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The impact factor and other performance measures – much used with little knowledge about

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ABSTRACT

It is generally believed that the IF is an objective measure of a journal's scientific quality. However, the IF is good for a relative comparison at best because it is not directly related to the journal's quality. It is the aim of this paper to provide important information on how the IF is derived and what it can tell you.
The value of the IF is, however, affected by sociological and statistical factors.

Sociological factors:

- Type of journal (publishing mainly letters, full papers or reviews)
- Average number of authors per paper (this is related to the subject area)
- Time (month) of publication
  The publish or perish phenomenon

Factors specific to the technical field:

- Subject area of the journal (i. e. number of scientists working in this area)
- Size of the journal
- Number of scientists working the field
- Type of scientists working in the field (industry vs. university)

Further, IFs are statistical measures and as such they are correlated to the number of workers in a certain area. Since this number varies greatly for various fields of science the respective IFs are not directly comparable. Hence, comparisons of IFs should only be made for journals in the same subject area.
This knowledge is essential for every scientist but it is only infrequently discussed.

In addition, a multitude of further performance measures have been recently proposed for both:

- The evaluation of journals and
- The quantification of an individual's scientific research output
  It is attempted to give a short overview on this still developing field as far as it seems necessary for general use in the scientific community rather than in the highly specialized field of bibliometrics.

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1. Definition of the Impact Factor

As Editor-in-Chief of the International Journal of Refractory Metals and Hard Materials I am frequently asked about the Impact Factor (IF) of this journal, whereby it is generally believed that the IF is an objective measure of the journals scientific quality. This is, however, not so easy. It is the aim of this paper to provide important information on how the IF is derived for a certain journal and what it can tell you. First of all it is necessary to learn how the IF is defined. There is an excellent article on all aspects of this factor available [1]. The present paper closely follows the argumentation of the authors of [1] and I would like to cite the introductory passage of this communication:

> "The ISI® Journal Citation Reports (JCR®) impact factor has moved in recent years from an obscure bibliometric indicator to become the chief quantitative measure of the quality of a journal: Its research papers, the researchers who wrote those papers and even the institution they work on. This paper looks at the limitations of the impact factor, how it can and how it should not be used."

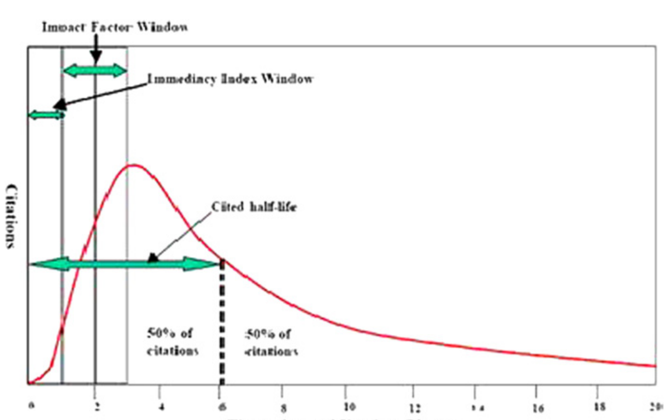

Fig. 1. Generalized citation curve with most important related terms (from [1] with permission of the authors).

The IF is based on the measure of the way a journal receives citations to its articles over time. The build up of citations tends to follow a curve like that of Fig. 1. Citations of articles published in a given year rise sharply to a peak between two and six years after publication. From this, peak citations decline exponentially. The relative size of the curve (in terms of area above the abscissa), the extent to which the peak of the curve is close to the origin, and the rate of decline of the curve are defining a specific citation curve. These characteristics form the basis of the ISI indicators **impact factor**, **immediacy index** and **cited half-life**.

The **impact factor** is a measure of the relative size of the citation curve in years 2 and 3. It is calculated by dividing the number of current citations a journal receives to articles published in the two previous years by the number of articles published in those same years. So, for example, the 2009 impact factor for a given journal is the citations in 2009 to articles published in 2007 and 2008 divided by the number of articles published in 2007 and 2008. The number that results can be thought of as the average number of citations the article receives per annum in the two years after the publication year [1].

2. Definition of the Immediacy Index

The **immediacy index** gives a measure of the skewness of the citation curve, that is, the extent to which the peak of the curve lies near to the origin of the graph. It is calculated by dividing the citations a journal receives in the current year by the number of articles it publishes in that year, i. e. the 2009 immediacy index is the average number of citations in 2009 to articles published in 2009. The number that results can be thought of as the initial gradient of the citation curve, a measure of how quickly papers in that journal get cited upon publication [4].

3. Definition of the Cited Half Life

The **cited half-life** is a measure of the rate of decline of the citation curve. It is the number of years that the number of current citations takes to decline to 50% of its initial value. In Fig. 1 the cited half-life is 6 years. It is a measure of how long articles in a journal continue to be cited after publication.

4. Dependency of the IF on sociological and statistical factors

Of the three measures described above, the IF is the most commonly used and also most misunderstood one. The value of the IF is affected by sociological and statistical factors:

Sociological factors include:

- the subject area of the journal
- the type of journal (letters, full papers, reviews)
- the average number of authors per paper (which is related to the subject area)

Statistical factors include:

- the size of the journal
- the size of the citation measurement window

4.1. Dependency of the IF on the subject field

Fig. 2A shows how the absolute value of the mean impact factor exhibits significant variation according to subject fields. In general, fundamental and pure subject areas have higher average impact factors than specialized or applied ones. The variation is so significant that the top journal in one field may have an IF lower than the bottom journal in another area.

The reason for this pronounced subject variation in IFs has to do with the number of workers in a certain field. Understandably, the more workers are active in a field, the more citations will accumulate. In addition, there will be differences between industrially applied areas and such of fundamental sciences. Researchers in industry will write significantly less papers than their colleagues in fundamental sciences. Consequently the rate of citations will be much lower for the first group and, hence, IFs of journals in industrially related fields will be much lower than for journals dedicated to fundamental sciences.

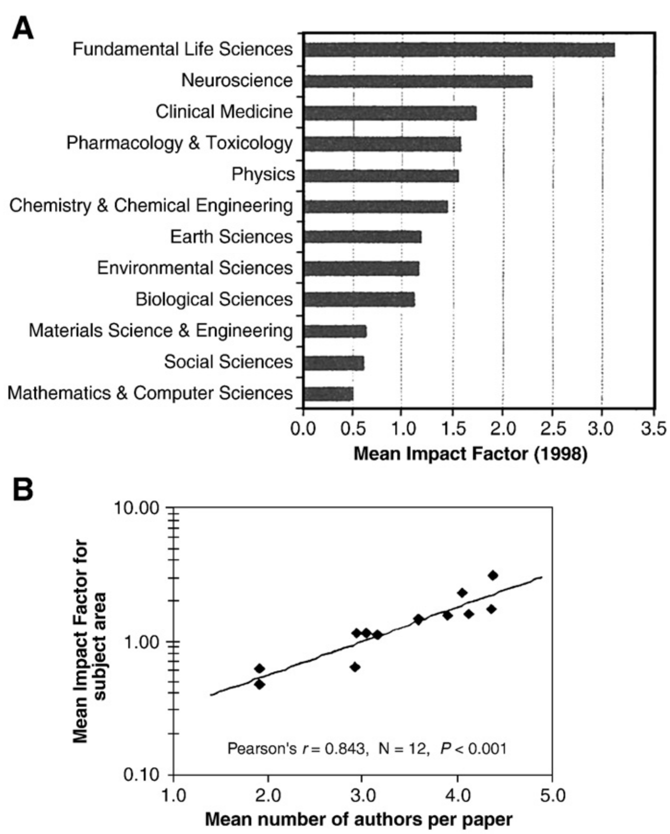

Fig. 2. A. Subject variation in Impact Factors (from [1] with permission of the authors). B. Impact Factors and number of authors per paper (from [1] with permission of the authors).

Closely connected to subject area variations is the phenomenon of multiple authorship. The average number of collaborators on a paper varies according to the subject area, from social sciences (with about two authors per paper) to fundamental life sciences (where there are over four). Not unsurprisingly, given the tendency of authors to refer to their own work, there is a strong and significant correlation between the average number of authors per paper and the average impact factor for a subject area, Fig. 2B.

The most important conclusion is, therefore, that comparisons of IFs can only be made for journals in the same subject area.

4.2. Dependency of the IF on the article and journal type

Even within the same subject area there will be significant variation of the IF according to the journal type or article type. This is illustrated in Fig. 3.

A short or rapid publication journal (often called a “Letters” journal, publishing short papers, not to be confused with letters to the editor) will have greater **immediacy** but a lower **cited half life**. That is, the peak of the citation curve will decline rapidly after the peak. As a consequence, a large proportion of citations it receives will tend to fall within the two-year window of the IF. By contrast, the full paper journal will have a citation peak around three years after publication, and therefore, a lower *immediacy* than the rapid or short paper journal. It will also have a gentler decline after its peak, and consequently a larger *cited half-life*. The proportion of citations that fall within the two-year window will be smaller as a result of the different curve shape, and the IF of such a journal will tend to be smaller than its rapid or short paper relative. In the case of a review journal, the *immediacy index* relative to other measures is very low, citations slowly rising to peak many years after publication. The *cited half-life* is also correspondingly long, as the citations decline equally slowly after the peak. The proportion of the curve that sits within the two year IF window is also relatively small, but because the absolute number of citations to reviews is usually very high, even this proportion results in higher IFs for review journals over all other journal types. So, given that the IF measures differing proportions of citations for different article types, care should be taken when comparing different journal types or journals with different mixes of article types [1].

4.3. Dependency of the IF on the number of pages per year: Journal size matters

A simple consideration should demonstrate that journal size matters. If one assumes that in average three citations per page have been determined for a certain journal, then the total number of cites

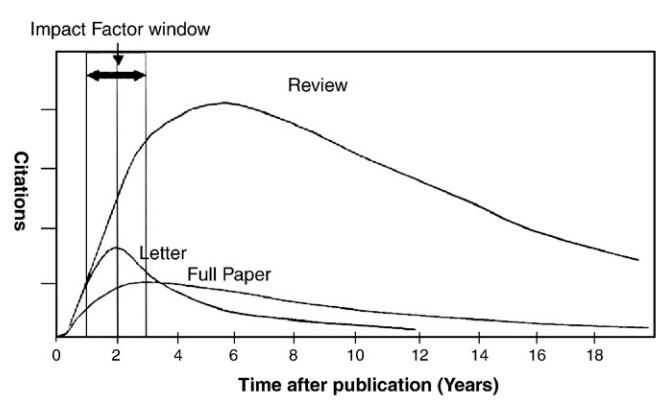

Fig. 3. Impact Factors and journal type (from [1] with permission of the authors).

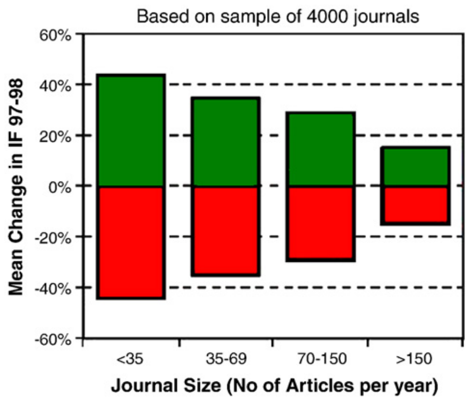

Fig. 4. Impact Factor fluctuation versus Journal Size (from [1] with permission of the authors).

will depend on the total number of pages of this journal per annum. Should the number of pages vary from year to year, the number of cites will also vary from year to year, and so will the IF for this journal. The IF is an average value and hence, it also shows variation to statistical effects. These relate to the number of items being averaged, that is the size of the journal in terms of articles published per annum.

4.4. Impact Factor fluctuation also depends on journal size

It is clear that the IF as a statistical mean value also exhibits a standard deviation and that the extent of the mean variation from one year to the next is dependent on the journal size. This is shown in Fig. 4. If a larger number of journals (4000, arranged in quartiles based on the size of journal) are examined and the mean variation in IF from one year to the next is plotted against the size of the journal, there is a clear correlation between the extent of the IF-fluctuation and the size of the journal [1]. This means that when IFs are compared between years it is important to consider the size of the journal. Small titles (less than 35 papers per annum) on average vary in IF by more than +/-40% from one year to the next. Even larger titles are not immune, with a fluctuation of +/-15% for journals publishing more than 150 articles per annum. Consequently, care should be exercised to avoid inferring too much from small changes or differences in IFs [2].

5. Recent data for IJRMHM

Let us now see which place this journal takes in terms of its IF and important related values.

5.1. Journal size

It is quite informative to observe the flow of published papers from the year 2000 until present, Table 1 [3]. As can be seen, the average number of published papers per year without Special Issues rose from 30 to 40 papers in 2000, 2003, 2004 to 85 in 2008. Understandably the number is significantly higher in the years when Special Issues have been published (2005, 2006, 2009). Hence, there are considerable variations in journal size from year to year. Consequently, the Impact factor also varies which is especially visible for 2005 (cf. Table 2).

5.2. The fluctuation of the impact factor for IJRMHM

Table 2 shows the fluctuation of the IF for IJRMHM for the years 2002 – 2008 [3]. It exhibits a constant rise with one exception in 2006. This exception is not understandable since the number of papers in 2006 was high (98) and definitely higher than in 2007 (69) for which year the IF rose again. There might be a considerable retardation in citations after the appearance of articles in a certain year. However, the general trend of rising IFs for IJRMHM throughout the period for which IFs are available (2002 – 2008) is very assuring. For 2009 we have an even higher number of papers (161) which should result in a high IF for 2009. This IF, however, will only be available before July 2010.

Table 1
Overview of the number of published manuscripts from the year 2000 until present including Special Issues on various occasions ([3], updated).

Year/Volume	Number of published papers in volumes	Special Issues
2000/18	34	
2001/19	66	Special Triple Issue on the ICSHM 7
2002/20	47	No.1 Special Issue: Fine-Grained Hard Metals: Selected Papers from the 15th Intern. Plansee Seminar No.2 Special Issue: Advanced Coatings
2003 / 21	32	
2004 / 22	42	
2005 / 23	110	Nos. 4-6: Special Issue on the ICSHM 8, Part I
2006 / 24	98	Nos.1-2: Special Double Issue on the ICSHM 8, Part II No.4: Selected Presentations from the 16th Int. Plansee Seminar 2005 No.5: Anniversary Issue in Honour of Benno Lux
2007 / 25	68	Note: 139 manuscripts submitted
2008 / 26	85	Note: 227 manuscripts submitted
2009 / 27	161	No.2: Special Issue on the ICSHM 9 (46 papers)

5.3. IF comparison for journals in the field of Materials Science

For comparison, Table 3 shows IFs for a series of Elsevier journals in the field of Materials Science from 2006 to 2008 [4,5]. As can be seen, there is a wide scatter of IFs according to the field the journal covers. Very general topics like “Progress in Materials Science” or “Biomaterials” lead the field whereas very special topics like “Cement and Concrete Composites” or IJRMHM are found at the lower end of the list. As already discussed this is primarily related to the number of scientists working in the field. The year to year variations are also higher.

6. Further journal performance measures

There is a rising number of ways in which journal performance is measured and compared. The most appropriate measure(s) will depend on the aspect of the journal that is being evaluated, and no single approach will always be the most useful for a given title or at any given time [6].

6.1. The five year impact factor

Expanding the size of the measurement window from the two years of the standard JCR IF will smoothen some of the statistical

Table 2
The impact factor for IJRMHM for the years 2002 – 2008 [4].

Impact factor as supplied by ISI for IJRMHM		
Year	Total cites	Impact factor
2002	266	0.43
2003	318	0.51
2004	370	0.74
2005	513	1.09
2006	565	0.80
2007	800	1.11
2008	941	1.22

Table 3
Impact Factors of Journals in the field of Materials Science from 2006 trough 2008 [5].

Journal Title	2006 Impact Factor	2007 Impact Factor	2008 Impact Factor
Progress In Materials Science	10.229	20.846	18.132
Biomaterials	5.196	6.262	6.646
Nano Today		5.929	
Carbon	3.884	4.260	
Journal of Controlled Release	4.012	4.756	
Acta Materialia	3.549	3.642	3.729
Acta Biomaterialia	2.132	3.113	3.727
Polymer	2.773	3.065	3.331
Scripta Materialia	2.161	2.481	2.887
European Polymer Journal	2.113	2.248	2.143
Intermetallics	1.943	2.219	2.034
Composites Science and Technology	2.027	2.171	2.533
Corrosion Science	1.885	1.895	2.293
Materials Chemistry and Physics	1.657	1.871	
Journal of Nuclear Materials	1.261	1.643	1.501
Reactive and Functional Polymers	1.561	1.720	2.039
Materials Letters	1.353	1.625	1.748
Materials Science & Engineering C	1.325	1.486	1.812
Materials Research Bulletin	1.383	1.484	1.812
Journal of Alloys And Compounds	1.250	1.455	1.510
Ceramics International	1.128	1.360	1.360
Polymer Testing	1.312	1.357	1.736
Solid-State Electronics	1.159	1.259	
Computational Materials Science	1.104	1.135	1.549
Composite Structures	1.002	1.116	1.454
Materials & Design	0.983	1.028	1.107
Cement & Concrete Composites	0.791	0.962	1.312
Materials Characterization	0.741	0.932	1.225
IJRMHM	0.80	1.11	1.221

variations. The effects of doing this are illustrated in Fig. 5**.** Here the average 2 – and 5-year IFs for around 200 chemistry journals have been plotted against time. The two year IFs show considerable variability, jumping up and down in value each year. The five year measures, however, while still showing changes over time, present a much smoother curve [1].

6.2. Ranking

Journals are often ranked by impact factor in a Thomson Reuters subject category [2]. As there are now two published IFs, this rank may be different when using a two or a five year IF and care is needed when assessing these ranked lists to understand which metric is being utilized. In addition journals can be categorized in multiple subject categories which will cause their rank to be different and consequently a rank should always be in context to the subject category being utilized [2]. The exact number in the metric may differ, but often this difference disappears when one looks at the relative position of a journal within its subject field. If the whole field evolves slower and

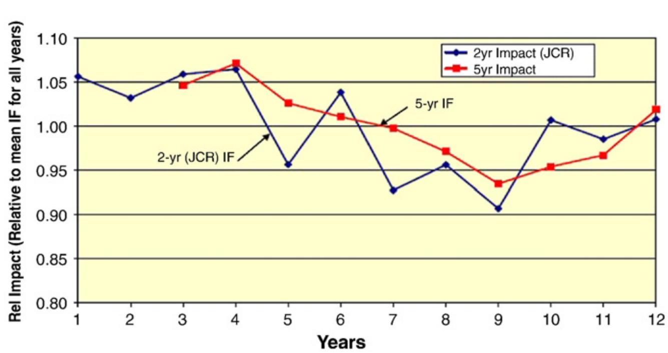

Fig. 5. Impact Factor measurement window fluctuations (from [1] with permission of the authors).

benefits from a 5 year measurement, the rankings will not differ much.

6.3. The journal h-index

The h-index was proposed in 2005, by Prof. Jorge Hirsch as a metric for evaluating individual scientists [7]. However, the h-index can be applied to any group of articles, including those published in a particular journal in any given year [2].

If a set of papers is arranged in descending order of the lifetime citations received, the h-index is the highest number for which it is true to say that h articles have each received at least h citations. Further relevant information can be found in the White Paper on the h-index of Scopus [8]. The h-index for an individual's scientific research output will be discussed in chapter 7.

6.4. SCImago journal rank (SJR)

The SCImago Journal Rank was recently developed by SCImago, a research group from the University of Granada, Extremadura, Carlos III (Madrid) and Alcalá de Henares, dedicated to information analysis, representation and retrieval by means of visualization techniques. The SCImago Journal Rank is based on citation data of the more than 15,000 peer-reviewed journals indexed by Scopus from 1996 onwards, and is freely available in [9] The SCImago Journal Rank of journal J in year X is the number of weighted citations received by J in X to any item published in J in (X-1), (X-2) or (X-3), divided by the total number of articles and reviews published in (X-1), (X-2) or (X-3).

SCImago Journal Rank is a measure of the number of times an average paper in a particular journal is referred to, and as such is conceptually similar to the Impact Factor. A major difference is that instead of each citation being counted as one, as with the Impact Factor, the SCImago Journal Rank assigns each citation a value greater or less than one based on the rank of the citing journal. The weighting is calculated iteratively from an arbitrary constant using a three-year window of measurement. The detailed methodology can be found in [10].

The SJR is a novel approach that provides a different bibliometric perspective to the Impact Factor. Key points include:

- Freely available on the web.
- Calculated for many more journals than the IF.
- Calculation is more complex than for the IF but may better reflect a journal's prestige.

6.4.1. Comparison to the impact factor

The dataset for the SJR include all journals in the Scopus dataset in the appropriate years. New journals are somewhat disadvantaged by the SJR because a 3-year window of measurement is used (c.f. a 2-year window for the Impact Factor). Generally journals with a high IF value and rank will have a high SJR value and rank. Most journals receiving an IF will note a shift up in their rank position (overall or within a subject field) due to the inclusion of many predominantly lower-SJR journals lacking an IF. However, their rank relative to other journals receiving an IF will change very little. Only very small journals (for which the effects of database coverage and citation weighting might be great) will see dramatic SCR value and rank changes. This may be due to the effects of database coverage and/or citation weighting.

A potentially controversial issue related to the calculation of the SJR is the use of weighted citation counts. Since 1976, the validity of citation weighting based on the citation profile of the citing journal has been disputed. Some argue that it incorporates a measure of journal prestige, while others argue that it is arbitrary: a citation from a very ordinary paper in a prominent journal will be weighted higher than a citation from an excellent paper published in an unknown third-tier journal. Recent attempts at reformulating journal-level citation weights have been poorly received in the bibliometrics community [11].

6.5. Eigenfactor and article influence [2]

The Eigenfactor and Article Influence are recently developed metrics based on data held in Thomson Reuters' Journal Citation Reports. They are freely available in [12].

The Eigenfactor of journal J in year X is defined as the percentage of weighted citations received by J in X to any item published in (X-1), (X-2), (X-3), (X-4), or (X-5), out of the total citations received by all journals in the dataset. Only citations received from a journal other than J are counted. The Eigenfactor is not corrected by article count, and so is a measure of the influence of a particular journal; bigger and highly cited journals will tend to be ranked highly.

As with the SCImago Journal Rank, each (non-self) citation is assigned a value greater or less than one based on the Eigenfactor of the citing journal. The weighting to be applied is calculated iteratively from an arbitrary constant. Detailed methodology can be found in [13].

Main characteristics of the Eigenfactor:

- Developed by Carl and Ted Bergstrom of the University of Washington[14].
- Estimates the percentage of time that library users spend with that journal. The higher the Eigenfactor score, the more time is estimated to be spent on this journal.
- Eigenfactor ranking system accounts for difference in prestige among citing journals, such that citations from Nature or Cell are valued highly relative to citations from third-tier journals with narrower readership.
- The pre-calculated metric is freely available to all at [12] and has been added to Thomson's JCR in February 2009.

Position on the Eigenfactor [11]: The Eigenfactor is an interesting approach that provides a different bibliometric perspective to the Impact Factor.

Key points include:

- The Eigenfactor algorithm uses the structure of the entire network (instead of purely local citation information) to evaluate the importance of each journal.
- The Eigenfactor generally identifies journals that have most impact (influence) in their subject areas - see analysis below.
- Bigger and highly cited journals will tend to be at the top of rankings according to Eigenfactor.
- Exclusion of journal self cites in the calculation of the Eigenfactor minimises citation engineering practices of some journals but will penalise journals that serve small niches.

Comparison to the Impact Factor [11]: The dataset for the Eigenfactor and Article Influence includes all journals cited by Thomson-indexed journals but excludes very small journals (i.e. those publishing less than 12 articles/year). Journal-level self-citations are ignored, which discourages citation manipulation but also disfavours new and/or niche journals. New journals are also disadvantaged by the Eigenfactor (but not by Article Influence) because a 5-year window of measurement is used (c.f. a 2-year window for the Impact Factor). Both metrics intrinsically account for differences in citation behaviour between fields by taking a full 5-year measurement window and by accounting for local citation density in the network.

Article Influence is calculated by dividing the Eigenfactor by the percentage of all articles recorded in the Journal Citation Reports that were published in J. Article Influence. It therefore is conceptually similar to the Impact Factor and SCImago Journal Rank [2].

6.5.1. SNIP (Source Normalized Impact per Paper) & SJR (SCImago Journal Rank): A new perspective in journal metrics

As publishing and research trends change, the tools used to measure them must also change. The use of journal metrics by journal editors and research institutions becomes more complicated every day. Scholarly publishing can no longer rely on a single metric to serve all of its needs.

SNIP and SJR offer the value of context in the world of citations.

The tools:

- Apply to nearly 18,000 journals, proceedings and book series
- Are refreshed twice per year to ensure currency of metrics
- Eliminate the risk of manipulation
- Correct for citation behavior and database coverage
- Provide multidimensional insights into journal performance
- Allow for a direct comparison of journals, independent of their subject classification
- Are publicly accessible and are integrated into **Scopus Journal Analyzer** [15]

For more information on SNIP see [16]. SJR has been discussed in chapter 6.4.

6.6. Comparison of journal measures for journals in the field of Materials Science

Table 4 gives a comparative overview of important journal measures for quite a series of journals in the field of Materials Science. Since all these measures are based on the number of citations

Table 4
2008 Impact factors, Eigenfactors, Article Influences and 2007 SCImago Journal ranks for journals in the field of Materials Science.

Journals	2008 Impact Factor	Eigenfactor	Article Influence	2007 SJR
Progress in Materials Science	18,132	0,01283	7,235	0,697
Biomaterials	6,646	0,13141	1,848	0,428
Nano Today	8,795	0,00283	3,278	0,262
Carbon	4,373	0,06073	1,486	0,202
Journal of Controlled Release	5,69	0,04426	1,327	0,363
Acta Materialia	3,729	0,11185	1,834	0,201
Acta Biomaterialia	3,727	0,00702	1,262	0,287
Polymer	3,331	0,11649	1,034	0,179
Scripta Materialia	2,887	0,07118	1,215	0,139
European Polymer Journal	2,143	0,02844	0,687	0,117
Intermetallics	2,034	0,01425	0,678	0.117
IJ Refractory Metals and Hard Materials	**1,221**	**0,00234**	**0,478**	**0,074**
Composites Science and Technology	2,533	0,03661	1,171	0,114
Corrosion Science	2,293	0,02088	0,787	0,106
Materials Chemistry and Physics	1,799	0,03493	0,605	0,104
Journal of Nuclear Materials	1,501	0,03411	0,578	0,086
Reactive and Functional Polymers	2,039	0,0082	0,555	0,096
Materials Letters	1,748	0,0584	0,576	0,096
Materials Science & Engineering C	1,812	0,01305	0,574	0,112
Materials Research Bulletin	1,812	0,01706	0,606	0,095
Journal of Alloys And Compounds	1,51	0,06733	0,503	0,086
Ceramics International	1,369	0,01282	0,521	0,081
Polymer Testing	1,736	0,00778	0,544	0,086
Solid-State Electronics	1,422	0,01773	0,533	0,107
Computational Materials Science	1,549	0,01707	0,747	0,070
Composite Structures	1,454	0,01705	0,627	0,069
Materials & Design	1,107	0,00765	0,442	0,087
Cement & Concrete Composites	1,312	0,00993	0,845	0,085
Materials Characterization	1,225	0,00636	0,519	0,067

a journal receives (weighted or not) it is not surprising that the structure of these data is more or less the same and the same restrictions relating to their interpretation apply as discussed in chapter 4 for the IF. The main parameter influencing the size of all these factors is the number of people working in the respective field. However, some data are difficult to interpret as, e. g. the low Eigenfactors for Progress in Material Science and Nano Today as opposed to their very high IFs.

6.7. Open Access

It is becoming popular that some journals are published with “Open Access”. This means that access and download in the internet are free of charge for readers. Thereby it is anticipated that the number of readers will be essentially increased [17]. However, it has recently been found that article Open Access status alone has little or no effect on citations. Scientific citation is influenced, overwhelmingly, by the relevance and importance of a given scholarly work to other scholars in the field. While other factors might have moderate effects, the process of science is driven not by access, but by discovery [17]. On the other hand the financial load is simply transferred from the reader to the authors whose articles are published in the respective journal. This would exclude authors from financially weak institutions. Hence the problem is not eliminated as it might seem at first glance but switched to the other partner and the fees for authors are not really negligible but usually in the order of several hundred Euros. This bears two essential advantages for the publisher:

1) He receives the money from the authors before the journal or book is printed.
2) Hence, any financial risks due to articles of little interest and consequently little or no numbers of downloads are eliminated.

This could also lead to a situation in which the number of contributors is of paramount interest to the publisher and not any more the quality of the contributions, even if this would lead to an eventual decrease in the Impact Factor of the respective journal.

7. Indices to quantify an individual's scientific output

7.1. The h-index

The h-index was originally proposed by Jorge Hirsch in 2005 [7] to quantify the scientific output of an individual researcher. It was conceived as an improvement on previous indices, which tended to focus on the impact of the journals in which the researcher had published, and so assumed that the author's performance was equivalent to the journal's average. If a scientist's publications are ranked in order of the number of the lifetime citations they have received, the h-index is the highest number, h, of his papers that have each received at least h citations.

The h-index quickly gained widespread popularity. This is largely due to the fact that it is conceptually simple, easy to calculate and gives a robust estimate of the broad impact of a scientist's cumulative research.

However, the h-index has received some criticism, most notably [18]:

- It is not influenced by citations beyond what is required for entry to the h-defining class. This means that it is insensitive to one or several highly cited papers in a scientist's paper set, which are the papers that are primarily responsible for a scientist's career, meaning only scientists with similar years of service can be fairly compared.
- A scientist's h-index can only rise (with time) or remain the same. It can never go down, and so cannot indicate periods of inactivity, retirement or even death.

However, in the face of the popularity of the h-index, it has been suggested that as a measurement of the impact of individual scientists, it is equivalent to the journal impact factor for journals [19].

7.2. The g-index [20]

While the h-index can measure an individual author's IF, it has limitations of its own. It is insensitive to the tail of infrequently cited papers. But it is not sufficiently sensitive to the level of highly cited papers. Once an article belongs to the h-top class, the index does not take into account whether that article continues to be cited and, if so, whether it receives 10, 100 or 1000 more citations.

7.2.1. Lotka's Law

This is where the g-index has evolved from its predecessor. It has all the advantages and simplicity of the h-index, but also takes into account the performance of the top articles. It was in direct response to his criticisms of the h-index that Egghe developed the g-index. No newcomer to bibliometrics, Egghe's main area of expertise is Lotka's Law. The premise of this Law is that as the number of articles published increases, the authors producing that many publications decreases. This principle forms the basis of the h- and the g-indices, the formulae for both of which Egghe was the first to prove. The difference between them is that while the top h papers can have many more citations than the h-index would suggest, the g-index is the highest number g of papers that together received g^2 or more citations. This means that the g-index score will be higher than that of the h-index. It also makes the differences between two authors' respective impacts more apparent [20].

7.2.2. Access to funds

For many scientists, there is a direct correlation between where they are ranked in their field and the amount of funding they can attract. “Everything is measured these days, which explains the growth of bibliometrics as a whole,” says Egghe. “The g-index enables easy analysis of the highest cited papers; but the reality is that as time passes, it's not going to be possible to measure an author's performance using just one tool. A range of indices is needed that together will produce a highly accurate evaluation of an author's impact'[20].

7.3. Critical Résumé for the attempt to quantify human qualities for job assessment purposes

We have seen how complex the attempt becomes to carry out a fair and objective analysis of a researchers performance by the generation of (comparative) values of the addressed indices. It is claimed that these quantitative metrics are easy to benchmark, objective and globally comparative. However, important human qualities of a researcher such as his/her cooperative good will, integrity, tolerance cannot be converted into simple numbers. Hence, personal indices – if at all available – might help an evaluation of a researcher, but they are certainly not sufficient for personnel recruiting. I therefore doubt that decision-making bodies throughout the world can switch to metric-based assessments in favour to traditional methodologies [8]. In addition the mere number of publications of a researcher and the number of respective citations gives an incomplete picture of his/her endeavours. Contrary, scanning through his/her list of publications will give a valid impression of the fields he/she is and was active in. Only a personal discussion with him/her will provide valuable and necessary information and impression on his/her respective activities, successes and also limitations.

8. Index inflation

Variants of the h-index that have been developed in an attempt to solve one or more of its perceived shortcomings include the m-quotient, h(2)-index, a-index, m-index, r-index, ar-index and h_w-index [18,19]. There truly seems to be an inflation of indices which might be of interest in the field of bibliometrics. However, for colleagues active in other fields this development is confusing and unnecessary for general application. Hence, the above indices will not be further elucidated here.

9. Applied research – where actuality is inversely proportional to the number of citations

I would like to finally address a very important area of usually most intensive research where the principle of measuring actuality and significance of a technical development by the number of citations in this field does not work at all. If companies are in competition for technological leadership in a certain area publications are usually strictly forbidden up to the time where the project reaches maturity and respective patents are filed. It can even be stated that the more important a technological development in a certain field is the less publications will be found on it so that the significance of the development is inversely proportional to the respective number of citations. It is very queer that this most common behaviour in industry has never been discussed or even mentioned by the experts of bibliometrics. It seems that the most relevant area of applied industrial research has carefully been omitted in the respective boards.

And there is another observation which I personally made in some industrial working groups: Some of the bosses considered publications of their subordinates as an indication that they don't have enough to do. Hence, they are loading them up with further responsibilities, projects etc. Whether this has to do with envy of the boss on the scientific endeavour of the respective subordinate is usually difficult to say….

10. Conclusions

It is, of course, understandable that mankind is always longing for a clearly quantifiable figure of quality. In most cases, however, this is not possible and it was shown in this paper how many factors influence the number of citations. What becomes obvious is the old fact that quality of scientific articles and of a journal in general can only be judged by scientists in the respective field, after having used the journal for their own work. Journal quality greatly depends on its refereeing system and how authors are treated by the Editorial Board of the journal and especially by its editors and the staff of the publishing company of the journal. I am sure that a journal's quality cannot be judged by a simple number. The decisive measure is experience of scientists using the respective journal for their scientific work. To relate this quality to journals in completely different fields was proven impossible already by the use of the IF. Hence, the use of the absolute value of an IF to measure quality should be strongly avoided, not only because of the variability discussed in this paper, but also because of the variation in long-term average trends. It is also foolhardy to penalize authors for publishing in journals with IFs less than a certain fixed value, say 2.0 given that for the average sized journal, this value may vary between 1.5 and 2.25 without being significant [1].

Further, it has been attempted to give an overview of some novel journal performance measures as well as of new indices which attempt to quantify an individual's scientific research output. A critical view is presented for the attempt of quantifying human qualities for job assessment purposes. Such data can help but they cannot substitute a relevant personal discussion with an applicant.

The use of journal impact factors for evaluating individual scientists is even more dubious, given the statistical and sociological variability in journal impact factors. IFs are useful in establishing the influence journals have within the literature of a discipline. Nevertheless, they are not a direct measure of quality and must be used with care [1].

Finally, there is unfortunately a rising number of ways in which journals performance is measured and compared (see chapter 6 of this paper). The most appropriate measure(s) will depend on the aspect of the journal that is being considered, and no single approach will always be the most useful for a given title or at any given time.

There is another ultimate consideration which might be even more important than all discussed measures of journals evaluation: If a journal serves a relatively small and specialized group of scientists such as IJRMHM does in this field of refractory metals and hard materials, it is the medium which is most read by this scientific community – irrespective of all citation-based measures – and authors can be sure that their here published papers will reach this specialized community safer than in any other journal. If it comes to quantitative measures to assess human qualities e. g. for the recruiting of scientists for certain projects or jobs, the problem becomes even greater. It is probably possible to quantify an individual's scientific research output. However, it is not possible to quantify human qualities as a whole for job assessment purposes. It is unlikely that even a greater number of personal indices can substitute a personal meeting with an applicant for a job or project.

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