Application of *h* and *h*-type indices at meso level: A case of Malaysian engineering research

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ABSTRACT

Quantity and quality of research publication productivity are the main areas of concern for the scientific community. The way of accountability of research performance evaluation has been changing with the advent of new metrics. The research performance evaluation clearly emphasizes on peer review approach. This approach possesses a central position in making an economic decision and monitoring of research and development programs of Higher Education Institutions. The combined use of various indicators is consistently recommended for Research Performance Evaluation (RPE). The study empirically examines and evaluates the feasibility of new RPE development by applying the h and h-type indices along with traditional metrics for the case of Malaysian Engineering Research at the meso level. This study helps in understanding the application of h and h-type indices and establishes that these indices are helpful in supporting and monitoring RPE and can be used along with traditional activity and impact metrics. Among the studied h-type indices, the revised development was found comparatively more meaningful with a less statistical error.

Keywords: Research performance; Engineering research; Publication productivity; h indices; Citation analysis; Scientometrics assessment.

INTRODUCTION

A study of the application of mathematical and statistical methods to books and other media of communication is called bibliometric (Pritchard 1969). In the same year, Nalimov and Mulchenko (1969), as cited in Glanzel (2003, p.6), defined scientometric as “the application of those quantitative methods that are dealing with the analysis of science viewed as an information process”. According to Lundberg (2006) and Zavaraqi and Reza Fadaie (2012), these terms are almost used as synonyms. Scientometric is more multi-faceted encompassing sub-areas such as structural, dynamic, evaluative and predictive endeavor of scholarly communication (Zavaraqi and Reza Fadaie 2012). In general, research publication productivity dimensions are explored by quantity (number of publications) and quality (total citation counts) of output records with traditional activity and impact measures (Van Raan 2004; Hirsch 2007). In this study, the term ‘scientometric’ is used instead of ‘bibliometric’ because our purpose is to carry out scientific research productivity analysis for Research Performance Evaluation (RPE).

Scientometricians believe that citing and cited by is a complex process, and there is no ideal monitoring mechanism that works in isolation. This requires objective measures to supplement or complement the peer process (Borgman and Furner 2002; Van Raan 2003; Moed 2005; Bornmann et al. 2012). Mostly, this approach is focused to address the quantitative core (i.e. publication productivity or growth patterns) of research. However, the qualitative core (i.e. impact) of research is going to become crucial and difficult with the advent of online reference enhanced databases. The introduction of new *h*-type indices and global trends of institutions' ranking by well-known agencies such as Times Higher Education World University Rankings, QS top universities ranking, Academic Ranking of World Universities, National Taiwan University Ranking, and the Leiden Rankings of Universities have made it an interesting topic of study for less studied disciplines. Consequently, examining the capabilities of traditional metrics and seeking the feasibility of newly introduced indices for RPE have become an important area of study.

The challenge to gauge the impact has captured the attention of researchers, evaluators and policy makers. The legitimacy of metrics like Publications (P), Citations (C), Citation per publication (CPP), Journal Impact Factor for RPE has been challenged (Leydesdorff 2009). Literature observed noteworthy fluctuation in the ranking criteria for the application of new and traditional indicators (Schreiber 2008; Schreiber 2013; Ghane, Khosrowjerdi and Azizkhani 2013). Such discrepancies lead to evaluate the existing practice for the potential use of new development(s) and to explore for further improvement for RPE purpose. Van Raan (2006) was the first who examined the application of original *h*-index for RPE. Several studies were conducted later to inspect the usefulness of Hirsch's *h*-index in relation to other commonly used indicators to evaluate the scientific research publication productivity for policy level purpose (Prathap 2006; Imperial and Rodriguez-Navarro 2007; Mingers 2007; Bouabid and Martin 2009; Lutz et al. 2008 ; Lazaridis 2010; Norris and Oppenheim 2010a; Tahira et al. 2014a). They emphasized the need to conduct further studies to examine its application in different contexts and disciplinary perspectives. Soon after *h*-index, many h-type indices have been introduced, and several empirical studies argued that few *h*-type indices performed better than the original *h*-index (Li et al. 2010; Bornmann et al. 2008).

In various modifications of *h*-index, field dependence, self-citation, multi-authorship, and career length are also taken into account (Bornmann, et al. 2011; Norris and Oppenheim 2010b). The head and tail cores remain ignored due to their formulaic limitations (Prathap 2010; Bornmann, et al. 2011; Zhang 2009; 2013). The underpinnings of newly introduced index have led to the introduction of numerous *h*-type indices, mostly focused on citation distribution issues (Norris and Oppenheim 2010b; Bornmann et al. 2011), while the head and tail cores remain ignored due to their formulaic limitations (Prathap 2010; Bornmann, et al. 2011; Zhang, 2009; 2013). Several *h*-index advantages such as ignoring the head, tail and zero citations are criticized and taken as its demerits (Tahira et al. 2014a). The flux in metrics/indices is playing an important role to think, re-plan and re-evaluate of indicators for RPE.

This study is an extension of the study "Scientometric Assessment of Engineering in Malaysians Universities" (Tahira, Alias and Bakri 2013), where we examined the *h*-index with two size independent *h*-type models (Glänzel-Schubert model '$h_{G\text{-}H}$' (Schubert and Glänzel 2007) and Molinari and Molinari model h_m (Molinari and Molinari 2008)) along with TP (Total Publications), TC (Total Citations) and Citations per publications (CPP). One objective of this study was to seek the relationship between the studied indicators and Malaysian Institutional Research Performance by the Ministry of Higher Education (MOHE) Malaysia. The goodness of fit test indicated that these indicators (including *h*-index) exhibited the similar behavior for RPE, when we considered the whole set of universities and grouping them into RU and non-RU. Nonetheless, the productivity and citation metrics along with new development (*h*-index) did not help to make a difference at the group level. The only exception in our case was CPP that helped in making a difference between research universities (RU) and non-RU research status group. The present study is conducted to answer the research question, "Which *h*-type index is the best to address the different dimensions of RPE, with less reservation at meso level? "

MATERIALS AND METHOD

Our unit of analysis was 'Engineering Research', one of the nine Web of Science (WoS) engineering subcategories. Our sample consisted only those universities that have at least 50 or more than 50 publications in the WoS database, and 12 Malaysian universities (five Research Universities and seven non-Research universities) were considered in this study. Their publication data of ten years (2001-2010) was retrieved from WoS. All data were retrieved in Excel spreadsheet and each record was checked manually. We computed the values of these three indicators for meso (institutional) level. The *h* and *g* indices were calculated manually while other *h*-type indices were computed using their formulas. The selected seven *h*-type indices and one proposed index (*h*-cpp) fall under three designed categories (modified, *h*-core dependent, *h*-core independent). These categories are concerned with *h*-core, head, and tail citation distributions. These indices are introduced to overcome the core citation distribution issues as inherent in the original *h*-index. The salient features of these selected set of three indicators: Activity Indicator (AI), Observed Impact Indicator (OII), *h* and *h*-type indices, including proposed revision, are described in Table 1.

Table 1: Set of Studied Indices

Indicators		**Definition**
1. Activity Indicator (AI)		
TP		Total publications over the period of ten years (2001-2010) of each university including the research article and reviews only from WoS.
2. Observed Impact Indicators (OII)		
TC		Total citations during the period 2001-2010 of each university publications records
CPP		Citation per publication for the ten year
3. *h* and *h*-type indices	**Category**	**Definition**
h	Original *h*-index	"A scientist has index *h* if *h* of his /her Np papers has at least *h* citations each and the other (Np − *h*) papers have no more than *h* citations each" (Hirsch 2005 p. 16569).
g	modified	"The *g*-index is the highest number *g* of articles that together received g^2 or more citations" (Egghe 2006 p.8).
m	*h*-core dependent	"*m*-index is the median number of citations received by papers in the Hirsch core (Bornmann et al. 2008).
A	*h*-core dependent	*A*-index is the average number of citations received by the articles in the *h*-core (Jin 2006).
R	*h*-core dependent	R-index (Jin et al. 2007) is the square root of the total number of citations received by the articles in the *h*-core.
q2	*h*-core dependent	A composite index computed by the product of the *h*-index and median of the *h*-core citations (Cabrerizo et al. 2010).
hg	modified	*hg* a composite index (Alonso et al. 2010) is the square root of the product of *h* and *g* indices.
H'	*h*-core independent	It deals with the citation distribution function with head and tail core ratio and formalize as h'= e.h/t (Zhang 2013). Where 'e' is the access citation above the *h*-core and t is the tail core.
h-cpp	*h*-core independent	The proposed revision deals with head, tail, and zero citation distribution issues. It incorporates the original h-index and CPP as a 'Corrected Quality Ratio' introduced by Lindsey (1978). It is expressed as a multiplicative connection between *h* and CPP with the geometric mean of these functions ($\sqrt[3]{h \times h \times CPP}$) (Tahira 2014b).

FINDINGS

The objective of this research study was to explore the application of *h*-index; revised development (*h*-cpp) and a set of *h*-type indices for meso level data and to seek the feasibility of newly introduced indices for RPE purpose. We employed three indicators (AI, OII, and h and h-type indices) to meso level data. Firstly, a snapshot of the results of application of Activity, Impact, *h* and *h*-type indices are presented on the whole dataset of 12 Malaysian universities (Table 2). Later the results of descriptive statistics, the correlation matrix and regression analysis (Table, 3, 4 and 5) are presented to analyze the performance of *h* and *h*-type indices and proposed revision.

a) Application of AI, OII, *h* and *h*-type Indicators at Meso Level

The application of our selected set of indices from three indicators (AI, OII, *h* and *h*-type indices) and corresponding institutional ranking is presented in Table 2. The findings exhibit a considerable variation in the ranking order. Few cases are more noteworthy to be discussed. Comparatively, the first five universities (RU status) have high *h*-index. Two cases of non-RU status universities, MMU and UNMC, compete equivalently (with *h*-index of 19 and 13 respectively). Two cases, UPM and MMU, have almost the same number of publications but a lower *h*-index values from UM and UTM. Four universities UPM, UM, UTM and MMU (2309, 2388, 2259, and 2231) have small differences between citation records and their *h*-index values (20, 23, 23, and 19). Two cases from RU status universities (UM and UTM) have a *h*-index of 23, and two from non-RU status universities (UiTM and UTP) have a *h*-index of 9 each. UNMC is the second ranked among seven non-research universities. It has almost the same publications as UiTM and IIUM but, a reasonable difference in citations and *h*-index values.

Scientometric positioning of each university based on TP, TC and *h*-index and *h*-type indices are ranked in Table 2. USM and UNITEN are positioned first and last respectively, in ranked order. The first and the last case fluctuated from its position with three indices m, A and H’ and CPP, *h*-index and H’. Other institutions also showed variation based on these various indices. Six cases with reference to total citation (TC) and 10 cases for *h*-index vary their positions with respect to the publication indicator. The major change in positioning can be observed with respect to CPP. In the accumulation of *h*-type indices application, the m, A and **H’** indices revealed more fluctuation in the positioning order of institutions.

b) Descriptive Statistics of AI, OII, *h* and *h*-type Indicator

In order to seek the correlation of selected set of indicators, first, we tabulated the results of descriptive statistic (Table 3). This statistics reports the range, minimum, maximum, mean and standard deviation values. TC has very high standard deviation and range. Among all indicators CPP, as an OII, possesses the lowest value of standard deviation and range whereas, among *h* and *h*-type indices, *h*-cpp has less standard deviation followed by **H’** and *h*-index.

Spearman’s rho correlation matrix of the *h*-index, a proposed revision (*h*-cpp) and a set of *h*-type indices (g, A, R, m, q2, **H,'** hg) with traditional AI (TP) and OII (TC) are presented in Table 4. The results indicate that all indices show a high correlation with traditional metrics, but this relation is stronger with OII. Other OII metric ‘CPP’ exhibits no correlation with TP, but it shows a strong correlation (>0.8) with TC, *h*, *h*-cpp, R, q^2, **H**’, hg, and a good correlation (>0.7) with g, A, and m-indices. The original *h*-index and the studied *h*-type indices (h, g, A, R, m, q2, **H’** and hg) including *h*-cpp exhibits a very high significant ‘R’ (>0.9) (Table 5). However, low values of Mean Square Error (MSE) and Mean Absolute Error (MAE) are observed for *h*-cpp from all other competitors’ indices including original *h*-index.

Table 2: Analysis of Complete Dataset with the Application of AI, OII, *h* and *h*-type Indices

University	TP	Rank	CPP	Rank	TC	Rank	h-index	Rank	h-cpp	Rank	m-index	Rank	A-index	Rank	R-Index	Rank	q^2-index	Rank	g-index	Rank	hg-index	Rank	H'-index	Rank
USM	724	1	5.56	1	4027	1	26	1	15.55	1	31.5	3	44.23	4	33.91	1	28.62	1	37	1	31.08	1	10.55	5
UPM	551	2	4.19	5	2309	3	20	3	11.88	4	29.5	5	46.95	2	30.64	3	24.29	5	34	3	26.08	4	12.54	2
UM	495	4	4.83	3	2388	2	23	2	13.68	2	33	2	47.61	1	33.09	2	27.55	2	36	2	28.77	2	15.22	1
UTM	475	5	4.76	4	2259	4	23	2	13.6	3	30	4	39.17	5	30.02	4	26.27	4	32	5	27.13	3	12.04	3
UKM	386	6	3.86	7	1490	6	17	5	9.96	6	26.5	6	31.24	6	23.04	6	21.22	6	25	6	20.00	6	9.10	7
UiTM	139	8	2.58	8	359	8	9	8	5.94	9	12	9	16.67	9	12.25	9	10.39	9	13	9	10.82	9	5.17	9
IIUM	138	9	1.82	11	251	11	7	9	4.47	11	10	11	10.14	11	8.43	11	8.37	11	9	11	7.94	11	2.45	12
MMU	532	3	4.19	5	2231	5	19	4	11.48	5	37	1	46.79	3	29.82	5	26.51	3	33	4	25.04	5	11.92	4
UNMC	126	10	4.88	2	616	7	13	6	9.38	7	23	7	24.54	7	17.86	7	17.29	7	20	7	16.12	7	9.24	6
UTP	142	7	2.31	9	329	9	9	8	5.73	10	11	10	11.44	10	10.15	10	9.95	10	11	10	9.95	10	2.81	11
MONASH	76	11	3.97	6	302	10	10	7	7.35	8	17.5	8	17.30	8	13.15	8	13.23	8	14	8	11.83	8	7.52	8
UNITEN	71	12	1.96	10	139	12	6	10	4.13	12	9	12	9.67	12	7.62	12	7.35	12	8	12	6.93	12	3.13	10

Table 3: Descriptive Statistics of AI, OII, *h* and *h*-type Indices (N=12)

Indices	Minimum	Maximum	Mean	Std. Deviation
TP	71	724	321.25	229.123
CPP	2	6	3.74	1.263
TC	139	4027	1392.17	1247.536
h-index	6	26	15.08	6.986
m-index	9	37	22.50	10.131
A-index	10	48	28.98	15.622
R-index	8	34	20.83	10.320
q2-index	7	29	18.37	8.211
hg-index	7	882	89.36	249.649
g-index	8	37	22.67	11.380
h-cpp	4	16	9.43	3.888
H'	2	15	8.47	4.271

Table 4: Results of Correlation Matrix AI, OII *h* and *h*-type Indices (N=12)

Indices	**TP**	**TC**	**CPP**	**h-Index**	**h-cpp**	**g-index**	**A-index**	**R-index**	**m-index**	**q2-index**	**H'-index**	**hg-index**
TP	1	.902**	0.185	.835**	.629**	.757**	.825**	.853**	.811**	.839**	.699*	.832**
TC	.902**	1	.600**	.965**	.893**	.943**	.923**	.979**	.895**	.951**	.806**	.872**
CPP	0.564	.827**	1	.868**	.813**	.722**	.774**	.862**	.774**	.862**	.874**	.874**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 5: Results of Regression Analysis for *h* and *h*-type Indices

Indices	h-Index	**h-cpp**	g-index	A-index	R-index	m-Index	q^2-index	**H'**-index	hg-index
R	0.9854	**0.9910**	0.9905	0.9793	0.9892	0.9769	0.9905	0.9471	0.9908
MSE	1.319	**0.2458**	2.184	9.291	2.0051	4.568	1.1519	1.689	1.279
MAE	0.8574	**0.3830**	1.0376	2.428	1.0883	1.602	0.8630	0.9305	0.8658

All of the studied *h*-type indices showed a discriminatory power for ranking purpose. We observed more fluctuation in ranking order with several *h*-type indices such as m, **H,'** A and hg. TC, TP and hg indicated a large deviation from the mean while CPP, *h*-cpp, and **H'** had the least deviation from the mean.

We have evaluated the discriminating power of *h*-type indices along with one activity (TP) and two observed impact metrics (TC, CPP). We have observed a high and strong degree of correlation in most of the cases. This implies that the *h*-index and other developments based on core underpinnings of *h*-index are potential indices to add in as they show a good correlation and relationship with P, C, and CPP.

To corroborate the loss of citations in the head and tail cores as inherent underpinnings in *h*-index, an improvement in the original index named *h*-cpp was proposed. This proposed composite development incorporates the CPP as balancing correction with a geometric mean. To examine the feasibility of the proposed index to probe for any improvement at the institutional level, we employed regression (R), Mean Square Error (MSE) and Mean Absolute Error (MAE). In conjecture with the statistical results, this comparison was made to the original *h*-index, and with seven *h*-type indices (h, g, A, R, m, q^2, **H'** and hg). The results revealed that the *h*-cpp successfully performed like other indices and had quite less MSE and MAE value. The proposed revision (*h*-cpp) has been also evaluated at researchers' level for the case of 100 most productive Malaysian related engineers and 100 prolific economists as considered by Tol's study (Tahira et al, 2014a). Results showed a very strong correlation (>.9) of h-cpp with AI and OII. The proposed revision exhibited low MSE and MAE values.

This finding implies that the incorporation of CPP with a geometric mean as a function to the original *h*-index helps to perform well for positioning purpose with a less statistical error. The inclusion of 'Corrected Quality Ratio' can incorporate the shortcoming of *h*-index such as the same *h*-index issue, ignoring of head, tail, and zero citations issues.

DISCUSSION AND CONCLUSION

Concurrently, there is a continuous debate among scientometricians, policymakers, as well as researchers in other fields regarding the application and feasibility of newly introduced indices in a different context and potential use for RPE. The foremost aim of scientometric studies is to build, to improve or to reconsider the research evaluation policy of the intellectual and scholarly community for allocation of funds, to set new promotion criteria, to the award of fellowship, to employ on the tenure track, and to make or improve new strategies by evaluating the existing situation at different aggregate level (Norris and Oppenheim 2007; Moed 2005; Borgman and Funner 2002).

There are several consensuses on the use and application of scientometric for RPE purposes. Evidently these metrics/indices are considered very important, supporting and monitoring aid for decision-making, ranking purposes and understanding the game playing at different aggregate levels. However, there are consensuses on several points by the prolific authors of scientometric or related field. Firstly, the peer review has a central position; secondly, metrics/indices are helping aid to make the process more accurate, transparent and fair for all and the sole use of metric is strongly discouraging because no single metric alone can capture all aspects of RPE; thirdly, CPP as a quality measure is also criticized owing to its penalizing of high productivity and finally, metrics based performance evaluation is certainly not perfect, however these indicators endorse peer review in terms of 'robustness,' 'validity,' 'functionality,' 'costs' and 'execution of time.'

The present study addresses the application of a selected set of *h*-type indices along with the original *h*-index, proposed revision, the traditional activity and impact metrics at meso level with a unit of analysis of Malaysian Engineering Research. *h*-index is evolving rapidly as an accepted indicator along with others established indicators. Since 2005, the relevant literature has provided such examples in which the application of this single metric and its variants alone or with other metrics provided meaningful results, insight and showed discriminate power as well.

The present study is based on limited cases and a selected set of *h*-type indices based on core citation distribution issues. The composite index *h*-cpp which combines *h*-index as a quantity and CPP as an impact of the 'productive core' of research productivity addresses the reservation of a good indicator, fairly justified citation distribution issues by incorporating the underpinning of *h*-index and may feasible for RPE purpose among the most noted *h*-type indices.

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REFERENCES

Alonso, S., Cabrerizo, F. J , Herrera-Viedma, E., and Herrera, F. 2010. h-Index: A review focused in its variants, computation and standardization for different scientific fields. *Journal of Informetrics,* Vol*.,* 3, no.4: 273-289.

Borgman, C.L., and Furner, J. 2002. Scholarly communication and bibliometrics. In B. Cronin (Ed.), *Annual Review of Information Science and Technology*. Medford, NJ: Information Today: 3-72.

Bornmann, L. Marx, W., Gasparyan, A.Y., and Kitas, G. D. 2012. Diversity value and limitations of the journal impact factor and alternative metrics. *Rheumatology International,* Vol. 32: 1861-1867.

Bornmann, L., Mutz, R., and Daniel, H.D. 2008. 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,* Vol. 59, no 5: 830–837.

Bornmann, L., Mutz, R., and Hug, S. E. and Daniel, H.D. 2011. A multilevel meta-analysis of studies reporting correlations between the h index and 37 different h index variants. *Journal of Informetrics,* Vol. 5, no 3: 346-359.

Bouabid, H., and Martin, B. 2009. Evaluation of Moroccan research using a bibliometric-based approach: Investigation of the validity of the h-Index*. Scientometrics,* Vol. 78, no.2*:* 203-217.

Cabrerizo, F. J., Alonso, S., Herrera-Viedma, E., and Herrera, F. 2010. q^2-Index: quantitative and qualitative evaluation based on the number and impact of papers in the Hirsch core. *Journal of Informetrics*, Vol., 4, no.1: 23–28.

Egghe, L. 2006. An improvement of the h-index: The g-index. *ISSI Newsletter,* Vol. 2, no.1: 8-9.

Ghane, M.R., Khosrowjerdi, M. and Azizkhani, Z. 2013. The ranking of Iranian universities based on an improved technique. *Malaysian Journal of Library & Information Science,* Vol. 18, no. 2, 2013: 33-45.

Glanzel, W. 2003. *Bibliometrics as a research field: A course on theory and application of bibliometric indicators*. Course handout pp.115. Available at: nsdl.niscair.res.in/ jspui/bitstream/123456789/.../Bib_Module_KUL.pdf.

Hirsch, J. E. 2005. An index to quantify an individual's scientific research output. *Proceedings of the national Academy of Sciences of the United States of America*, Vol. 102, no. 46: 16569-16572.

Hirsch, J. E., 2007. *Does the h index have predictive power*? Available at: www.pnas.org/content/104/49/19193.

Imperial, J., and Rodriguez-Navarro, A. 2007. Usefulness of Hirsch's h-Index to evaluate scientific research in Spain. *Scientometrics,* Vol. 71, no.2: 271-282.

Jin, B. 2006. h-index: an evaluation indicator proposed by scientist. *Science Focus,* Vol. 1, no.1:8-9.

Jin, B., Liang, L., Rousseau, R., and Egghe, L. 2007. The R- and AR indices: complementing the h-index. *Chinese Science Bulletin,* Vol. 52, no.6: 855–863.

Lazaridis, L. 2010. Ranking university departments using the mean h-Index. *Scientometrics*, Vol. 82:211-216.

Leydesdorff, L. 2009. How are new citation-based journal indicators adding to the bibliometric toolbox? *Journal of the American Society for Information Science and Technology,* Vol. 60, no.7:1-27.

Li, J. Sanderson, M. Willett, P. Norris, M. and Oppenheim, C. 2010. Ranking of library and information science researchers: comparison of data sources for correlating citation data, and expert judgments. *Journal of Informetrics,* Vol. 4, no.4: 554-563.

Lindsey, D. 1978. The Corrected Quality Ratio: A composite index of scientific contribution to knowledge. *Social Studies of Science,* Vol. 8, no.3:349-354.

Lundberg, J. 2006. *Bibliometrics as a research assessment tool-impact beyond the impact factor.* PhD thesis, Karolinska Insitute. Stockholm, Sweden.

Luz, M. P. D., Portella, C. M., Mendlowicz, M., Gleiser, S. Coutinho, E.S. F. and Figueira, I. 2008. Institutional h-Index: The performance of a new metric in the evaluation of Brazilian Psychiatric Post-graduation Programs. *Scientometrics,* Vol. 77 no. 2: 361–368.

Mingers, J. 2007. Measuring the research contribution of management academics using the Hirsch Index. *Journal of the Operational Research Society,* Vol. 60: 1143-1153.

Moed, H. F. 2005. *Citation analysis in research evaluation.* Dordrecht, Springer.

Nalimov, V.V., and Mulchenko, Z.M. 1969. *Scientometrics. The study of science as an information process,* Nauka, Moscow, 1969. [In English-*Measurement of Science. Study of the Development of Science as Information Process*, Washington, DC: Translation Division, Foreign Technology Division, United States Air Force Systems Command, 13 October, 1971.]

Norris, M., and Oppenheim, C. 2007. Comparing alternatives to the Web of Science for coverage of the social sciences' Literature. *Journal of Informetrics,* Vol. 1 no.2: 161-169.

Norris, M., and Oppenheim, C. 2010a. Peer Review and the *h*-index: Two studies. *Journal of Informetrics*, Vol. 4, no.3:221-232.

Prathap, G. 2006. Hirsch-type indices for ranking institutions' scientific research output. *Current Science*, Vol. 91, no. 11: 10.

Prathap, G. 2010. The 100 most prolific economists using the p-index. *Scientometrics,* Vol.84:167–172.

Pritchard, A. 1969. Statistical bibliography or bibliometrics, *Journal of Documentation,* Vol. 25:348-349.

Schreiber, M. 2008. An empirical investigation of the g-index for 26 Physicists in comparison with the h-index, the A-index, and the R-index. *Journal of the American Society for Information Science and Technology,* Vol. 59, no.9:1513–1522.

Schreiber, M. 2013. Do we need the g-index? *Journal of the American Society for Information Science and Technology,* Vol. 64, no.11: 2396-2399.

Tahira, M., Alias, R. A., and Bakri, A. 2013. Scientometric assessment of engineering in Malaysians universities. *Scientometrics,* Vol. 96:865–879.

Tahira, M., Alias, R. A., and Bakri, A. 2014a. Research performance evaluation approaches and new evaluation development. Paper presented at *Knowledge Management International Conference*, August 12-15 at Langkawi, Malaysia

Tahira, M., Alias, R. A., Bakri, A. and Bakri, Ani Shabri. 2014b. h-index, h-type Indices, and the role of Corrected Quality Ratio. *Journal of Information Science Theory and Practice*, Vol. 2, no. 4: 20-30.

Van Raan, A.F.J. 2003. The use of bibliometric analysis in research performance assessment and monitoring of interdisciplinary scientific developments. *Technikfolgenabschätzung – Theorie und Praxis*, Vol. 1: 20-29.

Van Raan, A.F.J. 2004. Sleeping beauties in science. *Scientometrics,* Vol. 59, no.3: 461-466.

Van Raan, A.F.J. 2006. Comparison of the Hirsch-Index with standard bibliometric indicators and with peer judgment for 147 Chemistry research groups. *Scientometrics,* Vol. 67: 491–502.

Zavaraqi, R., and Gholam-Reza, F. 2012. Scientometrics or science of science: quantitative, qualitative or mixed one. *Collenet Journal of Scientometrics and Information Management. Available at* http://www.tarupublications.com/journals/cjsim/cjsim.htm.

Zhang, C.T. 2009. The e-index, complementing the h-index for excess citations. *PLoS ONE,* Vol. 4: e5429.

Zhang, C.T. 2013. The h' index, effectively improving the h-index based on the citation distribution. *PLoS ONE*, Vol. 8, no.4: e59912.