

A Mathematical Model for Increasing the Productivity of a Scientific Team

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Abstract—The study is based on the idea of introducing the necessary practical, productive component and optimization into the creative process of producing scientific publications. The productivity of a research team is considered as a relative assessment of its publication activity. The problem of distributing tasks among members of the research team in order to maximize labor productivity is formulated both substantively and formally. An appropriate distribution of tasks can be determined by solving an optimization problem. In this problem, the lower limits are formed based on the publication plan for the current state assignment, the upper limits are based on the maximum job load of team members, and the objective function is the ratio of the team’s publication activity assessment to the total number of workload hours. The proposed approach is illustrated by calculations based on accumulated statistics. Calculations based on current criteria for assessing publication activity revealed that the most productive research, according to the assessment scale of the Ministry of Education and Science, will be primarily in the direction of publishing Level I articles from the “White List of Scientific Journals,” while to ensure a high performance indicator for scientific activity according to the current scale of the V.A. Trapeznikov Institute of Control Sciences of the Russian Academy of Sciences (ICS RAS) has found that preparing presentations for Scopus conferences and publications in Tier IV journals is the most preferable approach. However, recommendations are highly dependent on the allocation of employee time to various tasks. Calculations based on actual data show a significant increase in labor productivity in one of the ICS RAS laboratories as a result of applying the proposed approach.

Keywords: modeling, management, optimization, labor productivity, publication, scientific work

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1. INTRODUCTION

Scientific research is a complex, multilayered process whose creative components are difficult to formalize and plan. Nevertheless, government and private grantors impose specific requirements on the results of this process to ensure they are obtained and applied in a timely manner. Therefore, researchers and their teams face the challenge of systematizing and planning the publication process to increase productivity. The issue of increasing labor productivity is currently relevant for many sectors of human activity. For example, the Russian Federation’s National Project “Labor Productivity” [1] plans to increase this indicator by at least 40% by 2030 at enterprises in the basic and raw materials sectors of the economy and social institutions. Developing relevant models and

methods for solving this problem is essential for maintaining and enhancing the country's competitiveness in the modern world. Labor productivity can be considered as an indicator of national development [2].

Applied and fundamental science should be considered among the priority areas for achieving this goal. However, in creative industries, which include scientific research, the task of increasing productivity has its own specific challenges. When evaluating a team's scientific work, it's generally assumed that the primary criterion is the theoretical and practical significance of the research results. However, understanding and recognition of this significance by the community may not come immediately. Therefore, in the information age, it is especially important to intensify the implementation of scientific results. To achieve this, the authors of this article believe that the process of scientific creativity must be accompanied by systematic and targeted efforts to promote it in leading specialized journals and scientometric systems. Successful promotion of scientific results not only facilitates their recognition but also provides the necessary incentive, including financial incentives, to continue the team's work. Systems for assessing scientific productivity proposed by the state, qualified clients, and expert councils are designed to address these issues. In Russia, the main such systems are the "List of peer-reviewed scientific publications in which the main scientific results of dissertations for the degree of candidate of science and for the degree of doctor of science must be published" [3] and the "White List of Scientific Journals" of the Russian Center for Scientific Information [4] (hereinafter BS RCSI). Internationally, these are Scopus [5], Web of Science [6], and other systems. The active representation of researchers and publications in these spaces is associated with well-known and accepted systems and methodologies for evaluating scientific work, such as the Hirsch index [7], the FWCI index of the ratio of the total number of citations to the average number of citations in a subject area [8], as well as other indicators, for example, based on bibliometric indicators [9] and the assessment of opinions on social networks [10]. However, these estimates and the algorithms for calculating them do not directly answer the questions of the collective organization of scientific work.

For these reasons, improving scientific productivity and publication activity in such systems requires systematic study and support with specialized mathematical models and algorithms. These models and algorithms will be aimed at managing the productivity of individual researchers, laboratories, institutes, and the country's scientific sectors as a whole. This article is devoted to the construction of such models and algorithms.

2. STATE OF THE ART

2.1. Methodological Foundations

The theory of inventive problem solving [11] can provide a number of useful recommendations for the rational preparation of collective publications:

- analysis and resolution of contradictions (immersion in the topic versus limited time, a uniform article style versus the personal writing style of different authors, thorough review versus prompt execution);
- application of the basic principles and tools of the theory of inventive problem solving (resources, automation, etc.);
- assignment of roles within the team (lead author, researcher, theorist, practitioner, editor).

However, this theory does not recommend using mathematical methods and calculations to distribute the workload in the form of tasks that best suit specific performers.

Similar recommendations can be derived from the concept of scientific work organization [12]. When creating publications, there should be a systematic approach to distributing responsibilities among process participants, with each specialist performing strictly defined functions:

- the project manager coordinates the work and performs final editing;
- the researcher collects and analyzes data;
- the methodologist develops the research approach;
- the writer forms the text;
- the editor is responsible for stylistic editing and proofreading.

It is important to consider the participants' qualifications: the supervisor provides expert review, co-authors develop the methodology, graduate students perform the initial data processing, and junior research fellows perform support tasks.

We believe that mathematical models and analytical calculations to support and justify decision-making when distributing publication assignments will be a development and refinement of these approaches. This will take into account the principles of Lean Manufacturing methodology [13], the Japanese methodology of continuous improvement [14], and the 5S system (5S—sorting, systematization, cleaning, standardization, improvement (self-discipline)) [15], which largely overlap with these concepts.

2.2. Mathematical Models and Methods

Finding an appropriate distribution of tasks when preparing publications can be based on classical mathematical programming methods [16] and their modifications [17], used in organizing and planning production, as well as for improving the predicted performance of organizational systems [18–20]. Both methods of individual incentives [21] and problems related to distributing work among performers are considered, where variations of classical methods for solving the assignment problem [22] should be mentioned. These methods are aimed at distributing work for its fastest completion, which partially corresponds to the goals of the problem under consideration.

2.3. Modern Research and Practices on Labor Distribution

The problem under consideration can be interpreted as a time management problem; however, modern time management techniques and methods primarily provide strategic, qualitative recommendations.

Improving human productivity is currently being explored in various industries, including using artificial intelligence: in logistics [23], in tourism supply chains [24], and elsewhere. The issue of balancing humans and robots [25] is also being widely explored in the field of intelligent manufacturing. [26] proposes using a system dynamics model to analyze the interrelations of factors influencing labor productivity in a team. Although this article does not provide recommendations for the appropriate distribution of work, we note the potential of system dynamics for analyzing and modeling the feasibility of such appropriate distribution plans.

Modern publications demonstrate that talent management can play a significant role in improving labor productivity [27]. However, it is used primarily in team formation rather than in assigning tasks to employees.

The proposed recommendations include increasing researcher mobility [28] and changing residence and organization after completing their studies [29]. The conclusions in such studies are based on a fairly extensive statistical analysis, but they do not provide specific recommendations for the work of research teams.

In other works, some strategic recommendations are made primarily for individual researchers. Regularity, consistency, and moderation are recommended: working on texts no more than 40–45 hours per week, avoiding procrastination and perfectionism, and taking “small steps” when writing articles [30].

The Institute of Control Sciences of the Russian Academy of Sciences is developing an information system for the analysis of scientific activity (ISAND) [31] in the field of control theory [32, 33]. As of January 15, 2025, 186 000 publications by 185 000 authors have been processed. The ISAND ontology is described, focused on representing and collecting knowledge in the field of control theory: both scientific knowledge (the control theory ontology) and knowledge related to the scientific activities of agents in this field (organizations, journals, conferences, and individual researchers).

The authors of various publications separately note the benefits of collaborative work when creating publications. It is believed that a scientist can increase their productivity by working on joint projects with other researchers. This suggests that the overall assessment of a research team's publication activity will be higher when distributing work on individual articles among researchers than when they only produce their own individual publications. This assumption is consistent with experience: high-ranking publications typically have a fairly large number of co-authors. However, collaborative work on publications, when the number of required publications is sufficiently large, in some cases requires some regulation in terms of the appropriate distribution of tasks and the transfer of information between the authors of individual papers. The issues of organizing research teams, whose members possess individual characteristics, varying abilities, and technical capabilities for performing a particular task, have apparently not been explored in open publications. This study is devoted to finding analytical models and methods for addressing such issues. The problem under consideration has the following formal and substantive formulation.

3. STATEMENT OF THE PROBLEM

Let there be a team of n employees who, over a period of time T , produce m types of publications. Each publication of the type ($i = 1, \dots, m$) is valued at ($p_i \geq 0$) points. Further, unless otherwise specified, the index i will be used for publications and it will be assumed that $i = 1, \dots, m$.

A set of publication part types $S = \{s_1, \dots, s_k\}$ is given (for example: review, model, calculation, etc.) so that a publication of each type i can be represented as a certain set of parts $S_i \subseteq S$.

We call a part of a publication of a certain type a task, for example: introduction, conclusion, mathematical model, etc. Consider the universe U —the set of all tasks, i.e., parts of all types s_1, \dots, s_k of all publication types. We assume that different employees can complete tasks from U in any order. A publication is considered complete when all tasks in it are completed.

For each employee $j = 1, \dots, n$, the time $t_{j,i}$ for successful completion of any task $u_i \in U$ is known. This value is determined empirically, taking into account the employee's position, experience, inclinations, and technical capabilities. It may reflect both the employee's creative qualities (e.g., "creativity" as the ability to quickly come up with a productive research idea), organizational skills (successfully coordinating publication parts from different co-authors), and executive abilities, as well as organization (e.g., quickly completing and submitting a new publication to a journal). Further, unless otherwise specified, the index j will be used to denote employees, and it will be assumed that $j = 1, \dots, n$.

The task is to assign a set of tasks $U_j(T) \subseteq U$ to each employee j in such a way that the overall assessment of the completed publications of the members of the scientific team for the period T in relation to the regular working time for this period is maximum:

$$\frac{\sum_{i=1}^m k_i p_i}{\sum_{j=1}^n T_j} \rightarrow \max,$$

where $k_i \geq 0$ is the number of publications of type i produced by the team over period T , T_j is the employee's workload over period T .

The following constraints must be met:

- $k_i \geq a_i$, where $a_i \geq 0$ are specified numbers reflecting the publication plan from the application for the topic of the state contract or grant;
- the total workload of each employee j over period T does not exceed their workload T_j ;
- each task is assigned to no more than one employee. This is ensured by a sufficiently detailed breakdown of publications into tasks.
- We assume that an integer number of publications are prepared over period T . We do not consider cases where work on a publication takes several years. In real-world situations, a publication may be prepared but not accepted. In subsequent periods, it may be reworked and submitted to other publications, and the results of the efforts and resources expended in period T are not effectively assessed.

The substantive task is to distribute the resources of research staff in the most productive way.

4. MODELS FOR SOLVING THE PROBLEM

4.1. Publication Preparation Model

The proposed general framework for publication preparation is shown in Fig. 1. The process is iterative, as reflected by the feedback loops in the diagram. In practice, these loops can be more complex during publication creation.

In this paper, when calculating the decomposition by performer, the following main publication components (tasks) were identified. Each of these components, as evidenced by experience with article writing by a team of authors, can be assigned to a researcher depending on their available time, qualifications, and aptitudes.

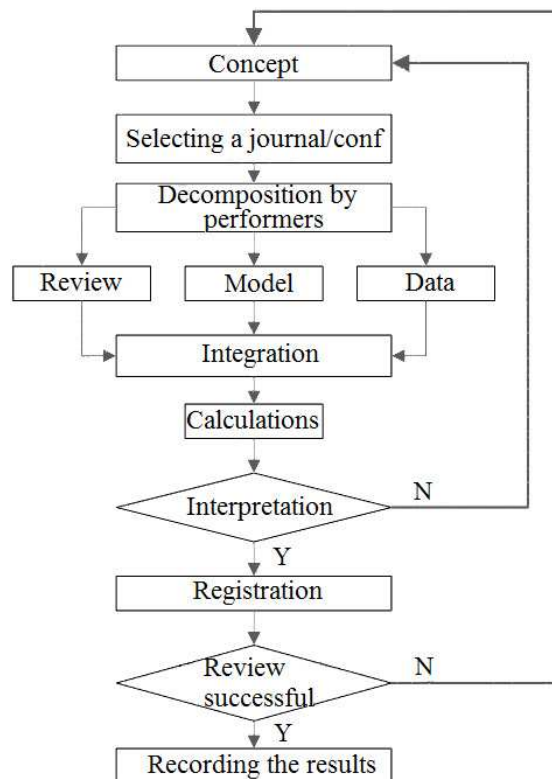


Fig. 1. High-level graph of the publication creation stages.

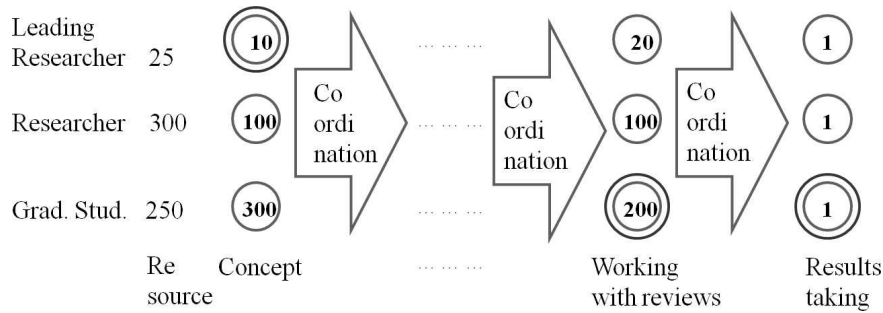


Fig. 2. A fragment of the task assignment process for a single publication.

1. Text

- 1.1. Title
- 1.2. Abstract
- 1.3. Introduction
- 1.4. Overview
- 1.5. Model
- 1.6. Algorithm
- 1.7. Data
- 1.8. Calculations
- 1.9. Discussion of Calculations
- 1.10. Conclusion
- 1.11. References
- 1.12. Section Coordination
- 1.13. Design

2. Expertise. Report

3. Submission to a Journal/Conference

4. Working with Reviews

5. Presentation, Speech

6. Recording Results (Publication awards, Best Paper Competitions)

Figure 2 shows a typical fragment of the task distribution process for a single publication (a Level III article of the White List). The current resource is defined as the employee's remaining time in hours at the time of planning; the circles indicate the number of hours required to complete the task; the vertices selected within the optimal or quasi-optimal solution are double-circled.

Next, we describe the proposed mathematical model for the efficient distribution of publication preparation tasks.

4.2. Mathematical Model

In general, the solution involves finding the task distribution as a 0-1 matrix X from n rows and $m' = \sum_{i=1}^m p_i e_i$ columns, where $p_i \geq a_i$ is a realistic upper estimate of the number of publications of type i over the period T (for example, a small team will likely publish no more than one or two Level I White List articles per year); e_i is the number of tasks in the publication breakdown of type i .

Each row of the X matrix determines whether an employee has completed or not completed each task in each of the team publications under consideration. Matrix element $[X]_{j,i}$ equals 1, if an employee is assigned a task corresponding to the column i of matrix X , and equals 0 otherwise.

We consider publication A to be completed (scheduled for completion) if the sums $\sum_{j=1}^n [X]_{j,i}$ for all columns of the matrix X corresponding to this publication are equal to 1 (provided that each task is assigned to no more than one performer).

Let's denote by $I(A, X)$ the indicator of whether this condition is met: $I(A, X) = 1$ if each task into which publication A is divided has an assignee, and $I(A, X) = 0$ otherwise. Some properties of the function $I(A, X)$ are given by the following statement.

Statement 1. *The function $I(A, X)$ is nonlinear with respect to the variables X , but can be represented using the multiplication operation.*

Proof of Statement 1. The nonlinearity of $I(A, X)$ follows from the fact that the matrix X_0 , in which publication A is complete, i.e., $I(A, X_0) = 1$, can easily be represented as the sum of matrices $X_0 = X_1 + X_2$, in each of which publication A is not complete, and therefore, $I(A, X_1) = I(A, X_2) = 0$.

Linearity of the function $I(A, X)$ in the variables X would require the equality $I(A, X_0) = I(A, X_1) + I(A, X_2)$, which is not satisfied in this case.

Representability using the multiplication operation follows from the fact that $I(A, X)$ can be represented as

$$I(A, X) = \prod_{i \in [X]_A} \sum_{j=1}^n [X]_{j,i},$$

where $[X]_A$ is the set of column numbers of X associated with A , as required.

Further, taking into account the introduced notations, the number of publications of type i performed in period T will be $k_i = \sum_{j=1}^{p_i} I(A_{i,j}, X)$, where $A_{i,j}$ is the publication of type i under number j . Then the assessment of the publication activity of the team is equal to

$$Pub = \sum_{i=1}^m p_i \sum_{j=1}^{p_i} I(A_{i,j}, X).$$

Given the dimensionality of the variable matrix X introduced above, we will now consider a Boolean programming problem with nm' variables. Most of the variables will be equal to 0, reflecting the non-participation of employees in some publications. Furthermore, the problem dimensionality in practice is significantly reduced by making assumptions about the numbers p_i , as well as by assigning similar tasks to the same employees.

Let the time standards required by employees to complete tasks U be written in a matrix $Norm$ of dimension $n \times \sum_{i=1}^m e_i$, where n is the number of employees, m is the number of publication types, and e_i is the number of tasks into which a publication of type i is broken down. An element of the matrix $Norm$ is equal to the number of hours required by an employee in a row to complete a task in the corresponding column.

Considering that publications of each type i can be considered in numbers from 1 to p_i , we construct a corresponding extended normalization matrix $Norm'$ of dimension $n \times m'$, where $m' = \sum_{i=1}^m p_i e_i$. The columns of $Norm'$ correspond to the tasks into which publications 1, ..., p_1 of type 1, 1, ..., p_2 of type 2, ..., 1, ..., p_m of type m are divided. Then, the time spent by employee j on completing all of their tasks is equal to the scalar product of row j of the matrix X and row j of the matrix $Norm$. The condition for limiting an employee's time based on workload then takes the form

$$\sum_{i=1}^{m'} [M]_{j,i} [X]_{j,i} \leq T_j.$$

Thus, the mathematical formulation of the problem, taking into account the notation introduced above, is as follows: Find a Boolean matrix X such that

$$\frac{\sum_{i=1}^m p_i \sum_{j=1}^{p_i} I(A_{i,j}, X)}{\sum_{j=1}^n T_j} \rightarrow \max,$$

under restrictions

$$\begin{aligned} \sum_{j=1}^{p_i} I(A_{i,j}, X) &\geq a_i, \quad i = 1, \dots, m, \\ \sum_{i=1}^{m'} [M]_{j,i} [X]_{j,i} &\leq T_j, \quad j = 1, \dots, n, \\ \sum_{j=1}^n [X]_{j,i} &\leq 1, \quad i = 1, \dots, m'. \end{aligned}$$

Note that in this problem, the first constraint and the objective function are nonlinear with respect to the problem variables, since they contain the publication indicator $I(A, X)$, the nonlinearity of which is shown above. Linearity can be achieved if the indicators of all publications under consideration are set to specific values, 0 or 1. However, this would also imply a certain selection of articles of different types, for example, one Level I article of the White List and two articles each of Levels II and III.

This means that the planned assessment of the team's publication activity will be known, and the team's productivity will have a specific value.

5. CRITERIA AND DATA

5.1. Criteria for Assessing Scientific Activity

Criteria for assessing scientific activity are typically based on the evaluation of a team's publications, and other results (rewards, grants, etc.) are usually derived from this evaluation. In the Russian Federation, the main criteria for assessing publications are currently provided by the guidelines of the Ministry of Education and Science [3, 4].

In addition to public motivation, it is advisable to consider possible personal criteria that influence the bonus component of remuneration. For example, the scientific performance indicator (hereinafter, SPI) of an employee of the Institute of Control Sciences of the Russian Academy of Sciences [34] is defined as

$$\text{SPI}_j = \sum_{i=1}^{k(j)} \frac{p_i}{n_i},$$

where $k(j)$ is the number of publications of the employee, n_i is the number of co-authors of publication i , p_i is the publication weight in points from Table 1.

Qualification requirements for Institute employees can be based on the correspondence from such tables (e.g., at least a certain number of points per year for a senior research fellow), or in conjunction with them (e.g., at least 10 publications in 5 years for a chief research fellow, the required level of technical readiness of scientific results, etc.). Employees are interested in increasing the productivity of the entire team, but issues of subtle interaction and mutual reinforcement of employee and team motivation as a whole require further study [35, 36].

Table 1. Weights in the ICS RAS Publication Assessment System

No.	Publication Types	Score
1	Publication in a Level I publication of the White List	400
2	Publication in a Level II publication of the White List	300
3	Publication in a Level III publication of the White List	200
4	Publication in a Level IV publication of the White List	150
5	Articles in journals, collections of articles, or conference proceedings, book chapters	72
6	Articles in journals included in the HAC List	24
7	Articles in journals, collections of articles, book chapters from the list of journals	6
8	Abstracts of papers at a scientific conference	2
9	Plenary paper at a scientific conference / at a conference whose proceedings are indexed by WoS or Scopus	12/96
10	Paper at a conference (at least three pages long)	6
11	Brochure (does not have an ISBN or is less than 6 p.s.), per p.s.	2
12	Monograph (ISBN and volume over 6 p.s.) / WoS, Scopus Monograph, per p.s.	12/24
13	Russian Federation Patent	18
14	Certificate of Registration of Software, Database, or Integrated Circuit	5

5.2. Initial Data

Working time, a scarce resource within the “cost-benefit” logic, was considered the primary resource enabling employees to complete publication preparation tasks [37, 38]. The data source was management accounting tables of actual time expenditure associated with publication preparation by a Doctor of Engineering Sciences, a leading research fellow at one of the ICS RAS laboratories. Time tracking is performed in Outlook and uploaded to Excel for analysis. The database is then processed using big data (Business Intelligence, BI) methods. Processing time is up to 15 minutes per month. Analysis time, with an established planning and analysis process, is 0.5–1 hour per month. Summary results for uploading time to the ICS RAS are presented in Table 2.

Table 2. Workload by activity, hours

Year	Publications	Research	Org.	Road	Report	New	Cons.	Preparation	Total
2020	507	467	198	48	84	97	26	19	1444
2021	602	636	164	107	69	14	60	30	1681
2022	475	715	92	135	22	6	28	11	1483
2023	468	680	73	184	19	28	11	14	1475
Overall total	2051	2499	526	474	194	144	125	73	6084
Average	512	626	131	119	48	36	31	18	1521

The following breakdown by activity was used:

- “Publications”—time associated with a specific publication. “Research” item—time not tied to a specific publication: general discussions, collecting and processing organizational data, organizing conferences, reviews, etc. This data/calculations may or may not be published later, but this is not currently factored into time tracking.
- “Org.” item—organizational issues.
- “New” item—developing new projects.
- “Cons.” item—consultations. “Travel” item—includes one-way time.

6. ANALYSIS AND CALCULATIONS

6.1. Analysis of Publication Preparation Activities

38 of the author's publications from 2020–2023 were analyzed, including “ineffective” publications (rejections received, partial work completed, including work for future use). The total estimated preparation time for these ineffective publications was 499 hours over 4 years.

The distribution of publications by year is shown in Table 3.

The following is observed:

- increase in the number of publications;
- increase in SPI;
- stabilization in the number of hours;
- increase in SPI points per hour.

Note that the average number of SPI points per hour remains relatively low.

Table 3. Distribution of publications by year

Year	Number of publications	SPI of author	Stab. Number of h	Average Score/h
2020	9	183	440	0.42
2021	10	168	530	0.32
2022	15	278	490	0.57
2023	16	327	461	0.71
Total	50	956	1921	0.50

The distribution of publications by type is shown in Table 4.

Table 4. Distribution of publications by type for 2020–2023

General, journal, or conference	Number of publications	Author	Hours	Average, points/hour
Monograph	3	115	104	1.11
Conference	24	630	876	0.72
Journal	11	210	442	0.48
(empty)	12	0	499	0.00
Total	50	956	1921	0.50

Based on the analysis of the presented data, it was concluded that conferences (0.72 points/hour) are slightly more productive than journal articles (0.48 points/hour).

6.2. Calculations

Each task requires a specific amount of time, depending on the volume, complexity, and level of the publication. Table 5 shows a sample table for estimating time expenditure by publication type for a researcher with a Doctor of Engineering qualification, a presenting research fellow. “UBS i ” in this and the following tables denotes White List level i .

It should be noted that at the time of preparation of this factual data, the concept of the White List had not yet been introduced into the publication activity assessment guidelines. Therefore, the White List is effectively accounted for as levels 2 and 4, along with the publication's submission to Scopus and the Higher Attestation Commission (HAC) of Russia.

The presented calculation, based on actual data, extrapolated the time standards for White List Level I articles. The current scenario assumes that the time and complexity of writing a Level I

article increases significantly due to the additional complexity of formulating the problem and discussing the results, preparing the review, and meeting reviewer requirements. Other research teams may have different average time standards for preparing publications in various categories, to which the proposed method can be adapted. Further in the article we will designate Level I of the White List as LW1, Level II as LW2, Level III as LW3 and Level IV as LW4.

Table 5. Estimated time for publication preparation. Author 1

Section	LW1	LW2	LW3	LW4	Scopus IEEE	HAC
Volume, in thousands of characters	1170	565	314	191	135	126
Total resources, h	965	450	253	160	96	117
1. Text	20	15	10	10	8	10
1.1. Concept	10	5	3	2	1	1
1.2. Title	10	5	3	2	1	1
1.3. Abstract	10	8	6	5	3	3
1.4. Introduction	200	50	20	15	10	12
1.5. Overview	100	40	20	20	15	20
1.6. Model, Algorithm	100	60	30	20	15	20
1.7. Data	400	200	120	60	30	30
1.8. Calculations	80	40	20	10	5	5
1.9. Discussion of calculations	5	4	3	2	1	1
1.10. Conclusion	10	8	6	4	2	4
1.11. Literature						
1.12. Section Coordination	20	15	12	10	5	10
1.13. Design	40	30	20	10	3	3
2. Submission to Journal/Conference, Expertise Report	160	80	40	20	5	5
3. Working with Reviews	0	0	0	0	30	0
4. Presentation, Speech (in person)	5	5	1	1	1	1
5. Recording results (SPI, best paper competitions)	5	5	1	1	1	1

The optimization problem based on the data in Table 5 was solved using nonlinear programming. Analysis of the calculation results (Table 6) shows that optimization should select publication types with the highest ratio of score to time spent.

Table 6. Hourly efficiency for one author (leading researcher)

Section	LW1	LW2	LW3	LW4	Scopus	HAC
Hourly efficiency, Ministry of Education and Science criterion	0.017	0.018	0.016	0.013	0.007	0.001
Hourly efficiency, SPI criterion	0.342	0.531	0.637	0.785	0.533	0.190

For a small team with low transaction costs, each operation is assigned to the performer with the highest productivity (efficiency). If the performer is overloaded, the task is assigned to the next most efficient employee. At its core, this approach is based on the cost-effectiveness methodology.

Let's consider an example of activity optimization in two cases: for Author 1, a leading researcher, and for Author 2, a researcher.

Example 1 (single author). Below are the results of the optimization calculations for Author 1 (leading researcher) using the Ministry of Education and Science criterion (Table 7) and the SPI criterion (Table 8).

Table 7. Optimization results for one Author 1 (leading researcher), Ministry of Education and Science criteria

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
Criterion scenario Ministry of Education and Science	15.6	4.8	10.0	0.8	0.0	0.0	0.0
Additionally: SPI	428.1	96.2	300.0	31.9	0.0	0.0	0.0
Number of publications	1.4	0.2	1.0	0.2	0.0	0.0	0.0
Total number of hours	896	281.24	565.00	50.12	0.00	0.00	0.00

Table 8. Optimization results for one Author 1 (leading researcher), criterion SPI

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
SPI scenario: Ministry of Education and Science criterion	13.2	0.0	0.0	8.2	5.0	0.0	0.0
Criterion SPI	627.6	0.0	0.0	327.6	300.0	0.0	0.0
Number of publications	3.64	0.00	0.00	1.64	2.00	0.00	0.00
Total number of hours	896	0.00	0.00	514.36	382.00	0.00	0.00

The difference in achieving the maximum values of the Ministry of Education and Science criterion is approximately 18%, while for the SPI criterion it is 47%. Similar optimization calculations for Author 2 (researcher) for the Ministry of Education and Science criteria (Table 9) and SPI (Table 10) show a slightly smaller difference in achieving the maximum values of the criteria—approximately 20%.

Table 9. Optimization results for one Author 2 (research fellow), Criterion Ministry of Education and Science

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
Criterion Scenario Ministry of Education and Science	7.8	0.0	1.6	6.2	0.0	0.0	0.0
Additionally: SPI	296.3	0.0	48.9	247.4	0.0	0.0	0.0
Number of publications	1.4	0.0	0.2	1.2	0.0	0.0	0.0
Total number of hours	896	0.00	177.57	718.79	0.00	0.00	0.00

Table 10. Optimization results for one Author 2 (research fellow), Criterion SPI

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
Scenario SPI: Criterion Ministry of Education and Science	6.4	0.0	0.0	1.4	5.0	0.0	0.0
Criterion SPI	356.6	0.0	0.0	56.6	300.0	0.0	0.0
Number of publications	2.28	0.00	0.00	0.28	2.00	0.00	0.00
Total number of hours	896	0.00	0.00	164.36	732.00	0.00	0.00

An analysis of the obtained data allows us to conclude that the main priority for achieving the maximum results according to the Ministry of Education and Science methodology is publications at Level I of the White List, and when achieving the maximum number of publications at Level IV, as well as conferences with publications in journals included in Scopus, the main priority is achieved.

According to the ICS RAS publication assessment methodology, publications at Levels III and IV of the White List are identified as the main priority (in the previous version of the SPI, the main priority was articles from journals included in Scopus).

Example 2 (two authors).

In this example, we use the following assumptions:

- publications are jointly prepared by two authors;
- the authors are related by topic and have sufficiently effective communication, so coordination is practically unnecessary;
- assignment distribution (matrix X) is established uniformly for all types of publications; the results of joint work take into account the number of authors (fractality).

An analysis of the calculation results shows that, according to both the Ministry of Education and Science criterion (Table 11) and the SPI criterion (Table 12), it is advisable to focus efforts on preparing articles at levels II and III of the White List.

Table 11. Optimization results for two authors, Criterion Ministry of Education and Science

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
Criterion Scenario Ministry of Education and Science	17.5	0.0	20.0	15.0	0.0	0.0	0.0
Additionally: SPI	1 198	0	600	598	0	0	0
Number of publications	4.99	0.00	2.00	2.99	0.00	0.00	0.00
Total number of hours	1 793	0	980	812	0	0	0

Table 12. Optimization results for two authors, Criterion SPI

Chapter	Total	LW1	LW2	LW3	LW4	Scopus	HAC
Criterion Scenario SPI	15.4	0.0	0.9	20.0	10.0	0.0	0.0
Additionally: Criterion Ministry of Education and Science	1 426	0	26	800	600	0	0
Number of publications	8.09	0.00	0.09	4.00	4.00	0.00	0.00
Total number of hours	1 793	0	43	1 087	663	0	0

The summary results are shown in Table 13. For collaborative work, combining efforts is beneficial for the team according to the SPI criterion. According to the Ministry of Education and Science criterion, Author 1 loses significantly (in the personal version, one LW2 article and 0.24 LW1 articles; in the joint version, taking fractality into account, one LW2 article and 1.5 LW3 articles).

Table 13. Summary of optimization results for the team of authors

Criterion	Author 1 (leading research fellow)	Author 2 (research fellow)	Author 1 and 2, Ministry of Education and Science	Author 1 and 2, SPI
Criterion Ministry of Education and Science	15.5	7.8	$8.75=17.5/2$	$7.7=15.4/2$
Criterion SPI	428	296	$599=1198/2$	$713=1426/2$

The estimated distribution of responsibilities between the Authors is shown in Table 14.

Table 14. Distribution of time between authors

Chapter	Author 1	Author 2
1. Text		
1.1. Concept	1.00	0.00
1.2. Title	0.00	1.00
1.3. Summary	1.00	0.00
1.4. Introduction	1.00	0.00
1.5. Review	1.00	0.00
1.6. Model, algorithm	1.00	0.00
1.7. Data	0.00	1.00
1.8. Calculations	0.00	1.00
1.9. Discussion of calculations	0.88	0.12
1.10. Conclusion	1.00	0.00
1.11. Bibliography	0.00	1.00
1.12. Coordination of sections	1.00	0.00
1.13. Design	0.00	1.00
2. Submission to a journal/conference. Expertise report	0.54	0.46
3. Working with reviews	1.00	0.00
4. Presentation, speech	0.00	1.00
5. Recording of results (SPI, best works competitions)	0.00	1.00

7. TESTING AND DISCUSSION

7.1. Testing the results

To test the described approach, we present the results of the ICS RAS “Large-Scale Systems” laboratory. Figure 3 shows the connectivity graph for publications from the ISAND system. Half of the authors (five people) are connected to each other, while the other half (five people) are weakly

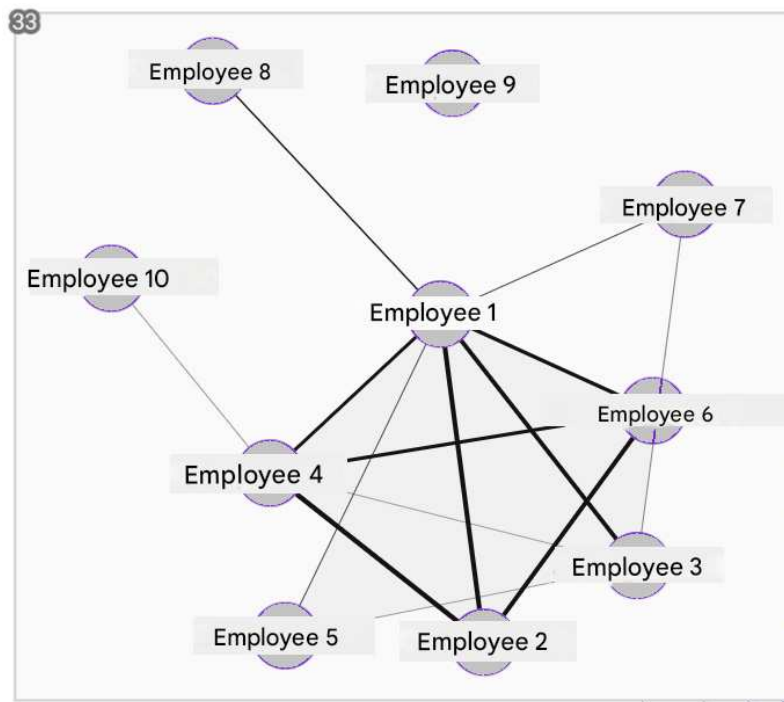


Fig. 3. Co-authorship connectivity network of the laboratory under study.

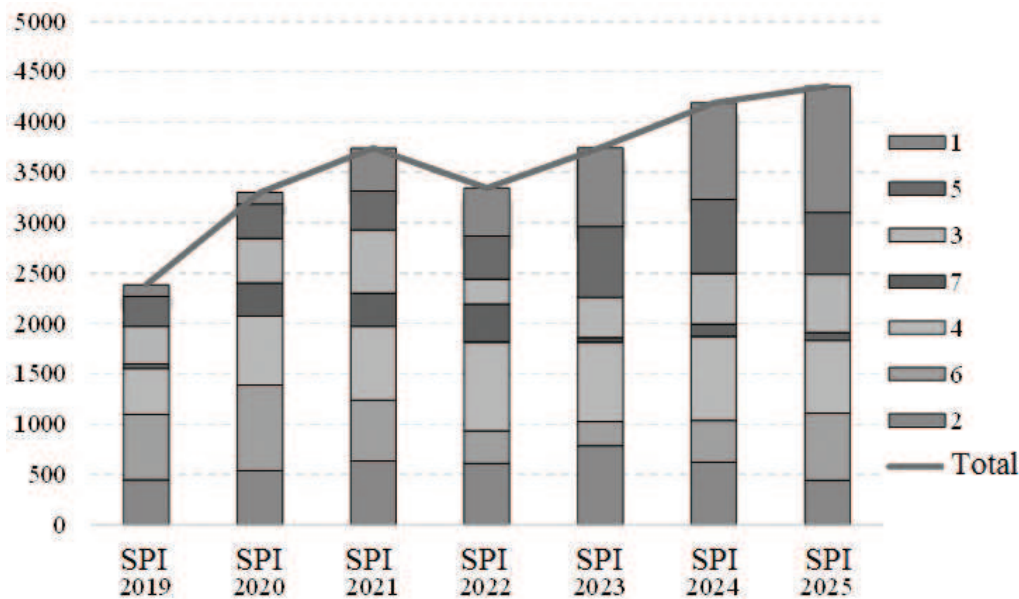


Fig. 4. Dynamics of authors' results according to the SPI methodology.

connected to each other. This group of authors can be considered moderately connected [32]. Figure 4 shows the SPI dynamics of the laboratory's authors (permanent staff). The results of some authors who recently joined the laboratory are not taken into account; their results were added in recent years. The calculations do not take into account the time spent by employees with short tenures. According to the SPI methodology for a given year, the results for the previous three years are taken into account. For example, the 2025 SPI is the results for 2022–2024. Figure 4 shows an increase in the laboratory's overall productivity. This increase was achieved by some authors who actively utilized the publication process with division of labor by section:

- Author 1: from 117 to 1251 points;
- Author 3: from 375 to 579 points;
- Author 5: from 297 to 614 points;
- Author 4: from 456 to 720 points.

7.2. Calculation Conclusions

- Teamwork is most effective, in which authors switch to tasks that best suit them (where they demonstrate the highest productivity based on their qualifications and inclinations);
- The next task in this type of work is assigned to the most effective and least busy author;
- The peak in publications corresponds to the highest efficiency in using the available working time of co-authors;
- For the full implementation of the proposed results, it is critical to track the time of various team members on various tasks;
- The higher the degree of team cohesion, the greater the opportunity to implement the obtained results and the greater the increase in scientific productivity resulting from this implementation.

7.3. Limitations of the Model and Approach

The proposed approach has a number of limitations, which are due to the following reasons:

- It requires time and effort to accumulate reliable statistics and determine time standards for authors to complete individual tasks;

- At the concept stage, which, according to Table 5, takes relatively little time, the researcher cannot always accurately assume how and to what extent this concept can be implemented. In some cases, implementation may prove ineffective;
- There may be significant transaction costs (information exchange, text approval, iterations during model formulation and calculations). In sufficiently large or relatively unconnected teams, it seems realistic to designate “cliques” of related authors, where each “clique” would work on its own set of publications using the proposed methodology.

7.4. Recommendations for Authors and Teams

In the case discussed above, the following options are proposed for increasing scientific productivity.

1. Reduction of ineffective time in “Research work” and “Organization”—shared work that does not directly lead to publications. With a possible 20 percent in time savings, this translates to 125 hours saved per year.
2. These freed-up hours are directed toward publication preparation. Change assessment: 512 hours previously + 125 additionally = 637 hours. Conduct a detailed analysis of individual tasks, with potential time reductions. Estimating potential time savings of 20 percent in time increases the target publication efficiency to $0.71 \times 1.2 = 0.85$ points/hour. Use software packages for calculations. Use generative artificial intelligence to prepare texts. This requires great care and has significant limitations. At its current stage, GAI can generate general descriptions (without taking into account the depth and specificity of the publication) and paraphrase the text, but it makes significant errors in calculations and generating references. Plagiarism checking systems limit the use of generative artificial intelligence. Write the publication text directly in the journal template (saving time on formatting).
3. When planning employee time, consider the feasibility of each employee having some time to develop more individual projects, the consideration of which is not always immediately communicated.

8. CONCLUSION

A substantive and analytical formulation of the problem of increasing the productivity of a team of researchers is presented. It is shown that the problem can be reduced to a nonlinear optimization problem. An approach to the solution is presented that utilizes the specifics of the subject area. Using an example of calculations with real data and an analysis of publication preparation times in one of the ICS RAS laboratories, a multiple increase in research productivity as a result of the proposed methodology is demonstrated. In the ICS RAS laboratory of “large-scale systems,” the results of a subgroup of employees actively participating in collaborative projects with division of labor significantly increased. Overall, it can be concluded that the proposed methodology is effective, but not fully or with maximum efficiency. This is due to limited communication among authors within the team, as well as difficulties in defining time standards for completing various tasks by different authors. We believe that this problem formulation and solution methodology are suitable for application not only in ICS RAS laboratories but also in the scientific activities of other research centers (universities, corporate institutes, engineering centers, and other organizations with creative work). This will require appropriate adaptation of the model, restrictions, and data collection and structuring procedures. The ongoing implementation and use of such systematic procedures for monitoring and improving the productivity of intellectual labor is necessary to maintain and develop the country’s achievements in the international competitive arena.

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