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ОРИГИНАЛЬНЫЕ СТАТЬИ / ORIGINAL ARTICLES

О связях в науке на примере редакционной коллегии научного журнала

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Аннотация

Анализируются связи между рецензентами научно-технического журнала, формируемые на основании подготовленных ими рецензий. Показано, что связи могут быть представлены в виде графа.

Для проведения исследования используются данные о рецензировании статей в научно-техническом журнале «Вестник Концерна ВКО «Алмаз — Антей» за шесть лет. Методами анализа являются комбинаторика и теория графов и связанные с ними вычисляемые характеристики графов: матрицы смежности, инцидентности, достижимости, полнота и связность графа, граф ближних соседей и связующее дерево графа. Показано, что сотрудничество рецензентов для рассматриваемого журнала формирует связный граф, в котором существует путь между любыми двумя вершинами, то есть любыми рецензентами. Проведен анализ графа и показаны способы его использования для расчета наукометрических показателей журнала.

В результате исследования выявлено, что у журнала, публикующего статьи по многим специальностям, формируются связи между всеми рецензентами. По данному параметру можно говорить о взаимозаменяемости в рамках научных направлений или, наоборот, о совместной работе в определенном научном направлении при рецензировании рукописей. По результатам исследования можно организовывать поиск новых рецензентов в областях, где компетенции недостаточно развиты, а по областям, где компетенции сильны, можно судить об основной компетенции рецензентов научного журнала, которая отражает основную направленность оцениваемых научных исследований.

Итогом работы являются сформулированные наукометрические показатели журнала, которые могут быть использованы для поиска и привлечения новых рецензентов или отражения данных о высокопрофессиональных рецензентах в определенной тематике, а также о наличии нового научного направления, которое только начинает развиваться.

Ключевые слова: граф связей рецензентов, научные направления издания, полный граф, связанный граф, рецензент, научно-технический журнал

Конфликт интересов: автор заявляет об отсутствии конфликта интересов.

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On relations in science: the case of the scientific journal editorial board

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Abstract

This article analyses the connections between members of the editorial board of a scientific journal which are formed based on their reviews of scientific articles. It is shown that the connections can be represented as a graph.

The research uses the data for six years of article reviewing in the scientific and technical Journal of "Almaz — Antey" Air and Space Defence Corporation.

The methods of analysis are combinatorics and graph theory, as well as the relevant graph characteristics: adjacency matrix, incidence matrix, reachability matrix, graph fullness and connectivity, nearest neighbours graph and graph spanning tree.

It is shown that cooperation of the reviewers of the Journal helps plot a connected graph with links between any two vertices, i.e. between any reviewers.

The graph is analysed and the methods of its application to calculate the Journal's scientometric indicators are demonstrated.

As the research reveals, a journal that publishes articles in numerous disciplines forms connections between all reviewers and this parameter can be indicative of interchangeability within the scientific fields or, conversely, of a joint work in this scientific field when reviewing manuscripts. Based on the research results, it is possible to search for new reviewers in the areas where competencies are underdeveloped. And by the areas where competencies are strong, we can determine the core competence of the reviewers of a scientific journal, reflecting the main focus of the evaluated scientific research.

The work resulted in the formulated scientometric indicators of the journal, which can be used to search for and involve new reviewers or to represent data on a strong team of reviewers on a specific topic, as well as on a new scientific field just emerging for research.

Keywords: reviewers connection graph, scientific fields of publication, full graph, connected graph, reviewer, scientific and technical journal

Conflict of interest: author declares no conflict of interest.

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Introduction

So far, publication citations are supposed to be the basic criterion for estimating connections in science. However, such connections can be established between scientists in the course of expert review of manuscripts prior to publication in a scientific journal. Reviewing research papers helps establish the connections between scientists both from allied sciences and from absolutely different fields. This is an indirect proof of certain connections between different branches of science.

Moreover, scientific connections being established between reviewers allow to understand the research

fields of a particular scientific journal and analyse scientific disciplines where reviewers can replace one another in validation of manuscripts.

We should note that some research papers are not published in the journal, because certain percentage of manuscripts is rejected or returned for revision. However, within a journal, connections between scientists are also established through co-reviewing of an unpublished manuscript. This allows to evaluate the science from the other side — it is not a research itself that is analysed, but review of the research papers that are not published. Further, this paper is not intended to draw a line between a published or un-

Table 1. Frequency of assigning the number of reviewers to articles by year

Number of reviewers (reviews) for articles	Year						
	2015	2016	2017	2018	2019	2020	2021*
0	6	2	1	11	2	8	5
1	53	33	84	36	41	24	10
2	5	22	22	25	38	35	16
3	1	8	11	16	27	17	12
4	1	5	4	10	9	7	6
5	1	1	3	3	1	1	1
6	—	—	—	—	—	—	—
7	—	—	—	—	1	1	1
8	—	—	—	1	—	—	—
Average number of reviewers per article	1,1	1,8	1,5	1,9	2,1	2,0	2,2

*2021 data represent the first half of the year only

published manuscript. The goal is to analyse relevant connections formed between scientists.

Researchers have already applied the methods described herein and related to the graph theory in order to analyse a science and its allied fields [1–8]. For example, an analysis of reviewer's work in editorial boards of several scientific journals and reviewer's connections with research activities at a higher education institution are described in [1]. The graph theory along with the graph connectivity used in this research is employed to identify relations in conflict resolution studies [2]. The graph theory is proposed for visualization in the cognitive science [3]; research papers [4, 5] describe the potential of the graph theory in information visualization. An overview of papers devoted to the scientometric research of editorial boards of scientific journals is given in [6]. A study in the field near to this research is given in [7], devoted to a graph theory-based analysis of the network of scientific journals and scientists, as well as the relevant united groups. Paper [8] analyses the influence of academic journals and their editorial boards on research fields and describes the formation of a social network consisting of interconnected editorial boards of scientific journals.

A graph theory-based analysis of connections between reviewers

Table 1 shows the frequency of assignment of a particular number of reviewers to articles submitted to the scientific and technical Journal of "Almaz — Antey" Air and Space Defence Corporation for the period of

2015–2021. The reference year is 2015, because since the second half of that year the journal's policy was changed to send an article to more than one reviewer.

As shown in Table 1, the maximum number of reviews distributed from one to two and more reviewers was shifted within the period of 2019 to 2020. This tendency continues in 2021.

It should be noted that articles that have failed to pass the check by the Antiplagiat plagiarism detection system are returned to authors unreviewed, with no reviewer assigned (number of reviews is 0).

Moreover, articles that do not meet the journal's requirements to documentation execution or those of a very low scientific value are rejected and returned to authors. In this case, only one reviewer is assigned (1 review per article). As stated in [9], conversion of articles, i.e. the ratio between the number of articles accepted for publications and the total number of submitted articles is a random value with normal distribution, which can be substituted with an average value equal to 0.4 (or 40 %) for the scientific and technical Journal of "Almaz — Antey" Air and Space Defence Corporation. In other words, one reviewer can be assigned to review 60 % of submitted articles, the quality of which fails to comply with the publication requirements.

A graph is plotted based on the relations forming between two and more reviewers working on an article [10].

This graph is plotted as follows. Assume that a journal contains only two articles, and three reviewers are assigned to review one of them (Reviewer 1, Reviewer 2,

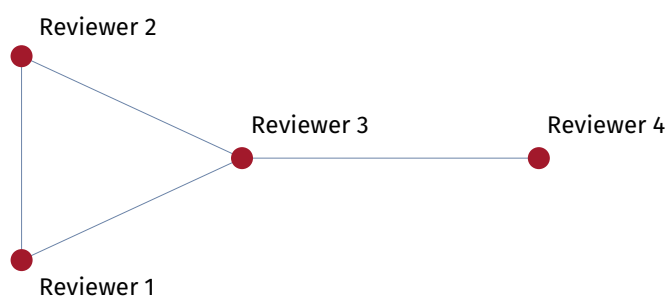


Fig. 1. An example of constructing a graph of reviewers relations

and Reviewer 3), while two reviewers are assigned to review the other one (Reviewer 3 and Reviewer 4). After all the reviewers issue their conclusions of the first paper, links between reviewers will be established in relation to this paper as shown in the left part of Fig. 1. As for the second article, links are established in the right part of the graph between Reviewer 3 and Reviewer 4 after reviewers draw their conclusions. However, Reviewer 3 has connections with Reviewer 1 and Reviewer 2, while Reviewer 4 has no such links.

We should note that the reviewing routine process at the scientific and technical Journal of “Almaz — Antey” Air and Space Defence Corporation includes a smooth-running review exchange between experts involved in manuscript evaluation, but only after they present their expert opinions. Besides, journal articles cover different areas of science and engineering such as automation, aerodynamics, hydraulics, gas and fluid dynamics, mechanics, radio location, radio navigation, radio electronics, radio engineering, power electronics, thermal physics, chemical technologies, electric engineering, and electrodynamics. The journal’s editorial board includes many researchers studying not only their own field, but a few allied sciences (for instance, automation and hydraulics, aerodynamics and thermal physics, etc.).

If there is a single reviewer, he or she is not considered in graph plotting; if there are two and more reviewers, they are considered in plotting the connection with the number of possible combinations taken

into account as well. For example, with three reviewers (1, 2, 3), all possible link combinations are considered (1-2, 2-3, 3-1). Directions are not considered, i.e. link 1-2 is identical to link 2-1. The number of combinations C_n^2 is calculated by the known formula [11, 12]

$$C_n^2 = \frac{n!}{2!(n-2)!} \cdot \quad (1)$$

The total number of combinations calculated by formula (1) is given in Table 2.

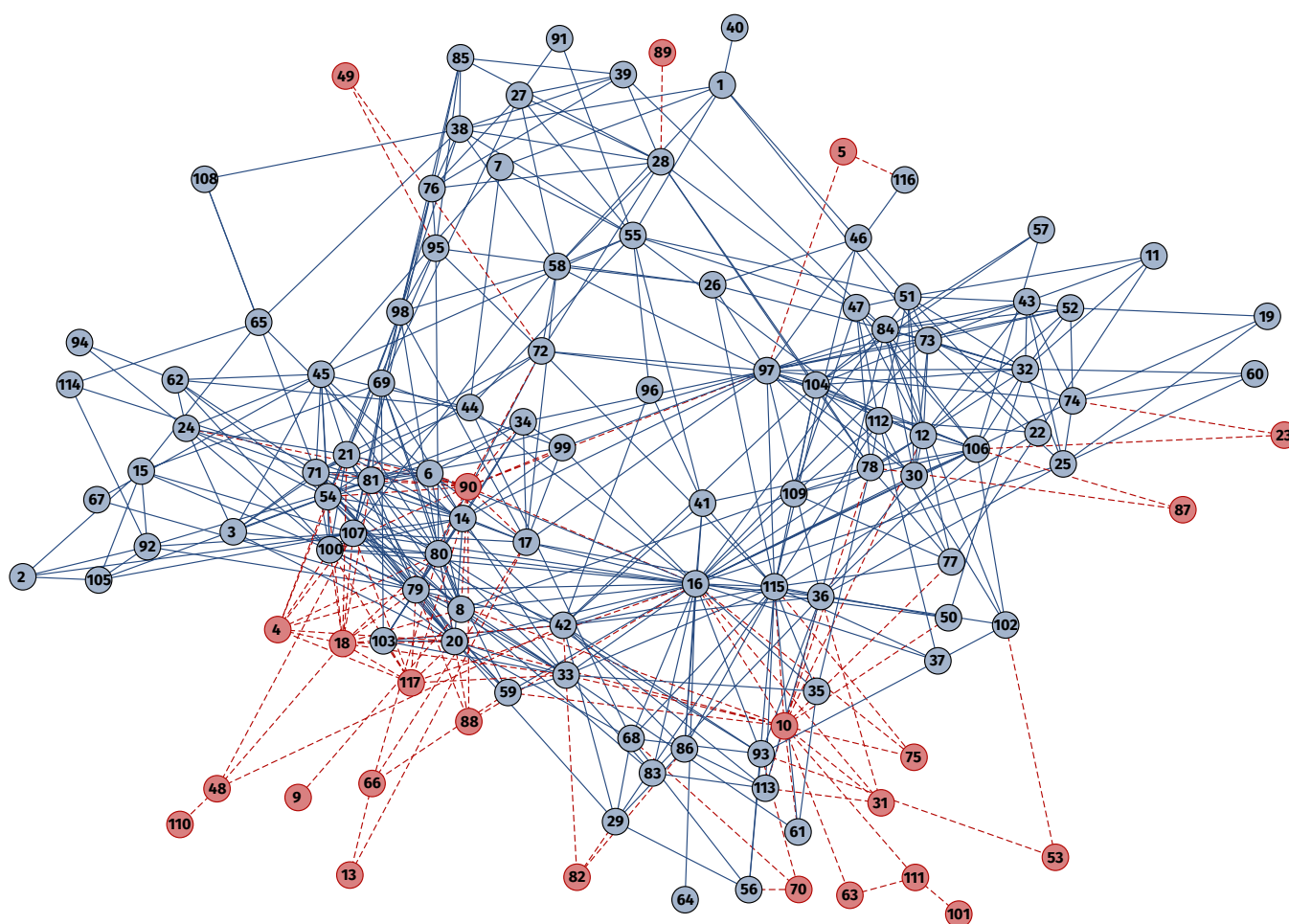
Research results

As a result, with 117 reviewers for the scientific and technical Journal of “Almaz — Antey” Air and Space Defence Corporation taken for research, 503 unique links have been identified (910 links result from 318 records of reviews made by several reviewers). Fig. 2 illustrates the graph linking 117 reviewers via 503 unique link combinations. The graph is plotted using the Graph[] function in the Wolfram Mathematica, a computer algebra system. Graph visualization is made with the help of the GraphPlot[] function, links between reviewers are identified using the Ksubsets[] function that generates combinations from a data array. The graph shown in Fig. 2 is modified in the graphic editor Adobe Illustrator in order to adjust its sizes and improve visualization. To see the detailed study, click the following link to an online platform <https://www.wolframcloud.com/env/3f0eb203-a684-4122-8554-b7a24dbdc986> or use a QR code below.



Table 2. The number of relations of reviewers from their number

Parameter	Meaning						
Number of reviewers per article	2	3	4	5	6	7	8
Number of combinations (relations)	1	3	6	10	15	21	28



The graph shown in Fig. 2 allows:

6. To calculate scientometric indicators based on the plotted graph of connections between reviewers

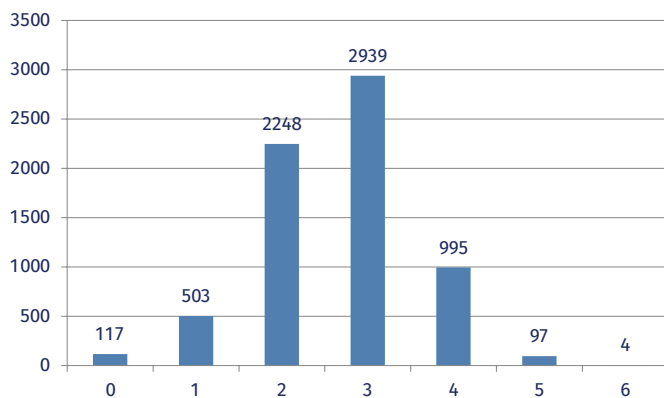


Fig. 3. The number of path lengths between vertices in the graph (between reviewers) along the ordinate axis and the path length along the abscissa axis

(for example, full interchangeability of reviewers indicates that a journal focuses on special research areas only; graph disconnectedness indicates disconnectedness of research papers published in a journal).

We should note that the full graph illustrates an ideal case — all reviewers are interconnected. For the case with 117 reviewers, the graph has 6,786 edges (formula $n(n-1)/2$) or connections between reviewers [11, 12]. This means that all reviewers are absolutely interchangeable. In fact, it is possible only if a journal focuses on very special disciplines, for example, on publications related to a single discipline as per the HAC list. If a graph plotted on the basis of reviews re-

ceived from reviewers is not connected and has two or more no longer connected sets of vertices and edges, such a journal can be classified as an interdisciplinary journal (for example, philology and biophysics). However, even for a multidisciplinary journal, with disjoint graphs illustrating connections between members of the editorial boards, relations between these connections and the connected graph can be established in order to determine the reviewers' interchangeability depending on the direction.

Another graph (Fig. 3) is plotted based on the analysis of the adjacency matrix. The graph analyses the length of connections between reviewers. Since this graph is a connected one, there is a path between any two vertices.

As shown in Fig. 3, the total amount of the longest paths between the members of the editorial board is not greater than 6. This is a proof of the six degrees of separation theory, which states that everyone in the world is connected by just six acquaintances [13]. The zero path length corresponds to the number of graph vertices, i.e. to the number of reviewers, and is equal to 117 as expected. We should emphasize again that the resulting graph for the journal under consideration is a connected graph with all the vertices connected with one another. The path length indicates the closeness of research activities within an organization and the connectivity of research findings.

The number of connections between reviewers and their colleagues can be calculated by plotting a spanning tree based on the nearest neighbors' graph, starting from the vertex with a certain reviewer number, as shown in Fig. 4 for Reviewer 32 ("Thermal physics").

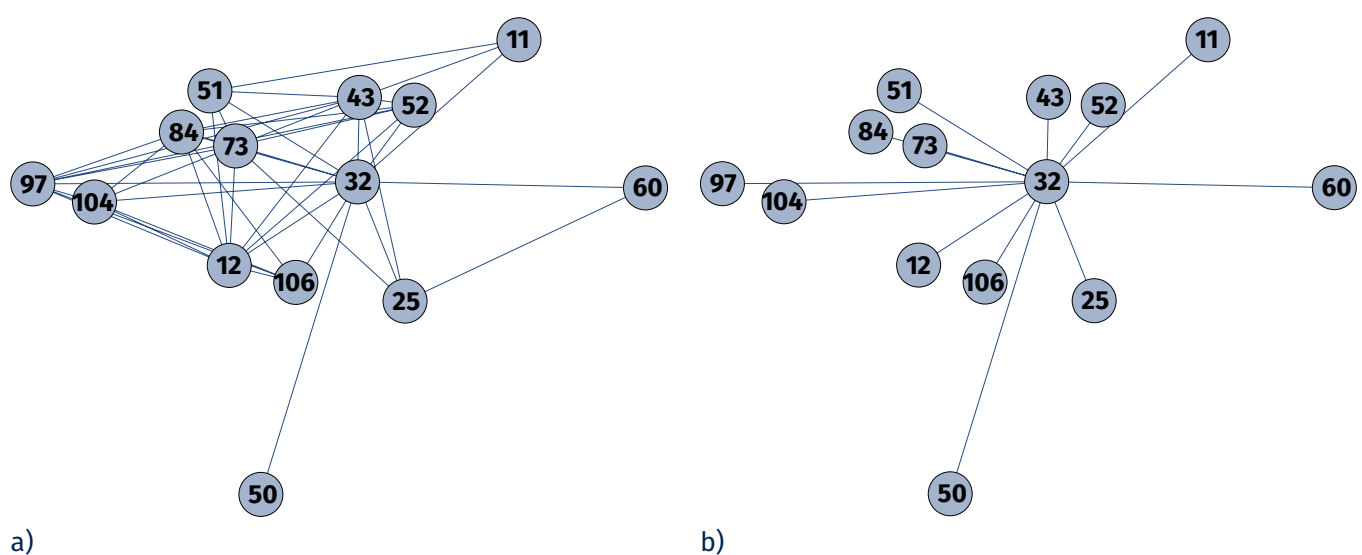


Fig. 4. The nearest neighbor graph for reviewer No. 32 (a) and the construction of a spanning tree on its basis (b)

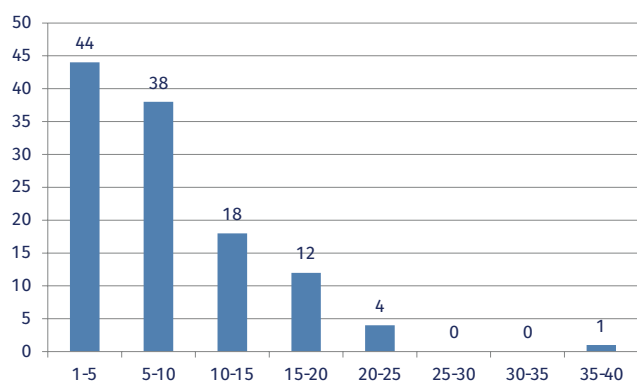


Fig. 5. The number of connections of reviewers along the abscissa axis and the frequency of occurrence of this event along the ordinate axis

Plotting a spanning tree based on the nearest neighbours graph (a connected acyclic graph with the number of vertices similar to that of the initial graph with the number of edges equal to the number of vertices reduced by one, with the central vertex degree equal to the number of edges, and with the degree of other vertices equal to one; the incidence matrix of such a graph contains unities in the row with the central vertex, unities in the column of edges incident to a given vertex, and zeros in all other elements of the incidence matrix) allows to estimate the number of reviewer's connections with other reviewers [10]. As shown in Fig. 4b, it is easy to calculate the number of connections of Reviewer 32, which is equal to 13. Fig. 5 shows the number of connections for all 117 reviewers calculated as demonstrated above.

Discussion of results

As shown in Fig. 5, the maximum number of connections between reviewers is 1–5 with further decrease. The more connections a reviewer has with other reviewers within the editorial board, the higher the reviewer's competence in reviewing manuscripts related to the specific research area or to allied sciences. It should be noted that a reviewer making poor-quality reviews is removed from the editorial board of the scientific and technical Special Journal of "Almaz — Antey" Air and Space Defence Corporation.

Those reviewers who are located beyond the centre of the graph and have a small number of connections with other reviewers, can belong to three types:

- reviewers focused on a limited field of science (for instance, Reviewer 40 — "Radiology");
- reviewers recently included in the reviewer staff of the journal (Reviewer 91 — "Optoelectronic Systems and Drives");

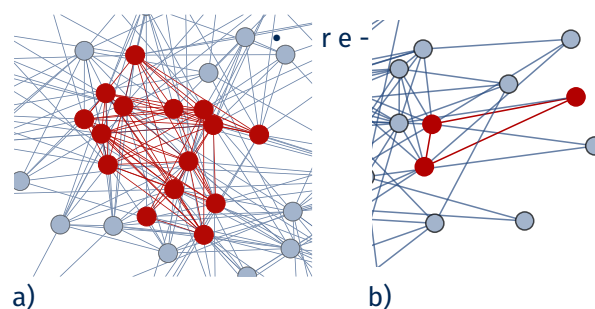


Fig. 6. Reviewers in the direction of "Electronics. Radio Engineering" (a) and "Gasdynamics" (b) and their connections

viewers who failed to build good working relationships with the editorial board (Reviewer 110).

For example, assume that the journal under consideration publishes articles related to the only discipline — "Electronics. Radio Engineering". In this case, the graph contains only those reviewers who review articles related to the specified subject (Reviewers 6, 8, 14, 17, 20, 21, 54, 71, 79, 80, 81, 90, 100, 103, 107). Except the connections with other reviewers, calculation of the number of connections between them (Fig. 6a) in relation to the number of edges of the full graph gives the value equal to 0.61 (64/105). This number is less than one, but the author supposes that such a result is obtained due to a short observation time: to form interconnections of all reviewers related to subject "Electronics. Radio Engineering", in case of 15 reviewers, at least 105 articles shall be reviewed.

Reviewers specialising in subject "Gas Dynamics" (Reviewers 25, 74, 60) form three connections with one another, as clearly shown in Fig. 6b: the ratio between the number of the connections and the number of edges of the full graph for three vertices gives the exact value equal to 1.

Data given in Table 2 can be used as follows: if a journal publishes articles related to several disciplines and its reviewers are not connected in terms of the discipline to be covered, it is reasonable to divide a journal in two or more, provided that articles related to each separated discipline are submitted on a regular basis.

For a limited-field journal, there are connections between all reviewers within the limit, because reviewers have competences to review any material to be published. The connection indicator can be viewed as an indirect estimate of a reviewer and the journal's editorial board: materials related to a certain subject area are to be reviewed by more than one reviewer. This approach allows to shape different opinions on the materials to be published, because

each reviewer has their own opinion regarding this or that research area.

Anyway, materials to be reviewed shall be sent to several reviewers. This works both for multidisciplinary and for limited-field journals. The experience gained by the staff of the scientific and technical Journal of "Almaz — Antey" Air and Space Defence Corporation proves that article processing involving more than two reviewers helps improve a manuscript.

Therefore, the ratio between the number of edges of the reviewers connections' graph and the number of edges of the full graph with the same number of vertices, the value of which in the limit is equal to one, is the scientometric indicator. For a multidisciplinary journal, the scientometric indicator is the existence of two or more disconnected graphs of connections between reviewers, but within each graph its number of connection in the limit tends to the indicators of a limited-field journal. The scientometric indicator equal to one as well as other indicators (impact factor, Gini index, etc.) can be used as a reference mark for the editorial board of a limited-field journal. For the editorial board, this parameter indicates that all reviewers shall take part in the expert review process, while the limit indicator requires that the number of reviewers per particle shall be at least two, and reviewers shall be rotated from one article to another.

Conclusions

1. The number of reviewer's connections indicates that a reviewer is a multi-discipline expert able to review articles related to allied sciences.
2. The ratio between the number of reviewers' connections and the number of connections of the full graph for the same number of reviewers indicates journal' multidisciplinary or limited field with all reviewers interchangeable.
3. A field-specific journal enables close connections between reviewers, and the path length in the connection graph is near or equal to one.
4. A multidisciplinary journal may have no connections between reviewers, and the connection graph of such a journal is not connected.
5. The length of the longest path in the journal reviewers' connected graph is not greater than six, thus proving the six degrees of separation hypothesis.
6. The graph illustrating connections between scientific journal's reviewers can be used for constructing an interchangeability matrix based on the published articles.
7. As a rule, a reviewer who fails to get along with the editorial board of a scientific journal, forms a small number of connections with other reviewers before he or she is removed from the editorial board.

Table 3. Limiting scientometric indicators for journals of one and several topics

Characteristic	Direction	
	One	Several
The ratio of the number of edges-connections between reviewers to the number of edges of the complete graph for a given number of vertices	1	-
Related graph of cooperation between reviewers	Yes	No
The number of unrelated graphs of cooperation between reviewers	0	2 and more
The length of the path between the vertices	1	From 1 and more
The number of links of each reviewer	[Number of reviewers] - 1	More than 1, but less than the number of reviewers

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