International Journal of Applied and Advanced Scientific Research (IJAASR)
Impact Factor: 5.255, ISSN (Online): 2456 - 3080
(www.dvpublication.com) Volume 2, Issue 1, 2017

COMPARATIVE STUDY OF VARIOUS RESEARCH INDICES USED TO MEASURE QUALITY OF RESEARCH PUBLICATIONS

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Cite This Article: Dr. P. S. Aithal, "Comparative Study of Various Research Indices Used to Measure Quality of Research Publications", International Journal of Applied and Advanced Scientific Research, Volume 2, Issue 1, Page Number 81-89, 2017.

Abstract:

The success of research projects funded by various agencies can be evaluated by studying the research publications generated from those projects and the research publications can be evaluated using impact factors and citation indices. There are several citation indices commonly used to assess the value/quality of a research publication or the research impact of an author or a journal. Research indices are calculated based on either citation values of research publications of a research scholar or the number of research papers published by a research scholar for a given period. There are many research indices developed by many types of research which include H-index, i10-index, G-index, H(2)-index, HG-index, Q2 -index, AR-index, M-quotient, M-index, W-index, Hw-index, E-index, A-index, R-index, W-index, J-index, etc. Out of these citation based research indices, h-index, G-index and i10-index are commonly used in some of the citation databases. Researchers have also studied the problems and limitations associated with these indices. In this paper, we have discussed the most popular research indices presently used which include h-index, G-index, and i-10-index along with their advantages, benefits, constraints, and disadvantages. Most of the research indices are calculated based on number of citations a paper receives. The major limitation of this model is that the citations usually increase with an increase in time even after the researcher dies, the citations and hence the indices continue to grow. It is argued that due to various reasons, a research publication may not attract citations initially for some years and after ten to twenty years some papers may attract citations. The best method of identifying the contribution to research is calculating the annual research index for an author by considering the annual research publications. Accordingly, based on annual research index of an author, his average research contribution for five years, or ten years, or twenty years or any desired period can be determined. Here, we have suggested some of the new research indices to be used for calculating research productivity of individuals as well as a team of people in an organization. The paper also contains some of our newly proposed indices including ARP-Index – (Annual Research Publication Index), RC-Index – (Research Continuation Index), RE-Index (Research expansion Index), Project Productivity Index, and Cost Index and the method of calculating these indices along with their advantages and limitations.

1. Introduction:

Higher educational institutions by definition have the responsibility of creating intellectual property in addition to imparting vigorous training in identified area [1-5]. The new trend and strategy in this responsibility are involving students along with faculty members in research. This is due to the fact that as generations progress, the intelligence of the youths improves so that present and future young generations are more susceptible to involve and contribute to research. The same argument is true in the case of young faculty members. The institutions and the administration whohavesensed such changes in generations progress plan for using it for creating intellectual property by shifting their focus on the creation of new knowledge by giving importance to research activities. The institutions set their priorities to research along with higher education allocates funds for the research projects and also encourages the faculty members to attract research project funds from both government schemes and from industries. The success of such research projects funded can be evaluated by studying the research publications and/or patents generated from those projects.The research publications can be evaluated using impact factors and citation indices whereas the patents can be evaluated based on its ability of commercialization. Since several years journals have been ranked based on their relative importance by their journal impact factor, but that system has been much commented and criticized. The importance placed on the journal impact factor, calculated by the average number of citations per article in the previous two years, has led to many journals manipulating the system. For example, by publishing certain types of articles like reviews, theories, and techniques, are highly cited and thus will contribute significantly to the journal impact factor. As per data shown by the journal Nature for the year 2004, 89% of its impact factor was generated by just 25% of its articles published in all issues of that year. There are several citation indices that are used to assess the value/quality of a research publication or the research impact of an author or a journal. In this paper, an extensive survey is conducted to evaluate the majority of the citation indices. Using examples, we demonstrated some of the limitations and problems with those indices. The evaluation showed that there is a need for more sensitive and comprehensive indices that can take into considerations all the factors that may impact a research publication or author. The study also showed that the majority of citation-indices score heavily depend on the most cited papers as in the case of H-index and other most successive indices.

2. Popular Research Indices Currently Used:

Research indices are calculated based on either citation values of research publications of a research scholar or the number of research papers published by a research scholar for a given period. There are many research indices developed in various by many researchers which include H-, i10-, G-, H(2)-, HG-, Q2-, AR-, M-quotient, M-, W-, Hw-, E-, A-, R-, W-, J-index, etc. [6]. Out of these citation-based research indices, h-index, G-index and i10-index are commonly used in some of the Citation databases. Table 1, lists some of the popular research indices used based on Citations.

Table 1: Some of the popular research indices used based on Citations

S.No	Research Indices	Developer	Commonly using in Citation Databases
1	h-index	Jorge Hirsch (2005)	Web of Science Indexing. Scopus Indexing. Google Scholar Indexing. Chemical Abstracts
2	G-Index	Leo Egghe (2006)	Encyclopaedia of Information Science and Technology
3	i10-Index	Google (2011)	Google scholar indexing.
4	R-index	Reserchgate	Reserchgate
5	m-index	Jorge Hirsch	Improvement in H-index

(A). h-Index:

The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. The index is based on the set of the research scholar's most cited papers and the number of citations that they have received in other publications.The h-index, originally described in 2005 by Jorge Hirsch [7], is a measurement that aims to describe the scientific productivity and impact of a researcher. Like all metrics, the h-index is not perfect, however, it addresses many of the problems associated with impact factors and the publication process in general and enables some very interesting analyses. The research index is a measure of the number of highly impactful papers a researcher has published. The larger the number of important papers, the higher is the h-index, irrespective of where the work is published.To calculate it, only two pieces of information are required: the total number of papers published (Np) and the number of citations (Nc) for each paper.The h-index is defined by how many h of a researcher's publications (Np) have at least h citations each (Figure 1).H-index increases with increase in number of publications and by increase in citations of increased number of papers. By publishing n number of papers each having n number of citations gives h-index value n.

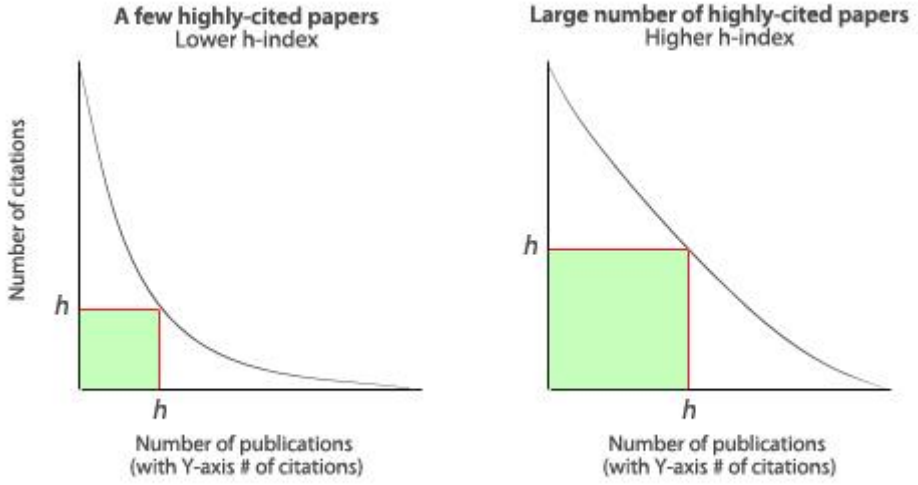

Figure 1: Variation of the h-index between two researchers with the same number of publications [8].

ABCD Listing Analysis of H-index: ABCD analysis framework recently developed by Aithal et. al. (2015) [9-19] has qualitative part of listing advantages, benefits, constraints, and disadvantages of a system or concept or a technique. Here we have made an attempt to ABCD listing of various indices including h-index.

Advantages: The index has several advantages over other metrics:

- ✓ It relies on citations to your papers, not the journals, which is a truer measure of quality
- ✓ It is not dramatically skewed by a single well-cited, influential paper (unlike total number of citations would be)
- ✓ It is not increased by a large number of poorly cited papers (unlike total number of papers would be).

- ✓ It minimizes the politics of publication. A high-impact paper counts regardless of whether your competitor kept it from being published in the top-tier journals.
- ✓ It's good for comparing scientists within a field at similar stages in their careers.
- ✓ It may be used to compare not just individuals, but also departments, programs or any other group of scientists.
- ✓ Since the most highly cited articles contribute to the *h*-index, its determination is a simpler process.
- ✓ The *h*-index is intended to measure the quality and quantity of scholarly published papers simultaneously.

Benefits: The important benefits of h-index value of individuals/institutions are :

- ✓ The h-index gives an idea on quantity and quality of scholarly published papers simultaneously so that based on h-index value of an individual or organization, one can judge the scientific contribution of individual or organization.
- ✓ H-index cannot be more than number of publication or number of citations so that an author intended to increase h-index has to continuously increase his publications along with citable papers.
- ✓ H-index value identifies the ranking of an author/organization in scientific community.

Constraints:

- ✓ It counts a highly-cited paper regardless of why it's being referenced- eg, for negative reasons.
- ✓ It doesn't account for variations in average number of publications and citations in various fields (some traditionally publish and cite less than others).
- ✓ It ignores the number and position of authors on a paper.
- ✓ It limits authors by the total number of publications, so shorter careers are at a disadvantage.
- ✓ It has relatively low resolution in that many scientists end up in the same range since it gets increasingly difficult to increase the h-index the higher it gets (an h-index of 100 corresponds to a minimum of 10,000 citations).
- ✓ It, like all metrics, is based on data from the past and may not be a valid predictor of future performance. However, in a follow-up publication Jorge Hirsch demonstrated that the h-index is better than other indicators (total papers, total citations, citations per paper) at predicting future scientific achievement.

Disadvantages: The important disadvantages of h-index value of individuals/institutions are :

- ✓ The *h*-index does not provide a significantly more accurate measure of total number of papers published by a given scholar.
- ✓ The *h*-index does not provide a significantly more accurate measure of impact than the total number of citations for a given scholar.
- ✓ The h-index only counts the number of papers (n) of an author which have n number of citations. It does not give any idea on the accounting for the rank in the sequence of authors.
- ✓ The *h*-index does not provide any idea on total time duration the published papers took to reach current h-index value.
- ✓ The scholars researching in a unique area may not get many citations so that even if they publish more papers their citations and hence the h-index may be at low value.
- ✓ The scholars with less number of publications but more citations per paper may have low value of h-index.
- ✓ H-index cannot be used to measure the annual research performance of the authors.
- ✓ H-index value does not give accurate value of author's publications as well as citations and hence confusing. For example, an author has 20 publications with citations more than 20 and 100 publications with citations close to 20 and his h-index is only 20. Another author has 20 publications only with citations more 20 and his h-index is also 20.
- ✓ The h-index only requires a minimum of n citations for the least-cited article in the set and thus ignores the citation count of very highly cited papers.
- ✓ H-index has a drawback of not considering self-citations of the authors. Self-citation by an author is like any other citation essential to present a research paper which is continuation of their work.

(B). i10-Index:

i10-Index is the number of publications of an author with at least 10 citations. This very simple measure is only used by Google Scholar and is another way to help gauge the productivity of a scholar.

ABCD Listing Analysis of i10-index:

Advantages of i10-Index:

- ✓ Very simple and straightforward to calculate
- ✓ My Citations in Google Scholar is free and easy to use
- ✓ Authors can identify the important papers out of their publications which have contributed for the continuation of research based on received atleast 10 citations.

- ✓ i10 index gives an idea of quantity and quality of scholarly published papers of an author simultaneously.

Benefits of i10-index: The important benefits of i10--index value of individuals/institutions are :

- ✓ Gives an idea of author's research impact in terms of a number of publications reached 10 citations.
- ✓ Continuous evaluation method without any timeframe.
- ✓ Gives comparative performance of published papers of different researchers in the same field.
- ✓ Can be shown along with other indices to show the impact of an author.

Constraints:

- ✓ Only 10 citations of a publication is counted.
- ✓ Citations of the papers lower than 10 are not counted in calculation and hence less specific.
- ✓ Total number of publications and total number of citations of an author is not taken into account for calculation of i10-index. Thus it gives a vague idea of authors research productivity.

Disadvantages of i10-Index:

- ✓ Used only in Google Scholar
- ✓ I10-index becomes stagnant once all published papers reach 10 citations.
- ✓ It does not count number of publications or number of total citations of an author.
- ✓ It does not signify the position of the author in the sequence of authors of the published paper.
- ✓ It does not identify single author papers, annual research contribution of an author.

(C). G-Index:

G-index is an improved version of h-index. In the theory and practice of the g-index, the inventor, Leo Egghe[20] aims to improve on the h-index by giving more weight to highly-cited articles. The g-index is an index for quantifying scientific productivity based on publications and calculated based on the distribution of citations received by a given researcher's publications. So, given a set of articles ranked in decreasing order of the number of citations that they receive, the g-index is the (unique) largest number such that the top g articles received (together) at least g^2 citations. For the citations received and given a number of papers ranked in a decreasing order according to the citations received till now, the G-index is the biggest number such that the top G articles received (altogether) at least G^2 (G square) citations. This index assists the h-index and gives more weight to the highly-cited papers.

ABCD Listing Analysis of G-index:

Advantages:

- ✓ Improved version of h-index and hence represents both number of publications and number of citations.
- ✓ G-index calculation methodology gives more weightage to highly cited papers.
- ✓ The g-index is an alternative for the h-index, which doesn't average the numbers of citations.
- ✓ In a group of authors of the same field, the variance of the g-indexes will be much higher than the one of the h-indexes which make a comparison between authors concerning their visibility in the world more apparent.

Benefits*:*

- ✓ G-index allows citations from higher-cited papers to be used to bolster lower-cited and hence in all cases the g-index value is in most cases higher than h-index value.
- ✓ G-index helps to make more apparent the difference between authors' respective impacts. The inflated values of the G-Index help to give credit to lowly-cited or non-cited papers while giving credit for highly-cited papers.
- ✓ More scientific than h-index.

Constraints:

- ✓ G-index saturates whenever the average number of citations for all published papers exceeds the total number of published papers and hence cannot be used in such cases.
- ✓ After introducing in the year 2006, the researchers have still confusion to replace g-index with h-index and hence not widely accepted.

Disadvantages:

- ✓ Like the h-index, the g-index is a natural number and thus lacks in discriminatory power.
- ✓ Like h-index, g-index failed to give absolute value of a total number of papers published by an author during a given period.
- ✓ G-index also fails to represent the total citations of an author during a given period.

(D). M-Index:

The m-index, also proposed by Hirsch, is defined as h-index divided by the number of years since the researcher's first publication. The index is meant to normalize the h-index so that early- and late-stage scientists can be compared. The m-index averages periods of high and low productivity throughout a career, which may or may not be reflective of the current situation of the scientist.

ABCD Listing Analysis of M-index:

Advantages:

- ✓ Improved version of H-index and hence can be better than h-index.
- ✓ Averages the low and high citations received during the long period of the career.
- ✓ Includes the number of years research as the third variable.

Benefits:

- ✓ More specific than h-index due to the usage of total years of research as a third variable component.
- ✓ While comparing the citation values of two or more people, their earlier stage of career or late stage of career can be identified and differentiated.
- ✓ Due to averaging of high and low productivity of scientists throughout their career, the low performance of one periodmaybe compensated with high performance during another period.

Constraints:

- ✓ Calculation of m-index needs time in years as the third variable unlike two variable based h-index calculation.
- ✓ Determining the first publication time for old researchers is a cumbersome process.
- ✓ Determining a number of publications, a number of citations, and a number of years of involvement in research and publications is a bit difficult compared to h-index or i-10 index calculation.

Disadvantages:

- ✓ The m-index averages periods of high and low productivity throughout a career, which may or may not be reflective of the current situation of the scientist.
- ✓ M-index may give fraction value for a given researcher unlike h-index, and i-10 index.

3. New Research Indices Proposed:

The research indices discussed above are calculated based on a number of citations a paper receives. The major limitation of this model is that the citations usually increase with an increase in time even after the researcher dies, the citations and hence the indices continue to grow. It is argued that due to various reasons, a research publication may not attract citations initially for some years and after ten to twenty years some papers may attract citations. The best method of identifying the contribution to research is calculating the annual research index for an author by considering the annual research publications. Accordingly, based on annual research index of an author, his average research contribution for five years, or ten years, or twenty years or any desired period can be determined. Here, we have suggested some of the new indices to be used for calculating research productivity of individuals as well as a team of people in an organization.

ARP-Index – (Annual Research Publication Index): Annual Research Publication index (ARP-index) is based on the annual research productivity of an author, or group of authors, or a research organization [21]. ARP index gives the weighted average of publications for a given year as the time period. This index will give annual research performance of any year (or any specific time period) of an author without considering the citations by considering the fact that usually the citations for a paper takes a long time and is variable quantity with time. This index is more useful for quick comparison of many researchers working in same or related fields for a given period of observation. This index will also stimulate the researchers to set the target for a given time period through proper planning to improve their annual research productivity. ARP-index makes use of ABC model of research productivity [21-27]. It is the weighted average of scholar's annual publications. The ARP index is exactly equal to annual research index (α) of a given person. ARP-index = annual research index (α) = [(2A + 5B + 1C)/8], where A is number of Articles published in refereed ISSN numbered journals during a given year, B is number of Books published with an ISBN number during a given year, and C is number of book Chapters or Case studies published with DOI during a given year. The ARP index can be calculated for a researcher, for a group of researchers/department or for a given organization. For a group of researchers/department or for a given organization, ARP-index can be calculated by considering a number of researchers (N) in the group or in that organization. Then ARP-index becomes [(2A + 5B + 1C)/8]/N. ARP-index can be used to compare researchers annual productivity for a given time period and the annual research output of higher education and research organizations.

RC-Index – (Research Continuation Index): As per general definition, self-citation is a process of citing some of the old published papers of the same authors in present paper if they are relevant and appropriate to mention in the reference. This self-citation of related works will avoid repetition of concepts and even avoids self-plagiarism. Authors working in a unique area as monopoly researchers will not find much-published work by others in current research area/topic may find only their previous works as relevant to quote in the introduction as well as in literature review. Thus depending on the research topic in hand, an author can cite any published article whoever's it may be as cited article including self-citation. Thinking honestly, self-citation has nothing to do with ethics of publication until it cites relevant work and adds the weightage of current publication. Thus self-citation indicates *research continuation* in a given field by a given researcher or team of researchers. Accordingly, we have developed a new research index called Research Continuation index (RC-Index). RC index is planned to consider both the number of publications for a given time period and the number of self-citation of previous articles in the publications so that one can have an idea of research continuation

responsibility of an author or group of researchers or a research institution. Accordingly, RC-index is defined as the product of the number of research publications during a given period and the number of self-citations in those published papers.

RC-index = (Number of journal publications × Number of self-citations in those papers) = (n × m), where n = number of journal publications of the researcher during a given period (maybe annually) and m = Number of self-citations in those papers during the same period. Research Continuation index assumes that any new research work publication if it is a continuation of previous research work or the continuation of previous research topic will contain by logically the self-citation of previous works and publications. If self-citation is zero, means the researcher is not continued his previous work/works. RC-index indicates the magnitude of activeness of researcher by his number of publications during a given period and ability of continuation of previous research topic/topics by a number of his self-citations. RC-index can be increased by a researcher by increasing his research contribution as well as effective self-citation during a given period.

RE-Index (Research expansion Index): In contrary to research continuation index (RC-index), a researcher can determine his research expansion index by knowing a number of journal publications and number of external citations during a given observation period.

RE-index = (Number of Individual publications × Number of Citations on those papers by other researchers) during a given observation period.

RE-index indicates how the research topics studied by the researcher have expanded to other researchers so that they also started to work on those topics and published papers by citing the initial researcher's papers in their publications. RE-index gives equal importance on Number of publications by an author (n) and a number of citations by others (p) on theses papers during a given observation time. RE-index gives an idea of how quickly others have picked up the idea/research work of a particular researcher and continued research on that topic.

Project Productivity Index: Many organizations do research by involving their researchers to work in externally funded projects as well as internally funded projects. Externally funded projects are given by Country government, various research agencies, or different industries. Internally funded projects are offered to researchers based on their department and on individual topics. The productivity of such project can be calculated by studying the number of research publication created/patents obtained from such projects. For such scenario, the funding agency can measure the productivity of a project using a quantity called project productivity index (PP-index). PP-index is defined as a ratio of Research productivity to Project funding. Research productivity can be measured by knowing the number of papers published or number of patents obtained from that project. If n is the number of journal papers published or/and patents accepted and A is the amount in Rs./$ spent for completion of a research project, then PP-index = (n/A). By increasing the number of publications from a project or by decreasing the expenditure of a research project, one can increase the Project productivity index. Using this index, one can determine the total cost per publication in a given project and hence the success or failure of the project can be judged.

PP-index = (Research Productivity / Project Funding) = (1/Cost per publication)

Cost per Paper Index: This includes both, the cost of research and the cost of publication. Cost of the research include the cost of writing the project by gathering information and literature, cost of availing and setting up experimental setup or empirical methodology, cost of various resources used for research, cost of gathering data, analysing them and interpreting the result, Cost of writing research publication papers and patents, coat of publication fee/article processing charge for creative commons publications etc. Depending on the ability of the researcher and depending on the research methodology used for the research, the cost of research varies. The cost per paper index is a new way of seeing the research expenditureas an investment to get better output. Generally, the cost of research increases from conceptual research to theoretical research, to empirical research, to experimental research. A researcher should plan how to decrease the cost of research even if he is supported by government or public sector funding agencies due to the fact that such money is from the taxpayers of the country. Thus every research organization should seriously think on the output of every research project carried out by its researchers through a measuring scale using cost per paper index. Cost per paper/patent index gives a fair idea on the average cost of each paper publication which is the output of a research project under completion. Both research organization and researcher should plan how to decrease average cost per paper without compromising the quality. Generally based on prediction, cost per paper is lowest for conceptual based papers and highest for experiment based papers. Some experiments need huge investment on machines, technology, and materials. But such experiments should be planned to get a good amount of output. Thus while planning for investment on research, organizations should target to decrease the cost per paper/patent to increase the productivity. Ideally, the cost per research paper including publication should be zero for good research and in all practical cases it should be as low as possible.

4. Conclusion:

The measure of research performance in the form research index is essential to set the target for most of the researchers. The value of research index based on various research parameters is expected to boost the self-motivation of researchers working in any area. Presently popular research indices like h-index, i-10 index,

g-index, R-index, m-index etc. have their own advantages, benefits, constraints, and disadvantages as listed in this paper. Based on analysing various research performance publications, some new, easy, and useful research indices are proposed in this paper. Here, we have suggested some of the new research indices to be used for calculating research productivity of individuals as well as a team of people in an organization. The best method of identifying the contribution to research is calculating the annual research index for an author by considering the annual research publications. Accordingly, based on annual research index of an author, his average research contribution for five years, or ten years, or twenty years or any desired period can be determined. The newly proposed indices including ARP-Index – (Annual Research Publication Index), RC-Index – (Research Continuation Index), RE-Index (Research expansion Index), Project Productivity Index, and Cost per paper Index and the method of calculating these indices are discussed. It is found that these new indices are effective and simple in the research output of an organization. The detailed analysis of these newly proposed indices using ABCD analysis framework [29-40] isin progress.

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