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**INFORMATION ANALYSIS**

# The Development of a Webometric Criterion for Ranking Researchers

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**Abstract**—This paper explores the possibility of extracting scientometric data from social media. Basic approaches to typification and classification of altmetrics are presented. The advantages and disadvantages of using altmetrics as scientometric indicators are investigated. The concept of webification of bibliometric indicators is introduced. Several examples of webometric indicators are discussed. Webometric indicators are designed to evaluate academic performance of researchers. A new criterion is introduced for the use in the performance-based ranking of researchers. This criterion applies webometric indicators that are calculated on the basis of altmetrics.

*Keywords:* altmetrics, webification, semi-webometric indicators, performance, publication, social media
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## INTRODUCTION

The methods of monitoring research and development based on the analysis of scientific information contained in specialized databases have been rapidly growing over the recent years. This growth is due to the development of text-based electronic document-processing technologies and web applications. The development of information and communication technologies accompanies the rise of a new paradigm of scientific and technological relationships.

The aim of this study is to create the basis for the development of an integrated system of scientometric indicators in view of the current trends in scientific communication. The aim of this study is to analyze the practices related to the assessment and encouragement of publication activity and to identify the most common shortcomings of the existing systems of scientometric indicators, which distort the understanding of the real results achieved by individual researchers, as well as by education organizations and scientific communities.

The analysis of indicators that define the shortcomings of the existing systems for encouraging publication activity was performed using the method of monitoring heterogeneous electronic resources of scientific-communication information. The specific functionalities of social media provide evidence for the present study.

### *Altmetrics Classification Methods*

The term "altmetrics" (i.e., an alternative metric) covers a wide range of different web platforms. Altmetrics reflect any event in some form that shows the level of a researcher commitment to scientific results. Altmetrics may take many forms, so it is highly important to consider the fact that some altmetrics are not equivalent and do not always reflect the same level of obligations. A large number of different potential sources of scientometric data are distributed across a variety of platforms that track altmetrics. Multiple ways of classifying altmetrics are often associated with the limited awareness of how different altmetrics reflect research results, as well as with the lack of altmetrics standards [1].

This study offers a new classification of altmetrics via user interactions:

- Likes $@_{like}$ can provide binary assessments such as "*good*" or "*bad*" or multiple emotions, such as "*interesting*" or "*funny*";
- File downloads $@_{load}$ on local disk;
- Views $@_{view}$ of electronic publications;
- Replies to questions of other users $@_{reply}$;
- New themes emerging in forums $@_{theme}$;
- Tags in special markup languages $@_{\#}$;
- Polls $@_{select}$ based on a qualitative or quantitative, ordered or unordered scale.

Furthermore, there are so-called "technological" altmetrics that are generally related to academic social platforms rather than to individual authors, publications, journals or organizations. Technological altmetrics count subscribers or readers $@_{CR}$; registered users $@_{CU}$; visits $@_{CI}$; and search engine rankings $@_{SSRP}$.

It is appropriate to perform an altmetric cross-section via individual metrics, for example, according to the characteristics recorded in the profiles of authors who are users of scientometric platforms, members of academic social networks, or other forms of networking communities. Such cross-sections particularly relate to users, since bibliometric indicators are sufficient for other objects. It is also necessary to consider the limitations that affect the result with decreasing coefficients: information resources that involve paid access, registration or local access restrictions.

Altmetrics dynamically evolve within short periods of time; thus, they are not used in calendar reports and need to be regularly monitored on a frequent basis. It is quite common to "drive up" altmetrics, for example, by using software such as adware or "bots" that are active software agents [2]. Typically, altmetrics can only be recognized through an interactive dialogue. However, a programming interface has been created by developers to perform queries to obtain altmetrics data.

### *Possibilities of Extracting Scientometric Data from Social Media*

Compared to conventional social networks, *Academic Social Networking Sites* (ASNS) offer more specific functions [3]. Scientific publications are quite fully represented on social media platforms, which makes the latter a more important source for assessing the impact of publications compared with scientometric databases. Despite the fact that the use of social media tools in research remains limited, users gradually learn about the potential of altmetrics extracted from social platforms [4].

The dependence of altmetrics on basic social media platforms cannot be definitely established. The capabilities of such platforms allow performing interactive actions while executing the tasks for which they were created. Most custom actions cannot be performed outside of a specific platform equipped with a variety of specific indicators that depend on the underlying tool. While the first wave of digitization of scientific communication, which involved the rise of e-mail and electronic journals, offered the scientific community the possibility of operational discussion, the second wave of digitization involved the use of tools that enabled a truly broad discussion outside the scientific community. However, the existence of platforms does not guarantee wide coverage. The means of social communication open up new channels for informal scientific discussion, rather than "building bridges" between the scientific community and society as a whole. An increased use of social media requires careful coordination between investors, research institutions, and managers.

Altmetrics provide indicators for measuring the following categories:

• attention, commitment or influence, as well as the social impact of research on different audiences;

• interaction, context, and networks;

• the importance of quantitative assessment and the uniqueness of research.

Altmetrics are characterized by the following features:

■ rapid accumulation following the publication of research results;

■ a more diverse set of tools for measuring different types of impact compared to conventional citations;

■ research communication formats going beyond scientific publications and formal citations;

■ a demonstrated context of the study that has some influence or impact on the audience;

■ the use of open data, which facilitates the replication of altmetrics compared with database information.

It remains to be seen whether means of social communication and altmetrics represent a by-product of the scientific environment or they will become central to research dissemination and evaluation methods. Some indicators and platforms might disappear because of the lack of practical importance and relevance, whereas others might be merged. The outcome will be similar in both cases due to the expired lifetime of the platforms and services they are based on [5].

Altmetric data is designed to track scientific research on a variety of web platforms, including news sites, social media platforms, blogs, and link-management tools. There is a very complex context for a systematic comprehensive analysis of altmetrics through the evaluation of social communication tools. Assuming that there is a correlation between altmetrics and citations, the question is of how knowledge generators and users can derive a benefit from this relationship. Measuring the relationship between the number of citations and altmetric factors requires the construction of a regression model. The regression model should be complemented by the analysis of the correlation between traditional, bibliometric indicators and webometric indicators [6].

### *Advantages and Disadvantages of Using Altmetrics as Scientometric Indicators*

Modern studies of scientometric indicators prioritize two topics:

(1) the analysis of developments based on the performance of financing systems and how they incorporate and limit accountability assessment methods;

(2) the analysis of the practical use of performance measurement metrics at different levels of the research system [7].

Almetrics and webometrics are used to emphasize the traditional technological aspect that is inherent to different metric features [8]. C. Hoffmann, C. Lutz, and M. Meckel pointed out differences between webmetrics and altmetrics. However, both of them tend to have a numerical form [9].

Some researchers do not use social communication platforms; therefore, measuring the impact of scientific publications on society and the economy always concerns a sample of people who mention the publication rather often. This useful contribution is not quantifiable due to the lack of accurate user statistics or demonstration descriptions for individual social platforms. The quantitative altmetric values are often presented as the number of corresponding references in the information environment of the social platform. The volume of information about user groups related to a scientific publication is key for measuring social impact. In practice, the description of the achieved social impact is often limited. Publications often have different versions, for example, publisher pre-prints and post-prints. Citations correspond to simple mentions or discussions of cited publications. The altmetric values also increase when altmetrics refer to negotiations through means of social communication. Each researcher knows precisely what is measured by the number of citations, for example, how many times the publication has been cited. In altmetrics, this indicator that measures the same value is often fuzzy. The following advantages of altmetrics compared with traditional metrics can be identified:

• Coverage: altmetrics measure both internal and external impact beyond "common" science;

• Diversity: altmetrics measure the impact on different types of intellectual results;

• Speed: altmetrics allow measuring the impact immediately after the publication or the achievement of the results;

• Access: altmetric data is usually rather easy to obtain [10].

Many people regularly communicate through web portals. E-mail attracts the attention of users to other potentially interesting users. Lack of communication or unwillingness of users to connect can lead to a decrease in the commercial profitability of a web portal. The contribution of altmetrics to the promotion of communications is still unclear. Evaluating the economic impact of this type of activity cannot be compared with any traditional bibliometric metric. Quoting each other is not encouraged among researchers. The importance of altmetrics will grow over time, considering the fact that platforms can replicate. Therefore, it is necessary to make additional efforts to normalize altmetric values.

Altmetrics not only provide opportunities, but also pose difficulties. The main opportunity provided by altmetrics, namely diversity and heterogeneity, presents its main problem. Altmetrics include various types of metrics, whose variety complicates the understanding of what metrics are. The problems related to their heterogeneity and lack of understanding are due to the limited conceptual basis, as well as a broad variety of social communication platforms, users, and behavior patterns.

Accuracy, consistency, and reproducibility of data are the main features of data quality. The quality of data is rarely in the forefront, especially in the context of research evaluation. In altmetrics, data quality is the main problem, which is more important than mistakes and statistical errors. In the context of citation, errors mainly refer to the discrepancy between actions and recorded events. Errors can be detected and measured by accessing various data aggregators or primary sources. While bibliometric sources are static documents, most altmetric data sources are dynamic, since altmetric traces are subject to change or complete removal. The dependence of altmetrics on social media platforms as data providers is even more complex than the dependence on aggregators. The degree of dependence on social platforms culminates when the nature of a platform directly affects user behavior and its technological features define the real actions of users [11].

### *Conversion of Bibliometric Indicators in Altmetrics*

Citation is the standard source of data in scientometrics. It represents a task-oriented metric that measures the scientific impact of publications. A reader impact indicator can reflect the ability of journals, countries, and academic institutions to issue printed works that are below or above the average impact of publications on a selected segment of society [12].

On the one hand, open social media data provides an accessible source for statistical analysis, which is readily accepted by the scientific community. Usually, it is rather difficult to obtain a large amount of data on the impact of a large set of publications in bibliometrics. On the other hand, the separation of this new data source reflects the need to measure a broader impact of scientific research.

The more social communication tools are available to people engaged in research, the higher the correlation between the relevant altmetrics and traditional citation. The results of frequent studies measuring the correlation between altmetrics and traditional citations can be seen as the first step towards research in the field of altmetrics. Altmetrics provide a good opportunity to focus on more profitable projects. Low correlations point to altmetrics that are particularly relevant for the measurement of a broad impact of research, that is, the impact on other spheres of social life that go beyond science. Future research should focus on such altmetrics to assess their potential and the breadth of impact [13]. It is therefore premature to use altmetrics in the fundamental problems of evaluating research [14].

We will use the term "webification" to denote the conversion of bibliometric indicators in altmetrics. Webification $\mathcal{W}$ is possible because a certain correspondence can be observed between altmetrics $\mathcal{A}$ and

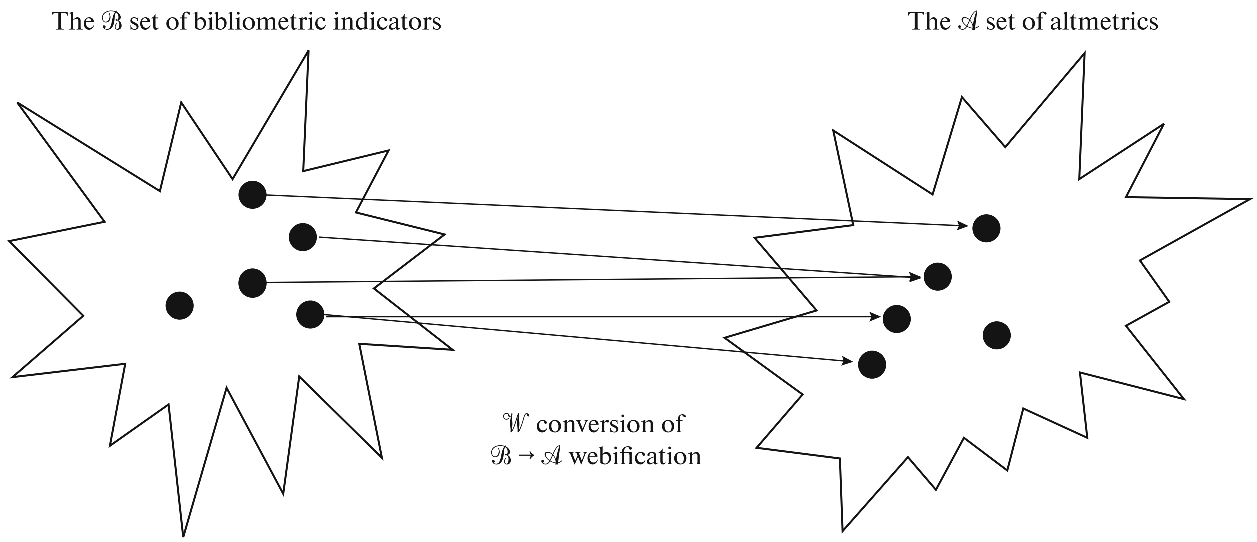


**Fig. 1.** A diagram that shows the conversion of bibliometric indicators into altmetrics.

bibliometrics indicators $\mathscr{B}$, although this relationship is not always very strongly expressed (Fig. 1).

The conversion from conventional to alternative metrics is a risky, if not doubtful, initiative. However, webification can be performed using a special Table 1.

The list of correspondences presented in Table 1 is far from being exhaustive; therefore, the data presented in Table 1 does not show that generally webification is not a strict transformation. Inaccuracy of webification is denoted as $@m \cong \mathscr{W}(m)$. The specific features of webification conversion are due to the fact that there are cases when the conversion is:

—ambivalent:

$$m \xrightarrow{\mathscr{W}} \{@m_x, @m_y\}, \quad (1)$$

where $m$ is the bibliometric indicator; $@m_x$ is the $x$th altmetric; $@m_y$ is the $y$th altmetric; and $\mathscr{W}$ is webification conversion;

—non-injective:

$$\{m_x, m_y\} \xrightarrow{\mathscr{W}} @m, \quad (2)$$

where $m_x$ is the $x$th bibliometric indicator; $m_y$ is the $y$th bibliometric indicator; $@m$ is altmetric; and $\mathscr{W}$ is webification conversion;

**Table 1.** The conversion of bibliometric indicators in altmetrics by using a table method

| № | Evaluation objects | Bibliometric indicators $\mathscr{B}$ | Webometric indicators (with altmetrics $\mathscr{A}$) |
|---|---|---|---|
| 1 | Author | The number of publications (***CP***) | The number of posted electronic texts ($@_{CP}$) |
| 2 | Author | The number of grants (***CG***) | The number of joint open network projects ($@_{CG}$) |
| 3 | Publication | The number of mentions in references (***CUR***) | The number of text files ($@_{CUR}$) |
| 4 | Author, publication | The number of citations (***TCC***) | The number of clicks on links to electronic texts ($@_{TCC}$) |
| 5 | Author, publication | The number of co-authors (***CCA***) | The number of subscribers ($@_{CCA}$) |
| 6 | Author, publication, journal, organization | Impact factors and other composite indicators (***CCI***) | Rankings linked to networking platforms ($@_{CCI}$) |

—non-surjective:

$$@m \xrightarrow{\mathcal{W}^{-1}} \{\varnothing\}, \quad (3)$$

where $@m$ is altmetric; $\varnothing$ is an empty set of bibliometric indicators; and $\mathcal{W}^{-1}$ is the conversion inverse to webification conversion;

—not always definable:

$$m \xrightarrow{\mathcal{W}} \{\varnothing\}, \quad (4)$$

where $m$ is the bibliometric indicator; $\varnothing$ is an empty set of altmetrics; and $\mathcal{W}$ is webification conversion.

Therefore, formulas (1)–(4) show that webification conversion has a relational rather than a functional form.

### *Examples of Webometric Indicators*

Altmetrics do not fully eliminate the shortcomings of traditional impact-assessment metrics. However, altmetrics do allow making estimates at the level of products rather than publications. In addition, they cover a growing diversity of academic products, platforms, and staff. The general uncertainty of scientometrics and, further, associated with altmetric values is due to the tendency of using composite indicators without target restrictions on the use of altmetrics [15].

The relative citation of the heterogeneous publication flow is a well-known bibliometric indicator applied for the evaluation of research papers. This indicator aims to normalize citation and the meaningful differences among the areas of science. A critical study of the theoretical basis of the normalization mechanism applied in the indicator for the relative citation of the heterogeneous publication flow underpins the use of an alternative normalization mechanism. As a result, it is possible to create a new indicator for the relative citation of the publication flow based on the alternative normalization mechanism [16].

To assess the social impact of scientific publications, it is suggested to use an alt-index equivalent to the $h$-index. The alt-index is an acceptable altmetric for the evaluation of studies and can help eliminate some gaps. The alt-index is calculated using the same formula as used for the $h$-index. The only difference between the $h$-index and the alt-index is that the latter is based on social rather than academic values of citation. Therefore, the formula that establishes the alt-index is as follows: *"if the x number of publications has at least x social citations, its alt-index will be x"*. The social index of researchers is calculated based on the proposed alt-index [17].

The citation-management software products are equipped with social communication tools that allow users to find and follow each other. Such analytics is new and is considered part of altmetric changes tracking unconventional bibliographic metrics. As noted above, *ResearchGate* has its own indicator, called RG-Score, which ranks the network participants based on their interaction with the content and with the rankings of participants who interact with the content. The content, such as profile information and answered or asked questions, affects the RG-Score ranking in addition to publication details (e.g., uploads, downloads, and citations). The RG-Score ranking cannot be measured by standard bibliographic methods. Hence, its application depends on the institution [18].

### *Design of Webometric Indicators for the Assessment of Research Performance*

Composite indicators include other types of primary indicators, so it is fair to call them *semi-webometric* indicators. The design of webometric indicators should consider scientific-citation patterns. At the same, altmetrics are designed based on the altmetric pattern. Composite webometric indicators should be designed using a mixed pattern. In this study, patterns for the design of scientific-citation indicators [19] are more broadly treated as patterns of designing arbitrary scientometric indicators. The design of webometric indicators should be limited to addition, subtraction, multiplication, discrete summation, and the product of primary indicators, that is, the webometric indicators of the lowest order or simple altmetrics.

The composite, semi-webometric indicator $@W$ of research performance is designed using table-based webification conversion (Fig. 2).

Starting from the $@h$ component of the $@W$ semi-webometric indicator, which reflects the impact of a researcher, we assume that the Hirsch-like alt-index $@h_\alpha$ is maximum $n$, so that the $n$ works of the same authors obtain $k^{n-1}$ views (downloads $\alpha = @_{load}$, likes $\alpha = @_{like}$ and so on), where $n \in \mathbb{N}$, $k \in \mathbb{N}$, $\alpha \in \mathcal{A}$. The definition of "Hirsch-like" points to the fact that this indicator is designed in a way similar to Hirsch's bibliometric index. The prefix "alto" indicates that the index is webometric, i.e., designed on the basis of altmetrics. For each altmetric, it is necessary to select and fix the parameter $k$. As an example, the parameter $k$ is equal to 10 for the number of views of scientific electronic texts. The assessment parameters $k$ and $\alpha$ are fixed for the full set of evaluation objects, namely researchers, since the performance assessment of each researcher must be carried out under equal conditions in line with the principle of objectivity.

The next component $@IPA$ of the semi-webometric indicator $@W$ characterizes the publication activity of a researcher. First, a simple indicator $IPA$ of a researcher's publication activity is designed. For this purpose, the following formula can be used:

$$IPA = ha_h m = h\frac{TCC}{h^2}\frac{h}{T} = \frac{TCC}{T}, \quad (5)$$

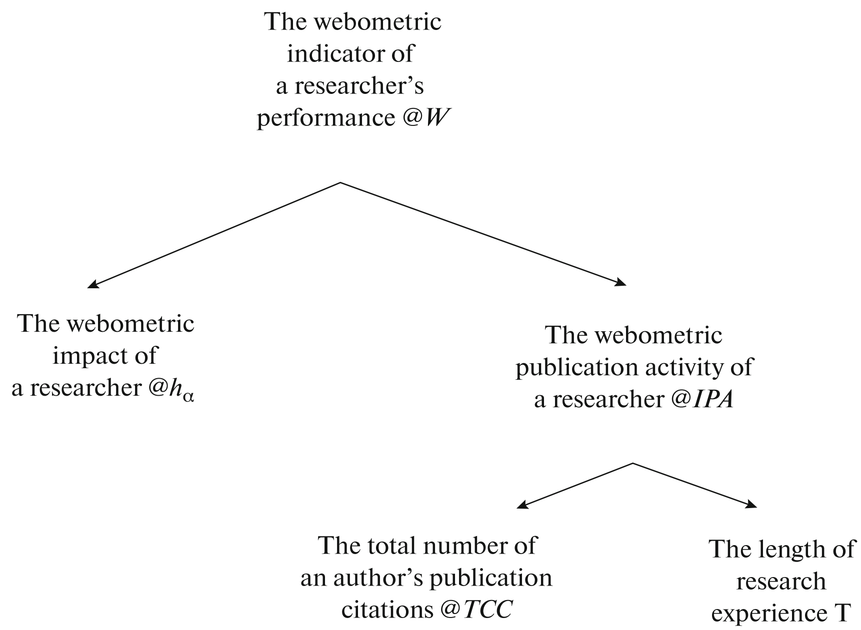


**Fig. 2.** The structure of a semi-webometric indicator of a researcher's scientific performance.

where $h$ is Hirsch's index; $a_h$ is the so-called $a_h$-index; $m$ is the so-called $m$-quotient; $TCC$ is the total number of a researcher's publication citations; and $T$ is the number of years of an author's research experience.

Using a table, the primary indicator $TCC$ of the total number of citations can be webified in the $@TCC$ indicator of the total number of links to the scientific electronic text calculated based on the $@_{TCC}$ altmetrics by using a search engine. The $T$ indicator cannot be webified, which is acceptable for the structure of semi-webometric indicators. The number of years of research experience $T$ can be conditionally viewed as the difference between the current year and the year of the first scientific publication of a given researcher.

Thus, the webometric indicator $@IPA$ of a researcher's publication activity can be calculated as follows:

$$@IPA = \frac{@TCC}{T}, \tag{6}$$

where $@TCC$ is the total number of references to a researcher's scientific electronic texts; $T$ is the number of years in the research experience of the respective author.

In practice, the webometric values are subject to strong, almost daily dynamic changes. In addition, conclusions are made on the basis of the rank of a particular object among other objects relative to the value of the selected webometric indicator, rather than on the basis of the webometric values of this object. Therefore, it is more appropriate to use the binary relationship $\prec$ to align $O_i$ and $O_j$ objects to the $@W$ webometric indicator, rather than to assign a target function (e.g., production of $@h_\alpha$ and $@IPA$):

$$\begin{aligned} &(@h_\alpha^{O_i} < @h_\alpha^{O_j} \Rightarrow @W_{O_i} \prec W_{O_j}) \\ &\vee ((@h_\alpha^{O_i} = @h_\alpha^{O_j}) \wedge (@IPA_{O_i} < @IPA_{O_j}) \Rightarrow @W_{O_i} \prec @W_j), \\ &\vee ((@h_\alpha^{O_i} = @h_\alpha^{O_j}) \wedge (@IPA_{O_i} = @IPA_{O_j}) \Rightarrow @W_{O_i} = @W_{O_j}), \end{aligned} \tag{7}$$

where $@h_\alpha^{O_i}$ and $@h_\alpha^{O_j}$ refer to the respective impact of the $i$th and $j$th researchers based on the $\alpha$th altmetrics; $@IPA_{O_i}$ and $@IPA_{O_j}$ refer to the publication activity of the $i$th and $j$th researchers, respectively, $@W_{O_i}$ and $@W_{O_j}$ refer to the publication activity of the $i$th and $j$th researchers, respectively; $\prec$ is the binary relationship of the aligned value of the webometric indicator $@W$.

The webometric criterion (7) operates as follows:

• The performance of a researcher with a higher impact given by the Hirsch-like alt-index according to the previously chosen altmetrics is considered higher;

• In case of equal impact, the researcher with greater publication activity as of the moment of comparison is considered more productive.

Criterion (7) allows one to identify researchers with higher performance. Although it is not possible to order the entire list of researchers at once using the proposed webometric criterion, the latter can be used to establish the binary order relationship in a paired comparison, where ranking of researchers is similar to the sorting of one-dimensional arrays.

## CONCLUSIONS

This study reviews the problems of a relatively young area of informatics—*webometrics*, which is also called "network scientometrics." In the context of the experimental transition to new ways of incentivizing researchers, the development of a webometric ranking of scientific authors acquires great practical importance among other relevant trends. Provided that the webometric ranking is pleasantly accepted and approved by the Russian scientific community, it could be included in the state system of scientometric indicators. The attempt to build a methodology for a webometric ranking of authors, or at least to conceptualize the design of such a webometric ranking, does not involve the technical aspects related to the implementation of specific software solutions.

However, another way of ranking researchers by their scientific performance indicators was chosen instead of the template design of a ranking model. The proposed criterion is based on the webometric indicators that are formed on the basis of calculated altmetrics. Furthermore, attention is paid to the general aspects of academic social networks, whose diversity generates various altmetric typologies and classifications. Against this backdrop, the strengths and weaknesses of altmetrics, which underpin the development of a new webometric criterion, are identified.

The *IPPA* (*Impact, Productivity & Publication Activity*) model helps formulate recommendations for adjusting the parameters of the publication evaluation systems. Optimization is achieved by clarifying the ideas about the real achievements of individual researchers, as well as academic organizations and the scientific community as a whole. The webometric criterion is to be used as a methodological component that serves the infrastructure needs of research management. In the longer term, the webometric criterion can be used for the integration of the mechanism that controls the financial and economic situation of science and research as one of the production components of the innovation economy.

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