The Disadvantages of Using Scientometric Indicators in the Digital Age

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Abstract. Scientometric data is now widely used in solving personnel issues, grants, and financing universities, as well as monitoring their activities. However, in the course of the study using a variety of theoretical and practical methods, it was found that the main scientometric indicators, such as the total number of publications, citation index, and Hirsch Index, even in the aggregate, can rarely give a relatively objective picture of the real scholarly contribution of a particular researcher or team. Therefore, the problem of expanding the list of basic scientometric indicators and the use of new scientometric instruments (as an example, the quartile index developed by the author) becomes more urgent than ever. It is necessary to abandon the indexing of “Collider publications,” self-citations, and negative links and go from the calculation of single citations to the full accounting of all references to the author’s work. In the era of digital technology it will not be difficult to implement at least some of such recommendations. After all, the more diverse the scientometric indicators are, the more fully and more accurately they will reflect the publication activity of an individual author, team, or university as a whole.

Key words: scientometrics, Web of Science, Scopus, Google Scholar, Russian Science Citation Index, citation index, h-index, quartile index.

1. Introduction

The modern era of digital technology provides scholars with unprecedented opportunities to create, edit, copy and distribute scholarly texts, which are now easily accessible anywhere in the world thanks to the Internet and the availability of appropriate technology. For example, to facilitate the search for electronic documents, books, and articles a Digital Object Identifier is now actively used: almost all leading scholarly journals assign their publications a DOI [1].

The volume of scholarly knowledge tends toward constant exponential growth. The main results of research by scholars are usually embodied in various kinds of publications – scholarly reports, (written down) speeches, articles, monographs, etc. The discipline of Scientometrics has emerged to continuously monitor these publications and the various bibliographic parameters associated with them. It studies the evolution of scholarship through numerous measurements and the statistical processing of bibliographic information (the number of scholarly articles, their citation, the significance of the journals in which they are published, etc.). With the aid of scientometric data, it is possible to determine the scholarly potential of an individual scholar, a research team, a university, and even an entire country with varying degrees of accuracy.

Scientometrics originated in the mid-1930s, and finally took shape in the 1950s in the United States, where its “father” was the American linguist Eugene Garfield [2, 3]. However, the term “scientometrics” was introduced by the Soviet mathematician Vasily Nalimov only in the second half of the 1960s [4–6]. The subsequent widespread introduction of computers, digital technologies, and the Internet has dramatically increased the efficiency of scholarly bibliographic information processing and stimulated the emergence in the 1990s–2000s of international bibliographic databases (BDB), such as Web of Science (WoS) and Scopus, which the world search engine Google Scholar (GS) joined.

Since foreign BDBs indexed no more than 10% of all scholarly journals published in Russia, it was necessary to somehow fill this gap and in 2005 the Russian Science Citation Index (RSCI) was founded.
on the basis of the Russian electronic library eLIBRARY [7]. Currently, the RSCI stores information on over 12 million publications of Russian authors, as well as citation of them from more than six thousand Russian journals. In September 2014, the management of the Scientific Electronic Library signed an agreement to place the best journals from the RSCI on the WoS platform in the form of a separate database of the Russian Science Citation Index (RSCI). It was thought that for Russian journals on the RSCI list this would become a kind of springboard for promotion in the Web of Science Core Collection. However, expectations have not been met so far, and domestic magazines selected for RSCI do not participate in the calculation of WoS metrics [8, 9].

At present, the role of the leading BDBs, primarily WoS and Scopus, is extremely large since they accumulate a huge amount of bibliographic information and the results of their scientometric processing. These data are not only academic, but also practical in connection with the need for ranking and encouraging scholars and universities by the official authorities in managing the field of scholarship (through a system of grants, state funding, when replacing scholarly personnel, etc.). Therefore, scientometrics are not a trivial calculation of numbers, but rather their analysis, interpretation, and often an occasion for making managerial decisions [10, 11].

The popularity of scientometry among managerial bureaucracies is determined by the cheapness and speed of verification, as well as the lack of the subjective “human factor” in the rapid assessment of the publication activity of scholars. At the same time, the threshold restrictions on scientometric indicators are a kind of filter that allows filtering out weaker candidates (for example, in receiving grants) and thereby reducing the cost of conducting expensive and time-consuming expert assessments of the quality of scholarly results [12].

The purpose of this study is to show all the complexity, ambiguity, and sometimes inferiority of the applied scientometric parameters when they are thoughtlessly used in practice (this is especially true for Russia). To achieve this goal, several interrelated tasks will need to be addressed:

1) to analyze in detail the main scientometric indicators and tools used by leading BDBs;
2) to show their advantages and to reveal shortcomings;
3) based on the results of critical analysis to formulate recommendations for improving the basic scientometric parameters.

2. Methods
In preparing this article, such standard theoretical methods of scholarship were used as induction and deduction, analysis and synthesis, a systematic approach, the method of social modeling, the comparative-typological and comparative-analytical method. Thus, a comparison of the main scientometric indicators of the bibliographic databases Web of Science and Scopus with Google Scholar and the Russian RSCI provides a lot of food for critical analysis and reflection.

In addition to theoretical methods, practical methods such as working with documents, analysis of printed and electronic sources of information, and the method of content analysis were widely used in writing this article. The use of the latter helped, for example, in identifying the entire block of articles directly or indirectly related to Russia in the general array of publications of two leading scientometric journals—Scientometrics and Journal of Informetrics. Statistical and mathematical methods were also used, in particular, the quartile index formula was developed, which can serve as an auxiliary tool for indirectly determining the quality of publications of a researcher, department, division, or university as a whole.

3. Results and Discussion
To begin with, for WoS, Scopus and RSCI, the most important scientometric indicators are three: 1) the number of scholarly publications, 2) the number of citations, and 3) the Hirsch Index ($h$-index). GS uses the last two indicators, supplementing them with $i_{10}$-index (this indicates the number of works by the author with 10 or more citations). Let us consider these indicators in more detail.

The simple total number of publications is the most primitive indicator of scholarly activity of a scientist or team (department, division, university). If we are talking about individual scholars, it should be borne in mind that the final figure of their publications can significantly depend on age, because, as a rule, the older the scholar, the more works he or she have. When comparing the scholarly productivity of a young and old specialist, the problem can be solved by introducing a time limit, for example, by taking
into account scholarly works only for the last 3, 5, or 10 years (in GS, along with the total number of publications, the number of works and their citation for the last 5 years are given).

Although the indicator of the total number of publications is very easy to calculate, such simplicity also has a negative side, since the complexity, volume and quality of scholarly work are not taken into account. A simple mechanical calculation of the number of publications erases the difference between a monograph, a journal article, a review, etc. Let us simulate a situation in which there are two applicants for the post of associate professor, the first of them, for example, with 40 publications and the second only 25. If the selection committee is guided only by these figures, it will certainly give preference to the first candidate. However, if the committee members are concerned about the quality and volume of the scholarly work carried out by each of the applicants embodied in the publications the picture will be completely different. It turns out that of the 40 publications of the first candidate, only six are full-fledged journal articles (the remaining publications are abstracts of scholarly reports, summaries, and reviews), while the second has a large monograph and 12 articles in highly rated journals, including overseas. At the same time, the total volume of the latter’s printed output is 2.5 times greater than that of the first applicant. If the committee is not biased and takes into account these indicators, it will certainly give preference to the second candidate. Thus, such a simple indicator as the total number of publications, under certain conditions, can become a kind of trap in making management decisions.

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When we deal with this parameter, we must bear in mind that no single BDB usually takes into account all the publications of the author, especially if there are a lot of them, thereby underestimating the final figure. Moreover, in the WoS and Scopus databases there are artificial limits for indexed work. Thus, the Web of Science traditionally focuses on journal articles from a limited circle of selected scholarly periodicals (materials from international symposiums and conferences and detailed reviews are also taken into account). At the same time, when calculating individual indicators, monographs and their citation are not taken into account, which is especially important for representatives of humanitarian disciplines, for whom monographs are the most valuable result of scholarly activity [13]. In addition, until recently WoS was characterized by a clear orientation to American scholarly periodicals and the English language, especially in the humanitarian and social disciplines, which put representatives of other countries in a clearly unequal position [14]. Suffice it to say that a few years ago Russian historical periodicals were represented in the WoS by only two journals—“Questions of History” and “Russian History,” and therefore it was hardly worth talking about an objective reflection in this bibliographic database of the real contribution of Russian historians to world scholarship. Fortunately, over the past three years the situation has changed and at the beginning of 2019 (according to the statistics revealed by the method of content analysis) WoS indexes at least 20 Russian journals (including regional ones) related to historical subjects.

Unlike WoS, the Scopus BDB, in addition to journal articles, uses monographs and articles from collections, in calculating individual scientometric indicators of scholars. However, only books and collections of articles published by the most famous and authoritative scholarly publishers, primarily English-speaking, are taken into account. As far as the author knows, the indexing of monographs from Russian book publishers has not yet been done (at least for the humanities field), and therefore Russian scholars are in a distinct disadvantage in this regard. Although the Scopus BDB presents significantly more scholarly periodicals in the national languages compared to WoS (Scopus has about twice as many
indexed scientific journals as its American competitor), through the content analysis method it was
determined that in the spring of 2019 there were still fewer Russian historical journals in Scopus than in
WoS (14 and 20, respectively).

The global search engine Google Scholar is not a bibliometric database in the strict sense of the word,
it does not have definite selection criteria based on types of publications, and therefore every scholarly
production is taken into account, and the authors themselves can add their works to their author profile. In
addition, GS also lacks a clear orientation toward English and publishers and as a result, the number of
publications registered in GS is several times greater than in Scopus and WoS, which allows for a much
fuller presentation of the contribution of the scholar by this criterion. At the same time, GS data are not
always accurate, for example, due to the duplication of works (as the author of the article has had to deal
with) and taking into account popular science literature, methodological developments, publications in
“junk” and “predatory” journals [15].

As for RSCI, like GS it registers everything, indexing not only every scholarly publication of Russian
authors, but sometimes also textbooks, manuals and other methodological literature that have no relation
to the actual scholarly works. As a result, the laxness of the RSCI leads to the fact that sometimes the
final figure of the number of scholarly works of a particular author is overstated by the inclusion of non-
scholarly works. At the same time, being a national BDB, the RSCI primarily records Russian-language
works, but is completely unsatisfactory in taking into account foreign publications (there is a “mirror
picture” here compared to WoS and Scopus with their focus on English-language works).

Finishing the story with the analysis of the problem of registration and accounting of the total number
of publications, it is impossible not to touch upon the problem of co-authorship. As well-known
scientometric experts John Mingers and Loet Leydesdorff noted in their big review article, if in the social
sciences and humanities the “solitary scholar” most often acts, then large collectives clearly prevail in the
technical and experimental sciences. So, in the article on physics published after the research at the Large
Hadron Collider and the discovery of the Higgs boson, there were 2932 authors! [16] Here we are faced
with an insoluble conflict of scientometrics. And this applies to works even with a few dozen co-authors.
It is impossible to imagine a situation when 75 people work on an article of 10 pages at the same time. It
is physically impossible. In fact, an article is usually written by one or three authors or a few more and the
rest, at best, add some touches, additions, small remarks, and often only the imperious surname of the
project manager. Nevertheless, after the publication of the work, all co-authors equally receive a
Corresponding entry in their author's profile in a particular bibliometric database.

Even this short sketch of one of the simplest and most universal scientometric indicators clearly shows
that this value is rather arbitrary, although it is the number of publications that most often serves as a
measure of the scientific activity of a researcher. At the same time, scientometrics offers another indicator
that is designed to solve the problem of the quality of scholarly work. This is the citation, which means
referring to the work of an author by another author or authors. It is believed that the more citations, the
higher the demand for the scholarly work, and thus its quality. Now the citation index (CI) is a generally
recognized indicator of the importance by the scholarly world of the works of a scholar. It appears in all
major BDBs. Of course, Google Scholar indexes links most quickly and fully (the average indexing delay
in Scopus is about two months compared to GS). However, the quality of citations in GS is lower due to
lack of control, which sometimes leads to double citation and taking into account references from
unscholarly sources [16, 17]. However, as the latest research by foreign experts shows, GS citation data is
an expanded set of WoS and Scopus indicators with significant additional coverage in all areas [18]. In
Russia, according to Order No. 406 of the Ministry of Education and Science of October 14, 2009, when
analyzing publication activity, citation is taken into account for the five years preceding the current year.

Along with the undoubted advantages, the citation index has many shortcomings, which have been
repeatedly pointed out by various experts, including Russian scholars [19, 20, 21]. These deficiencies,
which often result from imperfections of the quantitative index, are the following (I will mention the most
significant):

1. The citation index does not take into account the personal contribution of the author (when counting
the CI, did five people write the article or just one). This is a very significant defect of the CI that often leads
to substantial distortions in the resulting scientometric indicators, although various mathematical formulas
have now been developed that are designed to level this disadvantage.

2. The citation index takes into account references even to those works that are subject to serious
criticism and the results of which are considered erroneous or simply unreliable. It comes to the point of
absurdity: a negative reference, which, in theory (after checking by experts) should be credited with a minus sign, on the contrary, provides the criticized author an additional citation.

3. Some innovative works are undeservedly forgotten, and secondary works published later by other authors are cited.

4. The number of citations to a large extent depends on the branch of scholarly knowledge (the difference reaches about 6 times). For example, biologists have a very high citation frequency; it is much less for physicists and even less for historians. Moreover, even within the same scholarly field a certain differentiation is observed. Thus, among representatives of historical disciplines, the archaeologists and ethnographers (ethnologists) most often refer to the work of their colleagues, while archivists and historiographers—the least.

5. Citing is often initiated by random circumstances, personal relationships of scholars (friendly or, conversely, hostile), scholarly “fashion,” citation culture, and the like.

6. Artificial restriction of the range of the works being cited and that are citing, predominantly by journal publications of the “chosen circle,” is typical primarily for WoS, as a result of which the CI of a particular author is forcibly reduced. In this regard, Scopus takes a more objective position, indexing monographs and references to them, which can bring authors, especially those in the humanities, a considerable share of citations. The RSCI, as has been said, is very reluctant to take into account works published abroad and references to them. I will give as an example my own monograph published in 2005 in the United States: at the moment it has 26 references in Scopus, 50 in GS, and only 9 in RSCI.

7. A very significant defect of CI, in my opinion, is that there is a single reference to a specific work in the list of references used in the article, though there may be several references to this publication in the text. In other words, it does not matter to CI how many times the work has been cited—one time or ten. Only one reference will be taken into account, which often greatly distorts the scientometric indicators and dramatically reduces the objectivity of the scientometric approach as a whole.

8. There are various ways to artificially build CI through various manipulations, for example, when colleagues agree to cite each other’s results there is excessive citation, or the author abuses self-citation. At the same time, self-citation is necessary and justified in certain cases (for example, to avoid duplication of information) and is taken into account by all BDBs (in the RSCI there is a metric showing % of the author’s self-citation). However, self-citation can significantly distort the final scientometric indicators [22]. To prevent abuse on this basis, Academician Alexander Kholodov proposed limiting the registration of the percentage of authors’ links to their own works to 10–15% of their total number and not take into account in citation systems links that exceed this limit [23].

As we see, CI, as one of the main scientometric tools, is not spared serious flaws, and therefore cannot be absolutized. Nevertheless, the citation index of scholarly works has as its basis another scientometric index—the impact factor (IF) of journals. The impact factor is a formal numerical measure of the importance of a scholarly journal, which is demonstrated by the average number of times each article published in the journal was cited during the two years following publication. The introduction of the IF contributed to a better selection of scholarly journals carried out by the main databases, where they are divided into four categories—quartiles—from Q1 (highest) to Q4 (lowest). For obvious reasons, the RSCI and GS lack a quartile metric. At present, the SCImago Journal Rank (SJR) is a convenient and intuitive system that demonstrates quartiles of journals [24]. It should be borne in mind that the IF of journals is dynamic and can sometimes experience a rise or fall (a journal can raise its status and move, for example, from Q4 to Q2 or vice versa).

Like the previous indicators, the IF is not without drawbacks. In particular, there may be a situation where most of the links to certain articles will go beyond the two-year period of calculating the impact factor of the journal and, therefore, simply be ignored. The IF is fundamentally different for different disciplines and it is unreasonable to compare a journal from medicine with one from mathematics for this indicator. There may be manipulations with the IFs when the editors of several journals agree to encourage their authors to refer more often to each other’s articles in order to increase the IF (“contractual quotation”). The IF can be influenced by “scientific fashion,” etc. Unfortunately, the constant demands of ministerial and university bureaucracies to publish articles only in journals with a high impact factor (related to Q1–Q2) and to link such publications with the funding of universities and authors, places serious negative pressure on many scientists regarding their career growth and the awarding of grants, especially in developing countries [25, 26], Russia being no exception.

The last of the basic scientometric indicators is the Hirsch index ($h$-index). It was developed in 2005 by an American physicist of Argentine origin, Jorge Hirsch (from the University of San Diego, California,
USA), to obtain a more adequate assessment of the scholarly productivity of the researcher than such simple characteristics as the total number of publications and citations can give. According to the Hirsch index, “a scientist has index \( h \) if \( h \) of his or her \( N_h \) papers have at least \( h \) citations each and the other \( N_{p-h} \) papers have \( < h \) citations each” [27]. For example, an \( h \)-index equal to 3 means that a scholar has published at least 3 papers, each of which has been cited 3 or more times. Moreover, there can be any number of works cited a fewer number of times. The new index immediately became popular and began to be used to calculate scientometric indicators in various sciences and generated several variations [28, 29].

The \( h \)-index is always a positive integer that can not be reduced, but only increase over time in the case of growth of citations of a scholar’s works (the exception is the situation when the author has publications but there is no citation, in which case his \( h \)-index is zero). The specificity of the \( h \)-index is that it will be equally low both for the author of one very popular article and for the author of many works cited no more than once. This figure will be high only for those who have a lot of publications and all of them (or at least many of them) are quite popular, i.e., regularly cited by other researchers.

Since the \( h \)-index depends on citations, it is largely determined by the field of science with different citation models: medical specialists and biologists have the highest Hirsch indexes, physicists and chemists have a much smaller index, and that of historians is very small since they often cite documents and other written sources and not the work of their colleagues [30]. Since Scopus, unlike WoS, takes into account monographs (and articles from collections), and not just journal publications, the \( h \)-index of scholars with monographs indexed in Scopus DBs often have a higher \( h \)-index than in WoS. An even higher \( h \)-index will be in GS, and for a Russian scholar in the RSCI.

Despite the fact that the \( h \)-index has undeniable positive qualities, such as ease of calculation and relatively adequate assessment of scholarly productivity, it is also not without a number of drawbacks. Thus, the \( h \)-index figure cannot exceed the total number of works of the author; this index does not take into account information on the most important highly cited works; it takes into account even references from those works in which the author is deservedly criticized for errors and inaccurate information; the \( h \)-index does not solve the problem of possible abuse of self-citation, etc. [21]. Not surprisingly, soon after the creation of the \( h \)-index, the Belgian scholar Leo Egghe proposed his so-called \( g \)-index as an alternative for calculating scientific efficiency, but it was not widely recognized [31]. Now there are many developments of new indexes and formulas (for example, rectangle-index, EM-index, Scientific Quality Index (SQI), MZE-index), designed to compensate for the shortcomings of the existing ones, but they have not been widely used in practice in the calculations of the main bibliographic databases. Attempts to improve the methodology for calculating the \( h \)-index have so far not stopped [32, 33].

As can be seen, none of the three main scientometric parameters is imperfect and their thoughtless use can lead to various misunderstandings and abuses. This is especially true in Russia, where the pressure on scholars and university professors from the state bureaucracy and university administration to achieve high formal figures and indicators is particularly great. Thus, in 2006 the first serious attempt was made at the state level to regulate and stimulate the work of Russian scholars with the aid of special payments. By an order of the Ministry of Education and Science of the Russian Federation of November 3, No. 273/745/68, criteria for individual indicators of the effectiveness of scholarly activity (PRND) of employees of academic research institutions and representatives of the teaching staff of universities were issued. In the most general outline of the PRND formula had the following form:

\[
PRND = kJ + pM + rU + hD + sK + bP + gR + C,
\]

where \( J \) is publication in journals; \( M \)—monographs; \( U \)—textbooks; \( D \)—reports at conferences; \( K \)—science-education courses; \( P \)—patents; \( R \)—scientific leadership; and \( C \)—the number of citations in the work of an author for the reporting period; \( k, p, r, h, s, b, \) and \( g \) are weighting coefficients.

However, in general, the methodology for calculating the PRND proposed in the Ministry’s order was far from faulty. In particular, it includes such indicators as the development and processing of training courses taught at the university, the management of graduate and postgraduate students—all these types of work primarily relate to teaching and pedagogical, not scholarly work. Scholars in the humanities are not able to obtain patents for scientific and technical inventions, thereby losing part of the points without any compensation. Along with articles and monographs, the number of scholarly publications includes textbooks and teaching aids, which again cannot be recognized as full-fledged scholarly works [33]. Despite these obvious shortcomings, the PRND formula with various additions and variations still serves
as the basis for scientometric calculations in Russian universities and institutions of the Academy of Sciences.

Here is a fresh example of ill-considered decisions. In 2018, in accordance with the State National Project “Science” (2018–2024), it was proposed to consider any researcher a leading scholar who had in the past two years at least one article in journals related to Q1–2 in international databases, or at least one patent for an invention abroad (this information is available in the Russian segment of Wikipedia). Why such figures are given and why only a 2-year period is taken as a basis for the calculation is not entirely clear. Given the practice of representatives of most natural sciences to write articles in large groups and actively cite each other, it will not be surprising that the number of “leading scholars” will be disproportionately large among Russian non-humanities people, and the title “leading scholar” will be devalued.

For a more objective assessment, I developed a quartile index (Q_k), the mathematical design of which is as follows:

\[ Q_k = \frac{\sum_{j} k_i n_j}{N} \]

- \( Q_k \) – quartile index;
- \( k_i \) – weighted coefficients of quartile journals;
- \( n_i \) – number of publications of the author in the relevant quartile;
- \( N \) – total number of publications of the author.
- \( i \) – the index, which refers to quartiles, accordingly varies from 1 to 4;
- \( j \) – the index, which refers to the number of publications, varies accordingly from 1 to \( N \).

The upper limit of the index is 4, the lower limit is 1; the range between them is an indicator of the prestige of the international scholarly periodicals in which the author’s articles were published. Naturally, the closer the figure is to 4, the better; by contrast, the range from 1 to 2 of the quarterly index indicates publications in low-ranking journals of the lower quartiles. It is advisable to calculate the quartile index for a period of 5 or 10 years and only in relation to individual copyrighted works. The disadvantage of this index is the inclusion of only a limited number of journal articles with quartiles (monographs, articles from collections, conference proceedings, and reviews are not taken into account). In addition, as shown by practical testing of the quartile index by the example of analysis of the publication activity of leading Russian historians (the publication of data is being prepared), it will work well only if there is a sufficiently large sample: the smaller the sample, the less reliable the data. Therefore, it can serve only as an auxiliary tool for indirectly determining the quality of publications of a researcher, department, division, or university.

4. Conclusions

The study clearly suggests that a limited range of scientometric indicators can rarely give an absolutely objective picture of the real scholarly contribution of the researcher. To do this, ideally a scholar should publish the results of his scholarly activity exclusively in journal articles indexed in the international WoS and Scopus databases. Therefore, the objectivity of scientometrics, as a rule, is still very relative, and its digital indicators should be treated with great caution. This has been repeatedly stated in the literature. In particular, Canadian professor Yves Gingras writes in his monograph that it seems dangerous to impose a unified model of scholarly practice, taking as a model the publication of articles in specialized journals [35].

Nevertheless, it is clearly not necessary to completely abandon the services of scientometrics, although its indicators, tools, and objects of indexing certainly need to be improved. For example, contrary to all logic, WoS does not index scholarly monographs in authors’ profiles, but takes into account reviews of them. A fair assessment requires only individual works to be registered: no “Collider publications” with hundreds and thousands of collaborators! Negative references should be explicitly excluded from scientometric calculations, as well as self-citation. A common very significant drawback of all BDBs—accounting for only one citation—should be replaced by full consideration of all references to this work, which would turn the citation index into a truly high-quality indicator. In the era of digital technologies, it will not be difficult to introduce several additional scientometric indicators and monitor them. To begin with, at least a metric should be introduced that takes into account separately the number of scholarly articles in journals and collections, monographs, conference proceedings, and reviews. After
all, the more diverse the scientometric indicators are, the more fully and more accurately they will reflect the publication activity of an individual author, team, or university as a whole.

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