT J TECHNOL DES ED	0.300	0.560	12	0.158	0.300
	D	INT J ELEC ENG EDUC	0.031	0.560	16	0.003	0.031
Engineering, Mechanical (102)	A	FATIGUE FRACT ENG M	0.701	0.553	26	0.948	0.701
	B	INT J VEHICLE DES	0.432	0.553	51	0.394	0.432
	C	SOUND VIB	0.200	0.553	77	0.091	0.200
	D	DIESEL PROG N AM ED	0.003	0.553	102	0.0001	0.003
Mathematics (170)	A	COMPOS MATH	0.601	0.504	42	0.900	0.601
	B	FORUM MATH	0.421	0.504	84	0.425	0.421
	C	Q J MATH	0.299	0.504	126	0.156	0.299
	D	B UNIONE MAT ITAL	0.056	0.504	167	0.003	0.056

formula is entitled *Impact Factor Point Average* (IFPA), as shown in Equation 2:

$$IFPA = \left[\frac{I_j}{I_A}\right] \cdot \left[1 - \frac{R}{N+1}\right] \cdot [n] \qquad (2)$$

where I_J is the impact factor of the journal; I_A is the average impact factor of all journals having the same subject category; and R is the ranking of the journal's impact factor in the same subject category. N is the numbers of journal titles in the same subject category, and n is the number of research articles published by an individual.

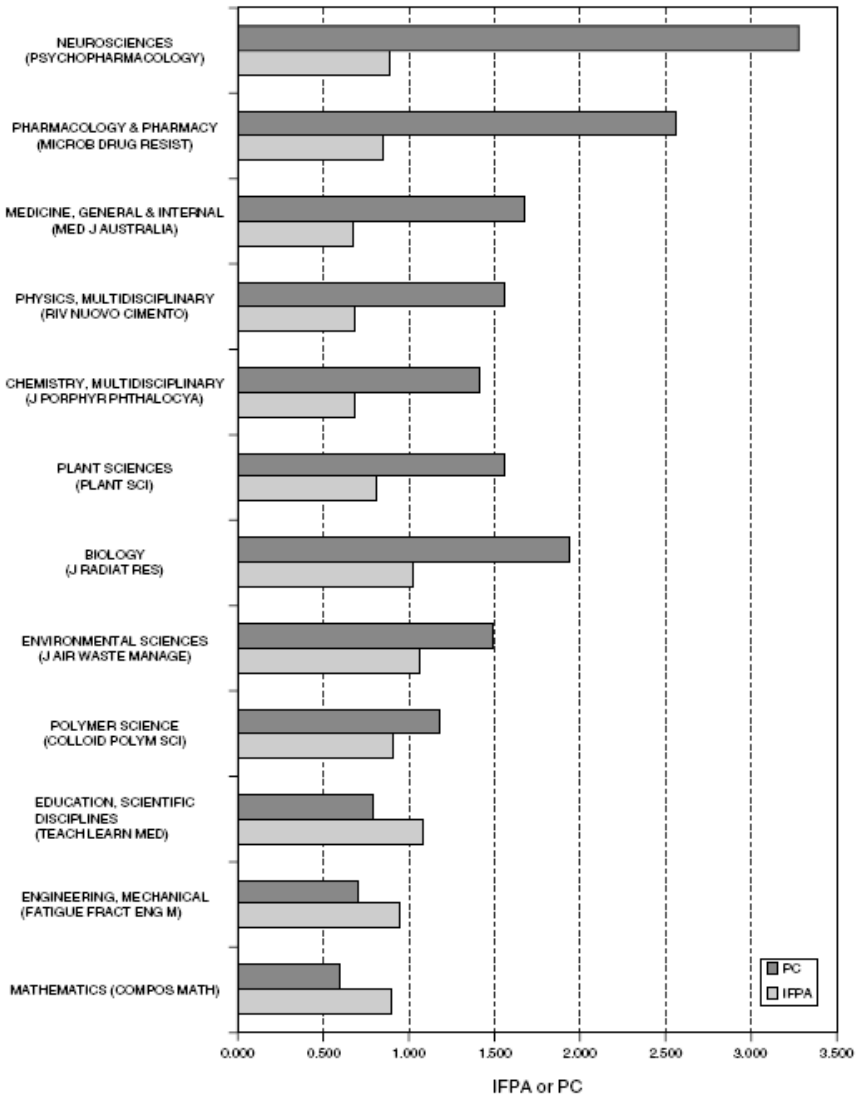

FIG. 1. Values of the IFPA and PC of journals in Group A.

Equation 2 can be characterized into three monomials:

1. Monomial#1 $[I_J/I_A]$ indicates the specific quality of the journal by the journal impact factor value, compared to the quality as a whole of other journals in the same subject category. This monomial can normalize the difference in impact factors of the journals in each subject category.
2. Monomial#2 $[1 - (R/N + 1)]$ indicates the specific quality of the journal by ranking the impact factors of the journal, compared to the quality as a whole of other journals in the same subject category. This monomial can normalize the difference in the numbers of journals in each subject category.
3. Monomial#3 $[n]$ indicates the specific quality of researchers or research institutions, by viewing the quantity of research articles published in the journal.

It is expected that the N value may have an effect on the impact factors of each journal within the category. More journal titles tend to result in lower impact factors for each journal within the category. For instance, *for a given total citation* within a subject category, the impact factors of an individual journal are expected to increase if the number of journal titles in the category is reduced as a researcher would have less choice of the journal titles to cite in his article. In this respect, the R value has to be taken into account to

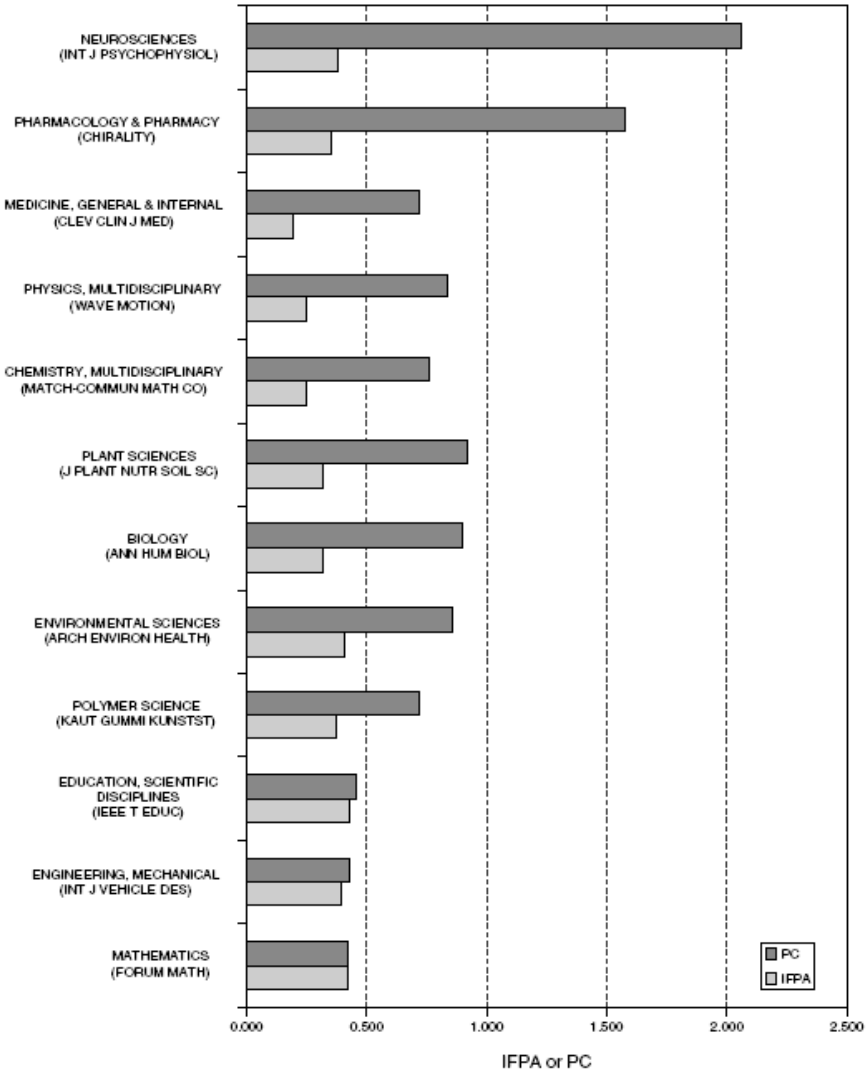

FIG. 2. Values of the IFPA and PC of journals in Group B.

normalize such impact variation, caused by the number of journal titles (*N* value), when evaluating the research quality across subject fields. The use of journal ranking in such an evaluation is of importance and useful, but it must be used carefully with consideration given to the placement of journals into their proper disciplines (Garfield, 1997).

Hypothesis and Proof for the IFPA Index

Our findings show the effectiveness of using the Impact Factor Point Average (IFPA) index to compare the quality of research works produced by researchers or research institutions working in various subject categories. The results of IFPA are then compared with the Publication Credit (PC) within the following hypothesis:

> The articles of researchers or research institutions published in the journal having high impact factors (e.g., ranking in the top 25% in the table of each subject category) might have more or less the same technical quality, despite the different subject categories and journal impact factors.

First we selected original research journals from 12 different subject categories. Four journal titles were then selected per subject category, i.e., a journal ranking in the top 25% of the table, a journal ranking in the middle of the table, a journal ranking in the bottom 25% of the table, and a

journal with the lowest ranking. The highest ranking journal was not used because in some subject categories such high impact factor journals publish review articles, which usually have very high impact factors. Thus, if these review journals were used in comparison with the original article journals, the IFPA may be affected by the difference in the types of articles, and not truly by the differences in subject category as intended. The impact factors used were retrieved from the *Journal Citation Reports* (*JCR*) of the year 2002 in the Science Citation Index database. The selected subject categories (average impact factors) were Neurosciences (2.766), Pharmacology and Pharmacy (2.296), Medicine-General & Internal (1.880), Physics-Multidisciplinary (1.733), Chemistry-Multidisciplinary (1.557), Plant Sciences (1.444), Biology (1.435), Environmental Sciences (1.062), Polymer Science (0.994), Education-Scientific Disciplinary (0.560), Engineering-Mechanical (0.553), and Mathematics (0.504).

An example is given below to illustrate how the IFPA index can be used for normalization of the assessment of research quality of researchers and research institutions in different subject fields. In this regard, four groups of journals in 12 different subject fields are proposed and the IFPA and PC indices are calculated as shown in Table 1 (It should be noted that, for each group the number of articles published by an author was equivalent to one, thus $n = 1$).

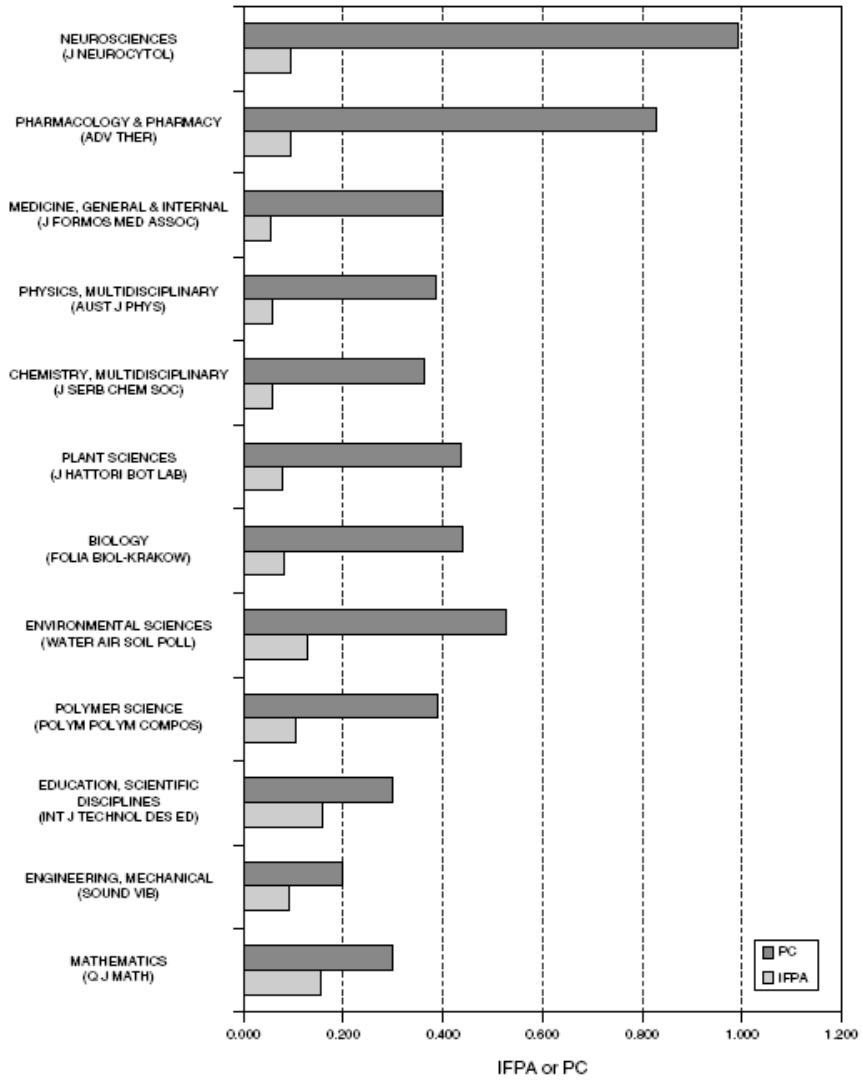

FIG. 3. Values of the IFPA and PC of journals in Group C.

- Journals in Group A (Figure 1): Each of the 12 researchers' articles was published in the journal ranking in the top 25% of the table of their own subject category.
- Journals in Group B (Figure 2): Each of the 12 researchers' articles was published in the journal ranking in the middle of the table of their own subject category.
- Journals in Group C (Figure 3): Each of the 12 researchers' articles was published in the journal ranking in the bottom 25% of the table of their own subject category.
- Journals in Group D (Figure 4): Each of the 12 researchers' articles was published in the journal ranking in the lowest of the table of their own subject category.

From the hypothesis, the 12 researchers within each group should be considered *equally* and evaluated in terms of their scholarly quality; although they work in different subject fields and their initial impact factors of the journals, they had published, were different. The results of the IFPA calculations in Table 1 and Figures 1–4 are in line with the hypothesis. Figures 1–4 also show that if impact factors were the only criterion used to assess the quality of research work (as used in Equation 1), the researchers working in relatively high impact factor subject categories, such as Neurosciences and Pharmacology and Pharmacy would have an advantage over those who work in some of the other categories, such as Engineering and Mathematics. The findings as shown in Figures 1–4 prove clearly that the use of the IFPA enhances the equality in assessing the quality of research works produced by researchers who work in different subject categories, the

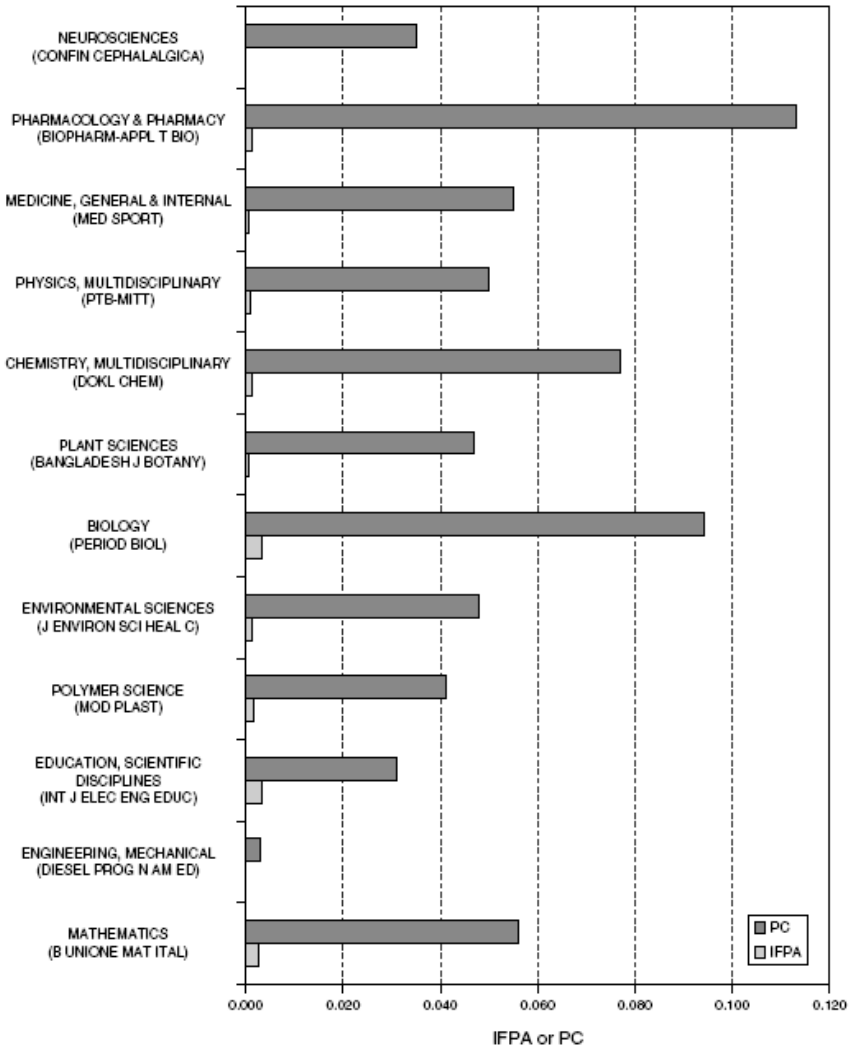

FIG. 4. Values of the IFPA and PC of journals in Group D.

assessment being more precise for journals with lower impact factors. Most subfield-related works by Vinkler (1997, 2002) attempted to introduce various scientometric indicators to assess the performance of researchers working in different subject fields. One of these was Relative Publication (RP) indicator, which was referred to as a ratio of the weighted sum of the ISI impact factors where the papers of a given researcher were published to the mean ISI impact factors of the journals dedicated to the respective field multiplied by the number of the papers evaluated. With this RP indicator, the unfairness remained, especially for the researchers in engineering science, since the mean value of the ISI impact factors, varying from one subject field to another, is dependent on the number of journal titles within each category. However, by using the IFPA index, the discrepancies of the impact assessment across the subject fields due to the number of journal titles were minimized by the journal ranking factor (Monomial#2 = $[1 - (R/N + 1)]$).

In conclusion, the findings in this work at least offer a promising practice for the assessment of the research quality of researchers and research institutions in different subject fields, although it is agreed among members of the bibliometrics community that the quality of an individual's research should have been computed from the numbers of times an individual's research article is referred to by others per number of research articles published (Garfield, 2001). But, this assessment may cause unfairness, especially in the case where the citation natures across disciplines are considered. For example, mathematics researchers rarely cite more than one or two references, whereas a typical paper in molecular biology cites more than 10, this causing a wide variation in impact factors (Abt & Garfield, 2002; Adam, 2002; Pudovkin & Garfield, 2002). However, as long as the ISI impact factors are internationally accepted the best thing we can do is to make them as equal as possible.

Conclusion

The Impact Factor Point Average (IFPA) index proposed in this article is very simple and can be used with equality as a suitable tool for assessing the research quality of researchers and research institutions in different subject fields through the use of the existing ISI journal impact factors. The use of the IFPA index is more precise for low impact factor journals.

Acknowledgments

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A modified method for calculating the Impact Factors of journals in ISI Journal Citation Reports: Polymer Science Category in 1997–2001

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This article introduces a new modified method for calculating the impact factor of journals based on the current ISI practice in generating journal impact factor values. The impact factor value for a journal calculated by the proposed method, the so-called Cited Half-Life Impact Factor (CHAL) method, which is based on the ratio of the number of current year citations of articles from the previous X years to that of articles published in the previous X years, the X value being equal to the value of the cited half-life of the journal in the current year. Thirty-four journals in the Polymer Science Category from the ISI Subject Heading Categories were selected and examined. Total citations, impact factors and cited half-life of the 34 journals during the last five years (1997-2001) were retrieved from the ISI *Journal Citation Reports* and were used as the data source for the calculations in this work, the impact factor values from ISI and CHAL methods then being compared. The positions of the journals ranked by impact factors obtained from the ISI method were different from those from the CHAL method. It was concluded that the CHAL method was more suitable for calculating the impact factor of the journals than the existing ISI method.

Introduction

The journal impact factor is one of three indexes created by the Institute for Scientific Information (ISI): the impact factor, the immediacy index, and the cited half-life, first introduced in the 1970s by Garfield, and published annually in *Journal Citation Reports* (JCR). However, the most prominent of all the three measures is the journal impact factor (IF), which, according to Garfield[1,2] is a measure of the frequency with which the average cited article in a journal has been cited in a particular year or period. The definition of IF is a ratio between citations and recent citable items published, the calculations being carried out by dividing the number of current year citations by the source items published in that journal during the previous two years.

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The impact factor becomes a citation-based measure for characteristic and significance of journals in international environment.

The journal impact factor has been widely used by many researchers and institutions, for instance, librarians to make decisions concerning journal subscriptions, academic staff and researchers to disseminate their research outcomes, and editors and publishers who use favorable impact factor values as promotional tools for their journals.[1] In addition, the impact factors has been increasingly used by science policy makers to monitor the status of science and technology activities locally, by accreditation organizations in the process of academic evaluation, and by granting agencies into the allocation of research funds. The impact factor has become perhaps the most popular bibliometric product and is widely used not only in the bibliometric environment, but also outside the scientific community. Impact factors used for various reasons are globally endemic. In Spain and Finland, for example, the journal impact factor has been canonized into law. In Spain, for instance, a system of publication bonus was passed into law in 1998 in order to improve the quality of Spanish science and its visibility in journal, and consequently, Spanish scientific publications doubled soon after. Universities in Germany are another example of where impact factors are used. They require impact factors of journals in which researchers publish in the process of determining departmental funding.[3,4] In Thailand, impact factors have been used as an essential part in the process of determining academic promotions and research fund granting for individuals, and also measuring the quality of universities and organizations. As a consequence, the Thai journal impact factor was created as is detailed in Sombatsompop et al.[5]

The factors that have caused the impact factor to become one of the most internationally prominent measuring tools are its comprehensive use, up-to-date, and fast availability. The JCR which contain these indexes are produced in either CD-ROM format or web-based version. In addition, journals with high impact factors in each discipline are regarded to be of high quality. The strict peer-review process, and high competition guarantees the quality of papers published in these journals. In addition, there are currently no other more suitable scientometric indicators standardized, regularly published and easily accessed for international journals' characteristics than the ISI impact factor. However, the ISI-IF has many limitations in both technical and methodological aspects,[6] particularly in the major factors the citation impact is mainly influenced by, which include the document type, the subject matter, the paper's age, the paper's 'social status', and the observation period ('citation window'). These include (i) there is no normalization for reference practices and traditions in the different fields and disciplines, (ii) there is no distinction in regard to the nature and merits of the citing journals,[6] (iii) there is a bias in favor of journals with lengthy papers, e.g. review journals, which are secondary publications, tend to produce higher impact factor than primary publication journals which carry original research articles,[7,8] (iv) the value of

the impact factors is affected by the subject area. Mathematics researchers, for instance, rarely cite more than one or two references, whereas a typical paper in molecular biology does more than ten. This practice causes a wide variation in impact factors,[4] (v) a high impact factor value of one journal does not correlate to the high citation rate of each article in that journal. It is possible that high-impact factor journals obtain most of their citations from a few articles published in the journal,[2,7,9] (vi) the concept of citable documents is not operationalized adequately. The "non-source" items (for the denominator), such as editorials, book reviews, and letters to the editor, may not count, while citations to such 'non-source' articles are counted in the numerator in the calculation method of the impact factor,[4,8] (vii) the journal impact factors published in ISI's *Journal Citation Reports* are sometimes inaccurate for a number of journals, and (viii) the two-years citation window used in the calculation method by ISI "is considered too short to detect the real impact of the publication in 'slow' evolving disciplines".[7] This statement is supported by Garfield[10] who wrote "if we change the two-year based period used to calculate impact, some types of journals are found to have higher impacts".

Literature review

The wide use of the ISI impact factors and limitations and shortfalls thereof have led a number of researchers and scholars in many countries conduct projects either to improve the impact factor based on the mentioned factors or to develop more sophisticated or alternative journal citation measures. Hirst[11] introduced the Disciplinary Impact Factor (DIF) to overcome the subject bias of citation measure and its measure was based on the average number of times a journal was cited in a given sub-field alone rather than across the complete set of *Science Citation Index*. Asai[12] introduced an Adjusted Impact Factor, which counts the weighted sum of citations over a period of four years. Glänzel and Schoepflin[13] found that the three-year citation window proved to be a good compromise between the fast obsolescence of technology oriented literature of most areas in life sciences, and of experimental physics literature, on the one hand, and of the slowly aging theoretical and mathematical topics in physics, on the other hand. Moed et al.[14] proposed a new classification of journals in terms of their aging characteristics. From an analysis across all subfields the authors concluded that aging characteristics are primarily specific to the individual journal rather than to the subfield. Vinkler[15] introduced a new indicator so-called "Standard Journal Impact, SJI" as a comparable impact indicator for journals in different subfields. He stated that the main reason for the lower impact factor journals was mainly caused by lower extent of the application of their results by other subfields. van Leeuwen and Moed[16] described the development and application of journal impact factors in 4 bibliometric studies in the Center for Science & Technology Studies (CWTS) in the Netherlands.

The appropriateness of the use of each study was evaluated. Furthermore, the so-called Journal to Field Impact Score (JFIS) was presented as an alternative journal impact measure. The JFIS is field-normalized. This means that a journal's impact is compared the world citation average in the fields it covers, which is defined by ISI in Journal Subject Categories. The JFIS is mostly based on citation windows of four to five years or even more. The length of the selected publication window can in principle be set to any length. The studies suggested that several indicators rather than one were needed in any specific decision making process. The Standard Journal Impact proposed by Vinkler[15] was based on the number of citations obtained in year Y, where the impact factor was calculated, to papers published in a single X year, prior to year Y, divided by the number of papers published in year X. The number of years used for SJI index was then calculated using a period which lasted from the maximum SJI value to its half. Glänzel and Moed[6] summarized many attempts to improve the ISI impact factors which included, for example, weighting a citation on the basis of the journals in which it is made rather than integer counting of citations; applying a range of citing years rather than application of a single citing year; disaggregating articles on the basis of document type (article, communication, technical note and review) or content (e.g. theoretical, methodological and experimental) rather than analyzing all "citable" documents; and analyzing articles from older "ages" rather than considering only papers of 1-2 years earlier. Vinkler[17] presented a new indicator called Specific Impact Contribution (SIC) to be used equally with the ISI impact factors in the assessment of the publications of the Hungarian Academy of Sciences. The SIC was relating the citation share of a respective team (or journal) in the total citations of the teams (or journals) evaluated to its share in publication. It was found that the normalized IF and the normalized SIC were identical measures within any selected set of journals.

Of the above studies, there were a number of papers that touched upon the citation window used in the calculation method for the IF. However, none of these papers paid attention to the cited half-life, which is another index produced simultaneously with the impact factor in the JCR. In this article, we have applied the cited half-life into the calculation of the impact factor as it is our opinion that these two factors have to be related to one another since they are calculated from the same source of data. The principle of the calculations of the impact factor proposed in this work is based on dividing the number of current year citations by the total number of articles published in that journal in X years, where X is equal to the value of the cited half life.

Research assumptions and rationale

Three research assumptions are proposed in this study as follows.

1. We do agree with previous studies,[7,12,13] which stated that the citation window of two years is not appropriate for generating the proper impact factor.

According to Garfield, the cited half-life value indicates the number of publication years from the current year, which accounts for fifty percent of current citations received. This means that articles of a journal published within the period of the cited half-life should have been worthy and citable, and they should be taken into the calculation of the impact factor of the journal. This also means that the window citation should (or must) vary from one journal to another journal, depending on their individual cited half-life values.

2. It is reasonable to think that the total citations (reported in JCR) for any journal should correlate with the impact factor value within the same year because if a journal receives higher total citations in the current year, its impact factor is expected to increase assuming that the number of papers published remains constant. However, this is not the case when calculating the impact factor with the ISI method. Therefore, a method for calculating the impact factor that could achieve such a correlation must be introduced.
3. The two-year citation window used in the calculation method by ISI is too short to calculate an appropriate impact of the publication. The citation window for each journal should not be the same, but should correlate with the cited half-life index whose value measures the number of publication years from the current year, which accounts for fifty percent of current citations received.

Experimental

Design of calculation

In this article, thirty-four journals listed in the Polymer Science Category in the *Journal Citation Reports* (JCR) were selected. Data were retrieved from the JCR on the total citations, impact factors, numbers of articles, cited half-life for the 34 journals during the past five years (from 1997 to 2001). Two preliminary criteria for choosing the journals for the present study were journals must have the values of cited half-life index during the past five years, and the work should cover different types of journals such as review and original article journals. The calculation of the impact factor proposed in this work is based on the ratio of the number of times cited in the current year of articles published in the previous X years, to the number of articles published in the previous X years (see also Equation 1), the X value being equal to the value of cited half-life of the journal in the current year. This method as proposed in this work is called the CHAL-Impact Factor (CHAL-IF). Table 1 shows the values of cited half-life, times cited and number of articles in the previous cited half-life years. In Equation 1, T_C is the number of times cited in the current year of articles published in the previous X years, and N_A is the number of articles published in the previous X years, both values being used for calculating the impact factor via the CHAL method. It should also be

noted that some of the values of T_C and N_A are shown in decimal points and this is because the value of X is not a full number.

$$\mathrm{CHAL} = \frac{T_C}{N_A} \quad . \tag{1}$$

Data analysis

Comparisons of the impact factors calculated by ISI and CHAL methods are made, in connection with the value of total citations and the stability of the impact factor calculated.

1. Correlation with total citations: This determines how the values of ISI and CHAL correlate with the total citations for each journal in the current year. This would prove our assumption in that the total citations (reported in JCR) for any journal should correlate with the impact factor value within the same year.
2. Impact factor stability. This is referred to as the stability of the impact factor values calculated by ISI and CHAL as compared with those of the total citations. The stability of the impact factor was expressed in terms of percentage coefficient of variation (%V), which was calculated using Equation 2:

$$\%V = \frac{SD}{\overline{X}} \times 100 \quad , \tag{2}$$

where SD is the standard deviation and
$\overline{X}$ is the mean of the data set.

Results and discussion

Table 2 shows the values of the total citations, ISI impact factor, and CHAL impact factor with their average values for 34 selected journals in Polymer Science Category during 1997–2001, the results being expressed from low to high values of average total citations. It can be observed that the average total citations of the selected journals ranged from 190.4 *(Polymer Testing)* to 44816 *(Macromolecules). Advances in Polymer Science,* and *Progress in Polymer Science* were the journals that gave relatively high impact factors whereas *Journal of Composites Technology and Research, Kautschuk Gummi Kunststoffe, Kobunshi Ronbunshu* and *Mechanics of Composite Materials* gave relatively low impact factors in this category. It should be noted that *Advances in Polymer Science,* and *Progress in Polymer Science* were review journals, which usually gain high citations in nature.[18] A relationship between average total citations and average impact factors calculated by the ISI and CHAL methods is expressed in

Figure 1. The average impact factors obtained from the ISI method for any given journals were found to be different from those obtained from the CHAL method, the CHAL impact factor values being slightly higher than the ISI impact factor values for most journals reported in this work. This would probably result from the fact that the citation window for the CHAL method was greater than that for the ISI method, this view also being supported by Bordons et al.[7] and Garfield.[10] However, Figure 2 shows that the relationship of the average impact factors obtained by the ISI and CHAL methods was linear, suggesting that the CHAL method was appropriate to an extent, for calculating the impact factors of the journals. The average values of the impact factor of the 34 selected journals obtained from the ISI and CHAL methods were 1.133 and 1.277, respectively, these values being calculated by including the two review journals *(Progress in Polymer Science* and *Advances in Polymer Science)* which had relatively high impact factors. If these two review journals were excluded, the average values of the impact factor, for journals mainly publishing original articles, obtained from the ISI and CHAL methods were then 0.882 and 0.984, respectively, the difference calculated to be ~11.56%. Again, it was found that the average impact factor calculated from CHAL was still higher. These average values are very important since the latest statistic by Amin and Mabe[18] reported that journals falling into the materials science and engineering, and materials related categories, including Polymer Science Category had an average impact factor of ~0.6. The results presented in this work clearly indicates that the average impact factor of the journals in Polymer Science Category have now increased by 50-65%.

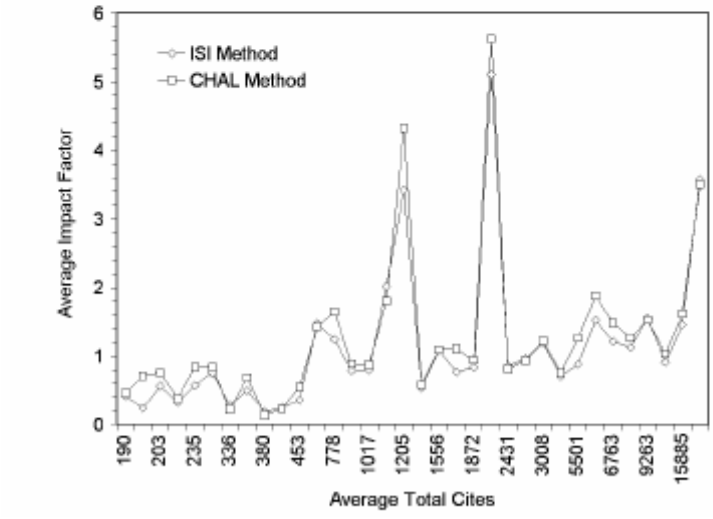

Figure 1. A plot of average total citations against average inpact factors calculated by the ISI and CHAL methods

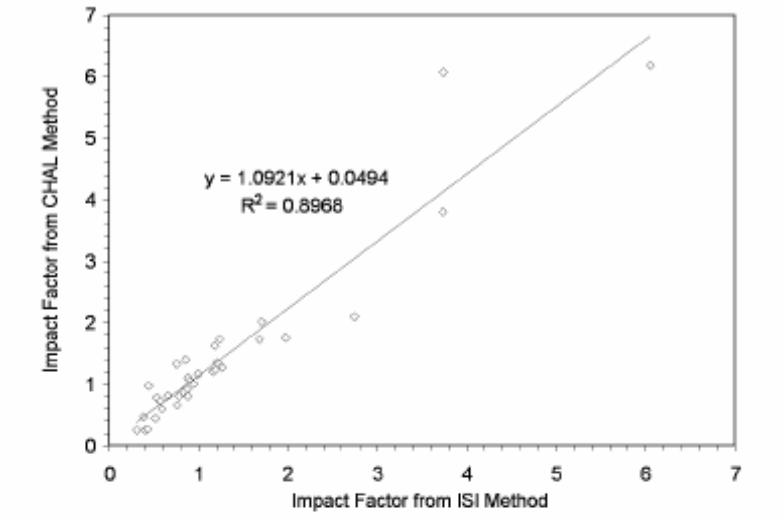

Figure 2. Relationship of the average impact factors obtained by the ISI and CHAL methods

Table 3 shows the values of the total citations, ISI and CHAL impact factors, and standard deviations (SD) and their percentage coefficient of deviations (%V) for the 34 selected journals in the Polymer Science Category during 1997–2001, the results being expressed from low to high %V values. The %V value indicates a stability of the interested values (total citations and impact factors in this case). As stated earlier in our assumptions and rationale, the impact factors of any journal should have been correlated with the number of total citations since the higher (more improved) total citations for a journal should have directly indicated greater popularity of the articles published in the journals which then reflects on higher impact factors. Therefore, the %V value was best used for comparing such a correlation of total citations and impact factors, which were obtained from the ISI and CHAL methods. The data from Table 3 were used to establish a relationship between the total citations and impact factors from the two methods and the results are shown in Figure 3. It can be clearly seen that the %V curve of the impact factors by the CHAL method was closer to the %V curve of the total citations, than that by ISI method. This effect was more pronounced for journals with low %V values. This also suggested that the change in impact factor calculated by the CHAL method had a better correlation with the total citations than that calculated by the ISI method.

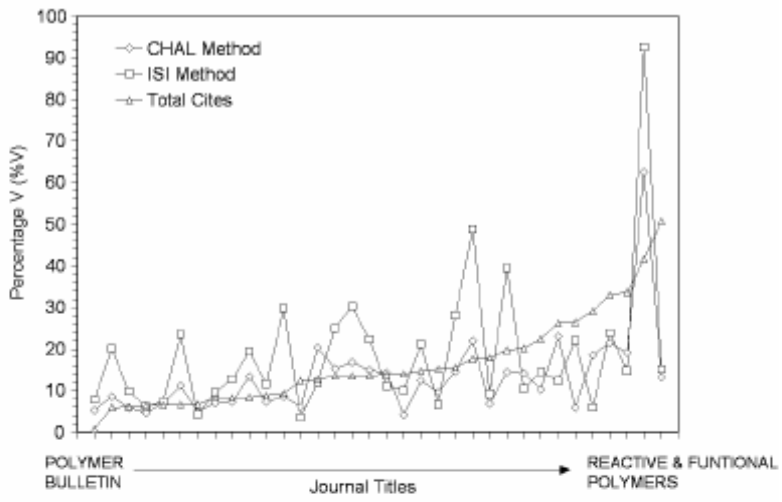

Figure 3. Percentage V (%V) for different journals with regard to total citations and impact factors

Table 4 shows the values of the total citations, the ISI and CHAL journal impact factors for 12 selected journals that have relatively low %V values (less than 10%). It can be clearly seen that the journal impact factors calculated from the CHAL method corresponded better with the total citations when compared with those calculated from the ISI method. The average %V values for total citations and CHAL impact factor were 6.863 and 7.577, respectively, whereas those by the ISI impact factor were 13.505.

Another interesting point to consider in the relationship between the total citations and impact factors was an abrupt change in the total citations for two continuing years. It is generally understood that if a journal obtained a significant increase in total citations, its impact factor is expected to increase considerably regardless of the calculation method proposed by ISI (calculating the impact factor from citation of 2 years back). Table 5 illustrates the changes in total citations and the impact factors of 7 selected journals that had an abrupt increase in the total citations, the results being expressed in terms of percentage difference of the changes in total citations and impact factors for the selected pairs. It can be seen that the %difference values of the impact factor pairs by the CHAL method were relatively more similar to those of the total citations.

All the results presented in this work clearly indicates that the journal impact factor calculated by the CHAL method was more suitable for evaluating the citations of articles published in journals than that obtained by the existing ISI method in the case where the change in the total citations of the journals was mainly considered.

Table 1. Values of cited half-life, times cited and number of articles during 1997–2001

No.	Full journal title	Cited halfe-life				
		2001	2000	1999	1998	1997
1	POLYMER TESTING	4.4	5.3	6.2	5.3	5.6
2	JOURNAL OF COMPOSITES TECHNOLOGY AND RESEARCH	7.9	7.6	6.9	5.6	5.9
3	JOURNAL OF BIOACTIVE AND COMPATIBLE POLYMERS	7.3	6.1	7.3	6.3	5.9
4	POLYMER-PLASTICS TECHNOLOGY AND ENGINEERING	6.7	6.8	7.3	7.7	6.6
5	ADVANCES IN POLYMER TECHNOLOGY	7.4	6.5	6.5	6.7	5.8
6	REACTIVE & FUNCTIONAL POLYMERS	3.6	3.6	3.2	2.6	1.7
7	KAUTSCHUK GUMMI KUNSTSTOFFE	8	7.4	6.7	6.4	6.2
8	INTERNATIONAL POLYMER PROCESSING	6.9	6.9	6.2	5.5	4.7
9	MECHANICS OF COMPOSITE MATERIALS	10	10	10	10	10
10	KOBUNSHI RONBUNSHU	8.2	8.4	7.4	8.2	7.6
11	JOURNAL OF REINFORCED PLASTICS AND COMPOSITES	6.5	6.7	6.3	5.9	5.1
12	MACROMOLECULAR THEORY AND SIMULATIONS	4.3	4.3	3.7	2.9	2.7
13	JOURNAL OF BIOMATERIALS SCIENCE-POLYMER EDITION	5	5.2	5.2	4.6	3.9
14	JOURNAL OF MACROMOLECULAR SCIENCE-PHYSICS	10	10	10	10	10
15	POLYMER INTERNATIONAL	4.4	4.5	4.3	4.5	3.8
16	ACTA POLYMERICA	5.4	5	5	4.8	4.7
17	PROGRESS IN POLYMER SCIENCE	6.2	6.2	6.1	5.7	5.2
18	ANGEWANDTE MAKROMOLEKULARE CHEM	8.6	9	8.4	8.9	7.6
19	CARBOHYDRATE POLYMERS	6.8	6.3	6.1	5.6	5.3
20	RUBBER CHEMISTRY AND TECHNOLOGY	10	10	10	10	10
21	POLYMER DEGRADATION AND STABILITY	5.9	5.9	5.9	5	5
22	ADVANCES IN POLYMER SCIENCE	10	10	10	10	10
23	POLYMER BULLETIN	9	8.6	7.8	7.3	6.8
24	POLYMER JOURNAL	10	10	10	8.6	8.3
25	COLLOID AND POLYMER SCIENCE	8.7	8.8	8.3	8.7	8.2
26	EUROPEAN POLYMER JOURNAL	10	10	10	10	10
27	POLYMER ENGINEERING AND SCIENCE	10	10	10	10	10
28	JOURNAL OF MEMBRANE SCIENCE	6.2	6.2	5.8	5.7	5.4
29	JOURNAL OF POLYMER SCIENCE PART B- POLYMER PHYSICS	10	10	10	10	10
30	SYNTHETIC METALS	5.7	5.5	5.2	5.2	4.7
31	JOURNAL OF POLYMER SCIENCE PART A- POLYMER CHEMISTRY	8.6	8.9	10	10	10
32	JOURNAL OF APPLIED POLYMER SCIENCE	8	7.9	8.1	8.2	8.1
33	POLYMER	7.2	7.1	7	6.7	6.4
34	MACROMOLECULES	6.4	6.2	6.2	5.9	5.6

Table 1 (continued)

No.	No. of times cited					No. of articles				
	2001	2000	1999	1998	1997	2001	2000	1999	1998	1997
1	150	122	96.6	89.5	71.4	251	237.7	250	207	199.8
2	168.4	114.2	118.2	111.4	112.6	211.9	202.6	185.9	159.6	163.1
3	130.4	110.4	98.9	113.5	128.3	178.6	156.4	163.4	141.4	135.2
4	158.4	141	123.4	103.5	110.6	355.3	336	326.5	347.9	280.2
5	157.4	162	139	118.5	113.2	193.4	170.5	164.5	157.3	135.2
6	342.4	353.6	252	211.8	101.1	372	372.2	318.8	254.4	149.8
7	222	175.6	196.8	170.6	176.8	823	890.2	845.9	831.4	924.8
8	261.6	234.9	242.8	152	118.9	335.3	330.6	294.6	259.5	226.1
9	163	140	111	62	41	653	774	843	902	957
10	227.4	218.6	238.2	253	220.6	889.4	1054.1	939.4	1066.4	983.2
11	277	302.3	265.3	301.7	234.5	591.5	602.4	531.5	473.5	376.1
12	380.7	390.4	323.1	350.5	317.6	298.6	296.6	264.4	207.8	196.5
13	606	545.4	531	470	447.6	350	353.4	339.4	287.2	254.3
14	361	343	322	242	228	413	382	326	297	266
15	912.4	719	551.9	492	425.4	824.6	730	662.3	693	572.6
16	640.4	649	657	565.8	426.3	305.2	343	357	309.8	315.2
17	924.6	781.6	729.6	600.2	517.8	152.4	187.4	180.3	162.1	141.8
18	728.8	692	805	713.4	658	1106.8	1330	1251.8	1353.8	1171.2
19	1162	898.2	896.4	808	725.5	862	941.6	806.1	763.6	726.7
20	642	604	693	562	478	483	541	537	538	624
21	1352.2	1194.3	1031.6	926	731	1281	1235.9	1164.5	929	904
22	157.4	162	139	118.5	113.2	193.4	170.5	164.5	157.3	135.2
23	1341	1377	1361.8	1344	1315.8	1657	1813	1706	1611.2	1504.2
24	1473	1497	1365	1356	1272	1463	1635	1548	1437.8	1344.9
25	1712.9	1676	1688.4	1589.2	1463.8	1382.8	1382.2	1288.6	1335.3	1260.6
26	1828	1582	1500	1488	1530	2258	2173	2121	1855	2034
27	2628	2576	2677	2592	2475	1878	2116	2071	2111	2110
28	4088.2	3770	3472	2936.6	2627	2032	1895	1743	1685	1493
29	3400	3359	3237	2704	2830	2091	2271	2130	2021	1940
30	5591.6	4984	5110.2	5078	4575.1	4641.5	4699	3595.6	4267.6	3132.6
31	6019	5001.3	5057	4201	3855	3424.2	3236.7	3039	3066	2950
32	9370	6982.2	7930.4	6795.4	6088.5	8023	7582.9	7182.3	6806.6	6214.2
33	10280.4	9132.4	8919	7718.4	7075	5940.8	5637.6	5567	4988.6	4466.2
34	29036.2	26923.4	25136.2	22861.8	22179.2	7643.4	7357.2	7355.2	6979.4	6555.2

Table 2. Values of the total citations and impact factors by ISI and CHAL methods for 34 selected journals during 1997–2001

No.	Full journal title	Total citations					
		2001	2000	1999	1998	1997	average
1	POLYMER TESTING	278	224	173	164	113	**190.4**
2	JOURNAL OF COMPOSITES TECHNOLOGY AND RESEARCH	251	187	195	174	163	**194**
3	JOURNAL OF BIOACTIVE AND COMPATIBLE POLYMERS	235	201	169	185	226	**203.2**
4	POLYMER-PLASTICS TECHNOLOGY AND ENGINEERING	286	249	221	177	190	**224.6**
5	ADVANCES IN POLYMER TECHNOLOGY	263	255	220	222	216	**235.2**
6	REACTIVE & FUNCTIONAL POLYMERS	537	470	301	242	120	**334**
7	KAUTSCHUK GUMMI KUNSTSTOFFE	416	318	358	290	297	**335.8**
8	INTERNATIONAL POLYMER PROCESSING	427	408	402	272	202	**342.2**
9	MECHANICS OF COMPOSITE MATERIALS	535	490	445	158	274	**380.4**
10	KOBUNSHI RONBUNSHU	419	408	444	450	389	**422**
11	JOURNAL OF REINFORCED PLASTICS AND COMPOSITES	508	516	425	454	364	**453.4**
12	MACROMOLECULAR THEORY AND SIMULATIONS	673	613	507	593	482	**573.6**
13	JOURNAL OF BIOMATERIALS SCIENCE-POLYMER EDITION	1027	907	783	681	494	**778.4**
14	JOURNAL OF MACROMOLECULAR SCIENCE-PHYSICS	930	876	884	773	756	**843.8**
15	POLYMER INTERNATIONAL	1478	1252	931	764	660	**1017**
16	ACTA POLYMERICA	1111	1110	1118	957	807	**1020.6**
17	PROGRESS IN POLYMER SCIENCE	1633	1376	1207	974	837	**1205.4**
18	ANGEWANDTE MAKROMOLEKULARE CHEM	1327	1320	1475	1330	1229	**1336.2**
19	CARBOHYDRATE POLYMERS	2043	1627	1535	1350	1225	**1556**
20	RUBBER CHEMISTRY AND TECHNOLOGY	2028	1755	2021	1670	1501	**1795**
21	POLYMER DEGRADATION AND STABILITY	2333	2213	1878	1628	1308	**1872**
22	ADVANCES IN POLYMER SCIENCE	2616	2546	2396	2236	2150	**2388.8**
23	POLYMER BULLETIN	2404	2441	2447	2441	2422	**2431**
24	POLYMER JOURNAL	2852	2834	2557	2595	2446	**2656.8**
25	COLLOID AND POLYMER SCIENCE	3191	3069	3148	2922	2711	**3008.2**
26	EUROPEAN POLYMER JOURNAL	3338	3141	3014	2870	2936	**3059.8**
27	POLYMER ENGINEERING AND SCIENCE	5808	5716	5741	5230	5012	**5501.4**
28	JOURNAL OF MEMBRANE SCIENCE	7218	6487	5915	5091	4604	**5863**
29	JOURNAL OF POLYMER SCIENCE PART B- POLYMER PHYSICS	7371	7096	6955	5995	6399	**6763.2**
30	SYNTHETIC METALS	9732	8564	8958	8069	7933	**8651.2**
31	JOURNAL OF POLYMER SCIENCE PART A- POLYMER CHEMISTRY	11142	9666	9636	8227	7642	**9262.6**
32	JOURNAL OF APPLIED POLYMER SCIENCE	17128	15459	14779	12709	11649	**14344.8**
33	POLYMER	19003	16820	15972	14261	13369	**15885**
34	MACROMOLECULES	51753	48704	44707	40831	38086	**44816.2**

Table 2
(contiunued)

No.	Impact Factor by ISI method						Impact Factor by CHAL method					
	2001	2000	1999	1998	1997	average	2001	2000	1999	1998	1997	average
1	0.590	0.392	0.330	0.419	0.370	**0.420**	0.597	0.513	0.386	0.432	0.357	**0.457**
2	0.438	0.209	0.167	0.140	0.258	**0.242**	0.974	0.563	0.635	0.697	0.690	**0.712**
3	0.571	0.426	0.378	0.651	0.800	**0.565**	0.730	0.705	0.605	0.802	0.948	**0.758**
4	0.515	0.345	0.317	0.152	0.310	**0.328**	0.445	0.419	0.377	0.297	0.394	**0.386**
5	0.659	0.714	0.583	0.280	0.623	**0.572**	0.813	0.950	0.844	0.753	0.837	**0.839**
6	0.873	0.836	0.592	0.784	0.687	**0.754**	0.920	0.950	0.790	0.832	0.674	**0.833**
7	0.429	0.231	0.274	0.274	0.236	**0.289**	0.269	0.197	0.232	0.205	0.191	**0.219**
8	0.529	0.514	0.490	0.500	0.451	**0.497**	0.780	0.710	0.824	0.585	0.525	**0.685**
9	0.405	0.333	0.196	0.019	0.012	**0.193**	0.249	0.180	0.131	0.068	0.042	**0.134**
10	0.307	0.191	0.275	0.200	0.250	**0.245**	0.255	0.207	0.253	0.237	0.224	**0.235**
11	0.383	0.312	0.321	0.368	0.404	**0.358**	0.468	0.501	0.499	0.637	0.623	**0.546**
12	1.267	1.348	1.134	1.916	1.729	**1.479**	1.274	1.316	1.222	1.686	1.616	**1.423**
13	1.234	1.669	1.192	1.228	0.901	**1.245**	1.731	1.543	1.564	1.636	1.760	**1.647**
14	0.833	0.792	0.897	0.647	0.776	**0.789**	0.874	0.897	0.987	0.814	0.857	**0.886**
15	0.882	0.920	0.822	0.721	0.634	**0.796**	1.106	0.984	0.833	0.709	0.742	**0.875**
16	2.740	1.935	2.229	1.817	1.379	**2.020**	2.098	1.892	1.840	1.826	1.352	**1.802**
17	3.738	3.698	3.625	2.737	3.300	**3.420**	6.066	4.170	4.046	3.702	3.651	**4.327**
18	0.755	0.469	0.482	0.488	0.465	**0.532**	0.658	0.520	0.643	0.526	0.561	**0.582**
19	1.203	1.184	0.987	1.129	0.956	**1.092**	1.348	0.953	1.112	1.058	0.998	**1.094**
20	0.752	0.678	0.924	0.733	0.762	**0.770**	1.329	1.116	1.290	1.044	0.766	**1.109**
21	0.905	0.960	0.641	0.854	0.811	**0.834**	1.055	0.966	0.885	0.996	0.808	**0.942**
22	6.053	5.446	4.976	4.486	4.563	**5.105**	6.184	5.804	5.702	5.131	5.325	**5.629**
23	0.880	0.794	0.853	0.941	0.777	**0.849**	0.809	0.759	0.798	0.834	0.874	**0.815**
24	0.941	1.026	0.918	0.979	0.974	**0.968**	1.006	0.915	0.881	0.943	0.945	**0.938**
25	1.186	1.132	1.269	1.116	1.268	**1.194**	1.238	1.212	1.310	1.190	1.161	**1.222**
26	0.779	0.745	0.720	0.600	0.677	**0.704**	0.809	0.728	0.707	0.802	0.752	**0.760**
27	0.854	0.797	0.902	0.975	0.878	**0.881**	1.399	1.217	1.292	1.227	1.172	**1.261**
28	1.706	1.587	1.581	1.406	1.360	**1.528**	2.011	1.898	1.991	1.742	1.753	**1.879**
29	1.180	1.268	1.265	1.031	1.327	**1.214**	1.626	1.479	1.519	1.337	1.458	**1.484**
30	1.158	0.802	1.376	1.054	1.254	**1.129**	1.204	1.060	1.421	1.189	1.460	**1.267**
31	1.975	1.711	1.630	1.237	1.202	**1.551**	1.757	1.545	1.664	1.370	1.306	**1.528**
32	0.992	0.881	0.953	0.886	0.841	**0.911**	1.167	0.920	1.104	0.998	0.979	**1.034**
33	1.681	1.529	1.344	1.370	1.358	**1.456**	1.730	1.619	1.602	1.547	1.584	**1.616**
34	3.733	3.697	3.534	3.440	3.500	**3.581**	3.798	3.659	3.417	3.275	3.383	**3.506**

Table 3. Values of the total citations, ISI and CHAL impact factors, SD and %V for the 34 selected journals

No.	Full journal title	Total citations						
		2001	2000	1999	1998	1997	SD	%V
1	POLYMER TESTING	2404	2441	2447	2441	2422	18	0.732
2	JOURNAL OF COMPOSITES TECHNOLOGY AND RESEARCH	419	408	444	450	389	25	5.997
3	JOURNAL OF BIOACTIVE AND COMPATIBLE POLYMERS	3338	3141	3014	2870	2936	185	6.058
4	POLYMER-PLASTICS TECHNOLOGY AND ENGINEERING	3191	3069	3148	2922	2711	195	6.489
5	ADVANCES IN POLYMER TECHNOLOGY	5808	5716	5741	5230	5012	357	6.495
6	REACTIVE & FUNCTIONAL POLYMERS	1327	1320	1475	1330	1229	88	6.604
7	KAUTSCHUK GUMMI KUNSTSTOFFE	2852	2834	2557	2595	2446	179	6.726
8	INTERNATIONAL POLYMER PROCESSING	7371	7096	6955	5995	6399	557	8.232
9	MECHANICS OF COMPOSITE MATERIALS	2616	2546	2396	2236	2150	198	8.287
10	KOBUNSHI RONBUNSHU	9732	8564	8958	8069	7933	729	8.424
11	JOURNAL OF REINORCED PLASTICS AND COMPOSITES	930	876	884	773	756	76	8.948
12	MACROMOLECULAR THEORY AND SIMULATIONS	263	255	220	222	216	22	9.361
13	JOURNAL OF BIOMATERIALS SCIENCE-POLYMER EDITION	51753	48704	44707	40831	38086	5577	12.445
14	JOURNAL OF MACROMOLECULAR SCIENCE-PHYSICS	2028	1755	2021	1670	1501	229	12.735
15	POLYMER INTERNATIONAL	1111	1110	1118	957	807	137	13.445
16	ACTA POLYMERICA	235	201	169	185	226	28	13.560
17	PROGRESS IN POLYMER SCIENCE	673	613	507	593	482	78	13.682
18	ANGEWANDTE MAKROMOLEKULARE CHEM	508	516	425	454	364	63	13.817
19	CARBOHYDRATE POLYMERS	19003	16820	15972	14261	13369	2212	13.925
20	RUBBER CHEMISTRY AND TECHNOLOGY	11142	9666	9636	8227	7642	1372	14.816
21	POLYMER DEGRADATION AND STABILITY	17128	15459	14779	12709	11649	2186	15.241
22	ADVANCES IN POLYMER SCIENCE	416	318	358	290	297	52	15.506
23	POLYMER BULLETIN	251	187	195	174	163	34	17.594
24	POLYMER JOURNAL	7218	6487	5915	5091	4604	1050	17.907
25	COLLOID AND POLYMER SCIENCE	286	249	221	177	190	44	19.713
26	EUROPEAN POLYMER JOURNAL	2043	1627	1535	1350	1225	314	20.187
27	POLYMER ENGINEERING AND SCIENCE	2333	2213	1878	1628	1308	420	22.450
28	JOURNAL OF MEMBRANE SCIENCE	1633	1376	1207	974	837	317	26.274
29	JOURNAL OF POLYMER SCIENCE PART B- POLYMER PHYSICS	1027	907	783	681	494	205	26.385
30	SYNTHETIC METALS	427	408	402	272	202	100	29.106
31	JOURNAL OF POLYMER SCIENCE PART A- POLYMER CHEMISTRY	278	224	173	164	113	63	33.002
32	JOURNAL OF APPLIED POLYMER SCIENCE	1478	1252	931	764	660	342	33.583
33	POLYMER	535	490	445	158	274	159	41.745
34	MACROMOLECULES	537	470	301	242	120	170	50.778

Table 3.
(continued)

No.	Impact Factor by ISI method							Impact Factor by CHAL method						
	2001	2000	1999	1998	1997	SD	%V	2001	2000	1999	1998	1997	SD	%V
1	0.880	0.794	0.853	0.941	0.777	0.066	7.824	0.809	0.759	0.798	0.834	0.874	0.043	5.244
2	0.307	0.191	0.275	0.200	0.250	0.049	20.142	0.255	0.207	0.253	0.237	0.224	0.020	8.590
3	0.779	0.745	0.720	0.600	0.677	0.069	9.814	0.809	0.728	0.707	0.802	0.752	0.045	5.910
4	1.186	1.132	1.269	1.116	1.268	0.073	6.081	1.238	1.212	1.310	1.190	1.161	0.057	4.637
5	0.854	0.797	0.902	0.975	0.878	0.065	7.413	1.399	1.217	1.292	1.227	1.172	0.088	6.981
6	0.755	0.469	0.482	0.488	0.465	0.125	23.528	0.658	0.520	0.643	0.526	0.561	0.065	11.182
7	0.941	1.026	0.918	0.979	0.974	0.041	4.245	1.006	0.915	0.881	0.943	0.945	0.046	4.908
8	1.180	1.268	1.265	1.031	1.327	0.115	9.474	1.626	1.479	1.519	1.337	1.458	0.105	7.044
9	6.053	5.446	4.976	4.486	4.563	0.654	12.803	6.184	5.804	5.702	5.131	5.325	0.414	7.348
10	1.158	0.802	1.376	1.054	1.254	0.218	19.309	1.204	1.060	1.421	1.189	1.460	0.169	13.319
11	0.833	0.792	0.897	0.647	0.776	0.092	11.675	0.874	0.897	0.987	0.814	0.857	0.064	7.249
12	0.659	0.714	0.583	0.280	0.623	0.170	29.746	0.813	0.950	0.844	0.753	0.837	0.071	8.512
13	3.733	3.697	3.534	3.440	3.500	0.128	3.566	3.798	3.659	3.417	3.275	3.383	0.215	6.135
14	0.752	0.678	0.924	0.733	0.762	0.092	11.965	1.329	1.116	1.290	1.044	0.766	0.225	20.318
15	2.740	1.935	2.229	1.817	1.379	0.505	25.016	2.098	1.892	1.840	1.826	1.352	0.274	15.207
16	0.571	0.426	0.378	0.651	0.800	0.171	30.253	0.730	0.705	0.605	0.802	0.948	0.128	16.822
17	1.267	1.348	1.134	1.916	1.729	0.330	22.290	1.274	1.316	1.222	1.686	1.616	0.212	14.929
18	0.383	0.312	0.321	0.368	0.404	0.040	11.120	0.468	0.501	0.499	0.637	0.623	0.078	14.352
19	1.681	1.529	1.344	1.370	1.358	0.146	10.038	1.730	1.619	1.602	1.547	1.584	0.069	4.262
20	1.975	1.711	1.630	1.237	1.202	0.329	21.189	1.757	1.545	1.664	1.370	1.306	0.191	12.477
21	0.992	0.881	0.953	0.886	0.841	0.061	6.668	1.167	0.920	1.104	0.998	0.979	0.100	9.663
22	0.429	0.231	0.274	0.274	0.236	0.081	28.036	0.269	0.197	0.232	0.205	0.191	0.032	14.691
23	0.438	0.209	0.167	0.140	0.258	0.118	48.721	0.974	0.563	0.635	0.697	0.690	0.156	21.932
24	1.706	1.587	1.581	1.406	1.360	0.142	9.318	2.011	1.898	1.991	1.742	1.753	0.127	6.783
25	0.515	0.345	0.317	0.152	0.310	0.129	39.387	0.445	0.419	0.377	0.297	0.394	0.056	14.545
26	1.203	1.184	0.987	1.129	0.956	0.114	10.410	1.348	0.953	1.112	1.058	0.998	0.154	14.107
27	0.905	0.960	0.641	0.854	0.811	0.122	14.570	1.055	0.966	0.885	0.996	0.808	0.097	10.274
28	3.738	3.698	3.625	2.737	3.300	0.419	12.245	6.066	4.170	4.046	3.702	3.651	0.997	23.039
29	1.234	1.669	1.192	1.228	0.901	0.274	22.049	1.731	1.543	1.564	1.636	1.760	0.097	5.891
30	0.529	0.514	0.490	0.500	0.451	0.030	5.943	0.780	0.710	0.824	0.585	0.525	0.127	18.553
31	0.590	0.392	0.330	0.419	0.370	0.100	23.883	0.597	0.513	0.386	0.432	0.357	0.098	21.440
32	0.882	0.920	0.822	0.721	0.634	0.118	14.777	1.106	0.984	0.833	0.709	0.742	0.168	19.149
33	0.405	0.333	0.196	0.019	0.012	0.179	92.538	0.249	0.180	0.131	0.068	0.042	0.084	62.627
34	0.873	0.836	0.592	0.784	0.687	0.115	15.189	0.920	0.950	0.790	0.832	0.674	0.110	13.201

Table 4. Values of the total citations, the ISI and CHAL impact factors for 12 selected journals that have relatively low %V values (less than 10%)

No.	Full journal title	Total citations							Impact Factor by ISI method							Impact Factor by CHAL method						
		2001	2000	1999	1998	1997	SD	%V	2001	2000	1999	1998	1997	SD	%V	2001	2000	1999	1998	1997	SD	%V
1	ADVANCES IN POLYMER SCIENCE	2616	2546	2396	2236	2150	**198**	**8.287**	6.053	5.446	4.976	4.486	4.563	**0.654**	**12.803**	6.184	5.804	5.702	5.131	5.325	**0.414**	**7.348**
2	ADVANCES IN POLYMER TECHNOLOGY	263	255	220	222	216	**22**	**9.361**	0.659	0.714	0.583	0.280	0.623	**0.170**	**29.746**	0.813	0.950	0.844	0.753	0.837	**0.071**	**8.512**
3	ANGEWANDTE MAKROMOLEKULARE CHEM	1327	1320	1475	1330	1229	**88**	**6.604**	0.755	0.469	0.482	0.488	0.465	**0.125**	**23.528**	0.658	0.520	0.643	0.526	0.561	**0.065**	**11.182**
4	COLLOID AND POLYMER SCIENCE	3191	3069	3148	2922	2711	**195**	**6.489**	1.186	1.132	1.269	1.116	1.268	**0.073**	**6.081**	1.238	1.212	1.310	1.190	1.161	**0.057**	**4.637**
5	EUROPEAN POLYMER JOURNAL	3338	3141	3014	2870	2936	**185**	**6.058**	0.779	0.745	0.720	0.600	0.677	**0.069**	**9.814**	0.809	0.728	0.707	0.802	0.752	**0.045**	**5.910**
6	JOURNAL OF MACROMOLECULAR SCIENCE-PHYSICS	930	876	884	773	756	**76**	**8.948**	0.833	0.792	0.897	0.647	0.776	**0.092**	**11.675**	0.874	0.897	0.987	0.814	0.857	**0.064**	**7.249**
7	JOURNAL OF POLYMER SCIENCE PART B-POLYMER PHYSICS	7371	7096	6955	5995	6399	**557**	**8.232**	1.180	1.268	1.265	1.031	1.327	**0.115**	**9.474**	1.626	1.479	1.519	1.337	1.458	**0.105**	**7.044**
8	KOBUNSHI RONBUNSHU	419	408	444	450	389	**25**	**5.997**	0.307	0.191	0.275	0.200	0.250	**0.049**	**20.142**	0.255	0.207	0.253	0.237	0.224	**0.020**	**8.590**
9	POLYMER BULLETIN	2404	2441	2447	2441	2422	**18**	**0.732**	0.880	0.794	0.853	0.941	0.777	**0.066**	**7.824**	0.809	0.759	0.798	0.834	0.874	**0.043**	**5.244**
10	POLYMER ENGINEERING AND SCIENCE	5808	5716	5741	5230	5012	**357**	**6.495**	0.854	0.797	0.902	0.975	0.878	**0.065**	**7.413**	1.399	1.217	1.292	1.227	1.172	**0.088**	**6.981**
11	POLYMER JOURNAL	2852	2834	2557	2595	2446	**179**	**6.726**	0.941	1.026	0.918	0.979	0.974	**0.041**	**4.245**	1.006	0.915	0.881	0.943	0.945	**0.046**	**4.908**
12	SYNTHETIC METALS	9732	8564	8958	8069	7933	**729**	**8.424**	1.158	0.802	1.376	1.054	1.254	**0.218**	**19.309**	1.204	1.060	1.421	1.189	1.460	**0.169**	**13.319**
Sort by %V of total citations								average = 6.863							average = 13.505							average = 7.577

Table 5. Changes in total citations and the impact factors of some selected journals that had an abrupt increase in the total citations

No.	Full journal title	Total citations						Impact Factor by ISI method						Impact Factor by CHAL method					
		2001	2000	1999	1998	1997	% difference of underlined pair	2001	2000	1999	1998	1997	% difference of underlined pair	2001	2000	1999	1998	1997	% difference of underlined pair
1	CARBOHYDRATE POLYMERS	2043	1627	1535	1350	1225	**25.57**	1.203	1.184	0.987	1.129	0.956	**1.60**	1.348	0.953	1.112	1.058	0.998	**41.45**
2	INTERNATIONAL POLYMER PROCESSING	427	408	402	272	202	**47.79**	0.529	0.514	0.490	0.500	0.451	**2.00**	0.780	0.710	0.824	0.585	0.525	**40.85**
3	JOURNAL OF COMPOSITES TECHNOLOGY AND RESEARCH	251	187	195	174	163	**34.22**	0.438	0.209	0.167	0.140	0.258	**109.57**	0.974	0.563	0.635	0.697	0.690	**73.00**
4	JOURNAL OF POLYMER SCIENCE PART B-POLYMER PHYSICS	7371	7096	6955	5995	6399	**16.01**	1.180	1.268	1.265	1.031	1.327	**22.70**	1.626	1.479	1.519	1.337	1.458	**13.61**
5	MECHANICS OF COMPOSITE MATERIALS	535	490	445	158	274	**181.65**	0.405	0.333	0.196	0.019	0.012	**931.58**	0.249	0.180	0.131	0.068	0.042	**92.65**
6	POLYMER INTERNATIONAL	1478	1252	931	764	660	**34.48**	0.882	0.920	0.822	0.721	0.634	**11.92**	1.106	0.984	0.833	0.709	0.742	**18.13**
7	RUBBER CHEMISTRY AND TECHNOLOGY	2028	1755	2021	1670	1501	**21.02**	0.752	0.678	0.924	0.733	0.762	**26.06**	1.329	1.116	1.290	1.044	0.766	**23.56**

Conclusion

A new modified method for calculating the impact factor of journals was proposed, the case study being based on 34 selected journals in the Polymer Science Category during 1997-2001. The average impact factors calculated using the cited half-life (CHAL) method during 1997-2001 appeared to be slightly higher than those calculated by the ISI method. The stability of the average impact factor by the CHAL method was better than that by the ISI method. The average coefficients of deviation (V value) for total citations and CHAL impact factor were 6.863% and 7.577% respectively, whereas those by the ISI impact factor were 13.505%. The average values of the impact factor of the 34 selected journals obtained from the ISI and CHAL methods during 1997–2001 were 0.882 and 0.984, regardless of the impact factors of *Progress in Polymer Science* and *Advances in Polymer Science*. The positions of the journals ranked by impact factors were found to change with calculating method. Taking all the presented results into account, it is our opinion that the CHAL method was more suitable for calculating the impact factor of the journals than the existing ISI method.

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