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THE TASK OF CHOOSING PARTNERS FOR THE ORGANIZATION OF COOPERATION IN THE FRAMEWORK OF SCIENTIFIC AND EDUCATIONAL PROJECTS

Abstract: The primary objective of this article is to establish a set of fundamental criteria for the selection of scientific partners for collaborative research efforts. Achieving this objective entails addressing the challenge of identifying criteria that are both objective and universally applicable, capable of encompassing various fields of scientific research, such as natural sciences, technical sciences, and economic sciences, among others.

One such criterion, applicable to scientists, may involve assessing their publication activity within specific research areas that align with the objectives of the relevant scientific research or international projects. In the contemporary landscape of scientific research, there is a growing urgency to enhance the effectiveness of research endeavors and to foster efficient collaboration within scientific communities. This is particularly vital for organizations oriented towards project-based research.

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In the formation of research project teams, a conventional approach is to select partners from the pool of scientists possessing the requisite qualifications and experience in the execution of such projects. A widely accepted yardstick for evaluating the outcomes of scientists' research endeavors is the citation metrics associated with their publications. Typically, these metrics take the form of scalar values. While this approach offers several advantages, it is not without its limitations. One notable drawback is the potential loss of information when converting raw data into scalar metrics, and the existence of certain edge cases where the parameter remains unchanged despite variations in the number of citations and publications.

Hence, it is pertinent to explore the development of new methodologies or modifications to existing ones that can effectively evaluate the results of scientists' research activities while mitigating these limitations. The article describes the criteria for the search and selection of partners for joint scientific research. This will make it possible to effectively form teams for narrowly focused scientific research or international collaboration projects in interdisciplinary scientific projects such as the European Horizon Program or educational projects such as the Erasmus plus program. Also, the proposed solution will allow the formation of small teams for joint scientific publications. It is imperative to acknowledge that the process of partner selection is predominantly driven by a consideration of the knowledge, whether it be novel or foundational, possessed by prospective partners who are entrusted with the execution of a project. It becomes crucial to delineate the specific criteria governing partner selection which can vary contingent upon factors such as the typology of partners, the nature of project tasks, the depth of knowledge possessed, and related contextual variables. A vital underpinning for the formation of project consortia is the mathematical conundrum of choice which furnishes a formal rationale for the judicious selection of a particular partner.

Keywords: search for scientific partners; scientific collaboration; scientific research; criteria for choosing scientific partners; scientific cooperation; educational cooperation.

Introduction

Within the framework of the open innovation paradigm, it is imperative that scientific and educational projects are executed in close collaboration with external stakeholders or partners. Extensive research has been conducted concerning the establishment of criteria for partner selection at the overarching project objectives level. However, there remains a notable dearth of both theoretical foundations and practical frameworks for the selection of partners with regard to localized project tasks. Formal mathematical representations of this challenge are also notably lacking. Regrettably, partner selection is frequently conducted devoid of any empirically substantiated conclusions and often guided solely by the pragmatic considerations and personal subjective preferences of the project manager.

A pressing imperative is the development of factors for partner selection tailored to specific project tasks, contingent upon the typology of partners, their competencies, and their potential contributions to project realization, encompassing technical, innovative, legislative, and scientific dimensions among others. An imminent task lies in the formal articulation and resolution of the quandary associated with partner selection for project implementation under predetermined conditions.

The selection of partners for collaborative endeavors primarily hinges on the assessment of their knowledge base, whether it is novel or foundational, and their capacity to act as effective project executors. It is imperative to establish a framework that delineates the criteria for partner selection, taking into consideration factors such as partner typology, project-specific tasks, and the level of knowledge possessed among others. Within this context, the mathematical problem of choice assumes a pivotal role, as it offers a formalized rationale for the judicious selection of a particular partner.

In the context of globalization, characterized by the increasing mobility of scientific communities and the need for open innovation, it becomes crucial to streamline the selection of partners by making thoughtful and strategic choices:

In the context of partner selection for project implementation, several key steps are essential:

1. Clearly defining the potential contributions of partners to project execution, categorizing them into relevant domains such as legislative, innovative, technical, educational, or scientific. In the case of partners categorized as scientific, it's essential to identify the precise areas of scientific research, both at the individual and institutional levels.
2. Evaluating the qualifications and capabilities of prospective partners based on well-defined criteria that align with their respective categories.
3. Formulating vector-based criteria for partner selection, thereby addressing the complexities of multi-criteria decision-making in partner selection.

As an initial step towards addressing the first issue within the realm of scientific communities, a partial solution was presented in reference [1]. This study proposed a method for clustering scientific publications authored by researchers within specific scientific fields. Two distinct approaches for measuring the distance between publications were introduced within this method. The first approach utilized the length of the citation graph path connecting publications, while the second approach involved the computation of similarity between publication annotations using the locally sensitive hashing technique.

The second task which involves the evaluation of research activities based on the publication records of scientists has also seen partial resolution. In reference [2], a method is presented for deriving comprehensive assessments of the outcomes of scientific research endeavors conducted by researchers. This method holds applicability in conducting a holistic evaluation of scientists, universities, and their constituent units.

In reference [3], a method is introduced for conducting a comprehensive assessment of the performance of higher education institutions. This approach involves calculating a generalized volume within the m-simplex, with vertices representing evaluations of the institutions across various categories. It is essential not only to evaluate the outcomes of research activities but also to gain insights into how these assessments might evolve over time.

Addressing this aspect, reference [4] presents a method for predicting the potential trajectories of research directions, thereby contributing to a more comprehensive understanding of research dynamics.

Reference [5] analyzes recent scientific research focused on evaluating the research activities of both subjects and objects within scientific environments. The paper also outlines the primary drawbacks of existing methods for assessing scientific activity and suggests potential solutions.

In reference [6], it is established that within scientific communities, three distinct forms of relationships can exist between pairs of subjects: partnership, competition, and neutral relationships. Importantly, these relationship dynamics extend beyond individual subjects to encompass their structural units, such as departments, faculties, research divisions, project teams, and more.

Reference [6] also elaborates on the key attributes characterizing partners, including universities, research institutes, public authorities, private enterprises, professional associations, and foundations, all of which play pivotal roles in shaping communication and collaboration modes. References [7] and [8] delve into the critical factors influencing the establishment of collaborative scientific frameworks. These factors revolve around the reputation levels of the involved entities and the intricacies of the mechanisms governing their cooperation which may be subject to specific constraints.

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The literature also delves into mathematical methodologies for the selection of partners in collaborative ventures, as outlined in references [9] and [10]. Reference [11] employs the analytical hierarchy method for this purpose, while reference [12] advances the idea of employing a modified genetic algorithm in partner selection processes.

Moreover, reference [13] delves into the theoretical underpinnings associated with the formulation of criteria for partner selection in the context of collaborative innovation projects. Reference [14] provides insights into the partner selection process within international joint ventures, offering valuable insights that can be leveraged in the context of partner selection for the execution of scientific and educational projects. Document connectivity analysis provides significant information about the structure of the document space which can be used for a wide range of practical tasks. In particular, clustering methods of scientific publications are regularly used to determine the directions of scientific research.

In [15], the methods of clustering the citation graph were compared, in particular, the spectral method [16], the method of maximizing modularity [17], matrix factorization [18], and the method of mapping random walks [19]. The result of the study shows that the quality of constructing clear clusters of documents based on graph analysis by connections strongly depends on the density of the graph. It means qualitative clustering is possible only if there is a sufficient number of related documents in the collection. Among the 11 algorithms considered in the study, the Louvain method became the best according to the criteria of the modularity of the clustered citation graph [20]. Also, this method builds the smallest number of clusters. According to the Flake function criterion, which shows the ratio of the number of vertices with a large external degree to the number of vertices with a large internal degree in the Louvain cluster, took second place slightly behind BPA. Finally, according to the criterion of time, only three methods can be used for clustering very large graphs: Louvain, Walktrap and BPA. The authors of the study also compared the results of the clustering methods considered with the expert method and concluded that all the methods considered are significantly inferior to the expert method, therefore they require further refinement.

The paper [21] presents an information-theoretical approach to finding the weight distribution of the feature space. Using the feature space to increase the initial similarity of documents makes it possible to achieve better clustering. Thus, the construction of complex methods that, in addition to the citation graph, consider other properties of publications makes it possible to improve the quality of clustering.

The aim and objectives of the study

The purpose of the article is to develop key criteria for the selection of scientific partners for joint research.

To achieve the purpose of the article, it is necessary to solve the problems of selecting objective and universal criteria that can cover scientific research in different directions, such as natural sciences, technical sciences, economic sciences, and others. For scientists, the evaluation criterion may be publication activity on a topic that meets the objectives of the relevant scientific research or international project.

Materials and methods

The choice of partners for collaborative projects, be they scientific institutions, universities, or companies, entails several key features that influence the nature of communication and cooperation:

1. Geographic Dispersion: Partners may be located in different countries or even on different continents, necessitating significant communication via the Internet.

2. Unique Competencies: Each partner may possess distinctive competencies vital for the project's success which should be considered when assigning tasks.
3. Legal Framework: Partners operate within their own legal systems, with decision-making influenced not only by project needs but also by the legislation of their respective regions. This legal aspect should be factored in when entering into contracts and conducting tender procedures.

Organizational Flexibility: Each partner may have a specific role in the organizational structure, and this structure can evolve dynamically based on project requirements, contributing to trust and shared interests in the project.

Conceptually, the selection of a partner can encompass four components that are critical when establishing a consortium:

- Partner Type
- Project Objectives
- Knowledge Utilization
- Factors Influencing Partner Selection.

The types of partners for scientific projects include universities, research institutes, private companies (encompassing hubs, incubators, startup financiers), foundations, and professional associations. Public-private partnerships are often organized within scientific consortia to ensure the sustained impact of results.

Project objectives can be categorized as follows:

- Strategic Objectives: Involving long-term collaboration within the project framework.
- Situational Objectives: Aimed at risk reduction.
- Competency Development Goals: Focused on enhancing competencies among consortium participants.
- Financial Results Goals: Aimed at achieving financial gains, such as increased profitability for consortium participants.

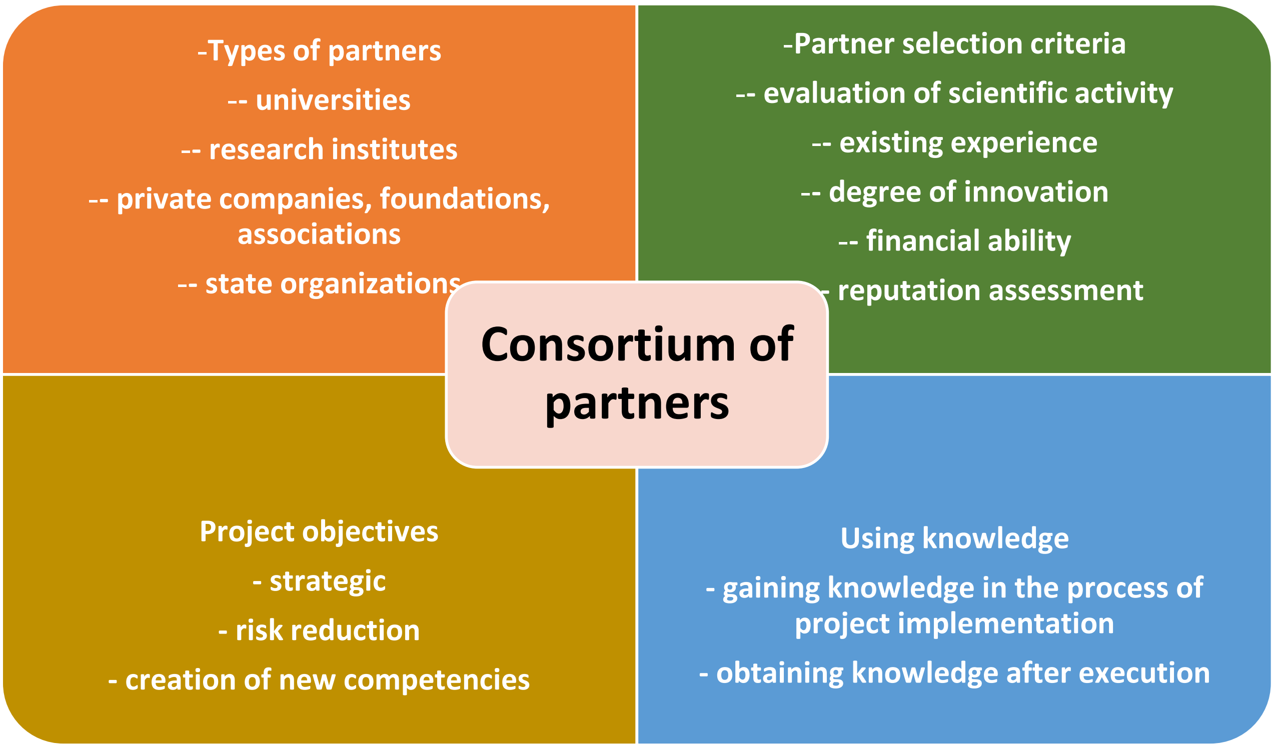

Figure 1. Components that are taken into account when selecting partners in a scientific consortium

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The use of knowledge involves two components:
- gaining knowledge in the process of project implementation;
- gaining knowledge after the project is completed.

The partner can be selected according to the following criteria:
1. Comprehensive assessment of scientific activity for a certain period on a certain topic.
2. Previous project experience and role in them.
3. The degree of innovation in the activity.
4. Financial ability.
5. Reputation assessment.

Let there be a completed set of scientific and educational projects or grants $G = \{G_1, G_2, \dots G_n\}$, n is the number of projects for which you need to select performers. Let the completed set of potential performers of these projects be given $V = \{V_1, V_2, \dots V_t\}$, "t" represents the count of prospective participants within the educational and scientific sphere who can serve as performers. These potential performers encompass various roles, including researchers, project managers, research institutions, and institutions of higher education, among others.

Any project consisting of a number of work packages $G_i = \left\{g_1^i, g_2^i, \dots g_{r_i}^i\right\}$, r_i is the number of work packages of the project G_i, $i = \overline{1,n}$ which are executed in a certain sequence and are associated with the results. To complete each of these work packages, it is necessary to select performers who have the experience and competence to complete the package on time and efficiently. That is, it is necessary to find such a multitude of potential performers:

$$W\left(g_j^i\right) = \left\{v_d \in V \middle| \left(v_d, g_j^i\right) \in Q^i\right\},\ Q^i \subset V \times G_i,\ j = \overline{1, r_i},\ i = \overline{1,n},\ d = \overline{1,t} \tag{1}$$

For each working package of each project, a list of key criteria for selecting partners should be formed. That is , the vectors of the evaluation criteria will look like:

$$f^{ij}(v) = \left(f_1^{ij}(v), f_2^{ij}(v), \dots, f_{N_{ij}}^{ij}(v)\right),\ v \in V, \tag{2}$$

N_{ij} is the number of criteria for evaluating potential partners of work packages of g_j^i projects G_i, $j = \overline{1, r_i}$, $i = \overline{1,n}$.

Some criteria are maximized, so the set of indexes of such criteria is denoted by $J_1^{ij} = \left\{1, 2, \dots, h_{ij}\right\}$. Other criteria with indexes $J_2^{ij} = \left\{h_{ij}+1, h_{ij}+2, \dots, N_{ij}\right\}$ are minimized, $J^{ij} = \left\{1, 2, \dots, N_{ij}\right\}$, $J_1^{ij} \cup J_2^{ij} = J^{ij}$. Then

$$\sum_{k \in J_2^{ij}} \delta_k f_k^{ij}(v) \to \min,\ \sum_{k \in J_2^{ij}} \delta_k = 1, \tag{3}$$

for each package and project, a constraint is built on the set of potential performers $v \in V^{ij}$, $V^{ij} = \left\{v \in V \middle| y_u^{ij}(v) \geq \rho_u^{ij}, u = \overline{1, z_{ij}}, j = \overline{1, r_i}, i = \overline{1,n}\right\}$, where z_{ij} is the number of threshold values for the vector function of constraints $y_u^{ij}(v)$. The coefficients λ_k and δ_k determine the importance of each of the criteria in the calculation of a comprehensive assessment.

The choice of performers for the execution of specific project components is typically made by the project management team or the designated decision-maker. To ascertain the most suitable lineup of individuals or entities to carry out the tasks within each project, one viable approach is to employ the method of aggregating expert assessments.

Let there be a set of experts $E = \{E_1, E_2, \dots E_s\}$, s is the number of experts. Each of the experts makes up the advantages of potential performers, taking into account the vector of criteria. An incomplete benefits profile is allowed. Let $\xi_{c,b}^{ij}$ be the average frequency of occurrence of each of the advantages between potential performers v_c and v_b, $c \neq b$, $v_c \in V$, $v_b \in V$. Then we get the advantage matrices of the form:

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$$\Psi^{ij} = \begin{pmatrix} \xi^{ij}_{1,1} & \xi^{ij}_{1,2} & \cdots & \xi^{ij}_{1,t} \\ \xi^{ij}_{2,1} & \xi^{ij}_{2,2} & \cdots & \xi^{ij}_{2,t} \\ \vdots & \vdots & \ddots & \vdots \\ \xi^{ij}_{t,1} & \xi^{ij}_{t,2} & \cdots & \xi^{ij}_{t,t} \end{pmatrix}, \tag{4}$$

$j = \overline{1, r_i}$, $i = \overline{1, n}$.

Using the methods of forming a collective solution based on a matrix of paired comparisons, it is possible to obtain an ordered list of potential performers for each project package: $v^{ij}_{k_1} \succ v^{ij}_{k_2} \succ \ldots \succ v^{ij}_{k_t}$, $k_1 < k_2 < \ldots < k_t$, $k_q \in \{1, 2, \ldots, t\}$, $v^{ij}_{k_q} \in V^{ij}$, $q = \overline{1, t}$. Considering this list, the project manager selects specific performers and forms a working group.

The specific statement of the problem can vary based on the type of partners under consideration, which may include universities, research institutions, private companies, government organizations, and individual scientists. Depending on the goals and roles of these potential partners within the project, appropriate criteria for their evaluation can be selected.

For instance, in the case of scientists, one evaluation criterion might be their publication activity on a topic aligning with the objectives of the corresponding work package. The collection of all publications by a potential partner in this context is denoted by a specific term or identifier.

$$P(v_d) = \{p_e \in P \mid (v_d, p_e) \in T\}, T \subset V \times P, e = \overline{1, M}, d = \overline{1, t}, \tag{5}$$

where P is the set of all publications of scientists available in the database, $M = card(P)$

The set of publications in which the scientist's publications are cited is denoted by

$$C(v_d) = \{p_e \in P \mid (p_e, p_E) \in C, p_E \in P(v_d), E = \overline{1, M}, e \neq E\}, e = \overline{1, M}, \tag{6}$$

where $C \subset P \times P$ sets the citation of publications.

Then the task of evaluating the results of scientific research activities of scientists for their selection in the project is to find for each scientist v_d, based on the given information on the citation of his publications, some evaluation q_d, which can be presented in the form of a functional

$$Q^{ij} : V \to R, \tag{7}$$

defined depending on the needs of the project and the corresponding project package. The score will then look like:

$$q_d = Q^{ij}(P(v_d), C(v_d)), d = \overline{1, t}, j = \overline{1, r_i}, i = \overline{1, n}. \tag{8}$$

Then the advantages between scientists are determined by the value of the assessment v_d. The greater the value q_d, the greater the advantage the corresponding scientist has for the selection of project g^i_j packages G_i in working groups .

If the potential partner is a university or a research institute, and the scientific aspect of the institution's activity is crucial for the objectives of the work package, the following scheme can be employed. In this scenario, an assessment of research activity is computed for each scientist within a specific structural unit q_d or the entire university. The overall evaluation of the university is then determined as the average value of these individual assessments.

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$$O = \frac{1}{t}\sum_{d=1}^{t} q_d \;. \qquad (9)$$

Also, international indexes can be used to evaluate universities as potential partners, such as:

- rating of the British consulting company Quacquarelli Symonds (QS);
- Academic ranking of world universities compiled by the Institute of Higher Education of Shanghai Jiao Tong University (Shanghai Ranking);
- Top 200 rating;
- simplex rating.

The selection of project executors, which may include foundations, associations, and government agencies such as ministries and departments, introduces additional dimensions to the decision-making process. In such cases, the criteria for choosing an executor extend to factors like prior experience in project implementation, innovation in decision-making processes, financial capability (particularly when their involvement entails financial commitments), and reputation assessment. Evaluation based on these criteria can involve expert surveys, accommodating fuzzy statements when assessing criteria.

It is important to note that the selection criteria can be tailored to align with the overarching goals of the project, including strategic objectives, the development of new competencies, financial gains, risk mitigation, and more. Furthermore, the criteria for partner selection may evolve depending on project timelines, either during the project, after predefined milestones, or within a specified post-project period.

Upon forming working groups for project components, the consortium or cluster of the project is legally formalized. It is essential to consider the possible involvement of stakeholders in the project implementation process. However, integrating new interested organizations or individuals into an ongoing project necessitates careful delineation of functional responsibilities, taking into account the interests of all consortium or cluster participants.

To address the complex task of partner selection within scientific and educational projects, the development of a multi-criteria decision-making method is imperative. This method must fulfill several conditions:

1. Comprehensive Criteria and Alternatives: The criteria and alternatives should adequately capture the intricate selection processes of project executors, accommodating project specifics, types of executors, and other relevant factors.
2. Clarity and Interpretability: The results of the evaluation process should be clear and interpretable, necessitating the creation of suitable scales and result descriptions to facilitate decision-makers' understanding.
3. Flexibility: Decision-makers should have the flexibility to consider alternative options if the initially proposed ones do not align with their requirements. This can be achieved by establishing clear differentiators among alternatives.
4. Adaptability and Integration: The method should allow for adaptation and the possibility of employing alternative decision-making techniques. Moreover, results should be exportable between methods, enabling confirmation or refutation of evaluation outcomes.

The proposed tasks for the development of an information technology system for partner selection within scientific cooperation encompass the following:

1. Information Model Construction: Creating an information model for the representation of scientific and educational projects and their executors.
2. Partner Category Determination: Developing a method to categorize potential partners. Specifically, for the scientific category, a method to identify the research directions of individual scientists is required.

3. Criteria, Alternatives, and Selection Method: Constructing criteria, alternatives, and a multi-criteria selection method for potential partners drawn from the active entities within scientific communities.
4. Evaluation Method: Building an evaluation method for assessing potential partners.

Information and Analytical System: Establishing an information and analytical system capable of generating a curated list of potential partners for scientific and educational projects, aligning with project objectives and criteria.

In adhering to these requirements, a multi-criteria decision-making method can be formulated for the selection of potential partners for scientific and educational initiatives. This method will be underpinned by a comprehensive set of criteria that consider partners' knowledge, organizational type, and other pertinent attributes. Furthermore, the development and implementation of a suitable information technology solution will enhance the efficiency of project execution, ultimately contributing to the attainment of sustainable infrastructural, educational, and scientific outcomes over the medium and long term.

Conclusion

The article suggests criteria for the search and selection of partners for joint scientific research. This will make it possible to effectively form teams for narrowly focused scientific research or international collaboration projects in interdisciplinary scientific projects such as the European Horizon Program or educational projects such as the Erasmus plus program. Also, the proposed solution will allow the formation of small teams for joint scientific publications.

In the future, it is planned to develop methods for constructing subject spaces of scientific subjects based on a probabilistic thematic model, models of similarity of scientific publications, as well as intelligent analysis of citation networks and scientific cooperation. A conceptual model of automation of data collection and classification will also be developed for the construction of subject spaces of scientific subjects, while the use of only reliable data from open sources will be a prerequisite.

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