Bibliometric scoring of an individual's research output in science and engineering

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The relevance of various citation metrics used for parameterization of the research outputs of scientists is reviewed. The rationale of judging the performance of scientists on the basis of the total number of research papers published, the total citations received for these papers or the average citation reckoning per paper has often been criticized. The significance of impact factor of journals in which the papers have appeared has also been debated. The *h*-index introduced by Jorge E. Hirsch in 2005 has gained some acceptance in this regard but its value is highly dependent on the academic discipline concerned and also varies across sub-disciplines. Because citation practices exhibit wide variations among different fields, a scientist working in a particular discipline need not be disheartened with a low *h*-index as compared to fellow scientists of a different discipline. The *h*-index has been successful in assessing the performance of scientists of the same field and at the same stage of their careers. By appropriately scaling the discipline-dependence of *h*-index, it has also enabled comparison among those working in different disciplines, serving as a simplified, robust, intelligible measure. Several metrics proposed to overcome the flaws of *h*-index are briefly described.

Introduction

There has been a natural worldwide tendency and a steady growth of interest in quantitative measurement of research output[1]. This is because academic performance of a researcher is primarily judged by the number and quality of publications, which are presupposed as the essence of scholarship. Not surprisingly, the anxiety to publish for the purpose of academic eminence or promotion is enormous[2]. People try to quantify their own research output or that of others for a variety of reasons. But mainly, they want to evaluate the impact of their own work/other's work for new positions and promotions in academic career, or to compare the performance of scientists of a given field objectively. These kinds of comparative analyses are imperative not only for individual researchers but also for institutions and countries across the globe. At the bottom of all endeavours lies the rudimentary cause that colossal research grants are sanctioned annually and there must be a yardstick to measure the output.

A scientist's ability is often judged by the number of research papers published in journals and the citations accrued to his/her published research over a given length of time. Of course, it is undeniable that not all scientists who read a paper and get benefitted from it, have the opportunity to publish papers and cite them, or even if they publish, they may not necessarily cite all papers from which they have acquired knowledge. Bibliometrics refers to measuring the impact of an accomplishment by counting citations of that particular work by other workers[3]. Despite fundamental reservations, bibliometric methods are widely used for evaluation purposes by administrators and selection committees in their assessment. This is possible because large library resources such as electronic data bases in scientific citation indexing services for scholarly literature across various publishing formats and disciplines, e.g., Web of Science (WoS), Scopus and Google Scholar[4], allow a realistically speedy determination of publication lists and corresponding citation records by drawing on information from journal publishers, university repositories, etc. In this paper, the different methods used for assessment of scientific and industrial research are reviewed, comparing their relative advantages and pitfalls.

Total number of research publications and citations garnered

Publication of a large number of research papers by a researcher irrefutably indicates that the researcher has been active, otherwise the papers will not be accepted. But it is not a convincing indicator of the quality of the published papers because quality is judged by people who read them and apply their results. Total citation count of research papers too does not give definitive assurance of the capability of a particular researcher because of the following reasons:

   (i)   Citation analysis is jeopardized by flaws, such as self-citing and reciprocal citing by collaborators[5-6].

   (ii) The researcher may be part of a large active author team and the work is done in co-operation with others. Being a member of an agile research team, incorporation of one or two highly-cited papers in the publication list of a researcher may considerably boost his/her citation count irrespective of the fact that the researcher may be a passive contributor to that work. Thus there is always likelihood of reflection of a higher (false) citation count in the publication record of an otherwise dull worker. From these considerations, even if a researcher has a high citation count of publications, it cannot be said beyond doubt that the researcher performed in a satisfactory manner[7].

   (iii) For scientists working in a field with limited scope, it is difficult to capture citations, but this should not discourage such workers[8].

   (iv) Publications in languages other than English cannot be judged by citations as citation databases do not include all languages[8].

   (v) Publications in media other than journals such as book chapters or books are not covered by many databases[8].

For similar reasons, the mean citations per paper does not guarantee a high degree of research activity because inclusion of one or two highly-cited papers can exaggerate the average count appreciably, providing an unrealistic estimation[7]. Moreover, narrow-field workers as well as those writing in non-English journals or non-journal media are not recognized.

The above remarks should do not be misconstrued as derogatory to the importance of either the total number of research papers or the total citations thereto. They are cardinal criteria because they are the pointers of utility of a paper although their value can be unequivocally judged through a different mechanism. In other words, these metrics are quite valuable, but the influence of aforementioned subtle forces on them often leads to misinterpretation.

The notion of the Journal Impact Factor

The concept of impact factor (IF) was pioneered by Eugene Garfield[9] of the Institute for Scientific Information (ISI), Philadelphia, in 1955. This impact factor referred to articles, not journals, and was still vaguely defined without proposition of any mathematical formula for its calculation[10]. Several years later, Eugene Garfield and Irving H. Sher created the journal impact factor (JIF)[11-12]. This index was designed for comparing journals regardless of their size, and was a natural result of the establishment of the Science Citation Index (SCI)[13]. Initially launched by the Institute for Scientific Information (ISI) in 1964, and presently owned by Thomson Reuters, the comprehensive version termed the 'Science Citation Index Expanded' is a multidisciplinary index, encompassing the globally top-tier journals of science and technology, presently 8637 journals, and providing the cited references captured from indexed articles.

Indeed, JIFs were devised in the 1960s to help in selecting journals for inclusion in the Science Citation Index[14]. Now, the JIF is published by Thomson Scientific Reuters on a twelve-monthly basis in the Journal Citation Reports (JCR)[15-16]. The use of the JIF as a measure for journal visibility is widespread. The JIF has been used as an indicator of how well-read a journal is, proclaiming the vastness of its circulation and readership.

As the impact factor of a journal shows the relative importance of the journal in a given field, publishing in high impact factor SCI journals is desirable. The impact factor of a journal measures the frequency of citation of the average article in a journal during a discrete year or period. On yearly basis, it is calculated by dividing the number of current year citations to the source items published in that journal during the foregoing two years. The journal impact factor (JIF) is the average number of citations

received from papers published in the given journal in year t to papers published in the journal in previous two years, $t - 1$ and $t - 2$, e.g., the impact factor of a journal in the year 2014 will be the average number of citations from papers published in that journal in year 2014 to papers published in the journal in preceding two years, 2013 and 2012. As citations of many papers may not reach the pinnacle until after the second year of publication, i.e., beyond the short period of time prescribed in defining the impact factor, it has been frequently objected that the two-year window may not provide an accurate estimate.

Higher cited journals are more subscribed and in greater propagation, which means that they are more widely read. This is only possible if they maintain higher standards of peer review. If this argument is valid, the high impact factor journals in a field are naturally the ones more prestigious, and the impact factor expresses the relative importance of a scientific journal within its field. Notwithstanding that a high journal impact factor means more visibility, it must be noted that several artefacts affect the impact of a journal and its ranking besides the marketing and advertising endeavours[17]. Review articles or letters generally receive several fold more frequent citations than original research papers because they serve as bridges to antedate literature. Consequently, the highest impact factors are attained by review journals. Commonly, the top most journals in high-impact category are review journals. Another notion is that the articles describing methods or techniques of experimental studies performed invite more citations than other articles. However, this is only partially true, although most highly classical papers seem to

reinforce this view. As journal citation counts do not demarcate among letters, reviews, or original research papers, a journal publishing a large number of review articles or letters brings forward an increase in references to those articles or letters. These facts suggest that it is possible to manipulate and manoeuvre JIF.

With passage of time, the implication of the term 'JIF' has grown immensely. The term 'JIF' has gradually evolved into description of both journal and individual author impact. The latter impact is misleading. The major contention is that a research publication in a high impact factor journal does not essentially acquire a large citation because citation depends on the quality of the paper, not on the journal. There have been representative examples of papers published in high impact factor journals that have been poorly cited. Still the journal has a high impact factor because it is an averaged value obtained by summing the citations of all the papers published so that the average value remains high even if a few papers fail to make impact. This is illustrated by the hypothetical case of two journals P and Q whose paper citation details are given in Table 1.

In journal P, five papers, viz. serial nos. II, III, VII, VIII and IX received high citations ≥ 10, remaining received low citations < 10. The citations of papers I, IV, V, VI and X were very poor. Thus the impact factor of the journal P was the result of contributions towards citations, mainly from papers II, III, VII, VIII and IX. Papers I, IV, X had only 1 citation, paper V had 2 citations, and paper VI had no citation.

In journal Q, three papers, viz. serial nos. III, IV, VI received high citations > 10, remaining got low < 10.

Table 1—Hypothetical example of two journals P and Q

	Sl. No of Papers published in journal P in 2011										Sl. No. of Papers published in journal Q in 2011									
	I	II	III	IV	V	VI	VII	VIII	IX	X	I	II	III	IV	V	VI	VII	VIII	IX	X
Citations to individual papers in 2012	1	5	3	1	2	0	4	25	12	1	0	1	4	17	5	10	1	0	0	0
Citations to individual papers in 2013	0	6	7	0	0	0	9	10	15	0	2	3	7	15	4	13	2	2	3	0
Total citations for each paper	1	11	10	1	2	0	13	35	27	1	2	4	11	32	9	23	3	2	3	0
Total citations for all papers						101										89				
JIF						10.1										8.9				

The citations of papers I, II, V, VII, VIII, IX and X were not impressive. The impact factor of the journal *Q* was largely due to the high citations of papers III, IV, VI. Apart from paper V, papers I, II, VII, VIII, IX and X contributed insignificantly towards the impact factor.

It is logical to infer that in a high-impact factor journal, all the papers are not equally cited, some are highly cited and others are poorly cited. Therefore, publication of a paper in a high impact factor journal does not necessarily imply that it will have a high citation rate and therefore will be more impactful. Consequently, correlation of the quality of a paper with impact factor of the journal is outright ridiculous, which connotes that an author cannot claim about the quality of his/her paper by mentioning that it has been published in such a journal. Therefore, the impact factor should not be used for evaluating an individual scientist's performance[18], although it is certainly an attribute of the journal effectuality.

The *h*-index as a parameter of productivity and quality of research

Many of the problems associated with impact factors are addressed by the *h*-index, proposed in 2005 by Jorge Hirsch, an Argentine American professor of physics at the University of California, San Diego, to describe the scientific productivity and impression of a researcher[7] (Hirsch 2005). The *h*-index measures the number of highly impactful papers published by a scientist. A scientist who has published a larger number of eye-catching impactful papers will have a higher *h*-index, regardless of the journals in which the papers have been published. Hirsch argued that[7]: (i) If a scientist has published a large number of research papers, the productivity is high but impact of these papers is not obvious, (ii) If a scientist has a large number of citations, the number may be unduly amplified by some papers in which he/she may be a complaisant co-author or they may have primarily originated from review articles instead of research papers. (iii) If a scientist is assessed on the basis of mean citations per paper, low productivity is rewarded and high productivity is penalized. (iv) If the number of citations of the most cited papers is selected as a parameter for comparing scientists, a single number is not obtained making the comparison intricate and awesome.

According to Hirsch's definition, a scientist is characterized by the index *h* if a number *h* of his/her N_p papers have received a minimum of *h* citations each, and the remaining $(N_p - h)$ papers have lesser number of citations than *h* each. The *h*-index of a researcher is determined graphically by plotting the number of times each paper of the researcher has been cited on the ordinate and the serial number of paper on the abscissa, as shown in Fig. 1. Then the intersection of the 45° line with the curve gives the *h*-index.
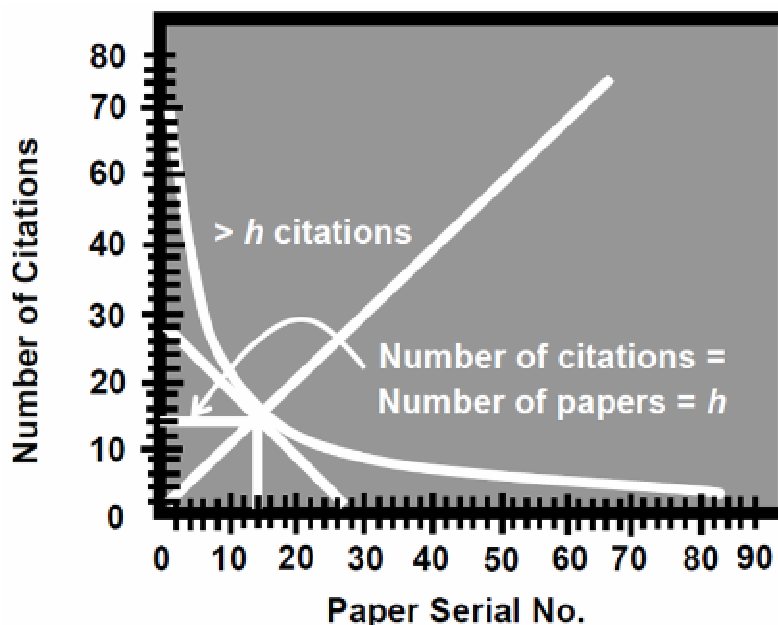

Fig. 1—Graph showing the variation of citation counts of papers of an author with paper serial number
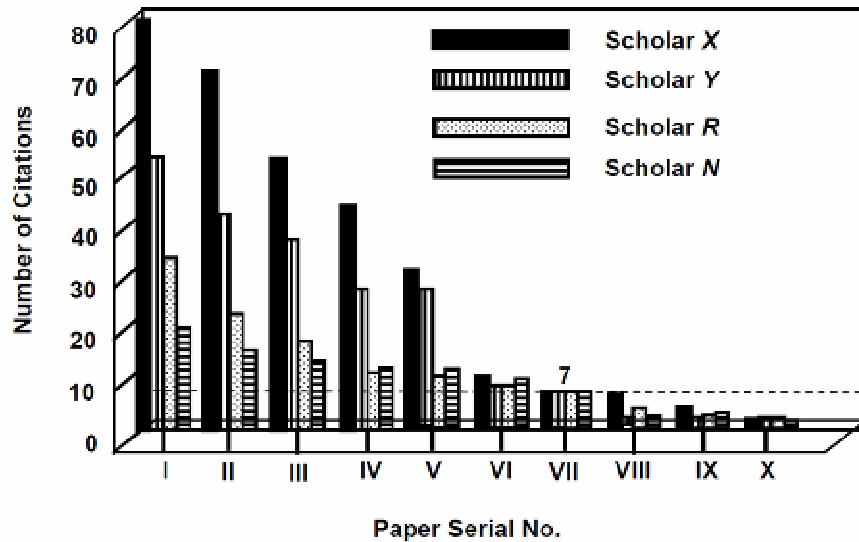
Fig. 2—Citation statistics of four authors with same *h*-index

In Fig. 2, the citation counts of four scholars *X*, *Y*, *R* and *N* are plotted for their most cited ten research papers. The papers of scholar *X* received 80, 70, 53, 43, 31, 9, 7, 6, 5, 0 citations, those of scholar *Y* got 53, 42, 37, 27, 26, 7, 7, 0, 0, 0 citations, those of Z got 33, 22, 17, 10, 8, 8, 7, 5,3, 2 citations, and those of *N* got 17, 15, 13, 12, 11, 9, 7, 4, 3, 1 citations respectively. It is noticed that in all cases the scholars have 7 citations for their 7 papers giving an *h*-index of 7 although scholar *X* had total 304 citations, scholar *Y* had 199 citations, scholar *Z* had 115 citations and scholar *N* had only 92 citations. Thus from *h*-index analysis, the four scholars having identical *h*-index values of 7 are equivalent in terms of their overall scientific impact, even if their total number of papers or their total number of citations may be markedly different.

Like any other metric, the *h*-index has several advantages and limitations[19], some of which are presented in Table 2. Among the controversial features of the *h*-index, the most important one that needs to be elucidated is the difficulty in making cross-disciplinary comparisons because *h*-index varies by broad intervals across disciplines[20]. This happens due to the habitual variations in the numbers of citations across disciplines. An engineer with a relatively low total number of citations can have higher impact in engineering than a physicist/chemist with a larger number of citations in physics/chemistry. On the basis of extensive and statistically proved studies, Lillquist and Green[21]

categorized sciences and engineering disciplines according to the decreasing median of *h*-index values for matured scientists/professors, as follows: Physics *(h*=32), Biology *(h*=31), Chemistry *(h*=30), Chemical Engineering *(h*=18), Electrical Engineering *(h*=14), Mechanical Engineering *(h*=13), Maths *(h*=11), Civil Engineering *(h*=10).

As an example, to elaborate the use of *h*-index in context of its interdisciplinary variation, the author observed that for active professor-level Indian researchers working on the physical and chemical characterization of unit processes in semiconductor fabrication and study of material properties, *h*-index values were high like those for physicists and chemists. In opposition, for those engaged in semiconductor device design and fabrication involving integration of unit processes, and their application in device technology development, i.e., on the engineering or technological aspects of the field, *h*-index values were significantly lower like those for electrical engineers. In Fig. 3, the *h*-index values of the two categories of researchers are shown. On the right-axis, the *h*-index values given by Lillquist and Green[21] are marked. It is evident that researchers working on unit processes and materials aspects had an *h*-index value (averaged over five cases) around (21+32+31+28+18)/5=26 while those pursuing device fabrication had to be contended with a meagre (15+16+14+10+12)/5=13.4 value of *h*-index, corroborating the trends shown by the findings of Lillquist and Green[21], although the values shown are

Table 2—Strengths and weaknesses of *h*-index over other metrics.

Strengths:

(i)   Unifies in a single numerical measure, both the quantity (publications) and impact (citations) of research output, making a large quantity of high-quality work visible. Acts as an indicator of lifetime achievements.

(ii)   Relies on citations to papers, not the journals.

(ii)   Not dramatically skewed by a single well-cited, influential paper.

(iii)   Not increased by a large number of poorly cited papers, discouraging the publication of unimportant work.

(iv)   Minimizes the politics of publication.

(v)   Superior to other single-number criteria commonly used to evaluate the scientific output of a researcher (impact factor, total number of papers, total number of citations, citation per paper and number of highly cited papers).

(vi)   Provides good quantitative comparison of the scientific output of researchers working in the same discipline at similar career junctures and, therefore, may play an important role when making decisions about promotions, fund allocations and rewarding.

(vii)   Valid not only for individuals, but also for departments, or programs.

Weaknesses:

(i)   Counts a highly-cited paper even if is being referenced for negative reasons.

(ii)   Ignores the number and position of authors in a paper.

(iii)   Allows the scientists to rest on their achievements because the number of citations received increases even after a scientist retires from work and publishes no further.

(iv)   Does not consider citations of highly cited papers once they are chosen to belong to the top *h* papers;   hence weakly sensitive to number of citations.

(v)   Does not account for inter-field differences in typical *h* values due to variations among fields in average number of publications and citation practices.

(vi)   Being dependent on the pool of publications and citations, and hence the duration of a scientist's career, puts the younger scientists at a disadvantage

(vii)   Being easy to obtain, it is vulnerable to indiscriminate use for the assessment of scientists because research performance is a complex multifaceted activity not amenable to be expressed in terms of a single indicator. May also trigger changes in publishing behaviour of scientists to artificially increase their citations.
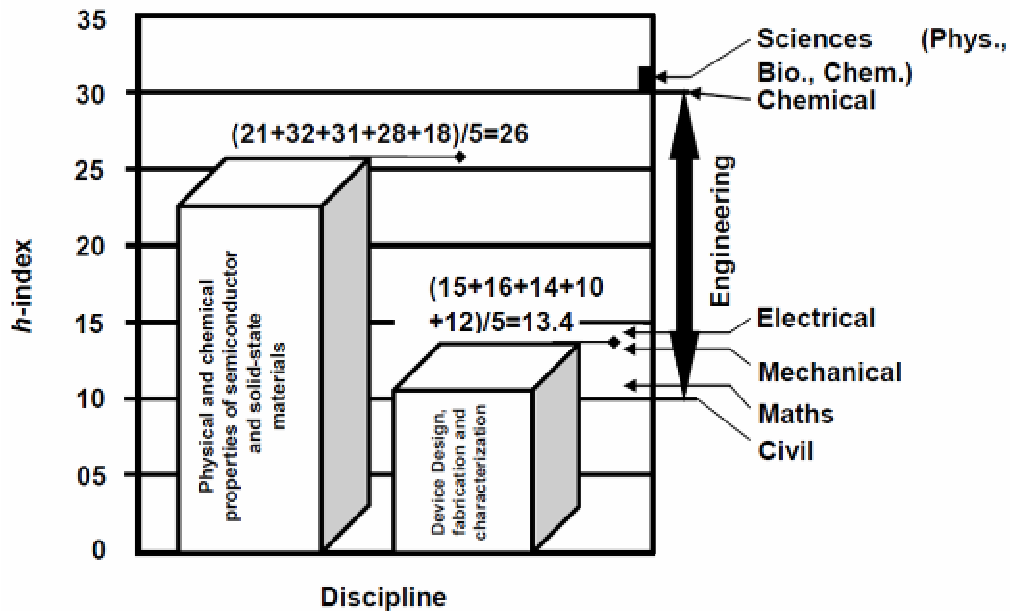

Fig. 3—Variation of *h*-index across disciplines for professor-level researchers, which agrees with the trends of numerical values for science and engineering according to Lillquist and Green 2010[21], as marked on the right-axis.

lower than their data. One possible reason for the large difference between *h*-index values of the two categories of researchers could be that device fabrication was a lengthy, arduous task entailing a large number of process steps leading to lower or at least longer-duration success rate with accompanying smaller publication rates of papers. Moreover, the number of citations per paper is much less in engineering than in physics/chemistry due to the fact that the numbers of scientists working as well as the total number of publications in engineering is less than in physics/chemistry[22].

h-index variants and extensions as bibliometric indicators

To overcome the shortcomings of *h*-index, some new citation indices have been proposed. Amongst the many ranking parameters that have emerged to evaluate research performance, the original *h*-index, and its variants, have become the most popularly and commonly used. Every index shows or highlights one perspective of the researcher or the other, while partially ignoring the remaining aspects. These extensions of the *h*-index bring new dimensions to the evaluation of scientific productivity. Many of these deserve to be used in research management, but very few have become known outside the bibliometrics community. These extensions are classified in Fig. 4, and will be briefly discussed below[23-24].

h-type indices adapting for the robustness of h-index to the h-core citation count

In examining the properties of the *h-index*, Rousseau 2006[25] coined the term 'Hirsch core' for all of the citations received by the first "*h*" ranked articles, which is the congregation of high-performance publications, with respect to the scientist's career. Although the *Hirsch core* or the *h*-core was not propounded as a replacement for the *h-index*, it is an expedient way of expressing the all-embracing impact that the best articles of a researcher have exercised.

- The most widely-known variant of the *h-index* is conceivably the **g-index***,* proposed as a way to capture the major chunk of citations that fall outside the coverage of the *h-index*. The g-index (Egghe 2006[26-27]) counts citations from highly cited articles, and is defined as the single, largest number such that the cumulative sum of the number of citations of the top g articles is $\geq g^2$. Clearly, $g \geq h$.

- Like the g-index, calculation of the **h(2)-index** also gives more stress to highly cited articles. The $h(2)$-index, (Kosmulski, 2006[28]) of an author is the highest natural number such that $h(2)$ most cited papers of the author received each at least square of $h(2)$ citations.

- Similar to h and $h(2)$ indices, **w-index** (Wu 2010[29]) of an author is w if w papers have at least $10w$ citations each and the other papers have less than $10(w+1)$ citations.

- The **hg-index** (Alonso et al. 2010[30]) is the geometric mean of *h*- and *g*- indices to retain the advantages of both measures as well as to minimize their disadvantages.

- The **h_w-index** (Egghe and Rousseau 2008[31]) proposed to enhance the *h*-index to give more attention to the highly cited publications, is a citation-weighted *h*-index,
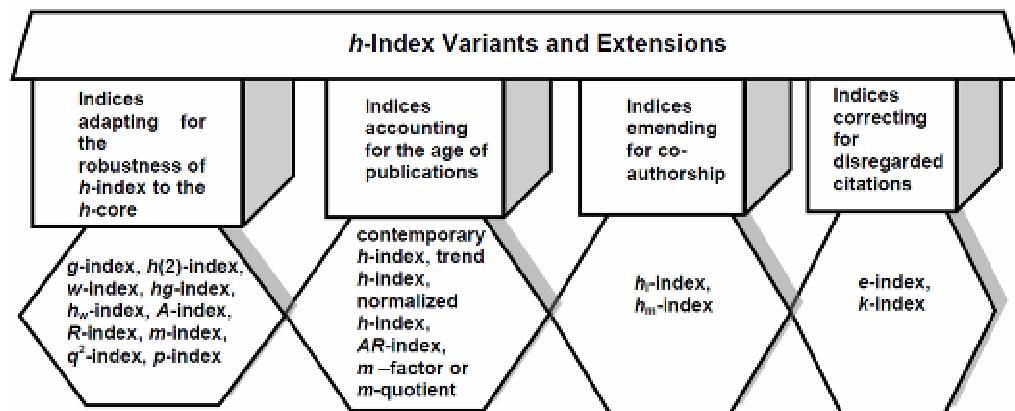

Fig. 4—Improved bibliometric indicators over *h*-index.

- Jin et al[32-33] (2006, 2007) proposed three new indicators: the *A*, *R*, and *AR*-indexes. The **A-index** (Jin et al. 2006[32]) is the average number of citations collected by the publications in the Hirsch core. Since averages are susceptible to extreme values, it is overly influenced by one or two "hit" papers, and may not reflect the true impact of a researcher.

- The **R-index** (Jin et al. 2007[33]) defined as the square root of the total summation of citations of *h*-core publications, measures the *h*-core's citation intensity. The **AR-index** will be defined in category (ii).

- The **m-index** (Bornmann et al, 2008[34]) is the median value of *h*-core citations. Like many other indices, the *m*-index depends on the *h*-core contents. The rest of publications which do not belong to *h*-core are ignored.

- The **q²-index** (Cabrerizo et al. 2009[35]) is the geometric mean of the *h*-index and the *m*-index of the *h*-core. The *h*-index is used because it is robust and seizes the number of the papers (quantitative dimension) in a researcher's fertile core, while the *m*-index is exploited because it depicts the impact of the papers (qualitative dimension) in a researcher's core and faithfully considers the citation distributions which are generally skewed.

- Prathap 2010[36] asserted that the capturing of imagination of scientometricians and bibliometricians by the *h* index has taken place to such a degree that the history of the subject is looked upon virtually as comprising a pre-Hirsch and a post-Hirsch era. In his quest for a rational strategy to rank authors/institutions, taking into account productivity (number of papers *P*) and quality (impact defined as the ratio of number of citations to number of papers, $i = C/P$), by applying concepts from mathematical modelling, Prathap[37-40] proposed a composite indicator $(C^2/P)^{1/3}$, which could mock the features of the *h*-index by connecting the number of papers and the mean citation rate per paper, to complement the **h**-index and impart more resolving power to it. Thus, $(C^2/P)^{1/3} = [C \times (C/P)]^{1/3}$ is an indicator that perceives both size and quality. It is called the **p-index** or performance index. Prathap and

Gupta[41-42] and Gupta[43] also proposed a more judicious procedure for ranking the research performance of universities.

h-type indices accounting for the age of publications

- The **Contemporary h-index** (Sidiropoulos et al. 2007[44]) of a researcher is h^c, if h^c of his/her N_p papers get a score of $S^c(i) \geq h^c$ each, and the rest $(N_p - h^c)$ papers have a score of $S^c(i) \leq h^c$, where $S^c(i)$ is the number of citations received by the paper divided by its age.

- The **Trend h-index** (Sidiropoulos et al. 2007[44]) of a researcher is h^t if h^t of his/her N_p papers get a score of $S^t(i) \geq h^t$ each, and the rest $(N_p - h^t)$ papers get a score of $S^t(i) \leq h^t$ each, where $S^t(i)$ is defined like $S^c(i)$ by an equation assigning an exponentially decaying weight to each citation of an article, which is a function of the 'age' of the citation.

- The **Normalized h-index** (Sidiropoulos et al. 2007[44]) of a person is $h^n = h/N_p$, if h of his/her N_p papers have received at least h citations each, and the rest $(N_p - h)$ papers received no more than h citations.

- The **AR-index**[33] takes the age of the publications into consideration by dividing the number of citations received by an article by the number of years since the publication of the article. It is determined as the square root of the summation of the average number of citations per year of papers in the *h*-core. Interestingly, the *AR*-index value can diminish over time. This makes it a more accurate measure of the current status of a researcher's career.

- The **m factor or m-quotient** (Burrell 2007[45]) is obtained by dividing the *h*-index by number of years since a scientist's first publication to compare scientists with different lengths of scientific careers.

h-type indices emending for co-authorship

- The **Individual h-index** h_I (Batista et al. 2006[46]) reduces the effects of co-authorship by dividing the standard *h*-index by the average number of participating authors in the papers.

- In the method of Schreiber 2008[47], fractional paper counts are used to account for shared authorship of papers. For counting the citations fractionally, the number of citations is divided by the number of authors for each paper. Then the **Multi-authored h_m-index** is determined as that number of papers for which this ratio is at least equal to h_m.

Indices correcting for disregarded citations

- The *e-index* is a simple complement to the *h*-index. This index tries to represent the excess citations that are ignored by the *h*-index. It is independent of the *h*-index, unlike any other related index. The *e*-index (Zhang 2009, 2010[48-49]) is the square root of the disregarded surplus citations, apart from the h^2 citations for *h*-core papers.

- The *k-index* (Ye and Rousseau 2010[50]) is based on tail-core ratio and the impact of publications (Citations *C* /Papers *P*), such that: *k*-index= {$C(t)/P(t)$}/Tail-core ratio(t). The publications that are not part of the *h*-core are significant for the *k* -index.

Judging the readership of a paper from viewing or downloading data

After the computer and information technology revolution, many journals have gone online. Gigantic amounts of information are available in web pages. Many new open access journals have been launched allowing free access to readers browsing the Internet. Computers have proliferated and most people have access to the Internet. The number of times a paper is viewed or downloaded is easily recorded. The more interesting a paper is, larger will be the number of downloads and more the number of people reading it, greater therefore will be the citation count. Even if there is no one-to-one correspondence between the number of downloads and that of citations, the greater number of downloads registered for a paper invariably speaks about its success. Many journals bring out lists of their top-downloaded or most-downloaded papers as a token of appreciation to authors[8]. Therefore, the number of downloads is a definite criterion for the esteem of an article available on the web.

Conclusions

Various parameters used to characterize the research output of scientists were described. The inadequacies of aggregate research publications as well as citations in evaluating the output were delved into. The intricacies of journal impact factor for this purpose were brought out. The emergence of *h*-index as a useful pointer was discussed and its proper use was explained, taking into consideration the research discipline being talked about. Merits and shortcomings of *h*-index were briefly touched upon. Some new proposed indices aimed at correcting the *h*-index value to remove its deficiencies were summarized. Undoubtedly, they provide valuable information and should be increasingly utilized. Presently, the *h*-index seems to stay primarily because of its unique simplicity.

Notwithstanding the availability of numerical measures, evaluators should refrain from being ebulliently dependent on the magic of numbers and statistics. Citation of a paper is not always a positive accreditation**.** It may be for a negative cause, pointing out the deficiencies or errors in a work or disproving a theory. If indices could discriminate between positive and negative citations, they would be more useful. Therefore, together with numerical evaluation, the time-honoured approach of soliciting appraisals concerning the significance of a candidate's work from carefully selected, unbiased scientific peers should be scrupulously applied.

Acknowledgements

References

1. Penner O, Pan R K, Petersen A M, Kaski K and Fortunato S, On the predictability of future impact in science, *Scientific Reports* 3, Article Number 3052 (2013) 1-8.

2. Loh L-C, Editorial-Understanding academic publications: Duplicate publication and role of impact factor in promotion, *International e-Journal of Science, Medicine & Education* 4(2) (2010)1-2.

3. Sammarco P W, As I see it: Journal visibility, self-citation, and reference limits: influences on Impact Factor and author performance review, *Ethics in Science and Environmental Politics* 8 (2008) 121–125.

4. Harzing A-W K and van der Wal R, Google Scholar as a new source for citation analysis, *Ethics in Science and Environmental Politics*, 8 (2008) 61–73.

5. Sarli C C, Dubinsky E K and Holmes K L, Beyond citation analysis: A model for assessment of research impact, *J Med Libr Assoc* 98(1) (2010) 17-23.

6. MacRoberts M H and MacRoberts B R, Problems of citation analysis: A study of uncited and seldom-cited influences, *Journal of the American Society for Information Science and Technology*, 61(1) (2010) 1–13.

7. Hirsch J E, An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, USA, 102(46) (2005) 16569–16572.

8. Kumar M J, Editorial: Evaluating Scientists: Citations, Impact Factor, *h*-Index, Online page hits and what else? *IETE Technical Review*, 26 (3) (2009)165-168

9. Garfield E (2005) The agony and the ecstasy—the history and meaning of the Journal Impact Factor. Presented at the International Congress on Peer Review and Biomedical Publication, Chicago, September 2005. Available at: http://garfield.library.upenn.edu/papers/jifchicago2005.pdf (Accessed on 31st December 2013)

10. Wu X - F, Fu Q and Rousseau R, Editorial: On indexing in the Web of Science and predicting journal impact factor, *Journal of Zhejiang University Science B* 9(7) (2008) 582-590.

11. Garfield E and Sher I H, *Genetics citation index.* Philadelphia, Pa: Institute for Scientific Information, *Essays of an Information Scientist*, 7 (1984) 515-522, Available at: http://www.garfield.library.upenn.edu/essays/v7p515y1984.pdf (Accessed on 31st December 2013)

12. Garfield E, Sher I H, and Torpie R J, 1964, The use of citation data in writing the history of science, © Copyright 1964 by the Institute for Scientific Information Inc. Philadelphia, Pennsylvania, US, 75 pages, http://www.garfield.library.upenn.edu/papers/useofcitdatawritinghistofsci.pdf (Accessed on 31st December 2013)

13. Garfield E, Science citation index- a new dimension in indexing, *Science*, 144 (3619) (1964) 649-654.

14. Ogden T L and Bartley D L, Commentary: The ups and downs of journal impact factors, *Annals of Occupational Hygiene*, 52(2) (2008)73–82.

15. Thomson Reuters Web of knowledge: Essays & white papers, Available at: http://wokinfo.com/essays/ (Accessed on 31st December 2013)

16. Thomson Reuters Journal Citation Reports, Available at: http://thomsonreuters.com/journal-citation-reports/ (Accessed on 31st December 2013)

17. Vanclay J K, Impact factor: outdated artefact or stepping-stone to journal certification? *Scientometrics* (2012) pp. 1-25, Available at: http://arxiv.org/ftp/arxiv/papers/1201/1201.3076.pdf (Accessed on 31st December 2013)

18. Russell R and Singh D, Editorial: Impact factor and its role in academic promotion, *International Journal of Chronic Obstructive Pulmonary Disease*, 4(2009) 265–266.

19. Bornmann L and Marx W, The *h*-index as a research performance indicator, *European Science Editing* 37(3) (2011) 77-80.

20. Czarnecki L, Kaźmierkowski M P, and Rogalski A, Doing Hirsch proud; shaping *h*-index in engineering sciences, *Bulletin of the Polish Academy of Sciences*, Technical Sciences, 61(1) (2013) 5-21.

21. Lillquist E and Green S, The discipline dependence of citation statistics, *Scientometrics* 84(3) (2010) 749–768.

22. Podlubny I, Comparison of scientific impact expressed by the number of citations in different fields of science, *Scientometrics,* 64 (1) (2005) 95–99.

23. *h*-index and variants - **SCI2S** 2010, Available at: http://sci2s.ugr.es/hindex/ (Accessed on 31st December 2013)

24. Maabreh M and Alsmadi I M, A Survey of impact and citation indices: Limitations and issues*, International Journal of Advanced Science and Technology* 40 (2012)35-53.

25. Rousseau R, New developments related to the Hirsch index, *Science Focus*, 1(4) (2006) 23–25 (in Chinese).

26. Egghe L, An improvement of the *h*-index: The *g*-index, *ISSI Newsletter*, 2(1) (2006) 8–9.

27. Egghe L, Theory and practice of the *g*-index, *Scientometrics*, 69(1) (2006) 131–152.

28. Kosmulski M, A new Hirsch-type index saves time and works equally well as the original *h*-index, *ISSI Newsletter*, 2(3) (2006) 4-6.

29. Wu Q, The *w*-index: A measure to assess scientific impact by focusing on widely cited papers, *Journal of the American Society for Information Science and Technology*, 61 (3) (2010) 609-614.

30. Alonso S, Cabrerizo F J, Herrera-Viedma E, Herrera F, *hg*-index: A new index to characterize the scientific output of researchers based on the *h*- and *g*- indices. *Scientometrics* 82(2) (2010) 391-400.

31. Egghe L and Rousseau R, An *h*-index weighted by citation impact, *Information Processing & Management*, 44 (2) (2008) 770-780.

32. Jin B H, *h*-index: An evaluation indicator proposed by scientist, *Science Focus* (in Chinese), 1(1) (2006) 8―9.

33. Jin B H, Liming L, Rousseau R and Egghe L, 2007, The *R*- and *AR*-indices: Complementing the *h*-index, *Chinese Science Bulletin,* 52(6) (2007) 855-863.

34. Bornmann L, Mutz R, and Daniel H D, Are there better indices for evaluation purposes than the *h*-index? A comparison of nine different variants of the *h*-index using data from biomedicine, *Journal of the American Society for Information Science and Technology*, 59(5) (2008) 830–837.

35. Cabrerizo F J, Alonso S, Herrera-Viedma E, Herrera F, q^2-Index: Quantitative and qualitative evaluation based on the

number and impact of papers in the Hirsch core, *Journal of Informetrics* 4(1) (2009) 23-28.

36. Prathap G, Is There a Place for a Mock *h*-index?, *Scientometrics*, 84(1) (2010) 153-165.

37. Prathap G, The Energy–Exergy–Entropy (or EEE) sequences in bibliometric assessment. *Scientometrics,* 87(3) (2011) 515-524.

38. Prathap G, Energy indicators and percentile ranking normalization. *Scientometrics*, 91(3) (2012) 997–1003.

39. Prathap G and Leydesdorff L, The world of science according to performance indicators based on percentile ranking normalization, *J Scientometric Res.*, 1(1) (2012) 53-59.

40. Prathap G, A comment to the papers by Opthof and Leydesdorff, Scientometrics, 88, 1011–1016, 2011 and Waltman et al., Scientometrics, 88, 1017–1022, 2011, *Scientometrics*, 90(2) (2012)737-743.

41. Prathap G and Gupta B M, Ranking of Indian engineering and technological institutes for their research performance during 1999-2008. *Current Science,* 97(3) (2009) 304-306.

42. Prathap G and Gupta B M, Commentary: Ranking of Indian universities for their research output and quality using a new performance index, *Current Science*, 97(6) (2009) 751-752.

43. Gupta B M, Ranking and performance of Indian Universities, based on publication and citation data, *Indian Journal of Science and Technology*, 3(7) (2010) 837-843.

44. Sidiropoulos A, Katsaros D and Manolopoulos Y, Generalized Hirsch *h*-index for disclosing latent facts in citation networks. *Scientometrics* 72(2) (2007) 253-280.

45. Burrell Q L Hirsch's *h*-index: a stochastic model. *Journal of Informetrics* 1(1) (2007)16-25.

46. Batista P D, Campiteli M G, Kinouchi O, and Martinez A S, Is it possible to compare researchers with different scientific interests? *Scientometrics,* 68(1) (2006) 179-189.

47. Schreiber M, To share the fame in a fair way, h_m modifies h for multi-authored manuscripts, *New Journal of Physics,* 10 (2008) 040201-1-8.

48. Zhang C – T, The *e*-index, complementing the *h*-index for excess citations, *Public Library of Science (PLoS) ONE*, 4(5) (2009)1–4.

49. Zhang C-T, Relationship of the *h*-index, *g*-index, and *e*-index, *Journal of the American Society for Information Science and Technology*, 61(3) (2010) 625–628.

50. Ye F Y and Rousseau R. Probing the *h*-core: an investigation of the tail-core ratio. *Scientometrics,* 84(2) (2010) 431-439.