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PHD THESIS

INFORMATION TECHNOLOGY OF THE SCIENTIFIC PARTNERS SELECTION BASED ON THE RESEARCH ACTIVITY RESULTS EVALUATION MODELS

126 Information Systems and Technology

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The PhD Thesis contains the results of own research. The use of ideas, results and texts of other authors are linked to the corresponding source

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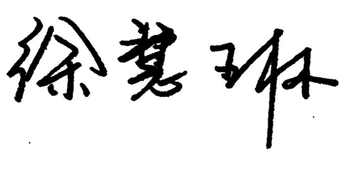

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SUMMARY

Huilin Xu. Information technology of the scientific partners' selection based on the research activity results evaluation models. – *Qualifying scientific work as a manuscript.*

Thesis for the Doctor of Philosophy Degree in Specialty 126 «Information System and Technology». – Taras Shevchenko National University of Kyiv, Kyiv, 2023.

Abstract. The dissertation is dedicated to developing information technology for selecting scientific partners for joint execution of scientific research, considering their competencies, which are assessed based on previous scientific activity results.

Over the past few decades, there has been a significant reevaluation of the importance of scientific research in ensuring sustainable economic development at the national and regional levels. International scientific research initiatives play a unique role in this process, contributing to the formation of integrated scientific approaches and synergy among different countries. Many international organizations actively support the participation of members from various states, emphasizing the importance of globalizing scientific efforts. High-quality implementation of such projects requires attracting executors who meet strict professional standards and competencies to address specific project tasks. These initiatives often have a complex structure, requiring the involvement of experts from various scientific fields, depending on the project's objectives. It's important to note that participants' competencies evolve during the project's implementation and are not static, allowing for adaptation to changing requirements and tasks.

For the quality execution of a scientific research project, involving executors with the necessary competencies is crucial. A model containing a system that assesses executors' competencies based on measurable indicators is required to achieve this. These indicators must be current, reliable, and verifiable from open sources.

This work addresses the critical task of developing mathematical models for evaluating researchers' scientific activity results dynamically to determine their suitability for complex-structured scientific research projects' requirements and decision-making models for quality personnel management in scientific research projects (scientific component), as well as developing information technology for selecting scientific partners based on models of evaluating scientific activity results, which allows automating the processes of collecting and processing candidate data (practical component).

The research object is the process of selecting executors for scientific projects, considering the results of scientific activities.

The research subject includes models for evaluating the results of scientific activities, methods, and means of selecting scientific partners.

Research methods. The research is based on knowledge representation and processing methods, decision-making, set theory, graph theory, monitoring and evaluation methods, and object-oriented programming.

The research aim is to enhance the efficiency of selecting partners for conducting joint scientific research by developing models and methods for evaluating the results of scientific activities and decision-making.

The scientific novelty of the obtained results**:**

- *For the first time*, an individually-oriented method for selecting scientific project partners based on the analysis of subject scientific spaces has been developed. This allows for the enhancement of the effectiveness of their implementation.
- The information technology for selecting scientific partners *has been improved* based on models for evaluating the results of scientific activities. The main distinction of the proposed technology from known information technologies for selecting scientific partners is that it includes a comprehensive assessment of knowledge, publication activity, and skills of the partners, which are determined through the experience of executing scientific projects. This enables an increase in the effectiveness of implementing scientific research projects.

- The model for assessing the influence of scientists within the global citation network *has been refined*, taking into account the age of scientific results in terms of increasing sensitivity to new publications. Unlike other models, the proposed model for assessing the influence of scientists considers the affiliation of publications to subject scientific spaces. This allows for a more accurate evaluation of scientists' activities in the context of selecting partners for joint scientific research.
- The method of forming specific scientific spaces *has been further developed*, expanding the theoretical and practical possibilities for identifying compliance with the requirements for performers of scientific research projects.

The first chapter of the dissertation contains an analysis of existing theoretical and practical research on managing scientific research projects in terms of selecting executors and forming teams. It examines changes in scientific collaboration, emphasizing the globalization of scientific networks. The chapter highlights how the globalization of collaboration networks facilitates interdisciplinary and transnational approaches to scientific research, involving experts from various fields to work on complex problems. The importance of international research consortia, conferences, symposiums, joint research centers of universities, and publications in specialized journals is underscored. Global scientific collaboration's significance and complexity in forming teams for joint research execution are demonstrated.

It is established that the task of evaluating the competencies of executors based on the results of scientific activities and their correspondence to the work packages of a scientific research project is fully resolved. To ensure effective management of executors in a scientific research project, it is appropriate to develop new or improved known models for evaluating the results of scientific activities and to build an information technology for selecting scientific partners based on these models.

The second chapter of the dissertation describes the conceptual framework of the research for evaluating the influence of scientists and their selection as partners-executors of a scientific project. Within this framework, a mathematical model for evaluating the influence of scientists in the global citation network, taking into account the age of scientific results, is considered.

An analysis of factors influencing the selection of potential executors for scientific projects is conducted. The analysis determines that critical factors in choosing partners-executors of a scientific project are the correspondence of the experience and competence of executors to the research direction. Determining the correspondence of experience and competence of executors to the direction of research is proposed to be carried out considering the affiliation of the scientific research project and the scientist to specific scientific subject environments. A method for forming scientific subject environments for scientists, institutions, and projects has been proposed.

The individually oriented method of selecting partners-executors of scientific projects based on the analysis of scientific subject environments allows for effective management of executors in a scientific research project and their correspondence to the work packages of the scientific research project. The method's main advantages are the high accuracy in selecting partners thanks to a detailed analysis of their competencies and experience, which allows the forming of effective teams based on complementary competencies, capable of adapting to the project's specific requirements due to the individual approach to selecting each partner.

The third chapter examines the technical and software requirements for implementing information technology for selecting scientific partners. Approaches and requirements for informational and organizational support are also considered. The main aspects of implementing the information system for selecting partner executors for creating scientific project environments are discussed.

The fourth chapter describes the implementation of information technology for selecting executors of scientific projects. It details the algorithms for accumulating and analyzing data gathered from various sources, including scientometric databases and academic profiles. The analysis includes professional certificates, activity in scientific conferences, publications, and project experience.

Practical significance of the obtained results. The leading scientific positions of the dissertation are brought to the level of methodological generalizations and applied tools, allowing for the formation of scientific spaces and the selection of partner executors for scientific projects based on an individually oriented analysis of scientific subject environments.

Verification of the information technology for selecting executors of scientific projects was conducted based on scientific projects at Astana IT University, Astana, Republic of Kazakhstan, for the year 2021, and Yancheng Polytechnic College, Yancheng, People's Republic of China, for the 2014 to 2020. It was established that, on average, about 46.55% of scientists met the requirements of project managers for each scientific subject space. Among the candidates selected by the proposed method, 24.07% were involved in the project. The verification shows that the developed method allows for forming a rational list of executors according to all established criteria, enhancing the efficiency of the selection process for participants in scientific research.

Keywords: Partner selection, scientific research project, project management, evaluation of scientific activity results, subject space, classification, university graduate profile, university environment, human resource, multidisciplinary developmental environment.

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АНОТАЦІЯ

Хуейлінь Сюй. Інформаційна технологія вибору наукових партнерів на основі моделей оцінювання результатів їх наукової діяльності. – *Кваліфікаційна наукова праця на правах рукопису.*

Дисертація на здобуття наукового ступеня доктора філософії за спеціальністю 126 «Інформаційні системи та технології». – Київський національний університет імені Тараса Шевченка, Київ, 2023.

Зміст анотації. Дисертація присвячена побудові інформаційної технології вибору наукових партнерів для спільного виконання наукових досліджень з врахуванням їх компетентностей, які оцінюються з врахуванням попередніх результатів наукової діяльності.

Протягом останніх кількох десятиліть відбулося значне переосмислення значущості наукових досліджень у контексті забезпечення сталого розвитку економіки на державному та регіональному рівнях. У цьому процесі особливу роль відіграють міжнародні науково-дослідні ініціативи, які сприяють формуванню інтегрованих наукових підходів та синергії між різними країнами. Багато міжнародних організацій активно сприяють залученню учасників з різних держав, підкреслюючи важливість глобалізації наукових зусиль. Висока якість реалізації таких проєктів вимагає привернення виконавців-партнерів, які відповідають строгим професійним стандартам і компетенціям, необхідним для вирішення специфічних завдань проєкту. Такі ініціативи часто мають комплексну структуру, вимагаючи залучення експертів з різноманітних галузей науки, в залежності від цілей проєкту. Важливо відзначити, що компетентності учасників еволюціонують у процесі реалізації проєкту та не є статичними, що дозволяє адаптуватися до змінних вимог та завдань.

Для якісного виконання науково-дослідного проєкту найважливішим є залучення виконавців з необхідними компетентностями. Для цього потрібно сформувати модель, яка містить систему, що дозволяє оцінити компетентності

виконавців на основі вимірних показників. Важливо, щоб ці показники були актуальними, достовірними та існувала можливість перевірки даних у відкритих джерелах.

В даній роботі вирішується важливе завдання, а саме: розроблення математичних моделей оцінювання результатів наукової діяльності дослідників в динаміці для виявлення відповідності їх кандидатур вимогам до виконавців науково-дослідних проєктів складної структури та моделей прийняття рішень для якісного управління персоналом науково-дослідних проєктів (наукова складова), а також розроблення інформаційної технології вибору наукових партнерів на основі моделей оцінювання результатів наукової діяльності, що дозволяє автоматизувати процеси збору та опрацювання даних про кандидатур (практична складова). Виконавці та партнери в даному дослідженні є синонімами.

Об'єктом дослідження є процес вибору виконавців наукових проєктів з врахуванням результатів їх наукової діяльності.

Предметом дослідження є моделі оцінювання результатів наукової діяльності, методи та засоби вибору наукових партнерів.

Методи дослідження. Проведені дослідження базуються на методах представлення і обробки знань, прийняття рішень, теорії множин, теорії графів, методах моніторингу та оцінювання, об'єктно-орієнтованого програмування.

Метою дослідження є розробка моделей і методів оцінювання результатів наукової діяльності та прийняття рішень з вибору партнерів для підвищення ефективності реалізації науково-дослідних проєктів.

Наукова новизна отриманих результатів :

- *Вперше* розроблено індивідуально-орієнтований метод вибору виконавців наукових проєктів на основі аналізу предметних наукових просторів, що дає можливість підвищення ефективності їх реалізації.

- *Удосконалено* інформаційну технологію вибору наукових партнерів на основі моделей оцінювання результатів наукової діяльності. Основною відмінністю запропонованої технології від відомих інформаційних технологій вибору наукових партнерів є те, що вона включає комплексну оцінку знань публікаційної активності та навиків партнерів, які визначаються через досвід виконання наукових проектів, що дає можливість підвищити ефективність реалізації науково-дослідних проектів.

- *Удосконалено* модель оцінювання впливовості науковців за глобальною мережею цитування з урахуванням віку наукових результатів в частині підвищення чутливості для нових публікацій. На відміну від інших моделей, запропонована модель оцінювання впливовості науковців враховує належність публікацій до предметних наукових просторів. Це дає змогу більш точно оцінити діяльність науковців в контексті вибору партнерів для спільних наукових досліджень.
- *Набув подальшого розвитку* метод формування предметних наукових просторів, що розширює теоретичні та практичні можливості ідентифікації відповідності вимогам до партнерів науково-дослідних проєктів.

Перший розділ дисертації містить аналіз існуючих теоретичних та практичних досліджень щодо управління науково-дослідними проєктами в частині вибору виконавців та формування колективів. Розглянуто зміни в науковій співпраці, акцентуючи увагу на глобалізації наукових мереж. Розділ висвітлює, як глобалізація мережі співпраці сприяє міждисциплінарному та транснаціональному підходу до наукових досліджень, залучаючи експертів з різних галузей для роботи над складними проблемами. Підкреслюється важливість міжнародних дослідницьких консорціумів, конференцій, симпозіумів, спільних дослідницьких центрів університетів та публікацій у спеціалізованих журналах. Показано важливість та складності глобальної наукової співпраці в частині формування команд для спільного виконання досліджень.

Встановлено, що не повністю розв’язаною є задача оцінювання компетентностей виконавців на основі результатів наукової діяльності та їх відповідність робочим пакетам науково-дослідного проєкту. Для забезпечення ефективного управління виконавцями науково-дослідного проєкту доцільно розробити нові чи вдосконалити відомі моделі оцінювання результатів наукової діяльності та побудувати інформаційну технологію інформаційної технології вибору наукових партнерів на основі цих моделей.

В другому розділі дисертації описано концептуальну схему дослідження з оцінювання впливовості науковців та їх відбору до складу партнерів для виконання наукового проєкту. В межах цієї схеми розглянуто математичну модель оцінювання впливовості науковців за глобальною мережею цитування з урахуванням віку наукових результатів.

Проведено аналіз факторів, що впливають на вибір потенційних виконавців до складу наукових проєктів. В результаті аналізу встановлено, що надзвичайно важливими факторами при виборі партнерів для виконання наукового проєкту є відповідність досвіду та компетентності виконавців напряму дослідження. Визначення відповідності досвіду та компетентності виконавців напряму дослідження пропонується здійснювати з урахування належності науково-дослідного проєкту та науковця до певних предметних наукових середовищ. Запропоновано метод формування предметних наукових середовищ для науковців, наукових закладів та наукових проєктів.

Розроблено індивідуально-орієнтований метод вибору партнерів для виконання наукових проєктів на основі аналізу предметних наукових середовищ, що дає змогу ефективно вирішити задачу управління виконавцями науково-дослідного проєкту та встановлення їх відповідності робочим пакетам науково-дослідного проєкту. Основними перевагами методу є висока точність у виборі партнерів завдяки детальному аналізу їх компетенцій та досвіду, що дозволяє формувати ефективні команди на основі взаємодоповнюючих компетенцій, які мають здатність адаптуватися до специфічних вимог проєкту завдяки індивідуальному підходу до вибору кожного партнера.

Третій розділ присвячений розгляду технічного та програмного забезпечення, яке необхідно для реалізації інформаційної технології вибору наукових партнерів. Також розглянуті підходи та сформульовані вимоги до інформаційного та організаційного забезпечення. Розглянуто основні аспекти практичної реалізації інформаційної системи вибору партнерів-виконавців для створення наукових середовищ проєктів.

Четвертий розділ описує реалізацію інформаційної технології відбору виконавців наукових проєктів. Описано алгоритми акумуляції та аналітичної обробки даних, що збираються з різних джерел, включаючи наукометричні бази даних та академічні профілі. Аналіз наявності професійних сертифікатів, активності у наукових конференціях, публікаціях та досвіду в проєктах.

Практичне значення одержаних результатів полягає в тому, що розроблені моделі та методи формування наукових просторів та оцінювання впливовості науковців в цих наукових просторах з урахуванням результатів їх наукової діяльності є основою для забезпечення ефективності виконання науково-дослідних проєктів, Використання теоретичних і практичних результатів дасть можливість покращити якість реалізації науково-дослідних проєктів та спростити менеджмент виконавцями таких проєктів. Також результати дослідження дають змогу зменшити час та кількість зусиль, які потрібні для формування нової команди проєкту.

Основні наукові положення дисертації доведені до рівня методичних узагальнень і прикладного інструментарію, що дає змогу здійснювати формування наукових просторів та вибору партнерів для виконання наукових проєктів на основі індивідуально-орієнтованого підходу.

Проведена верифікація інформаційної технології відбору виконавців наукових проєктів на основі наукових проєктів в Astana IT University, Astana, Республіка Казахстан за 2021 рік та Yancheng Polytechnic College, Yancheng, Китайська народна республіка за період з 2014 по 2020 рік. Встановлено, що в середньому близько 46.55% науковців відповідали вимогам менеджерів проєктів для кожного наукового предметного простору. Серед відібраних кандидатів за запропонованим методом 24.07% були залучені до участі у проєкті. Верифікація показує, що розроблена інформаційна технологія дозволяє формувати раціональний список виконавців, відповідно до всіх встановлених критеріїв, що підвищує ефективність процесу відбору учасників наукових досліджень.

Основні положення та результати дослідження впроваджено та застосовано в діяльності Yancheng Polytechnic College

Ключові слова: вибір партнерів, науково-дослідний проєкт, управління проєктами, оцінювання результатів наукової діяльності, предметний простір, класифікація, профіль випускника університету, університетське середовище, людські ресурси, мультидисциплінарне розвиваюче середовище.

CONTENT

INTRODUCTION

The dissertation is dedicated to the development of an information technology for selecting scientific partners for joint research, taking into account their competencies, which are assessed based on previous scientific activity results.

Over the past few decades, there has been a significant reevaluation of the importance of scientific research in the context of ensuring sustainable economic development at national and regional levels. In this process, international scientific research initiatives play a special role, contributing to the formation of integrated scientific approaches and synergy between different countries. Many international organizations actively facilitate the involvement of participants from various states, emphasizing the importance of globalizing scientific efforts. High-quality implementation of such projects requires the involvement of performers who meet strict professional standards and competencies necessary for solving specific project tasks. Such initiatives often have a complex structure, requiring the involvement of experts from various scientific fields, depending on the project's goals. It is important to note that the competencies of the participants evolve during the project implementation and are not static, which allows adapting to changing requirements and tasks.

For high-quality execution of a scientific research project, the most important aspect is the involvement of performers with the necessary competencies. To achieve this, it is necessary to develop a model that includes a system for assessing the competencies of performers based on measurable indicators. It is important that these indicators are relevant, reliable, and that there is an opportunity to verify the data from open sources.

In this work, an important task is addressed: the development of mathematical models for assessing the results of researchers' scientific activities over time, to identify the suitability of their candidacies for the requirements of performers in scientific research projects with a complex structure. Additionally, it involves the development of decision-making models for quality management of personnel in scientific research projects (the scientific component), as well as the development of information technology for selecting scientific partners based on models assessing the results of scientific activities, which allows for the automation of data collection and processing processes regarding candidates (the practical component).

The work's relation to scientific programs, plans, and themes. The dissertation was carried out in accordance with the research plan of Taras Shevchenko National University of Kyiv within the framework of the state budget theme of the Ministry of Education and Science of Ukraine: 'Development of methods for analyzing the quality of scientific research by scientists of higher education institutions of the Ministry of Education and Science of Ukraine and individual structural units', Taras Shevchenko National University of Kyiv, № DR 0119U100187 (2019-2021), supervisor A.O. Biloshchytskyi, responsible executor O.Yu. Kuchanskyi and within the framework of the topic: 'Information technologies for analysis and forecasting of processes invariant to the subject area', No. 0123U101621, scientific supervisor S.V. Paliy. The candidate developed a methodology for forming the information spaces of subjects of scientific activity and the information technology that implements it.

The dissertation is dedicated to the development of an information technology for selecting scientific partners for joint research, taking into account their competencies, which are assessed based on previous scientific activity results.

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For the quality execution of a scientific research project, the most crucial aspect is the involvement of performers with the necessary competencies. To this end, it is necessary to develop a model that includes a system for assessing the competencies of performers based on measurable indicators. It is important that these indicators be current, reliable, and verifiable using data from open sources.

This work addresses an important task, namely: the development of mathematical models for evaluating the dynamics of researchers' scientific activities to determine the suitability of their candidacy for the requirements of complex scientific research projects, as well as decision-making models for quality personnel management in scientific research projects (the scientific component). Additionally, it involves the development of information technology for selecting scientific partners based on models for evaluating the results of scientific activity, which allows for the automation of processes for collecting and processing data about the candidates (the practical component).

The object of the research is the process of selecting performers for scientific projects, taking into account the results of scientific activity.

The subject of the research is models for evaluating the results of scientific activity, methods, and tools for selecting scientific partners.

Research methods. The conducted studies are based on methods of knowledge representation and processing, decision making, set theory, graph theory, monitoring and evaluation methods, and object-oriented programming.

The aim of the research is to enhance the efficiency of selecting partners for conducting joint scientific research by developing models and methods for evaluating the results of scientific activities and decision-making

To achieve the goal, the following tasks must be solved:

Analyze the general theoretical principles of selecting partners-performers for scientific projects and the factors that influence the choice of potential performers for scientific project teams.

1. Construct a conceptual scheme of research for assessing the influence of scientists and their selection as partners-performers in a scientific project.

2. Improve models for assessing the influence of scientists based on the global citation network, taking into account the age of scientific results.

3. Refine models for assessing the influence of scientists to consider the affiliation of publications to specific scientific fields in order to more accurately evaluate scientists in the context of selecting partners-performers for scientific projects.

4. Enhance methods for forming specific scientific environments.

5. Develop a method for selecting partners-performers of scientific projects based on the analysis of specific scientific spaces.

6. Develop technical, software, informational, and organizational support for the information technology of selecting scientific partners.

7. Implement the information technology for selecting partners-performers of scientific projects within specific scientific environments.

The **scientific novelty** of the dissertation research lies in the following:

- For the first time, an individually-oriented method for selecting scientific project partners based on the analysis of subject scientific spaces has been developed. This allows for the enhancement of the effectiveness of their implementation.

- The information technology for selecting scientific partners has been improved based on models for evaluating the results of scientific activities. The main distinction of the proposed technology from known information technologies for selecting scientific partners is that it includes a comprehensive assessment of knowledge, publication activity, and skills of the partners, which are determined through the experience of executing scientific projects. This enables an increase in the effectiveness of implementing scientific research projects.

- The model for assessing the influence of scientists within the global citation network has been refined, taking into account the age of scientific results in terms of increasing sensitivity to new publications. Unlike other models, the proposed model for assessing the influence of scientists considers the affiliation of publications to subject scientific spaces. This allows for a more accurate evaluation of scientists' activities in the context of selecting partners for joint scientific research.

• The method of forming specific scientific spaces has further developed, expanding the theoretical and practical possibilities for identifying compliance with the requirements for performers of scientific research projects.

The first chapter of the dissertation contains an analysis of existing theoretical and practical research on the management of scientific research projects, particularly in terms of selecting performers and forming teams. It discusses changes in scientific collaboration, with a focus on the globalization of scientific networks. The chapter highlights how the globalization of the collaboration network facilitates an interdisciplinary and transnational approach to scientific research, involving experts from various fields to work on complex problems. The importance of international research consortia, conferences, symposiums, joint research centers of universities, and publications in specialized journals is emphasized. The complexity and significance of global scientific collaboration in forming teams for joint research execution are demonstrated.

It is established that the task of assessing the competencies of performers based on the results of scientific activity and their correspondence to the work packages of a scientific research project has been fully resolved. To ensure effective management of performers in a scientific research project, it is appropriate to develop new or improve known models for evaluating the results of scientific activity and to build information technology for selecting scientific partners based on these models.

In the second chapter of the dissertation, a conceptual scheme of research is described for assessing the influence of scientists and their selection as partners-performers of a scientific project. Within this scheme, a mathematical model for assessing the influence of scientists through the global citation network is considered, taking into account the age of scientific results.

An analysis of factors that influence the choice of potential performers for scientific projects was conducted. The analysis found that the correspondence of the experience and competencies of the performers to the research direction is extremely important when choosing partners-performers for a scientific project. It is proposed to determine the correspondence of experience and competencies of performers to the research direction by considering the affiliation of the scientific research project and the scientist to certain specific scientific environments. A method for forming specific scientific environments for scientists, scientific institutions, and scientific projects is proposed.

The individually-oriented method for selecting partners-performers of scientific projects based on the analysis of specific scientific environments effectively addresses the management of performers of a scientific research project and their correspondence to the work packages of the scientific research project. The main advantages of this method are the high accuracy in selecting partners thanks to a detailed analysis of their competencies and experience, allowing for the formation of effective teams based on complementary competencies that can adapt to specific project requirements through an individual approach to selecting each partner.

The third chapter is dedicated to the consideration of the technical and software support necessary for the implementation of the information technology for selecting scientific partners. Approaches and requirements for informational and organizational support are also discussed. The main aspects of the practical implementation of the information system for selecting partners-performers to create scientific environments for projects are examined.

The fourth chapter describes the implementation of the information technology for selecting performers of scientific projects. Algorithms for the accumulation and analytical processing of data collected from various sources, including scientometric databases and academic profiles, are described. Analysis of the presence of professional certificates, activity in scientific conferences, publications, and experience in projects is included.

The practical significance of the obtained results. The main scientific provisions of the dissertation have been brought to the level of methodological generalizations and applied tools, which allows for the formation of scientific spaces and the selection of partners-performers for scientific projects based on an individually-oriented analysis of specific scientific environments.

Verification of the information technology for selecting performers of scientific projects based on scientific projects was carried out at Astana IT University, Astana, Republic of Kazakhstan in 2021 and Yancheng Institute of Technology, Yancheng, People's Republic of China in the first semester of 2023. It was found that on average about 46.55% of scientists met the requirements of project managers for each scientific subject space. Among the candidates selected by the proposed method, 24.07% were involved in the project. The verification shows that the developed method allows forming a rational list of performers, according to all established criteria, which increases the efficiency of the selection process for participants in scientific research.

The main provisions and results of the research were implemented and applied in the activities of Yancheng Polytechnic College.

Personal contribution of the applicant. The applicant personally obtained the main provisions and results of the dissertation work. In work [1], the task of choosing partners for the organization of cooperation in the framework of scientific and educational projects was formalized. The personal contribution of the applicant lies in the review of partner selection methods and the generalization of the task formulation. In the solo work [2], methods of assessing the results of scientific activity were considered. In work [3], a mathematical model for partnership choices for scientific project cooperation was built. The personal contribution of the applicant lies in the conceptualization and formulation of this mathematical model. In work [4], an individually-oriented method for the selection of subjects for implementing scientific projects based on scientometric analysis was proposed. The idea of the method and the data processing for the validation of the proposed method belong to the applicant. In the solo work [5], the applicant proposed a mathematical model for assessing the influence of scientists based on the global citation network and the history of scientific results. In the solo work [6], the applicant investigated the issue of choosing partners for cooperation in carrying out joint research of international scientific consortia."

The materials from international conferences were also published, in which the provisions of the dissertation work are revealed in more detail [7-13].

Approbation of the results of the dissertation. The main results of the work were reported, discussed, and received a positive evaluation at IEEE conference "Smart Information Systems and Technologies" (SIST-2021), Astana, Republic of Kazakhstan, as well as at international conferences "Information technologies and interactions", Kyiv (2018, 2019, 2021), "Project Management in the Development of Society", Kyiv (2019), "Information Modeling Technologies, Systems and Complexes", Chernivtsi (2019), "Technology Development Management", Kyiv (2020) and “Scientific summary ot the 2021”, Kharkiv (2021).

Publications. Based on the dissertation materials, 10 scientific works have been published, including: 4 scientific articles in specialized publications of Ukraine, one of them in a publication that is indexed by the Scopus database, 1 article in a publication that is not included in the list of the Ministry of Education and Culture, 5 materials of international conferences. The main results of the work were obtained by the author personally. Of the scientific works published in co-authorship, the dissertation research describes those provisions resulting from the author's personal work.

Structure and scope of work. The dissertation consists of an introduction, four chapters, chapter conclusions, main conclusions, a list of references and appendices. The total volume of the dissertation is 145 pages, of which the central part is 124 pages, including 13 figures, 5 tables, a bibliography of 118 titles and 2 appendices.

CHAPTER 1. GENERAL THEORETICAL PRINCIPLES OF SELECTING PARTNERS-PERFORMERS FOR SCIENTIFIC PROJECTS

1.1. Global scientific collaboration network characteristics

In recent decades, significant changes have occurred in the geography of science and scientific collaboration. Scientific networks or networks of scientific collaboration, which previously operated locally within universities and scientific institutes, as well as spread across one or several countries and were more static, now encompass practically the entire world. The speed of creating new information and the use of tools for networked collaboration among scientists contribute to the dynamic development and diversification of scientific networks.

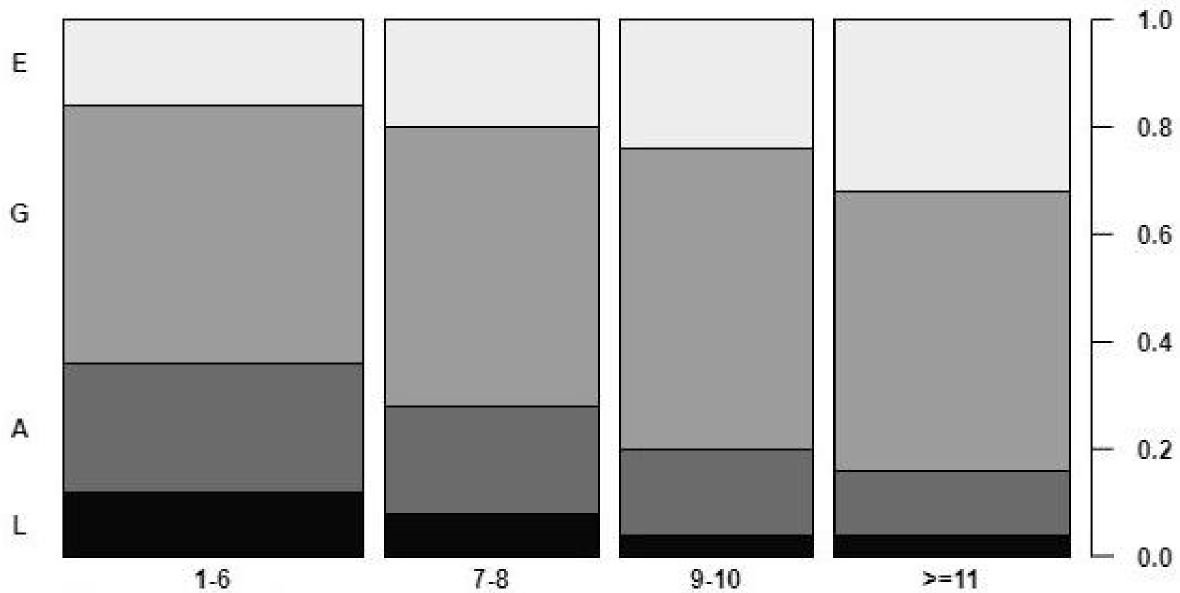

Figure 1.1 – The Relationship Between the Number of Authors and the Quality of Scientific Publications in the Field of Medicine [74]. Quality: E-excellent, G-good, A-acceptable, L-limited

The global network of scientific collaboration is a complex system that connects scientists, research institutes, universities, foundations, government agencies, and the private sector from different countries in joint efforts to conduct scientific research, exchange knowledge, resources, methodologies, and technologies. This network facilitates the globalization of science, providing an interdisciplinary and transnational approach to scientific research.

Key components of the global network of scientific collaboration:

1. Scientists and Researchers: Individual scientists and research groups working in various scientific fields.

2. Academic Institutions: Universities and research institutes that are primary centers of knowledge and innovation.

3. International Scientific Organizations: Such as UNESCO, WHO, which promote international cooperation in the scientific field.

4. Government Agencies: National and international government organizations that fund scientific research and define policies in the field of science.

5. Private Sector: Companies and corporations that invest in scientific research and development.

6. Foundations and Grants: Organizations that provide funding for scientific projects and research

Interdisciplinarity in science is an approach that brings together experts from various scientific fields to work collaboratively on complex problems that cannot be solved within the confines of a single discipline. This approach is important as many contemporary scientific and social challenges require a comprehensive approach that involves diverse knowledge and methodologies.

Interdisciplinarity is often realized through international research consortia and projects. For example, large scientific projects like the Large Hadron Collider involve physicists, engineers, mathematicians, and other specialists.

Scientific Conferences and Symposia create a platform for exchanging ideas and knowledge among scientists from different disciplines, fostering the development of interdisciplinary connections.

Universities and research institutions often establish joint research centers focused on interdisciplinary problems such as climate change, healthcare, or artificial intelligence.

Scientists publish the results of their interdisciplinary research in specialized journals, allowing the wide dissemination of new knowledge and ideas.

The internet and digital technologies provide powerful tools for collaboration, data sharing, and joint work among scientists from around the world.

Characteristics of the functioning of the global scientific collaboration network include the flexibility and openness of interdisciplinary teams to new ideas and methods, willingness to adapt and learn from each other, effective communication between participants with different professional languages and approaches. Interdisciplinary projects often require complex management, taking into account the different goals and expectations of participants. The synthesis and integration of knowledge from various fields are essential parts of interdisciplinary work.

Interdisciplinarity in science not only facilitates new discoveries and solutions to complex problems but also leads to the formation of new fields of knowledge and approaches.

Transnationality in science means the participation of scientists and institutions from different countries in joint research and projects. This approach ensures the exchange of knowledge, experience, resources, and ideas at the international level, which is key to addressing global scientific challenges.

International Partnerships and Consortia from different countries come together to work on projects. This can include large research initiatives, intergovernmental programs, as well as non-governmental and commercial partnerships.

International organizations and foundations provide international grants and funding for transnational research projects, promoting cooperation between countries.

Universities and research institutions collaborate through academic exchanges, joint training programs, seminars, and conferences.

Joint research is published in international scientific journals, facilitating the wide dissemination of knowledge.

The internet and digital technologies play a crucial role in communication and collaboration among scientists from different countries, allowing for real-time data and knowledge exchange.

Transnational collaboration requires consideration of cultural and linguistic differences for effective communication and mutual understanding.

Collaboration between countries can be accompanied by logistical challenges and legal issues related to copyright, patents, and regulation.

Transnational collaboration often focuses on addressing global issues such as climate change, healthcare, energy, and sustainability, excluding locally significant research.

Transnationality in science enables the creation of new knowledge and innovations that are impossible within individual national or disciplinary boundaries. It promotes the exchange of knowledge and experience on a global scale, increasing the impact and significance of scientific research.

Digitization and information technologies play a key role in building and operating the global scientific collaboration network. These technologies provide efficient communication, data exchange, and collaborative work among scientists worldwide.

Social networks, specialized forums, video conferences, and other online platforms for communication and collaboration allow scientists from different countries to communicate and collaborate in real time.

Cloud storage and data management systems provide centralized, secure storage and exchange of scientific data.

Document collaboration software, project tools, and coding platforms enable efficient work on joint projects, regardless of participants' geographical location.

Digital libraries and archives provide wide access to scientific publications, research materials, and other important resources. Extensive use of specialized software and analytical tools for data processing, modeling, and visualization.

IT solutions significantly speed up data and information exchange, allowing rapid response to new scientific challenges. Digital technologies enable easy scaling of projects and provide access to scientific resources for a wide range of researchers.

Digitization promotes openness in science, ensuring free access to scientific data and results. Ensuring the security and confidentiality of scientific data remains an important aspect, especially in the context of international collaboration. Digitization and information technologies are not just tools but also catalysts for global scientific collaboration, playing a key role in addressing complex interdisciplinary and transnational challenges.

Open access and resource sharing are important elements in building and operating the global scientific collaboration network. These practices ensure equal access to scientific publications, data, equipment, and other important resources, promoting progress in science and research.

Open access to scientific journals and archives, such as arXiv or PubMed Central, allows researchers to freely read and download scientific articles. Many funding organizations and universities now require open access to research results funded by their grants.

Cloud storage such as Google Cloud, Amazon Web Services, and specialized data repositories provide storage, management, and exchange of large data sets. Standardization of data formats and standards facilitates easier data exchange and analysis between different research groups.

Universities and research institutions often share equipment and resources, saving money and increasing research efficiency. Large scientific institutions like CERN offer their resources to the international scientific community.

Open access and resource sharing promote transparency and openness in science. Easy access to resources and data supports interdisciplinary and transnational research, fostering innovation. Open access helps reduce inequality in access to scientific resources, especially for researchers in resource-limited countries.

Ensuring the security and confidentiality of shared data is important, especially in sensitive fields like biomedicine.

Open access and resource sharing are fundamental to modern scientific collaboration, allowing the pooling of efforts and resources to achieve common goals in research and innovation.

Ethics and standards in scientific research and publications are critically important for maintaining integrity, credibility, and accountability in the global scientific collaboration network. They form the foundation on which trust and mutual respect among scientists, institutions, and the public are built.

Ethical norms in science ensure that research is conducted with respect for human rights, animal welfare, and environmental conservation. Standards of honesty and transparency in scientific publications include the absence of plagiarism, proper authorship attribution, and open data provision for verification.

Research Practice Standards include rules for data handling, experimental methodologies, and ensuring the accuracy of results.

International standards, such as those set by the World Health Organization or UNESCO, coexist with local norms and regulations, creating a complex but important ethical framework. Most universities and research institutions have ethics committees that review research for ethicality and compliance with standards.

Raising awareness and education in scientific ethics is important for researchers at all stages of their careers.

One challenge is aligning international standards and ethical norms between different countries and cultures. Rapid developments in scientific and technological innovations require continuous review and adaptation of ethical standards. Maintaining a high level of transparency and accountability in scientific research remains important for ensuring public trust.

Ethics and standards in the scientific community contribute to a strong, healthy, and trustworthy foundation for global scientific collaboration, which is an integral part of scientific progress and innovation.

Adaptability and flexibility in the context of the global scientific collaboration network mean the ability of the scientific community to quickly respond to changes in the scientific environment, technologies, global challenges, and societal needs. These qualities are critically important for supporting innovation, effective collaboration, and solving complex problems.

The global scientific community must be able to mobilize quickly to address new challenges, as was the case with the COVID-19 pandemic. This generates the need to adapt research plans and methods according to new data, technologies, and scientific directions. Rapid implementation of innovative technologies in scientific research and collaboration, for example, artificial intelligence and big data. Flexibility in creating and reorganizing interdisciplinary and transnational teams to address specific scientific problems. Effective project management capable of adapting to changes in funding, timelines, and priorities. Using digital platforms and technologies to support flexible and efficient collaboration.

It is important to maintain a balance between flexibility in adapting to new challenges and stability in long-term research programs. Rapid changes and adaptations can increase risks associated with research quality and ethical standards. Continuous learning and skill development are key to supporting the adaptability of scientists and organizations.

Adaptability and flexibility in the global scientific collaboration network enable effective response to rapid changes in the scientific environment, technologies, and societal needs, thus ensuring the sustainability and progress of scientific research.

The global network of scientific collaboration provides an important platform for advancing scientific knowledge, developing innovations, and addressing global challenges. The study [14] shows that the evolution of international scientific collaboration plays a significant role in the social construction of science, designing effective research policies, and supporting knowledge production. The research demonstrates that long-term models of international scientific collaboration lead to the convergence of applied and basic scientific fields. Such convergence in collaboration models between research fields can be one of the factors contributing to the evolution of scientific disciplines.

Numerous scientific studies are dedicated to international collaboration among scientists, particularly [15], which posits that collaboration in research has become the norm in all fields of scientific and technical research. The authors provide a critical review of the literature on research collaboration, focusing on collaborations among university scientists but also considering university researchers' collaborations with scientists from other sectors, including industry. The paper discusses both knowledge-oriented collaborations and those focused on creating economic value and wealth (property-oriented collaboration), including most research in the field of academic entrepreneurship. To organize the review, the authors develop a framework for analysis that considers the characteristics of collaborators, the collaboration process, and organizational features that influence the choice of collaboration and its outcomes.

The main idea of the book [16] is that the success of scientific research teams depends on effective collaboration and a strategic approach to team management. The book focuses on the importance of establishing effective communications, role distribution, conflict management, and coordination of work in diverse and often multidisciplinary teams. The authors offer practical advice and strategies to help scientists build and maintain productive and innovative scientific collaborations.

The study [17] focuses on understanding why scientists and innovators collaborate on some projects but not others. The main idea is that the choice of organizational form for collaboration is based on a trade-off between the productive efficiency of collaboration and the distribution of credit after the completion of joint work. The article develops a model that helps structure the understanding of factors shaping scientists' choices regarding collaboration, particularly the implicit distribution of credit among participants in scientific projects. The authors then explore the trade-off between collaboration and reward in the case of annual scientist surveys from the Massachusetts Institute of Technology.

The research [18, 19] examines the impact of geographic distance on scientific collaboration but from different perspectives and in different contexts: The first paper focuses on the impact of high-speed rail (HSR) lines in China on innovation collaboration between cities. The main idea is that improvements in transportation infrastructure facilitate an increase in the number and quality of innovative patents created in collaboration between universities and the corporate sector. HSR facilitates the search for new research partners beyond geographical borders, expanding opportunities for scientific collaboration. The second paper analyzes the changing impact of physical distance and territorial borders on the intensity of scientific collaboration between European regions. The main conclusion is that although the process of European integration reduces the impact of territorial borders, physical distance remains a significant factor. The article emphasizes that there is significant diversity among regions and countries in Europe in their willingness to collaborate, depending on the size, quality, and accessibility of regions. Thus, both articles acknowledge the importance of geographic distance in scientific collaboration, but the first demonstrates how infrastructural improvements can help overcome this barrier, while the second emphasizes that physical distance still has an impact despite political integration and the reduction of territorial barriers.

The study [20] posits that risk allocation in public-private partnership projects is structured so that the public sector is willing to take on most of the risks associated with government or public officials. Private consortia are not willing to take on these risks and prefer specific selection of performers for scientific projects. Commercial principles and contract terms between public bodies and private consortia are also made.

The authors of the study [21] focus on analyzing the impact of external networks on the innovative activity of small and medium-sized enterprises (SMEs). The main idea is that following the increasing complexity of innovation processes, SMEs increasingly utilize external networks. The study, based on a survey of 137 Chinese manufacturing SMEs using the structural equation modeling (SEM) method, shows that there are significant positive relationships between firm-to-firm collaboration, collaboration with intermediary institutions, collaboration with research organizations, and SME innovation activity. Among these, firm-to-firm collaboration has the greatest positive impact on SME innovation activity. Surprisingly, links and collaboration with government agencies do not show a significant impact on SME innovation activity. Furthermore, the results confirm that vertical and horizontal collaboration with clients, suppliers, and other firms play a more pronounced role in the innovation process of SMEs than horizontal collaboration with research institutes, universities, colleges, and government agencies. Thus, this article highlights the importance of external networks and collaboration for SME innovation activity, especially emphasizing the significance of inter-firm collaboration and the lesser impact of interactions with government agencies on innovation activity.

In [22], it is shown that negotiations require careful analysis and understanding for effective joint decision-making. Proposed methods for effective approaches to joint decision-making.

1.2. Organization of hubs and scientific environments for the implementation of scientific projects

The dynamic development of the scientific space of any country is an extremely important factor that contributes to increasing its prestige, developing the economy, and the emergence of new technologies in various spheres of human activity.

The organization of hubs and scientific environments is a key element in structuring and successfully executing scientific projects. Hubs, as nodes of scientific collaboration, and scientific environments that focus on specific research initiatives, ensure the integration of resources, knowledge, and expertise [23].

Key aspects of organizing scientific hubs include the integration of resources within the organization of scientific hubs and environments, which is crucial for the effective execution of scientific projects. This means combining equipment, funding, knowledge, and research efforts from various sources and disciplines to achieve common goals [24].

The organization of scientific hubs leads to the creation of centers where scientists from different disciplines can work together on complex problems. These centers are often equipped with specialized equipment and create specialized zones where universities, startups, and large companies can interact and collaborate on new technological projects [25]. Forming networks for sharing experiences, knowledge, and resources between different institutions and organizations.

Shared use of expensive equipment and infrastructure to optimize use and reduce costs. Integrating financial resources from various sources such as government grants, private investments, and academic funds.

Creating joint programs that bring together researchers from different institutions and countries to work on large projects fosters the consolidation of research. Scientific hubs and environments stimulate collaboration, exchange of ideas, and innovative activity. Providing access to high-quality infrastructure, laboratories, and technologies facilitates the ability to respond quickly to new scientific challenges and changes in the research landscape.

Integrating resources within scientific hubs and environments promotes effective execution of scientific projects, creating conditions for deep interdisciplinary collaboration, innovation, and the development of science at an international level [26].

A multidisciplinary approach in the context of organizing scientific hubs and environments is particularly important for implementing complex scientific projects. It involves engaging experts from different scientific disciplines who collaborate, sharing knowledge and experience, to solve complex problems [27].

Creating scientific hubs fosters the unification of experts from various fields such as biology, physics, engineering, social sciences, to work together on scientific projects. Using a variety of methodologies and theoretical approaches to consider problems from different perspectives enriches knowledge exchange. Developing specialized programs, including courses and research, oriented towards interdisciplinarity is one of the main features of multidisciplinary collaboration.

Multidisciplinary collaboration enriches research with new ideas and approaches that may not be obvious within a single discipline. The combination of knowledge and skills from different areas allows for effectively addressing complex interdisciplinary problems. Multidisciplinary teams often achieve breakthrough results through the integration of diverse perspectives and innovative solutions.

The importance of effective communication and understanding among professionals from different disciplines to overcome language and conceptual barriers. Organizing and managing multidisciplinary projects can be more challenging due to the diversity of interests and approaches. Ensuring adequate funding and resources for multidisciplinary projects, which often require larger investments [28].

A multidisciplinary approach in scientific hubs and environments facilitates the creation of an innovative and creative space for addressing complex scientific and societal challenges, combining diverse knowledge and experience to achieve common goals.

Creating an innovative environment within scientific hubs and environments is key to promoting creative thinking, idea exchange, and the development of new approaches. This requires not only physical resources but also a culture of openness and collaboration. Involving experts from different scientific fields to exchange knowledge and perspectives, which fosters the generation of new ideas. Forming a culture that values risk, experimentation, and accepts failures as part of the innovation process. Creating open and flexible spaces where participants can meet, communicate, and work together. Ensuring access to modern technologies, laboratories, and equipment necessary for the development of new approaches and ideas. Organizing events where participants can exchange ideas, learn new things, and get acquainted with the latest achievements in various fields.

Scientific hubs serve as knowledge concentrators where researchers, entrepreneurs, and innovators gather to work collaboratively. Hubs facilitate intersectoral collaboration and involve industry, academia, and government agencies to jointly solve complex tasks. Collaboration with international organizations and institutes for knowledge and skill exchange.

Ensuring that access to resources and opportunities is open to all participants is important. Effective management of financial, human, and material resources is key to supporting an innovative environment.

The ability to quickly adapt to new technologies, scientific discoveries, and societal needs.

Creating an innovative environment in scientific hubs and environments requires a comprehensive approach that not only provides the necessary resources but also shapes a culture that fosters creativity, collaboration, and innovation [29,30].

Promoting international cooperation is fundamental to the success of scientific hubs and environments focused on implementing complex scientific projects. This involves interacting with international scientific groups and organizations for knowledge exchange. Hubs as International Nodes: Scientific hubs can serve as nodes for international cooperation, gathering experts from different countries and disciplines.

Through international cooperation, scientific hubs can address global challenges such as climate change, healthcare, and sustainable development. Sharing unique resources and knowledge expands opportunities for innovation and development [31].

Promoting international cooperation within scientific hubs and environments opens up vast opportunities for knowledge and resource exchange, as well as addressing global scientific challenges. It fosters the creation of a more integrated and innovative scientific community.

Supporting young scientists and students is an important component of successfully implementing scientific projects within scientific hubs and environments. Creating conditions for their development, offering opportunities for internships, educational programs, and financial support helps to form a new generation of skilled researchers.

Internship programs in scientific hubs give young researchers the opportunity to gain practical experience working alongside experienced scientists. Organizing specialized courses, workshops, and educational programs focused on contemporary scientific issues and methodologies. Providing financial support for young scientists through grants, scholarships, and other funds aimed at supporting scientific research. Engaging experienced scientists to lead and mentor young researchers, promoting their professional development. Including young scientists in international scientific projects and collaborations, allowing them to develop their professional networks and gain unique experience.

Scientific hubs serve as ideal platforms for the development of young scientists, providing them access to resources, equipment, and knowledge. Creating networks that allow young researchers to exchange ideas, knowledge, and experience with colleagues from different fields and countries.

Scientific hubs stimulate innovation and creative thinking among young scientists, opening doors for experimentation and the development of new ideas [32].

However, there are a number of challenges and opportunities, particularly ensuring that young researchers from different backgrounds have equal access to opportunities and resources. The development of programs and initiatives should consider the individual needs and interests of young scientists. Developed support programs must be sustainable and effective in the long term.

Supporting young scientists and students in scientific hubs is key to developing a new generation of researchers capable of making significant contributions to science and society.

The characteristics of scientific environments include:

1. Focusing on specific scientific fields, such as biotechnology, physics, information technology, etc.

2. Creating conditions for conducting long-term scientific projects, ensuring stability and continuity of research.

3. Applying modern project management methods to optimize planning, execution, and monitoring processes.

4. Collaborating with companies and industrial partners for the commercialization of scientific developments.

Scientific hubs and environments are not only centers of knowledge but also key elements in the development of innovative technologies and the implementation of complex scientific projects that have a significant impact on society and the economy. They foster the attraction of talents, exchange of experience, and create a foundation for future scientific breakthroughs [33].

SWOT analysis in the context of finding scientific partners (Fig. 1.2) helps to identify key aspects and determine optimal strategies for effective scientific collaboration. It helps to understand which internal resources and competencies can contribute to successful collaboration, as well as to identify limitations or vulnerabilities. It reveals external opportunities for collaboration, such as access to new technologies, funding, interdisciplinary projects. It helps to identify potential threats to collaboration, such as conflicts of interest, political or economic instabilities.

It provides a basis for developing strategies that focus on leveraging strengths and opportunities while simultaneously reducing the impact of weaknesses and threats.

Thus, SWOT analysis contributes to a more reasoned and effective choice of scientific partners, directing attention to the most important factors for successful collaboration.

Research [34] confirms that information exchange plays a key role in scientific research, especially when scientists share their discoveries through publications, data, and software. With the increase in scientific software and the emergence of more open sources, the choice of appropriate software becomes an urgent issue. The article presents a collaborative model of provenance, designed to capture information about collaboration between users and software. The authors use an ethnographic method to explore the elements that influence user choices and quantitatively assess them. Based on this, an algorithm is introduced for selecting software for each process in the workflow, as well as an algorithm for selecting the composition for the entire workflow.

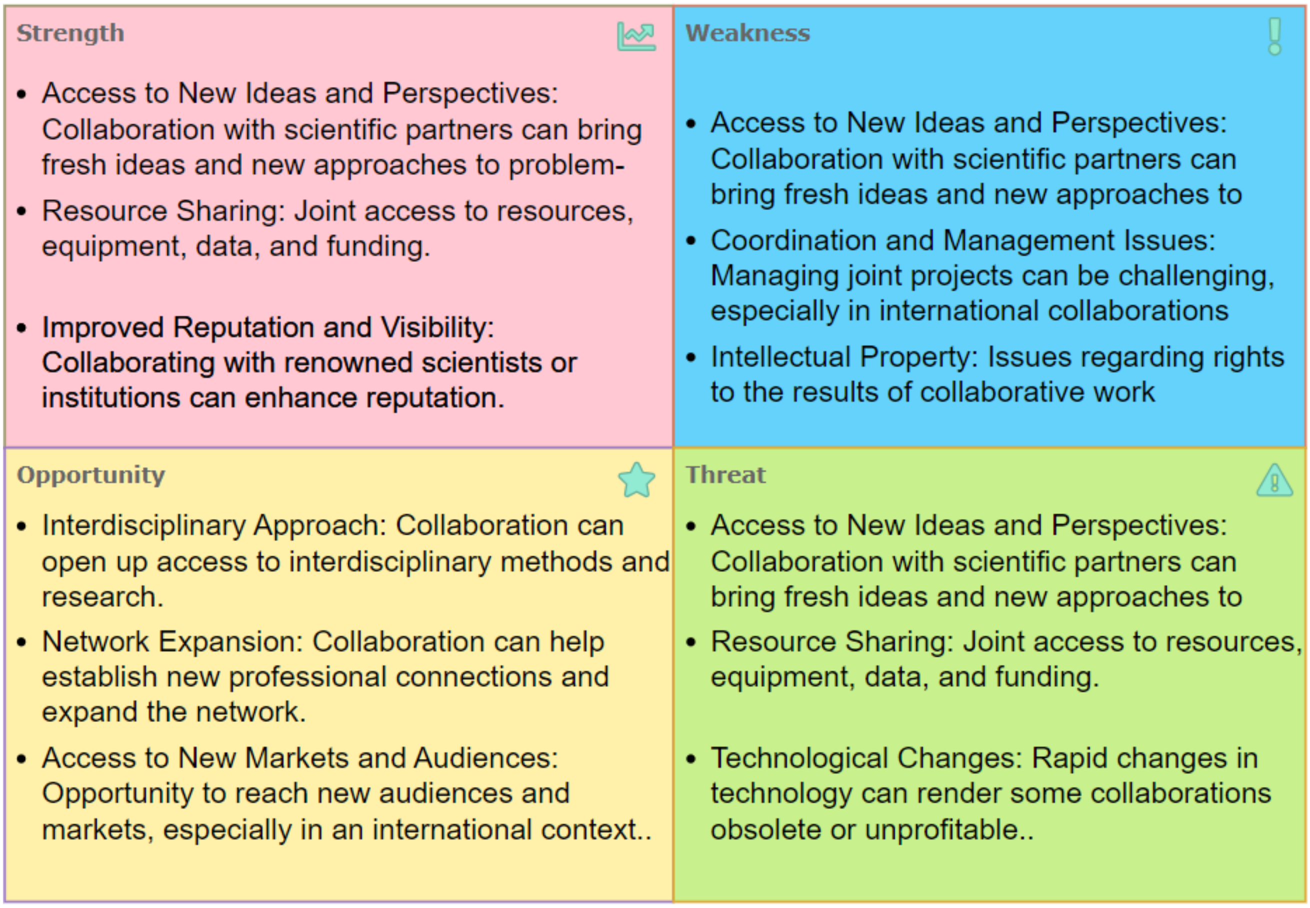

Figure 1.2. SWOT Analysis in the Context of Searching for Scientific Partners

The authors demonstrate the complexity of organizational and decision-making processes in large engineering projects. Theoretical tools are provided for understanding the complexity of large engineering projects from the perspective of human actors. It describes work on engineering interfaces in collaboration, showing how middle managers (mostly engineers) act as interfaces with other stakeholders and resolve complex socio-economic and technical issues. The potential application of the model is illustrated with two case studies of projects [35].

The authors emphasize the importance of open software and workflow descriptions for flexibility in academic research, especially in the context of new data collection and analysis methods. The article [36] also highlights the complexity and rapid development of tools in the field of computing, as well as the importance of well-abstracted workflows and their exchange among working groups to enhance research efficiency.

1.3. Principles for Choosing Partners to Build Scientific Environments

The dynamic development of the scientific space in any country is an extremely important factor that contributes to enhancing its prestige, developing the economy, and the emergence of new technologies in various spheres of human activity.

Selecting partners for collaboration or project execution is a familiar task that typically involves creating matrices of benefits and competencies by employing methods of multicriteria decision-making. Specifically, paper [37] discusses the evolution and decline of competencies in an innovative project. The use of hierarchical analysis to choose a project executor from multicriterial options was put forward in study [38], while paper [39] explores the partner selection process for company activities. Research [40] demonstrates that the selection of partners for collaborative efforts is influenced by factor analysis. The genetic algorithm for partner selection is outlined in study [8], and a more efficient hybrid algorithm compared to the genetic algorithm through numerical analysis is developed in article [41]. However, studies [39-41] overlook the intricate network dynamics among partners, such as competition and cooperation. The methods for evaluating a partner's significance, which bear upon maintaining a proper reputation and assessment of company activities, are detailed in paper [42]. Research [43] takes into account the network structure of partner relationships. Paper [12] considers the network's structure, self-organization, and the expansion of international cooperation in science as influential factors in choosing a cooperation partner. The influence of a partner based on a network of hub connections is examined in article [44], and paper [45] discusses the use of PageRank to evaluate the significance of nodes in a cooperation network, thus determining a partner's importance. The topic-adjusted PageRank method is described in study [15]. Nonetheless, to choose subjects of scientific activity, one must regard not only the citation and cooperation network links among scientists but also the dynamics of their scientific productivity, which is not addressed in papers [46-48]. While paper [49] considers performance assessments as a tool for selecting partners, it fails to consider dynamics.

Mathematical methods for selecting project executors are primarily associated with fuzzy mathematics and fuzzy logic inference, as noted in paper [50]. The task of selecting partners for a virtual enterprise using fuzzy logic is detailed in study [51], and the fuzzy technique for choosing scientific partners is described in paper [52]. A multifactor decision-making model using interval-valued intuitionistic fuzzy sets for selecting a scientific partner is proposed in paper [53]. However, the project's structure is not factored into partner selection in studies [54-57].

Evaluating competencies that align with project objectives and satisfy the project manager responsible for the desired outcome is central to choosing project executors. Research [58] outlines the necessary competencies and qualifications for a project executor. The automation of determining these competencies within an information system is detailed in study [60]. Papers [61-63] explore project management approaches to selecting executors, but they do not emphasize that project executors or partners possess their own dynamic informational space, just as subjects of scientific activity have an informational scientific space. The methodology for creating an informational space for subjects of scientific activity is described in research [64].

The productivity dynamics of scientific subjects are assessed through time series analysis, which is reflected in performance estimates. Paper [65] suggests that such series may exhibit self-similarity, thus fractal analysis could be applied for their analysis and forecasting. An expert-based evaluation model for executors is presented in paper [66]. Research [67] details information technology, and article [68] addresses developing methods for forecasting time series that incorporate expert opinion, modified to account for external impacts.

Neural networks are also utilized to locate scientific partners. An efficiency index system for collective scientific subjects based on neural networks is proposed in article [69], and MATLAB software for constructing a neural network is used in article [70], proving its efficacy in partner selection and evaluation. While research [71] describes networks for partner selection, it does not address the project structure's role in this selection. Paper [72] presents a project team formation approach, considering its structure. The creation of interdisciplinary scientific teams is explored in article [73], and paper [74] delves into the computational model for assembling a team in scientific disciplines. It reveals that the likelihood of cooperation is greater among individuals with longer tenure, lower institutional levels, lower H-indices, and higher rates of co-authorship and citation. Article [75] moves on to constructing an ecosystem for team interconnections within a shared environment. Article [76] compares the selection of scientists for research projects using five criteria. Overall, the literature tends to neglect the dynamics of potential partners' performance and the complex structure of scientific projects, which are crucial for selecting the right candidates. This underscores the need for research dedicated to developing an individually tailored method for selecting scientific subjects for executing scientific projects, leveraging scientometric analysis. Control processes which the choice of performers depends. All this makes it possible to assert that it is advisable to conduct a study de-voted to the development of an individually oriented method for choosing subjects of scientific activity for the implementation of scientific projects based on scientometric analysis.

In work [87], partnership relationships and the principles of managing them were investigated. Work [88] describes a multi-stage mathematical model for choosing partners. Work [89] suggests using the analytic hierarchy process for selecting the best partners from a small set of potential ones. Work [90] describes a model for choosing a partner based on a genetic algorithm.

Choosing partners to create scientific environments is a key step in forming effective research groups and projects. The main principles of choosing partners include [85,86]:

1. Complementarity of knowledge and skills. It is important to choose partners whose knowledge and skills complement each other, facilitating team formation.

2. Having necessary experience and reputation. Partners with an excellent scientific reputation and experience in relevant fields ensure the reliability and quality of scientific research.

3. Common scientific interests. Partnership should be based on common scientific interests and goals, which promotes team cohesion and ensures work efficiency.

4. Long-term collaboration potential. Choosing partners who have the potential for long-term collaboration ensures stability and development of scientific environments.

5. Availability of resources. It is important that partners have access to necessary resources, including funding, equipment, laboratories, etc. Partners who can jointly attract funding and grants significantly increase the potential for successful project implementation.

6. Shared ethical values and standards. It is important for all partners to share common ethical norms and adhere to high standards in scientific work. In an international context, it is necessary to consider cultural differences and establish mutual understanding among partners.

7. The ability to effectively exchange ideas and information is critical for the success of collaboration. Partners should be open to new ideas and innovative approaches in scientific research.

Considering these principles, effective scientific environments can be built that contribute to the development of science, innovation, and technology, ensuring high quality and efficiency of scientific research.

In the field of developing information technologies for assessing the results of activities in scientific communities, the creation of comprehensive assessment systems becomes relevant. These systems integrate various activity parameters and seek to reduce the impact of subjective factors on the evaluation process, as indicated in studies [72-78].

In the context of evaluating the effectiveness of higher education institutions, study [79] presents a parametric model and structure of processes aimed at predicting and assessing the quality of educational services. Authors [80,81] analyze project interaction models to improve the quality of education and explore issues of implementing international standards for evaluating project management competencies.

Study [82] contributes to understanding the probabilistic transitions in Markov chains that affect the characteristics of the project environment. Work [83] focuses on the peculiarities of using Markov chains to analyze the life cycle of scientific publications.

In study [84], approaches to integrating project management and decision support using a matrix model focused on key events in the project portfolio are proposed.

Therefore, for the information technology of searching for scientific partners, the following tasks need to be performed [3]:

1. Building an information model for presenting scientific projects and their performers.

2. Developing a method for identifying research directions of individual scientists.

3. Creating an adequate model for selecting potential partners among the active subjects of scientific communities.

4. Developing a model for evaluating partners to form a rational ranked list of potential partners who can be involved in the project.

5. Assessing the activities of competitors.

6. Creating an information-analytical system that, under the purposes of grants, will form a list of potential partners for collaboration.

Conclusions for chapter 1

1. Analysis of existing theoretical and practical research on managing scientific research projects in terms of selecting performers and forming teams. Changes in scientific collaboration are considered, focusing on the globalization of scientific

networks. The section highlights how the globalization of collaboration networks facilitates an interdisciplinary and transnational approach to scientific research, involving experts from various fields to work on complex problems. The importance of international research consortia, conferences, symposia, joint university research centers, and publications in specialized journals is emphasized. The significance and complexity of global scientific cooperation in terms of forming teams for collaborative research are shown.

2. It has been established that the task of evaluating the competencies of performers based on the results of scientific activity and their correspondence to the work packages of a scientific research project is not fully solved. To ensure effective management of performers in a scientific research project, it is advisable to develop new or improve known models for evaluating the results of scientific activity and to build an information technology for selecting scientific partners based on these models.

CHAPTER 2. MULTICRITERIA MODEL AND INDIVIDUALLY-ORIENTED METHOD FOR CHOOSING PARTNERS FROM SUBJECT-SPECIFIC SCIENTIFIC ENVIRONMENTS

2.1. Conceptual scheme of research on assessing the influence of scientists and selecting them as project partners

Let $V = \{ v_1, v_2, \ldots, v_t \}$ is the set of potential partners who can be involved in scientific projects. Potential project partners are scientists or academic staff members with scientific publications in journals indexed in bibliographic databases and working in scientific institutions or higher education institutions.

Each scientist is affiliated with one or several higher education institutions or research institutes. The development of any scientist occurs within the university's scientific space. During this process, each scientist accumulates information about their scientific achievements, scientific publications, citations of these publications by other scientists, and more. The information environment of each individual scientist is multi-layered and complex. This complexity arises from the fact that creative scientific activity is, by nature, creative. Over a certain period of scientific activity, a scientist may develop in one scientific direction and then switch to another, perhaps even in the opposite direction. At times, a scientist may work simultaneously in several scientific directions.

The development of a scientist in a specific scientific direction does not occur in isolation from the development of other scientists in the same field. Scientists publish scientific papers, cite each other's work, and may be co-authors on certain research projects. In other words, they collaborate in scientific research. It can be said that at a specific moment in scientific activity, a scientist develops in the university's academic-scientific space within the boundaries of a subject-specific scientific space. During this process, the scientist's own information environment is formed. The selection of a scientist for inclusion in a project space is based on:

1. Analysis of the influence of a specific scientist in the relevant subject-specific scientific space.

2. Analysis of the influence of a specific scientist in the university's academic-scientific space

3. Taking into account the dynamics of the scientist's publication activity, as recorded in the scientist's information space.

Figure 2.1 provides a general conceptual scheme of a scientist's place in the mentioned spaces.

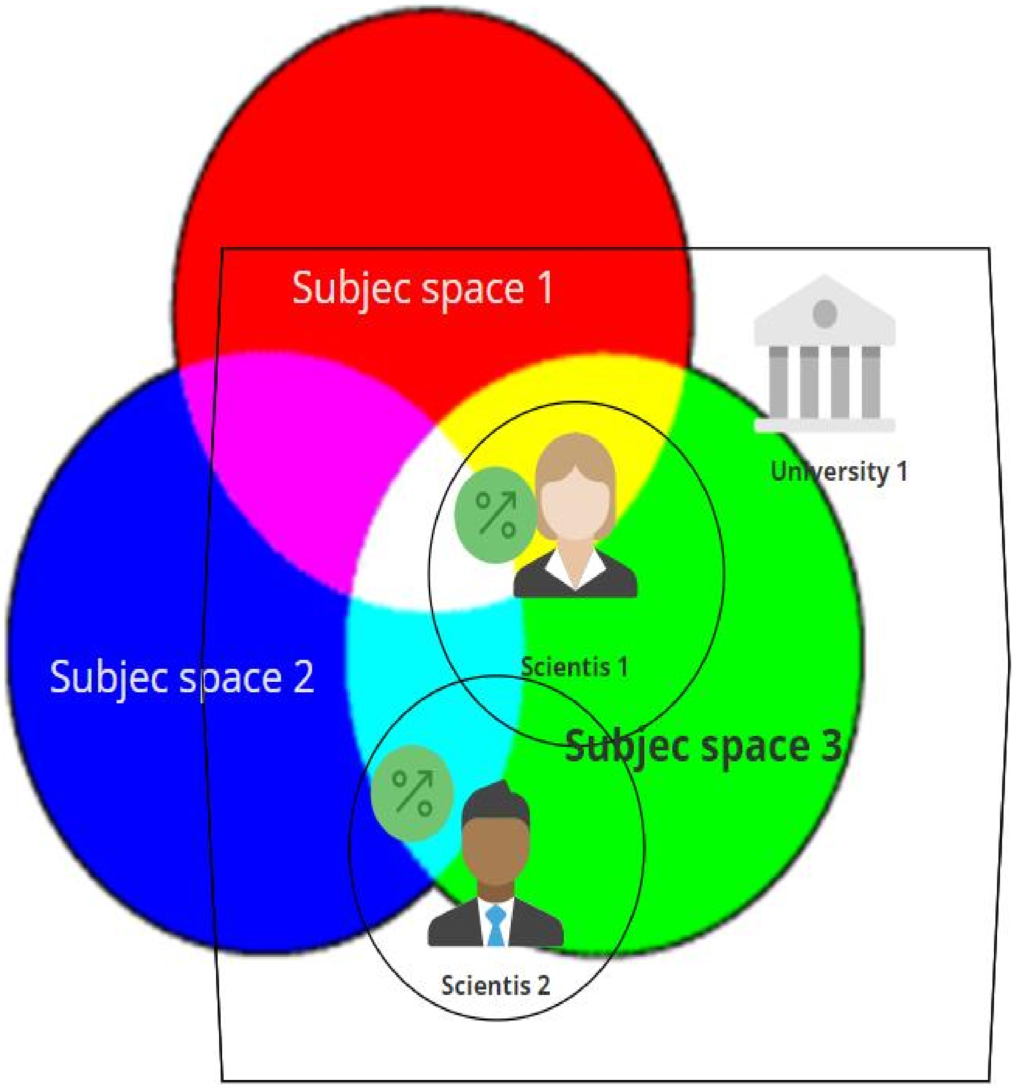

Figure. 2.1. Conceptual Diagram of the Scientist's Position in the Specified Spaces.

Based on this concept, the following definitions can be formulated:

A scientist is a specialist in one or several fields of science who uses scientific methods in their own or collective research, develops within their own informational environment, and as part of it, belongs to the corresponding subject-specific scientific space and the scientific space of a higher education institution or scientific institution with which they are affiliated.

The informational environment of a scientist includes identifiers that define their scientific activity at certain points in time, such as scientific publications, their citations, participation in scientific and educational projects, etc. This environment accumulates information about all their scientific activities.

The subject-specific scientific environment is the part of the scientist's information spaces that define the direction of their activities in a specific scientific field. Parts of subject-specific environments are formed from subject-specific scientific spaces, which consist of articles in a specific direction. A scientist's works can belong to several subject-specific scientific spaces at different times during their scientific activity, as their subject-specific scientific environment evolves over time. An important tool for assessing the relevance of a scientist's works to a subject-specific scientific space is to consider the age of that part of their informational environment related to that direction. For example, a scientist currently working in "Time Series Forecasting" may have previously published works in "Material Science". The older the publications in the latter field, the less they are related to the subject-specific scientific space of "Time Series Forecasting".

The university scientific space consists of scientists affiliated with a particular university. A scientist's personal research results influence the development of the university's scientific space and the university's overall rating.

The influence of a scientist is a quantitative indicator that evaluates a scientist's scientific activity and productivity over a certain period. This metric determines the impact of a scientist's research results in the respective subject-specific scientific space, compared to other scientists who belong to that space.

The project space includes scientists who are influential in respective subject-specific and university scientific spaces, formed according to the structure, theme, and objectives of scientific or educational projects. This discussion does not include potential subcontracting agreements that might be included in a project proposal for additional tasks by external organizations or employees. It only considers potential project executors who work in higher education institutions or scientific establishments and are proposed for scientific tasks within the respective project.

Every scientist is affiliated with a higher education institution or scientific establishment where they work. Generally, a scientist can have multiple affiliations. Let there

$$U = \{ u_1, u_2, \ldots, u_s \}$$

are institutions of higher education or scientific establishments where scientists

$$V = \{ v_1, v_2, \ldots, v_t \}$$

can work, then:

$$f : V \times U \to \{0,1\}. \tag{2.1.1}$$

If

$$V^q = \{ v_1^q, v_2^q, \ldots, v_{t_q}^q \}$$

is the set of scientists working in higher education institutions u_q, $q = \overline{1,s}$, $v_j^q \in V$, with $j = \overline{1,t_q}$, where is the total number of scientists working in higher education institutions u_q, $t_q < t$ and $V^q \subseteq V$.

The informational space of each scientist v_j, $j = \overline{1,t}$ can be represented as a tuple, the components of which are discrete time series that reflect changes in the indicators of a scientist's research activity, that is

$$I(v_j) = \left\langle \{p_w^j\}_{w=1}^{r_j}, \{C_w^j\}_{w=1}^{r_j}, \{\breve{C}_w^j\}_{w=1}^{r_j}, O^j \right\rangle \tag{2.1.2}$$

where p_w^j are the scientific publications published by scientist v_j, $w=\overline{1,r_j}$, r_j – is the number of all scientific publications published by scientist v_j. Thus, it's possible to identify sets of all scientific publications for each scientist

$$P^j = \left(p_1^j, p_2^j, \ldots, p_{r_j}^j\right), \ j=\overline{1,t} \tag{2.1.3}$$

$\left\{C_w^j\right\}_{w=1}^{r_j}$ are sequences of sets of publications citing the publications p_w^j of scientist v_j, $w=\overline{1,r_j}$.

$\left\{\breve{C}_w^j\right\}_{w=1}^{r_j}$ are sequences of sets of publications that cite the publications p_w^j of scientist v_j, $w=\overline{1,r_j}$.

Each publication belongs to a defined subject-specific scientific space. Accordingly, one can define the Cartesian product

$$\Lambda : P^j \times O \rightarrow \{0,1\}, \tag{2.1.4}$$

where $O=\{o_1, o_2, \ldots o_m\}$ is the set of subject-specific scientific spaces.

Therefore

$$O^j = \left\{o_i \middle| \Lambda\left(p_w^j, o_i\right) = 1, w=\overline{1,r_j}, j=\overline{1,t}\right\}, \ i=\overline{1,m}, \tag{2.1.5}$$

is the series of all subject-specific spaces recorded for the scientific publications of scientist v_j, $j=\overline{1,t}$ p_w^j.

Such a series O^j can be considered the subject-specific scientific environment of the scientist v_j.

The informational space can be expanded by including other components of a scientist's research activity into the tuple. This means it has the characteristic of expandability. However, for the task of selecting potential partners-executors for scientific projects, only these components are sufficient. Yet, for solving the task of choosing partners for scientific collaboration and organizing scientific projects, it is important to study the changes in a scientist's subject-specific scientific environment over time, as well as understand how the intensity of citations of a scientist's publications (i.e., their influence) changes over time. This is necessary so that at the time of deciding to include a scientist in a project, there is an adequate picture of their scientific activity over a certain period in a specific scientific direction.

Let

$$T = \left(T_1, T_2, \ldots, T_{N-1}, T_N\right)$$

are the moments when the scientific results of scientists are recorded, for example, at the end of each calendar year, T_N is the last moment in time when the results of scientific activities are recorded.

The informational space of each scientist v_j, $j = \overline{1,t}$ is time-dependent. Accordingly, it can be transformed into a tuple, the components of which are discrete time series that reflect the change in indicators of a scientist's research activity over time, that is

$$I\left(v_j, T^k\right) = \left\langle \left\{p_w^{j,k}\right\}_{w=1}^{r_j}, \left\{C_w^{j,k}\right\}_{w=1}^{r_j}, \left\{\breve{C}_w^{j,k}\right\}_{w=1}^{r_j}, O^{j,k} \right\rangle \tag{2.1.6}$$

where $p_w^{j,k}$ are the scientific publications published by scientist v_j and recorded at the moment T_k, $w = \overline{1, r_j}$, r_j is the number of all scientific publications published by scientist v_j at the moment T_k, $k = \overline{1,N}$,

$\left\{C_w^{j,k}\right\}_{w=1}^{r_j}$ are sequences of sets of publications citing the publications p_w^j of scientist v_j, $w = \overline{1, r_j}$ at the moment T_k, $k = \overline{1,N}$,

$\left\{\breve{C}_w^{j,k}\right\}_{w=1}^{r_j}$ are sequences of sets of publications that cite the publications p_w^j of scientist v_j $w = \overline{1, r_j}$ T_k, $k = \overline{1,N}$,

$O^{j,k}$ is the subject-specific scientific environment of scientist v_j at the moment T_k, $k = \overline{1,N}$.

It should be noted that the informational space of a scientist and their subject-specific scientific environment have an accumulative nature. That is, if up to a certain period T_g scientist had no scientific activity, then the set of their publications and sets of citations will be empty and accordingly the set of subject-specific scientific spaces will be empty. With the appearance of the first publications, these sets will begin to accumulate. If a scientist changes their scientific direction at some stage of their activity, from that period another direction will be included in their subject-specific scientific environment, and articles in this direction will be cited. Over time, the influence of the scientist will also change. This influence will be associated with a certain state of the subject-specific scientific environment of this scientist.

The informational space of a scientist and their subject-specific environment is accumulative. This means that as a scientist engages in research and publishes their findings, they gradually build up a body of work. This body of work, along with the citations it receives, constitutes their scientific footprint.

At the beginning of their career, a scientist might not have any publications or citations. During this phase, their subject-specific scientific environment is effectively empty. As the scientist begins to publish, they start to accumulate a set of publications and citations. This growing collection of work and references from others in their field forms the foundation of their subject-specific scientific environment.

If a scientist shifts their focus to a different area of research, this new direction becomes part of their subject-specific scientific environment. Publications in this new area start accumulating, and citations in this new field begin to reflect their changing interests and expertise.

Over time, the influence of a scientist changes. This influence is linked to the state of their subject-specific scientific environment. The more prolific and cited their work, the greater their influence tends to be. The scientist's impact can often be quantified through metrics like the number of publications, the number of citations and other bibliometric indicators. A scientist's move to a new field can also lead to interdisciplinary contributions, enriching both their original and new fields of study.

The scientist's influence and subject-specific environment are also shaped by their networks and collaborations with other researchers, which can lead to co-authored publications and shared citations.

In essence, the trajectory of a scientist's career and the development of their scientific environment are dynamic processes, shaped by their research activities, the evolution of their interests, and their interactions with the broader scientific community.

2.2. Model for evaluating the influence of scientists in the global citation network considering the age of scientific results

The sets $C_w^{j,k}$ and $\breve{C}_w^{j,k}$ for publications p_w^j of scientist v_j, $w=\overline{1,r_j}$, at time T_k, $k=\overline{1,N}$, form a network of citations of scientific publications. If all publishing scientists are considered, the network is global, otherwise it is local. All citations of some publications in others can be represented as a Markov matrix $C=\{c_{xy}\}_{x,y=1}^{R}$, where

$$R=\mathrm{card}\left(\sum_{j=1}^{t} r_j\right)$$

is the number of publications of scientists belonging to the citation network of scientific publications, and $c_{xy}\in[0,1]$ is the probability of transitioning from one state to another, determined by the number of citations of one publication in another. The matrix $C\geq 0$, where $\sum_{x=1}^{R} c_{xy}=1$, $y=\overline{1,R}$.

To find the influence of a scientist at time T_N, we use the PageRank method. However, to consider the changing influence over time, it's necessary to include the age of the citation in the calculation, which can affect the final score.

Let the coefficient corresponding to the weight of the publication p_x^j of scientist v_j, based on which the publication rank is determined at step q, be denoted as b_x^q. At step (q=0), coefficients for all scientific publications are equal and determined as $b_x^q = \frac{1}{R}$, $y = \overline{1,R}$. All other coefficients will be calculated iteratively using the formula:

$$b_x^{q+1} = \alpha C b_x^q + \frac{1-\alpha}{R}\mathbf{E} \qquad (2.2.1)$$

where E is the identity matrix, α is the damping factor, determining the probability of transitioning from one state (current publication) to another state (another publication).

For calculating coefficients b_x^q, a programmatic approach can be applied. Iteratively, we obtain that after a significant number of iterations, approximate values of the coefficients b_x^q will be calculated. For the iterative calculation of the coefficients b_x^q, the formula can be used, for $\forall \varepsilon > 0$

$$b_x^{q+1} = \sum_{y=1}^{R} b_y^q c_{yx} + \sum_{y=1}^{x-1} b_y^{q+1} c_{yx} \qquad (2.2.2)$$

if $\left|b_x^{q+1} - b_x^q\right| < \varepsilon$, then the calculation of coefficients b_x^q is terminated.

After reaching the condition $\left|b_x^{q+1} - b_x^q\right| < \varepsilon$, we obtain the vector of coefficients $(b_1, b_2, \ldots, b_R)$, where b_z is the value of the coefficient for the publication p_z^j $b_z \in [0,1]$, $z = \overline{1,R}$, $\sum_{z=1}^{R} b_z = 1$.

The scientific publication p_z^j, corresponding to the highest value b_z, receives the first rank. Then, the ranks of other publications are formed in descending order of the coefficients b_z, $z = \overline{1,R}$.

Using the ranking of scientific publications, we can determine the ranks or influence of scientists who are authors of these publications. Let the subject scientific environment of a certain scientist v_h include publications

$$P^h = \left(p_1^h, p_2^h, \ldots, p_{r_h}^h\right),$$

with ranks

$$G\left(P^h\right) = \left(g\left(p_1^h\right), g\left(p_2^h\right), \ldots, g\left(p_{r_h}^h\right)\right),$$

where $g\left(p_w^h\right) \in \mathbb{N}$ is the rank of publication p_w^h of scientist v_h, $w = \overline{1, r_h}$.

Then, the influence of scientist v_h is determined by the formula:

$$\gamma\left(v_h\right) = \frac{1}{r_h} \cdot \sum_{w=1}^{r_h} g\left(p_w^h\right) \tag{2.2.3}$$

where $\gamma\left(v_h\right)$ is the influence of scientist v_h.

We introduce changes to the PageRank method to consider the age of scientific publications and their affiliation to the relevant subject scientific environment. Initially, in the iterative method, determine the initial coefficients of scientific publications such that they correlate with their age. If the publication is recent, it receives more weight; if old, it receives less.

Publications $p_z^{j,N}$ published at time T_N are not considered, as they have not yet been cited by other publications, so their impact will be low. We consider publications that were published in periods

$$p_z^{j,N-1},\ p_z^{j,N-2},\ \ldots,\ p_z^{j,N-\pi}.$$

All publications published in time periods $T_{N-\pi-1}$, $T_{N-\pi-2}, \ldots$ will have a zero coefficient, π is the time period for calculating the weighted coefficient corresponding to the weight of the scientific publication.

If $\tilde{\pi} = \sum_{i=1}^{\pi} i$ then for the coefficients of scientific publications published in the period T_{N-1} at step q=0, we correlate the coefficient. For publications published in the period

T_{N-2} we correlate the coefficient $\bar{b}_x^q = \frac{\pi}{\tilde{\pi}} b_x^q$ and so on. For a scientific publication published in the period, we correlate the coefficient $\bar{b}_x^q = \frac{\pi - 1}{\tilde{\pi}} b_x^q$.

Accordingly, other coefficients will be calculated iteratively using the formula:

$$\bar{b}_x^{q+1} = \alpha C \bar{b}_x^q + \frac{1-\alpha}{R}\mathbf{E} \qquad (2.2.4)$$

where E is the identity matrix, α is the damping factor, stop condition $\left|\bar{b}_x^{q+1} - \bar{b}_x^q\right| < \varepsilon$

Introducing the aging coefficient of the publication increases the sensitivity of the PageRank method for evaluating the influence of scientists. As a result, we obtain the rank of a scientist using a similar method to the previous one. Determine the ranks of scientific publications of scientist using the weighted PageRank method as follows:

$$\bar{G}\left(P^h\right) = \left(\bar{g}\left(p_1^h\right), \bar{g}\left(p_2^h\right), \ldots, \bar{g}\left(p_{r_h}^h\right)\right) \qquad (2.2.5)$$

where $\bar{g}\left(p_w^h\right) \in \mathbb{N}$ is the rank of publication p_w^h of scientist v_h, $w = \overline{1, r_h}$

Then, the influence of scientist v_h is determined by the formula

$$\bar{\gamma}(v_h) = \frac{1}{r_h} \cdot \sum_{w=1}^{r_h} \bar{g}(p_w^h), \qquad (2.2.6)$$

where $\bar{\gamma}(v_h)$ is the influence of scientist v_h, obtained using the weighted PageRank method.

Considering that for solving the problem of selecting a scientist as an executor or partner of a scientific project, not only the productivity or influence of a potential partner-executor is important, but also his productivity within a specific subject scientific environment.

Identify for each scientist the sets consisting of articles that belong to each separate subject scientific space. The subject scientific environment of a scientist includes those spaces to which his scientific publications belong, and it is part of the scientist's information space at time T_k:

$$O^{j,k} = \left\{ o_i \middle| \Lambda\left(p_w^{j,k}, o_i\right) = 1, w = \overline{1, r_j}, j = \overline{1,t} \right\} \tag{2.2.6}$$

We form lists of scientific publications for each of the subject scientific spaces to which his publications belong:

$$P_i^{j,k} = \left\{ p_w^{j,k} \middle| \Lambda\left(p_w^{j,k}, o_i\right) = 1, w = \overline{1, r_j}, j = \overline{1,t} \right\},\ i = \overline{1,m} \tag{2.2.7}$$

where $P_i^{j,k}$ is the set of scientific publications of scientists at time T_k, belonging to the subject scientific space o_i, $card\left(P_i^{j,k}\right) \le r_j$.

Then, the influence of scientist in a certain subject scientific environment is determined by the formulas:

$$\gamma_f\left(v_h\right) = \frac{\sum_{p_w^{h,k} \in P_f^{h,k}} g\left(p_w^{h,k}\right)}{card\left(P_f^{h,k}\right)} \tag{2.2.8}$$

where $\gamma_f\left(v_h\right)$ is the influence of scientist v_h , obtained using the PageRank method in the subject scientific environment o_f ,

$$\overline{\gamma}_f\left(v_h\right) = \frac{\sum_{p_w^{h,k} \in P_f^{h,k}} \overline{g}\left(p_w^{h,k}\right)}{card\left(P_f^{h,k}\right)} \tag{2.2.9}$$

where $\overline{\gamma}_f\left(v_h\right)$ is the influence of scientist v_h, obtained using the weighted PageRank method in the subject scientific environment o_f.

As each scientist is affiliated with one or several universities, he is an integral part of their scientific environments. Let's analyze the influence of a certain scientist in the university's scientific environment.

Let

$$U = \{ u_1, u_2, \ldots, u_s \}$$

is the set of higher education institutions or scientific institutions where scientists

$$V = \{ v_1, v_2, \ldots, v_t \}$$

can work, then f is a mapping of affiliation.

$$f : V \times U \to \{0,1\}. \quad (2.2.10)$$

If

$$V^q = \{ v_1^q, v_2^q, \ldots, v_{t_q}^q \}$$

is the set of scientists working in higher education institutions $q = \overline{1,s}$, $v_j^q \in V$, $j = \overline{1,t_q}$, t_q, u_q is the number of scientists working in the educational institution u_q, $t_q < t$. Moreover, $V^q \subseteq V$. The information space of each scientist v_j, $j = \overline{1,t}$, can be represented as a tuple, the components of which are discrete time series reflecting the change in indicators of the scientist's scientific activity, that is,

$$I(v_j) = \left\langle \{p_w^j\}_{w=1}^{r_j}, \{C_w^j\}_{w=1}^{r_j}, \{\breve{C}_w^j\}_{w=1}^{r_j}, O^j \right\rangle. \quad (2.2.11)$$

where p_w^j are the scientific publications published by scientist v_j, $w = \overline{1,r_j}$, r_j is the total number of scientific publications published by scientist v_j. Therefore, we can identify the sets of all scientific publications for each scientist

$$P^j = (p_1^j, p_2^j, \ldots, p_{r_j}^j), \; j = \overline{1,t}, \quad (2.2.12)$$

$\{C_w^j\}_{w=1}^{r_j}$ is the sequence of sets of publications in which the publications of scientist are cited, v_j, $w = \overline{1,r_j}$.

$\{\breve{C}_w^j\}_{w=1}^{r_j}$ is the sequence of sets of publications that cite the publications of scientist v_j, $w = \overline{1,r_j}$.

Each publication belongs to a defined subject scientific space. Accordingly, a Cartesian product can be defined

$$\Lambda : P^j \times O \to \{0,1\}, \quad (2.2.13)$$

where $O=\{o_1,o_2,\dots o_m\}$ is the set of subject scientific spaces.

Accordingly

$$O^j=\left\{o_i\left|\Lambda\left(p_w^j,o_i\right)=1,w=\overline{1,r_j},j=\overline{1,t}\right.\right\},\ i=\overline{1,m}. \qquad (2.2.14)$$

is the series of all subject spaces recorded for the scientific publications of scientist v_j, $j=\overline{1,t}$ p_w^j.

Such a series O^j can be considered the subject scientific environment of scientist v_j. Then, for each university $u_q\in U$, $q=\overline{1,s}$, we can identify the set of publications ${}^qP=\left({}^qp_1,{}^qp_2,\dots.{}^qp_{{}^qh}\right)$, where ${}^qh$ is the number of publications published by scientists affiliated with $u_q\in U$. This set can be found as the union of the publication sets of scientists, that is

$${}^qP=\bigcup_{j=1}^{r_j}P_j,q=\overline{1,s}. \qquad (2.2.15)$$

The information space of each educational institution u_q, $q=\overline{1,s}$, can be represented as a tuple, the components of which are discrete time series reflecting the change in indicators of the scientists' scientific activity, that is

$$I\left(u_q\right)=\left\langle\left\{{}^qp_w\right\}_{w=1}^{h_q},\left\{{}^qC_w\right\}_{w=1}^{h_q},\left\{{}^q\breve{C}_w\right\}_{w=1}^{h_q},{}^qO\right\rangle, \qquad (2.2.16)$$

where ${}^qp_w$ are the scientific publications published by scientists affiliated with university u_q, $w=\overline{1,h_q}$, h_q is the total number of scientific publications published by scientists affiliated with university u_q.

$\left\{{}^qC_w\right\}_{w=1}^{h_q}$ is the sequence of sets of publications ${}^qp_w$ in which the publications published by scientists affiliated with university are cited, u_q, $w=\overline{1,h_q}$.

$\left\{{}^{q}\breve{C}_{w}\right\}_{w=1}^{h_q}$ is the sequence of sets of publications ${}^{q}p_{w}$ that cite the publications published by scientists affiliated with university u_q, $w=\overline{1,h_q}$.

Each publication belongs to a defined subject scientific space. Accordingly, a Cartesian product can be defined

$$\Lambda : {}^{q}P \times O \to \{0,1\}, \qquad (2.2.17)$$

where $O=\{o_1,o_2,\ldots o_m\}$ is the set of subject scientific spaces.

Accordingly

$$ {}^{q}O = \left\{ o_i \middle| \Lambda\left({}^{q}p_w, o_i\right)=1, w=\overline{1,h_q}, j=\overline{1,t} \right\},\ i=\overline{1,m}, \qquad (2.2.18)$$

is the series of all subject spaces recorded for the scientific publications published by scientists affiliated with university u_q, $w=\overline{1,h_q}$.

Such a series ${}^{q}O$ can be considered the subject scientific environment of university u_q $q=\overline{1,s}$.

We form lists of scientific publications of the university for each of the subject scientific spaces to which its publications belong:

$$ {}^{q}P_i^k = \left\{ {}^{q}p_w^k \middle| \Lambda\left({}^{q}p_w^k, o_i\right)=1, w=\overline{1,h_q}, j=\overline{1,t} \right\},\ i=\overline{1,m}, \qquad (2.2.19)$$

where ${}^{q}P_i^k$ is the set of scientific publications of scientists affiliated with university u_q at time T_k, belonging to the subject scientific space , o_i, $\operatorname{card}\left({}^{q}P_i^k\right) \le h_q$.

Then, the influence of university in a certain subject scientific v_h environment o_f is determined by the formulas:

$$\gamma_f\left(u_q\right) = \frac{\sum_{{}^{q}p_w^k \in {}^{q}P_f^k} g\left({}^{q}p_w^k\right)}{\operatorname{card}\left({}^{q}P_f^k\right)}, \qquad (2.2.20)$$

where $\gamma_f\left(u_q\right)$ is the influence of university in the subject scientific environment o_f.

The model for evaluating the influence of scientists in the global citation network considering the age of scientific results provide a more dynamic and time-sensitive evaluation of a scientist's influence in the global citation network, offering a comprehensive view that goes beyond simple citation counts. It would be particularly useful in understanding not just the scale of a scientist's impact, but also its evolution and current relevance.

2.3. Method of forming subject scientific environments

The formation of subject scientific environments requires a systematic approach that ensures cohesion, efficiency, and innovative potential of a scientific group or organization. A subject scientific environment focuses on a specific field of science, bringing together researchers, resources, and knowledge to achieve common goals.

The stages of forming a subject scientific environment can be outlined as follows:

Defining research requirements. Before forming a team for scientific research, it is necessary to formulate both functional and non-functional requirements of the project. One of these is defining the key direction of the research. Let $O = \{o_1, o_2, \ldots, o_m\}$ is the set of subject scientific spaces; then the research will belong to one or several of these scientific spaces. Let denote the degrees of affiliation of the research to each of the subject scientific spaces as

$$\mu(O) = \{\mu(o_1), \mu(o_2), \ldots, \mu(o_m)\},$$

where $0 \le \mu(o_j) \le 1$ and $j = \overline{1,m}$. The key direction of research will be the subject space o_{j^*}, where

$$j^* = \arg\max_{j=\overline{1,m}} (\mu(o_1), \mu(o_2), \ldots, \mu(o_m)).$$

This stage also includes selecting the specialization of the scientific environment, based on the relevance and development potential of a particular scientific field.

The second stage involves analyzing needs and resources. This includes determining needs for equipment, funding, human resources, and assessing available resources and opportunities for their involvement. This stage is not part of the method for forming subject scientific environments. The result of the second stage is the detailing of the project in the form of work packages. Let a project consist of work packages $B = \{b_1, b_2, \ldots, b_p\}$ where p is the number of work packages in the project. Then, for each of the work packages, there is a need to choose an executor. For this, the affiliation of each project package to one or several project spaces is determined $\mu(B) = \{\mu(b_1), \mu(b_2), \ldots, \mu(b_p)\}$.

Requirements for the executors of each of the work packages are also identified. For the method of forming subject scientific environments, the number of scientists needed to execute each of the project's work packages and the research direction is important. Let denote as k_l the number of executors needed for the project work package b_l, $l = \overline{1, p}$

The third stage involves attracting qualified scientists. This includes searching for and selecting scientists with relevant expertise and experience. In the set $V = \{v_1, v_2, \ldots, v_t\}$, a subset $W(b_l) \subset V$, $l = \overline{1, p}$. of potential executors of the package needs to be identified. The method of choosing executors requires further development.

The third stage also emphasizes the importance of creating conditions to attract young talents and students.

The fourth stage is the formation of infrastructure: establishing laboratory and research infrastructure and implementing modern IT solutions for research and communication.

This includes the development and equipping of high-quality laboratory facilities with necessary equipment and technologies for research. It may include specialized equipment, such as microscopes, spectrophotometers, laboratory reactors, etc., as well as appropriate laboratory apparatus and materials.

Integrating modern information technologies into the research process involves using software for data collection and analysis, computational resources for modeling and simulations, and implementing tools for effective information exchange and collaboration among researchers, which may include tools for video conferencing, collaborative document work, etc.

The final fifth stage involves developing collaboration and partnerships. This stage includes:

Establishing cooperation with other scientific institutions, universities, and the industrial sector.

1. Participating in international scientific projects and programs.
2. Stimulating innovation and research.
3. Ensuring conditions for innovative research.
4. Supporting scientific research and publications.
5. Organizing scientific activities and knowledge exchange.
6. Conducting scientific conferences, seminars, and workshops.
7. Developing a system for exchanging knowledge and experience among members of the environment.

Key aspects of the success of a subject scientific environment: Uniting experts from different scientific fields for a comprehensive approach to research. Creating conditions for the development of new ideas and technologies. The ability to adapt to changes in the scientific environment and emerging trends. Proper planning, resource management, and coordination of activities.

Forming a subject scientific environment requires a balanced approach, including strategic planning, engaging competent scientists, creating a favorable infrastructure, and developing cooperation. Such an approach ensures a dynamic and productive scientific environment capable of achieving significant results in its field.

2.4. Analysis of factors influencing the selection of potential executors for scientific projects

The dynamic development of the scientific space of any country is an extremely important factor that contributes to increasing its prestige, developing the economy, and the emergence of new technologies in various spheres of human activity. It is an important task.

The selection of executors for scientific projects is a critical stage that determines the quality and success of the research. Various factors influence this process, and they must be carefully analyzed to ensure optimal selection.

The main factors influencing the choice of executors are listed in Table 2.

Table 2. Factors for Choosing Executors

Indicator	Factor
I_1	Scientific competence and experience.
I_2	Qualifications and specialization of candidates.
I_3	Previous experience in similar projects.
I_4	Publications, patents, and other achievements in the relevant field.
I_5	Collaboration and teamwork skills:
I_6	Ability to interact effectively in a team.
I_7	Experience in multidisciplinary and international teams.
I_8	Communication skills and ability to work in a group.
I_9	Resources and availability.
I_{10}	Availability of necessary laboratories, equipment, and other resources.
I_{11}	Financial capabilities for participating in the project.
I_{12}	Time availability of candidates to dedicate to the project.
I_{13}	Motivation and commitment to the project:
I_{14}	Personal interest in the research topic.
I_{15}	Willingness for long-term cooperation.

I_{16}	Commitment to achieving the project's goals.
I_{17}	Ethical standards and professional behavior:
I_{18}	Adherence to high ethical norms in scientific work.
I_{19}	Professionalism and responsible attitude to work.
I_{20}	Reputation in the scientific community.

Analyzing these factors allows for the selection of executors who best meet the requirements of the project, contribute to effective teamwork, and maximize the potential for achieving research goals. Considering the entire spectrum of criteria ensures the formation of a strong, competent, and motivated team capable of effectively implementing the scientific project

Let us assume that

$$G = \{G_1, G_2, \ldots, G_n\}$$

is the set of scientific projects, n is the number of projects. The problem is choosing executors for these projects. Assume that

$$V = \{v_1, v_2, \ldots, v_p\}$$

is the set of potential partners that can be involved in implementing the projects from set G. We believe that potential partners are individual subjects of scientific activity who have articles in the journals indexed in scientometric bases and work at a scientific institution or institution of higher education. Higher education institutions and research institutes are collective subjects of scientific activity. In addition, the productivity of individual subjects of scientific activity, respectively, affects the productivity of collective subjects of scientific activity in general. This problem does not involve a possible subcontractor agreement that may be included in the project application to perform additional tasks by third parties or employees.The structure of projects implies the availability of working packages

$$G_i = \{g_1^i, g_2^i, \ldots, g_{r_i}^i\},$$

r_i is the number of working packages G_i, $i=\overline{1,n}$ .The execution of work packages has time limits and is linked to the Gantt chart of the entire project. Each work package is related to the results or complements other project packages and relates to a specific task or tasks (scientific, administrative, technical, educational, etc.). For each package, it is necessary to choose competent executors who will perform it at a high level. The overall assessment of the quality of the entire project depends on it. That is, the problem is to find a set of potential executors or subjects of scientific activity for each working package of each project:

$$\Theta(g_j^i)=\left\{v_d\in V\,\middle|\,(v_d,g_j^i)\in Q^i\right\},Q^i\subset V\times G_i\,, \tag{2.4.1}$$

$$i=\overline{1,n},\, j=\overline{1,r_i},\, d=\overline{1,t}\,, \tag{2.4.2}$$

where $\Theta(g_j^i)$ is the set of executors of the j-th work package of i-th project. The categories of executors are determined by the features and necessary project outcomes. However, for scientific and educational projects, it is possible to summarize them into the following five categories:

1. Project Leadership: This group encompasses the leaders of projects whose primary responsibilities are to ensure the on-time and efficient completion of project tasks and to select the right individuals or teams for project execution. The leader in charge of identifying potential collaborators assumes the role of the key decision-maker.

2. Administrative Staff: This group comprises the executive personnel or leaders of the entity engaged in scientific activities. Their duties include the formal signing of agreements, managing the flow of documentation, and facilitating the documentary coordination of collaborations with other entities and stakeholders. For project team selection, the administrative roles are assigned to seasoned employees with a track record of successful project implementation.

3. Technical Experts: This category includes IT professionals like programmers and system administrators, responsible for maintaining servers, equipment, and specialized apparatuses as required by the project. The selection of these individuals is

based on their relevant competencies, certifications, experience, and other professional qualifications.

4. Educators and Instructors: Pertaining mainly to educational initiatives, this segment is composed of certified academic and teaching personnel from the scientific entity. Their recruitment is based on the project's objectives and specific tasks, proficiency with educational platforms, and possession of necessary qualifications.

5. Research Personnel: While the staffing of the aforementioned roles can be relatively straightforward given the clear competencies required, selecting researchers or individual scientific contributors is more intricate. It necessitates an evaluation of their scientific productivity, which directly influences the project's overall quality. Researchers are crucial for the formal documentation, investigation, lab testing, and summarization of findings. The selection of researchers is tailored to the specific requirements of each project task and must align with the scientific domain in which a potential candidate is active.

In essence, the selection of partners or project executors for scientific or educational endeavors hinges on the nature of the project tasks, the categories of participants required, their skill sets, and their past and projected performance metrics. When it comes to individual scientific contributors, this selection process is complex and multi-tiered. The paper suggests an individual-centric approach to selecting scientific collaborators (or project executors), which accounts for the project's framework and integrates both historical and predictive assessments of their scientific output.

2.5. Individual-oriented method for selecting partners for scientific projects based on the analysis of subject-specific scientific environments

The dynamic development of the scientific space of any country is an extremely important factor, which contributes to increasing its prestige, developing the economy, and the emergence of new technologies in various spheres of human activity. It is an important task.

Let's analyze the collaboration model in scientific collectives, where partner entities (universities, research institutes, commercial organizations) initiate joint work on scientific projects, each of which has a specific theme. Within each project, participating organizations perform defined roles, which can include duties as an executor or coordinator of the research. When modeling the information system of collaboration, it is important to consider the intensity of each partner's participation in the project. For example, in a specific project, a partner may be involved at 20%, while in another — at 50%, possibly taking on a coordinating role. The level of partner participation often correlates with the amount of funding received within the project, which, in turn, can affect the volume of work carried out and the involvement of additional resources. Such interaction can be represented in the form of an undirected graph, where the vertices are projects and partners, and the edges are weight coefficients reflecting the degree of participation.

Conceptually, the choice of a partner involves the analysis of four main components that must be integrated when forming a consortium (Fig. 2.2):

• Partner typology.

• Strategic goals of the project.

• Models of assimilation and application of knowledge.

• Factors determining the choice of a partner.

Substantial factors that can influence the mechanism of communication and collaboration between partners may include:

1. Geographical location of partners, which may require active use of digital communication channels.

2. Unique competencies of each partner, which are critical for achieving the project's goals.

3. Legal frameworks of partners' activities, influencing decision-making processes and management aspects.

4. Organizational hierarchy, which can provide support for trust and protection of common interests.

The individual-oriented method for selecting partners for scientific projects entails a detailed analysis of specific scientific environments and selecting partners based on individual characteristics, competencies, and contributions to the relevant scientific field.

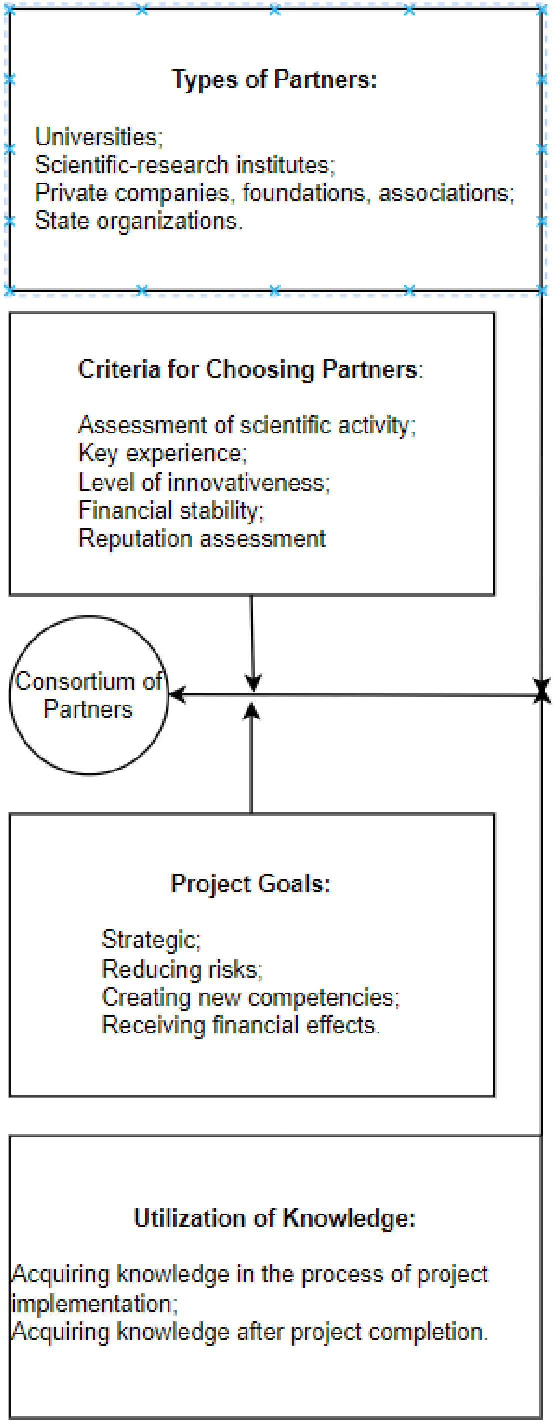

Figure 2.2 Components of Partner Selection for a Scientific Consortium

The main steps of the method:

1. Defining project specifics: Identify the key aspects of the scientific project, including its goals, research area, and skill and knowledge requirements.

2. Analyzing scientific environments: Analyze scientific environments, identify leading experts, research groups, and institutions specializing in relevant directions.

3. Evaluating individual competencies: Assess potential partners in terms of their individual achievements, scientific experience, publications, and projects they have implemented.

4. Checking the compatibility of goals and interests: Determine how well the goals and interests of potential partners match the goals of the scientific project.

5. Evaluating the potential for collaboration: Assess how well candidates can collaborate in a team, their readiness for multidisciplinary research, and interaction with other project participants.

Key advantages of the method:

• High accuracy in selecting partners thanks to detailed analysis of their competencies and experience.

• Ensuring high specialization and competence within the scientific project.

• Forming effective teams based on complementary competencies.

• Ability to adapt to specific project requirements thanks to an individual approach to selecting each partner.

• Efficient use of scientific and financial resources thanks to a precisely selected team of experts.

The application of the individual-oriented method allows for the formation of strong scientific teams with high potential for successful implementation of complex scientific projects, taking into account the unique requirements and goals of each specific research. Designate as

$$\varphi_k^j = \Phi(v_j, \tau_k)$$

the estimate of productivity of an individual subject of scientific activity v_j at moment $j=\overline{1,t}, k=\overline{1,T}$. A performance estimate is an aggregated indicator of the effectiveness of a subject of scientific activity, which may include the H-index in the relevant scientometric databases, the number of articles, the number of citations, etc.

Performance estimates of each individual subject of scientific activity are recorded at certain moments of time (monthly, quarterly, annually). Then performance is represented by discrete time series:

$$\left(\varphi_1^j, \varphi_2^j, \ldots, \varphi_T^j\right),\ j=\overline{1,t}. \tag{2.5.1}$$

Assume that

$$P=\{P_1, P_2, \ldots, P_Z\}$$

is the set of scientific subject spaces, Z is the number of spaces. Each project can be put in line with scientific subject space, X: G→P.

Besides, each work package can be put in line with a certain part of the scientific subject space, which corresponds to the subject matter of local problems of the package. Assume that

$$H=\{H_1, H_2, \ldots, H_Y\}$$

is the set of collective subjects of scientific activity, in this case,

$$\forall v \in V, \exists z \in [1, Z], v \in P_z, \tag{2.5.2}$$

$$\forall v \in V, \exists y \in [1, Y], v \in H_y, \tag{2.5.3}$$

Then assume that

$$P^z = \left\{ j \middle| j \in [1,t], v_j \in P_z \right\}, \tag{2.5.4}$$

$$H^y = \left\{ j \middle| j \in [1,t], v_j \in H_y \right\}, \tag{2.5.5}$$

where P^z is the set of numbers of individual subjects of scientific activity that belong to the corresponding scientific subject space P_z. H^y is the set of numbers of individual subjects of scientific activity that belong to the corresponding collective subject of scientific activity $y=\overline{1,Y}, z=\overline{1,Z}$

When selecting project executives, it is sometimes necessary to fix the region from which partners are selected. For example, in the projects of the Erasmus+ program, it is important that partner universities should not be repre-sented by one region. It is important that the consortium of partners should include universities from different regions of the country. Given this and the corresponding scientific subject spaces, it is possible to generate the time series of productivity, which includes only the required individual subjects of scientific activity:

$$\left(\varphi_1^j, \varphi_2^j, \ldots, \varphi_T^j\right), j \in P^z \cap H^y \quad (2.5.6)$$

For fixed working place z∈[1, Z] and y∈[1, Y]. If a working place of a potential executor is not important, $j \in P^z$.

Assessment of productivity of a subject of scientific activity, which was recorded recently should have more weight than the one that was recorded long ago. Accordingly, to calculate the quantitative estimates of productivity for each individual subject, it is proposed to apply a linearly weighed sliding mean from the following formula:

$$\varphi_{T+1}^j = \left(\sum_{m=1}^{p} m\right)^{-1} \bullet \left(\sum_{d=1}^{p} (p-d+1) \bullet \varphi_{T-d+1}^j\right), j \in P^z \cap H^y \quad (2.5.7)$$

φ_{T+1}^j is the productivity forecast with horizon 1 for the in-dividual subject of scientific activity v_j, $j \in P^z \cap H^y$,p is the parameter that determines the pre-history period for forecast calculation.

Then the optimal individual subject of scientific activity j* for project implementation in the area of scientific subject space P^z, which is a staff member of the collective subject of scientific activity H^y is determined from the following formula:

$$j^* = \underset{j \in P^z \cap H^y, \Delta_{T+1}^j > 0}{\arg\max} \left(\varphi_{T+1}^j\right), \quad (2.5.8)$$

where $\Delta_{T+1}^j = \varphi_{T+1}^j - \varphi_T^j$ is the increment in productivity of the individual subject of scientific activity. The subjects, for which an increment is negative, are removed from consideration.

If a potential executor who has proved to be the leader by this criterion does not agree to join the team of executors, the participation offer goes to the potential executor who is the nest by rating. Thus, it is possible to make a sequence of individual subjects of scientific activity with advantages according to criterion (2.5.7):

$$v_{j_1} \succ v_{j_2} \succ \ldots \succ v_{j_r}\ v_{j_q} \in V,\ j_q=\{1, 2, ..., t\}.$$

If it is necessary to involve a collective subject of scientific activity (university, institute, department, faculty, etc.) to execute a relevant work package, the potential executor is the subject in which v_j works.

If a project manager, in addition to the subjects' productivity of scientific activity, has an additional list of criteria for the selection of executors, it is necessary to solve the multi-critical problem of choice.For each working package of each project, a list of criteria for the selection of potential executors is generated. The vector of estimates by criteria has the form of:

$$f^{ij}(v_d) = \left(f_1^{ij}(v_d), f_2^{ij}(v_d), ..., f_{N_{ij}}^{ij}(v_d)\right). \quad (2.5.9)$$

N_{ij} is the number of criteria of an estimation of potential executors of work packages g_j^i of projects, $G_i, j = \overline{1, r_i}, i = \overline{1, n}, f^{ij}(v_d)$ is the vector of estimates for potential executor v_d, $d = \overline{1, t}$.

Maximize all criteria, then state the problem:

$$\sum_{k=1}^{N_{ij}} \alpha_k f_k^{ij}(v) \to \max, \quad (2.5.10)$$

$$\sum_{k=1}^{N_{ij}} \alpha_k = 1, \quad (2.5.11)$$

$$V^{ij} = \left\{ v \in V \middle| y_u^{ij}(v) > p_u^{ij}, u = \overline{1, z}, j = \overline{1, r_i}, i = \overline{1, n} \right\}, \quad (2.5.12)$$

$$v \in V^{ij}, V^{ij} \subset V, \quad (2.5.13)$$

where z_{ij} is the number of threshold values for vector-function of restrictions $y_u^{ij}(v)$, α_k is the value of criterion $f_k^{ij}(v)$, $k = \overline{1, N_{ij}}, j = \overline{1, r_i}, i = \overline{1, n}.$

Use the method of expert evaluation. Assign the set of experts $E=\{E_1, E_2, ..., E_s\}$, s is the number of experts. Experts form the incomplete profile of advantages of potential exec-utors based on the described criteria. Designate as $\xi^{ij}_{c,b}$ the average frequency of appearance of each advantage among potential project executors v_c and v_b, $c \neq b$, $v_c \in V$, $v_b \in V$. Then matrices of advantages Λ^{ij} take the form

$$\Lambda^{ij} = \left\{ \xi^{ij}_{q,w} \right\}^{t}_{q,w=1}, j = \overline{1, r_i}, i = \overline{1, n}. \quad (2.5.14)$$

Based on the matrix of pair-wise comparisons Λ^{ij} for each package g^i_j of project G_i, we will generate a collective decision in the form of an orderly list of potential project executors. Using the method for the formation of collective decision, according to the matrix of pair-wise comparisons, it is possible to obtain an orderly list of potential executors for each package g^i_j of Project G_i: $v^{ij}_{j_1} \succ v^{ij}_{j_2} \succ ... \succ v^{ij}_{j_t}, j_q \in \{1,2,...,t\}, v^{ij}_{j_q} \in V^{ij}, q = \overline{1,t}$. Next, a project manager selects specific executors and forms a working group for each working package. The project structure and dynamics of scientific productivity of executors in relevant subject spaces are an important aspect of the choice of subjects of scientific activity, which affects the project productivity in general.

Individual-oriented selection method focuses on forming strong scientific teams by considering unique requirements and goals of each project. The method uses a variety of metrics to estimate the productivity of individual scientific contributors. Productivity estimates are recorded over time, allowing for the observation of trends and patterns. Projects are aligned with specific scientific subject spaces, facilitating targeted selection of executors.

This approach represents a sophisticated blend of quantitative analysis, strategic alignment, and expert evaluation. It's designed to optimize the selection process of project executors, ensuring that the most suitable individuals and institutions are chosen based on a comprehensive evaluation of their scientific expertise, current productivity, and alignment with the project's objectives.

Conclusions for chapter 2

1. An analysis of factors influencing the selection of potential executors for scientific projects has been conducted. The analysis revealed that an extremely important factor in choosing partners-executors for a scientific project is the correspondence of the executors' experience and competencies to the research direction. It is proposed to determine this correspondence by considering the affiliation of the scientific-research project and the researcher to certain subject-specific scientific environments. A method for forming subject-specific scientific environments for researchers, scientific institutions, and scientific projects is proposed. The main factors determining the choice of potential executors for scientific and educational projects were analyzed. The functional responsibilities of project participants were described in accordance with the project structure, based on which the problem of choosing scientific partners was solved. The specific features of the selection of project executors of different categories were emphasized. It was indicated that the selection of researchers is associated with difficulties, which should take into account the assessment of the productivity of scientific activity over a certain period.

2. A conceptual scheme of research for assessing the influence of scientists and their selection as partners for a scientific project is described. Within this scheme, a mathematical model for assessing the influence of scientists in the global citation network is considered, taking into account the age of scientific results.

3. The development of an individually-oriented method for selecting partners for scientific projects based on the analysis of subject-specific scientific environments allows for effectively managing the executors of a scientific-research project and their correspondence to the work packages of the scientific-research project. The main advantages of this method include high accuracy in selecting partners thanks to a detailed analysis of their competencies and experience, allowing the formation of effective teams based on complementary competencies, capable of adapting to the specific requirements of the project thanks to an individual approach to selecting each partner.

4. The significance of the project structure and dynamics of scientific productivity in relevant subject spaces for the choice of subjects of scientific activity were established. The individually-oriented method for choosing scientific partners was devised, considering the project structure: the choice of executors for each project package separately, in accordance with the estimates of the performance of executors in subject spaces that correspond to the area of the package. The use of the devised method allows reducing the subjective impact on making a decision to choose project executors, guided only by open sources of information with the performance of potential performers, their competence, etc. This approach is rational in terms of achieving maximum quality and effectiveness of the implemented scientific project.

CHAPTER 3. INFORMATION TECHNOLOGY FOR SELECTING PARTNERS OF SCIENTIFIC PROJECTS WITHIN SUBJECT-SPECIFIC SCIENTIFIC ENVIRONMENTS

3.1. Technical and software provision of information technology for selecting scientific partners

Let W_s is a certain subject-specific scientific space $W_s \subset W$, W is the general educational-scientific space. Let

$$G = \{G_1, G_2, \ldots, G_n\}$$

be the set of scientific projects. The structure of projects implies the availability of working packages

$$G_i = \{g_1^i, g_2^i, \ldots, g_{r_i}^i\}$$

is the number of working packages $i = \overline{1,n}$.

Let

$$V = \{v_1, v_2, \ldots, v_p\}$$

is the set of all scientists that can be involved in implementing the projects from set G, p is the number of scientists.

Let

$$Q = \{q_1, q_2, \ldots, q_m\}$$

is the set of publications published by scientists from set V, m is the number of publications.

The information technology for selecting scientific partners should provide the implementation of models and methods for collecting, storing, and transforming these data in order to obtain information about potential partners for each of the work packages of each project. Formally, the output data of the information technology can be described as an orderd list of potential executors for each package g_j^i of each project G_i: $v_{j_1}^{ij} \succ v_{j_2}^{ij} \succ ... \succ v_{j_t}^{ij}, j_q \in \{1,2,...,t\}, v_{j_q}^{ij} \in V^{ij}, q = \overline{1,t}$.

Technical and software provision for selecting scientific partners in the field of information technology may include several key components:

Algorithms that implement the individually-oriented method for selecting partners of scientific projects based on the analysis of subject-specific scientific environments and the method of forming subject-specific scientific environments proposed in Chapter 2. These algorithms should be adapted for analyzing large volumes of data. The main goal of the developed algorithms is to identify potential partners with similar scientific interests or complement research teams.

Software implementation of the developed algorithms. Implement the algorithms as separate modules of the information system. It should be noted that for specific tasks, numerous libraries and frameworks exist, such as libraries for machine learning and data processing, and frameworks for developing web applications.

Databases and Database Management Systems designed for storing and organizing information about potential partners, their research interests, publications, and data about projects and their work packages and requirements for the executors of these packages. DBMS allow easy insertion, updating, deletion, and querying of data, making the process of searching and analyzing potential partners more efficient. With query functions, complex data analysis can be performed to find a match between project needs and the qualifications of potential partners. DBMS ensure the proper level of security as the information technology is intended for processing personal data. The choice of a specific DBMS and its configuration depends on the volume and complexity of the data, as well as on the integration with other modules of the information system and will be described in the next chapter.

Integration with scientific databases and platforms is an important part of systems for selecting scientific partners. It provides automated access to up-to-date information about researchers, their publications, and projects. The information system can integrate with various scientific databases, such as Scopus, PubMed, ORCID, Google Scholar. These platforms provide a wide range of information about scientific research, including publications, citations, co-authorship, etc. Using the API of these scientometric databases can be used for effective data extraction. The integrated system can automatically update profiles of potential partners with information about their latest publications and research projects. This allows system users to receive the most up-to-date information about the scientific achievements and interests of potential partners. Integration with databases can also include access to the full texts of scientific articles, allowing users to delve deeper into the work of potential partners. Metadata from scientific publications, such as keywords, abstracts, co-authors, can be analyzed to determine connections and common interests among researchers.

User Interfaces: Provide convenient access to the system, allowing users to enter search criteria, view results, and make selections. The interface should be easy to use for all users, regardless of their technical expertise. This means a clear and logical design, understandable instructions, and minimalism in design. This information system should provide powerful search capabilities, allowing users to enter specific criteria, such as the field of research, geographical location, level of experience, etc., to find suitable partners. The interface should allow users to easily view, sort, and filter search results. This may include viewing profiles of partners, their publications, research interests, etc. The interface should facilitate easy interaction with potential partners, possibly through integrated communication tools such as email, messengers, or online meeting systems.

Communication Tools are not mandatory, but a useful part of the information system for selecting partners of scientific projects. They provide a necessary channel for exchanging information, discussing ideas, and coordinating joint efforts. They may include simple text chat or more complex systems with support for files, images, and even video. Forums allow users to create discussion topics, where specific issues, ideas, or projects can be discussed in detail. The information system can integrate with email, allowing users to send messages directly from the system interface. This may include automatic creation of emails based on templates or triggers in the system. For more in-depth communication, video conferencing tools can be integrated. The system may have a function of automatic notifications about important events, updates, or new messages. This helps users stay informed about important events and facilitates a quick response to changes or requests.

The application of these technical and software tools can significantly enhance the quality and efficiency of the process of selecting scientific partners, simplifying the search and analysis of potential candidates.

The technical and software provision for selecting scientific partners in the field of information technology, indeed encompasses a comprehensive and multi-faceted approach. Each component plays a critical role in ensuring the system's effectiveness and user-friendliness. Here's a summary of each key component and its significance:

- Algorithms for Partner Selection.
- Software Implementation.
- Databases and DBMS.
- Integration with Scientific Databases and Platforms.
- User Interfaces.
- Communication Tools.

Each of these components contributes to creating a robust, efficient, and user-friendly system for selecting scientific partners. By combining advanced data analysis algorithms, effective data management, seamless integration with external scientific databases, intuitive user interfaces, and comprehensive communication tools, the system can significantly streamline the process of identifying and connecting with suitable scientific partners, thereby enhancing collaborative research opportunities in the field of information technology.

3.2. Informational and organizational provision for information technology for selecting scientific partners

Informational and organizational provisions are vitally important for the successful implementation of information technology, especially in the context of selecting scientific partners. Reliable information provision in the context of a system for selecting scientific partners plays a critical role in ensuring the quality and effectiveness of the selection process. Here are more details about the key aspects of such provision:

Centralized data storage in reliable databases ensures that all necessary informational resources are accessible and protected. Data storage must be structured and organized to provide easy access and efficient management.

Automation of data collection, input, and updating reduces the likelihood of human errors. It is important to use algorithms for checking the quality and validity of data.

Advanced data analysis, including the algorithms developed in this dissertation work that implement the developed models and methods, can be used to identify trends, discover connections between researchers and projects. This allows the system to recommend the most suitable candidates based on complex criteria and individual scientific interests.

Integration with external scientific databases and platforms ensures the timeliness and completeness of information about scientific publications, citations, and collaborations. Regular procedures for checking and updating data ensure their accuracy, timeliness, and reliability. Data quality is essential as it directly affects the results of analysis and partner selection.

The information system must be scalable and adaptable considering the growing volumes of data and changing user requirements. These aspects together ensure that the system for selecting scientific partners is efficient, reliable, and useful for making informed decisions based on accurate and up-to-date information.

Effective communication tools for information exchange between system users facilitate better understanding and coordination among potential partners.

Automation of repetitive tasks, such as tracking updates in scientific databases, saves time and improves the efficiency of the partner selection process. Automated systems can regularly scan scientific databases like Scopus, PubMed, or Google Scholar, to identify new publications or updates in researchers' profiles. This ensures the currency of data about potential partners, their latest research, and publications.

Organizational support in the context of systems for selecting scientific partners includes several key components that ensure the system meets the strategic goals and needs of the organization.

Defining clear strategic goals that the system should support is critically important. This may include increasing the efficiency of partner selection, expanding the volume and quality of scientific research, expanding the collaboration network, etc.

Developing policies regarding the use of the system, data management, privacy, and security are important to ensure its compliance with corporate standards and legislation.

Establishing clear procedures and standards for working with the system, including data entry processes, partner search, negotiations, etc.

Training and briefing for system users ensure they understand how to use the available tools correctly and efficiently.

Providing necessary resources such as computing and network infrastructure, access to scientific databases, and financial support. Support for IT infrastructure and technical support ensures the reliability and efficiency of the system.

It's important to consider the needs and expectations of various stakeholders, including researchers, university or research organization management, industry partners, etc.

Ensuring user feedback for continuous improvement of the system. Regular monitoring and evaluation of the system's effectiveness allow identifying areas for improvement and measuring how well it meets the set goals.

The system must be adaptable and flexible to make changes in response to changes in the scientific environment and user requirements.

As the system may store sensitive information, it is necessary to ensure its security and protect the confidentiality of users' data.

Regular updates and maintenance of the information system ensure its relevance and reliability in the long term.

All these aspects together form a solid foundation for an effective and reliable system for selecting scientific partners, contributing to the successful conduct of scientific research and project implementation.

These elements ensure an efficient process of selecting scientific partners, optimizing resources and time, and enhancing the quality and effectiveness of scientific research and projects.

3.3. Method scientific spaces formation

Space can be thought of as an arrangement of ordered entities or objects that possess a hierarchical organization, where the positioning within this hierarchy is defined by specific identifiers. The information space is a type of space comprised of informational entities arranged hierarchically, structured by identifiers set by certain criteria and protocols, resulting from society's collective efforts.

The outcome of scholarly pursuits, an intellectual and imaginative endeavor, is the acquisition of novel fundamental and/or practical insights. This endeavor entails a sequence of essential or circumstantial steps, such as the scrutiny and synthesis of data, the proposition of hypotheses and new theories, and the advancement of scientific understanding in a direction steered by the research premise. Considering the international scope of the scientific fraternity, it's essential to recognize that scientific pursuits are largely collaborative, influenced both directly and peripherally by the worldwide network of academic collaboration, which in turn, provides reciprocal feedback.

Therefore, the orchestration of scientific endeavors is a process designed to create, renew, or enhance these connections for heightened efficacy. The nexus of education and scholarly work is indispensable, with each complementing the other. These synergistic processes thrive within organizational systems that amalgamate a team under set protocols, unified by the common objective of achieving set goals. The accumulated outputs of these processes, in the form of informational entities, constitute an educational and scientific informational realm.

The informational expanse of entities engaged in scholarly work is a realm where informational objects, structured and identified based on the educational and scholarly outcomes of the entities, are stored. This includes the entities involved in scholarly pursuits and a historical display of their identifiers, as determined by their scholarly contributions. These informational spaces can overlap or be segmented when integrated within specific academic disciplines.

In this discourse, the entities in focus are higher education institutions and their subdivisions actively involved in educational and scholarly work. These subdivisions, such as institutes, faculties, and academic departments, encompass the academic and research personnel, groups of scientists collaborating on projects, and individual researchers. A fundamental aspect of these entities' work is scholarly research, which brings forth the need to measure the output of these endeavors quantitatively. Individual scholars represent the singular entities of scholarly work, while collective entities are comprised of research organizations and higher education institutions formed by these individual scholars. Each entity is characterized by a model of identification and its informational realm.

The productivity of entities engaged in scholarly work is a measurable reflection of their effectiveness. In computing this metric, both established and novel scholarly activity indices can be utilized, tailored to the objectives and context of the assessment. Productivity is often gauged as the yield of scholarly efforts relative to the time dedicated to scientific pursuits or in comparison with other scholarly entities. Thus, a thorough examination of the entities' informational realms and their interconnections is vital for this computation. This involves isolating a segment of the information space pertinent to a specific field of study.

A field-specific scientific realm is composed of scholarly entities and segments of their information spaces, organized and unified under the commonality of their research focus. At its core, it includes the scholarly entity and its portion of the information space with its respective identifiers.

The organizational and functional structure of scholarly entities, as an entity, is a network of connections that enforce the order, governance, and coordination of scholarly activities to achieve objectives, particularly to enhance the efficiency and potential of scientific research.

The method for forming scientific spaces of researchers includes several key stages:

Clustering of the citation graph of publications: At this stage, a graph is created that represents the relationships between various publications through their citations. This allows identifying which documents are often cited together, which may indicate their thematic similarity or relationship.

Use of additional data the similarity coefficient of annotations: For more precise clustering, an analysis of the similarity of publication annotations is used. This can be done using various methods of calculating textual similarity, for example, through vector representation of texts or other natural language processing techniques.

Identification of key words for each cluster: After forming the clusters, an analysis of the key words for each is conducted. This allows identifying the main themes or research directions that unite the documents in each cluster.

Determining the degree of a researcher's belonging to a cluster: At this stage, it is analyzed how closely a specific researcher is associated with each cluster. This is done by comparing the number of the researcher's publications that fall into a given cluster with their total number of publications. This allows determining which thematic areas are primary in their research.

Application of this method: This can help in identifying trends and relationships in scientific research, as well as in finding communities of researchers with similar interests and directions of work.

Calculation of textual similarity in the field of natural language processing (NLP): Here are some popular methods:

Cosine Similarity [112] measures the cosine of the angle between two vectors. In the context of NLP, these vectors often represent words or documents as high-dimensional term vectors (for example, using the "bag of words" method or TF-IDF). First, the text is transformed into a vector, where each dimension corresponds to a certain word from the dictionary and contains the weight of this word in the text. Then the cosine of the angle between these vectors is calculated, which is a measure of their similarity.

Jaccard Index [113] measures the similarity between two sets of elements. In the context of textual similarity, these sets can be words or characters. It is defined as the size of the intersection of two sets, divided by the size of their union. For example, if we have two textual documents, we first determine the set of unique words for each, then calculate the intersection and union of these sets, and finally determine the Jaccard index.

Levenshtein Distance [114] measures the distance between two lines of text, determining the minimum number of single character changes (insertions, deletions, substitutions) needed to transform one line into another. For two lines of text, the number of operations needed to transform one line into another is calculated. The fewer changes needed, the more similar the texts are.

Word Embeddings is a technique for representing words and phrases in the form of high-dimensional vectors that reflect the semantic meanings of words. Models such as Word2Vec [115] or GloVe [116] learn on large text corpora and assign a vector in space to each word in such a way that words with similar meanings have similar vectors. This allows calculating the semantic similarity between words or texts.

Bidirectional Encoder Representations from Transformers (BERT) [117] and other similar models use the transformer architecture to create context-dependent embeddings of words. Unlike traditional word embeddings, BERT and similar models take into account the context in which the word occurs, thereby more accurately determining the semantic similarity of phrases or texts, even if they use different words to describe similar concepts.

Key Components of BERT:

Transformers: The foundation of BERT is the transformer architecture/ Transformers use attention mechanisms to model the relationships between words in the text.

Bidirectional Processing: Unlike previous models that read text sequentially from left to right or right to left, BERT processes text in both directions simultaneously. This allows the model to better understand the context of each word.

Word Embeddings: Each word in the text is transformed into a vector in a high-dimensional space. These word embeddings consider not only the semantic meaning of the word but also its context within the phrase.

Principles of BERT's Operation:

1. Pre-training: BERT initially learns on a large corpus of text (e.g., Wikipedia). During this stage, the model learns to understand language by performing tasks such as filling in blanks in the text.

2. Fine-tuning: After pre-training, the model is fine-tuned on a specific NLP task (e.g., text classification, sentiment analysis, question answering, etc.) using a dataset specific to the task.

3. Attention Mechanisms: BERT uses attention mechanisms to determine which parts of the text to focus on more when processing each word.

Multi-layer Structure: BERT consists of several layers, where each level further processes the information received from the previous layers.

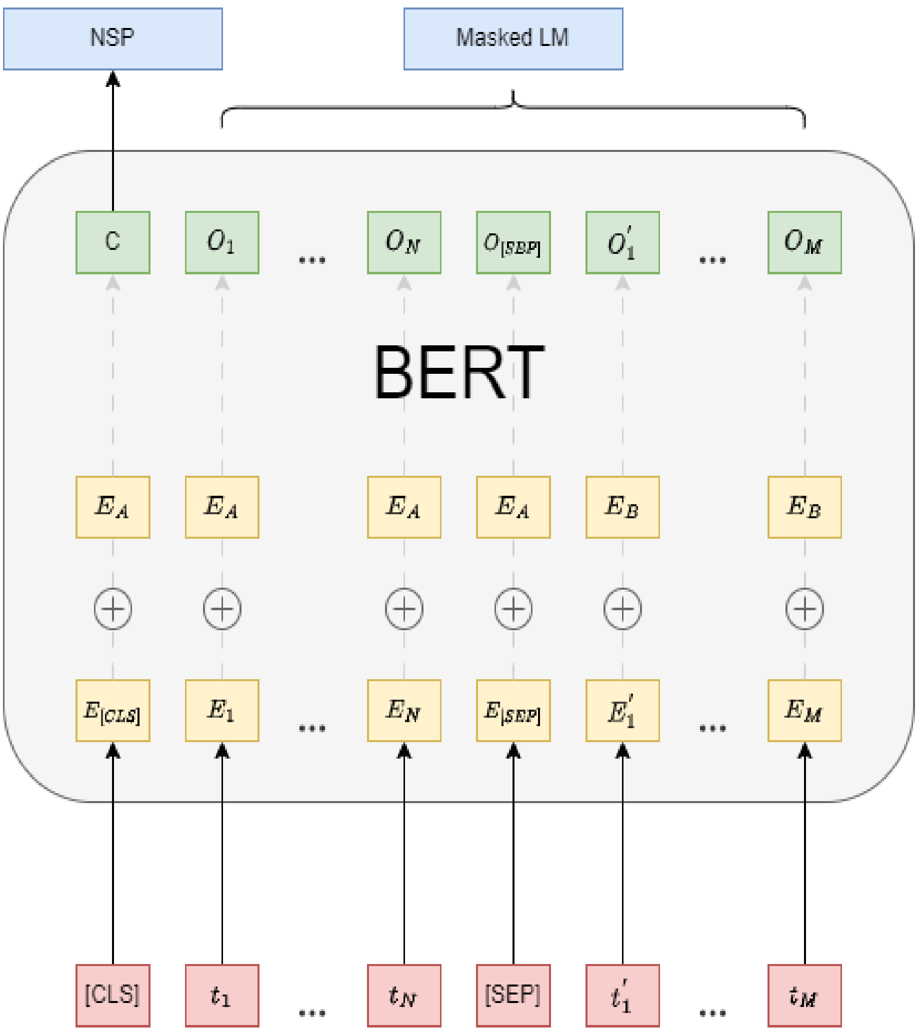

Figure 3.1 BERT architecture [117]

The application of BERT in the method of forming scientific spaces is appropriate for several reasons:

Context-Dependent Embeddings: BERT provides context-dependent word embeddings, meaning the vector representation of a word changes depending on its use in context. In scientific documents, where the same word can have different meanings in different contexts, this is critically important.

Complex Scientific Texts: Scientific texts often contain complex structures and specific terminology. BERT, with its deep learning and attention mechanisms, effectively processes such complex textual data, identifying meaningful connections and semantic relations.

Fine-tuning for Specific Tasks: BERT can be fine-tuned for specific tasks, including the analysis of scientific documents. This means that the model can be adapted for a better understanding of the specifics of scientific discourses and terminology.

Semantic Link Identification: In scientific spaces, it is important to identify semantic links between different studies, themes, and ideas. BERT, with its deep language processing capabilities, can effectively detect such links, facilitating the clustering and analysis of scientific texts.

Large Data Volumes: Scientific research often involves large volumes of data. BERT, with its ability to process large amounts of text, is an excellent choice for analyzing scientific databases.

Due to its properties, BERT is an ideal tool for forming scientific spaces where a deep understanding of the text, high accuracy in semantic analysis, as well as flexibility and scalability in processing large volumes of scientific data are required.

A comprehensive and multi-dimensional approach to understanding and organizing the scientific information space, especially within the context of scholarly research. This approach encapsulates several key concepts and methodologies, from the structuring of scientific spaces to the application of advanced natural language processing techniques.

Scientific information space includes hierarchical organization informational entities such as publications, researchers, and institutions that are arranged hierarchically, structured by identifiers based on criteria and protocols. And collaborative nature of science that allows to recognizes the global and collaborative nature of scientific research, influenced by a worldwide network of academic collaboration.

Formation of scientific spaces involves creating a graph representing relationships between publications through citations to identify thematic similarities or relationships. Utilizes NLP techniques to analyze publication annotations for more precise clustering and identifies key themes in each cluster and assesses a researcher's association with clusters based on their publication record.

Proposed approach offers a holistic and technologically sophisticated framework for the organization, analysis, and visualization of scientific research. It integrates hierarchical information structuring, NLP techniques, and advanced machine learning models like BERT to enhance the understanding and management of scholarly endeavors. This method not only aids in quantifying research productivity but also provides insights into the thematic and collaborative nature of scientific work, highlighting interconnections within the global scientific community.

Let W_s is a certain subject-specific scientific space $W_s \subset W$, W is the general educational-scientific space. Let $G = \{G_1, G_2, \ldots, G_n\}$ be the set of scientific projects. The structure of projects implies the availability of working packages $G_i = \{g_1^i, g_2^i, \ldots, g_{r_i}^i\}$ is the number of working packages $i = \overline{1,n}$. Let $V = \{v_1, v_2, \ldots, v_p\}$ is the set of all scientists that can be involved in implementing the projects from set G, p is the number of scientists. Let $Q = \{q_1, q_2, \ldots, q_m\}$ is the set of publications published by scientists from set V, m is the number of publications.

Let consider the formation of scientific spaces. To do this, let's represent each publication a$Q = \{q_1, q_2, \ldots, q_m\}$s a point in space W.

We introduce a distance function $\rho(q_i, q_j)$ in the general educational-scientific space W. For the metric function, three conditions must be met:

1. Non-negativity: $\rho(q_i, q_j) \geq 0$ for all $q_i \in Q, i = \overline{1,m}$ and $\rho(q_i, q_j) = 0$ if and only if i=j. This means the distance between any two publications is always non-negative and is zero precisely when the publications are identical.
2. Symmetry: $\rho(q_i, q_j) = \rho(q_j, q_i)$ for all $i, j = \overline{1,m}$ The distance from q_i to q_j is the same as the distance from q_j to q_i
3. Triangle Inequality: $\rho(q_i, q_j) \leq \rho(q_i, q_k) + \rho(q_k, q_j)$ for all $i, j, k = \overline{1,m}$

The rules for calculating the distance function can be quite complex. As already mentioned, one of the ways is BERT.

Also, for each subject-specific scientific space, we will establish publications that belong to this subspace. We will define key words for them and consider the function of membership of each in $V = \{v_1, v_2, \ldots, v_p\}$, $Q(v_i) \subset Q, i = \overline{1,p}$ where is the set of its publications. Then the distance from a scientist to a subject-specific scientific space $W_s \subset W$ can be calculated as:

$$\rho(v_i, w_s) = \frac{\sum_{q \in Q(v_i)} \sum_{e \in W_s} \rho(q, e)}{card(Q(v_i)) \bullet card(W_s)} . \quad (3.3.1)$$

Then the requirement for the knowledge of the performers of the work package $g^i_{r_i}$ of the project G_i in the subject-specific scientific space ws can be formulated as a certain function $c(g^i_{r_i}, w_s)$, i.e., define a mapping $c : G \times W \to [0,1]$.

Having such a function, the task of choosing scientific partners-performers can be considered as a certain optimization task. For this, we will calculate the correspondence of scientists to the work package of the project as a product

$$\psi(v_i) = \rho(v_i, w_s) \bullet c(g^i_{r_i}, w_s) . \quad (3.3.2)$$

Then, by ordering the scientists in descending order of the magnitude $\psi(v_i)$, we get a set of potential performers or partners for conducting joint scientific research.

This model uses a combination of metric space principles, natural language processing (BERT), and optimization techniques. Key elements of this model are:

1. Subject-Specific Scientific Space and General Educational-Scientific Space represent the realms of knowledge and research.
2. Set of Scientific Projects Set of Scientific Projects, each requiring specific knowledge and expertise.
3. Distance Function. BERT model can be used to calculate the distance between publications, likely based on semantic similarity, which is especially useful in cases where the distance function is complex.
4. Defining Membership. Publications are associated with specific subject-specific scientific spaces based on keywords and other relevant factors. The distance of a scientist to a specific can then be quantified.
5. Function for Knowledge Requirements defines the knowledge requirements for each work package of a project in relation to the subject-specific scientific space.
6. Optimization Task for Partner Selection.
7. Ranking and Selection: Scientists are ranked in descending order based on their suitability score for each work package, forming a list of potential partners or collaborators.

This model is both comprehensive and mathematically rigorous, employing advanced techniques from various fields including metric space theory, NLP, and optimization. It allows for a nuanced and data-driven approach to selecting scientific partners, ensuring that collaborators are well-matched to the specific knowledge and skill requirements of each project's work packages. This approach could significantly enhance the efficiency and effectiveness of forming research teams in the field of information technology and beyond.

Conclusions for Chapter 3

Technical, software, informational, and organizational provisions have been developed for the information technology for selecting scientific partners. The algorithms developed for the individually-oriented selection of partners of scientific projects are key for analyzing scientific environments. These algorithms are adapted for processing large volumes of data and are aimed at identifying potential partners with similar scientific interests or complementary competencies. The use of specialized libraries and frameworks for developing separate modules of the information system allows for the effective implementation of the developed algorithms. Database management systems play a critical role in storing, organizing, and querying information about potential partners and projects, ensuring the efficiency and security of the partner selection process. Automated access to current information from scientific databases, such as Scopus or PubMed, ensures the completeness and timeliness of information about researchers, their publications, and projects. Convenient user interfaces facilitate effective interaction with the system, allowing easy entry of search criteria, viewing results, and making selections. Effective communication tools in the system, such as chats, forums, and email, provide the necessary exchange of information, discussion of ideas, and coordination of efforts.

Strategic planning, development of policies for using the system, data management procedures, user training, and provision of necessary resources are important for the effective use of the system. These elements together form a solid foundation for developing an effective and reliable system for selecting scientific partners, contributing to the successful conduct of scientific research and project implementation.

Methods for forming subject-specific scientific environments have been improved. The proposed method includes 3 stages. The first stage involves clustering of publications. In the second stage, the proximity of publications is determined. The third stage involves the alignment between researchers and scientific spaces. Analysis shows that the application of BERT methods for the second stage has several advantages. This model is both comprehensive and mathematically rigorous, employing advanced techniques from various fields including metric space theory, NLP, and optimization. It allows for a nuanced and data-driven approach to selecting scientific partners, ensuring that collaborators are well-matched to the specific knowledge and skill requirements of each project's work packages. This approach could significantly enhance the efficiency and effectiveness of forming research teams in the field of information technology and beyond.

CHAPTER 4. IMPLEMENTATION OF INFORMATION SYSTEM FOR SELECTING PARTNERS FOR CREATING SCIENTIFIC ENVIRONMENTS OF PROJECTS

4.1. Architecture of information system for selecting partners for creating scientific environments of projects

The term "information technology for the selection of executors of scientific projects" describes a comprehensive set of methodologies, model constructions, and software for compiling, preserving, and analyzing data, aimed at enhancing the effectiveness of scientific research implementation. The efficiency in achieving the objectives of a scientific project correlates with the professional expertise of participants, which can vary depending on the evolution of the project. The deployment of this technology includes several phases, starting from identifying needs and ending with the strategic implementation of tools for selecting participants.

Assessment of the need to develop information systems for tracking the competencies of executors in scientific research. At this stage, a detailed analysis of user requirements is conducted, and specific tasks that the system must solve are established. Tasks must be articulated with a view to ensure that information technologies contribute to their efficient resolution. Key is the identification of issues, defining necessary data for collection, and specifying the functionality that the system must provide.

Accumulation and analytical processing of information are fundamental for the development of information systems designed for the selection of participants in scientific projects. At this stage, information is aggregated from a multitude of sources, including scientometric databases and academic profiles such as Scopus, Web of Science, Google Scholar, ORCID, ResearchGate, and others. Additionally, peer evaluations in the project may be used. The obtained data are subject to meticulous ordering, filtering, and classification for further analysis.

Let's delve into more detail about some of the key scientometric databases and academic profiles commonly used in research:

1. Scopus is a comprehensive, multidisciplinary database covering a wide range of research fields. It's known for its extensive abstract and citation database of peer-reviewed literature. Scopus includes scientific journals, books, and conference proceedings. Provides tools for tracking, analyzing, and visualizing research. Can be used for literature reviews, bibliometric analysis, and to track citations and h-index of researchers.

2. Web of Science is highly respected database providing access to multiple databases that reference cross-disciplinary research. Contains citation indexing and search services. It covers natural sciences, social sciences, arts, and humanities. Can be used for comprehensive citation search, understanding research impact, and exploring connections between research findings.

3. Google Scholar is freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines. Simple to use, it provides a broad search of scholarly articles, theses, books, abstracts, and court opinions. Popular for initial research, citation analysis, and quick access to full-text articles.

4. ORCID stands for Open Researcher and Contributor ID (Fig 4.1). It provides a unique identifier to researchers, helping them to distinguish their work from others with similar names. ORCID integrates with many research workflows, institutions, and publishers. It links researchers with their professional activities and outputs. Often used for maintaining an updated academic profile, ensuring proper attribution of work, and facilitating collaboration.

5. ResearchGate is a social networking site for scientists and researchers to share papers, ask and answer questions, and find collaborators. Users can upload and share papers, get statistics on views and downloads, and interact with other researchers. Popular for networking, discovering research in similar fields, and sharing early-stage research.

During data research for information systems for the selection of project participants, comprehensive analysis is performed using various methodologies and analytical models. The application of statistical analysis, machine learning, algorithms, and neural networks allows identifying significant information, establishing correlations and trends, and outlining key determinants and options for decision-making.

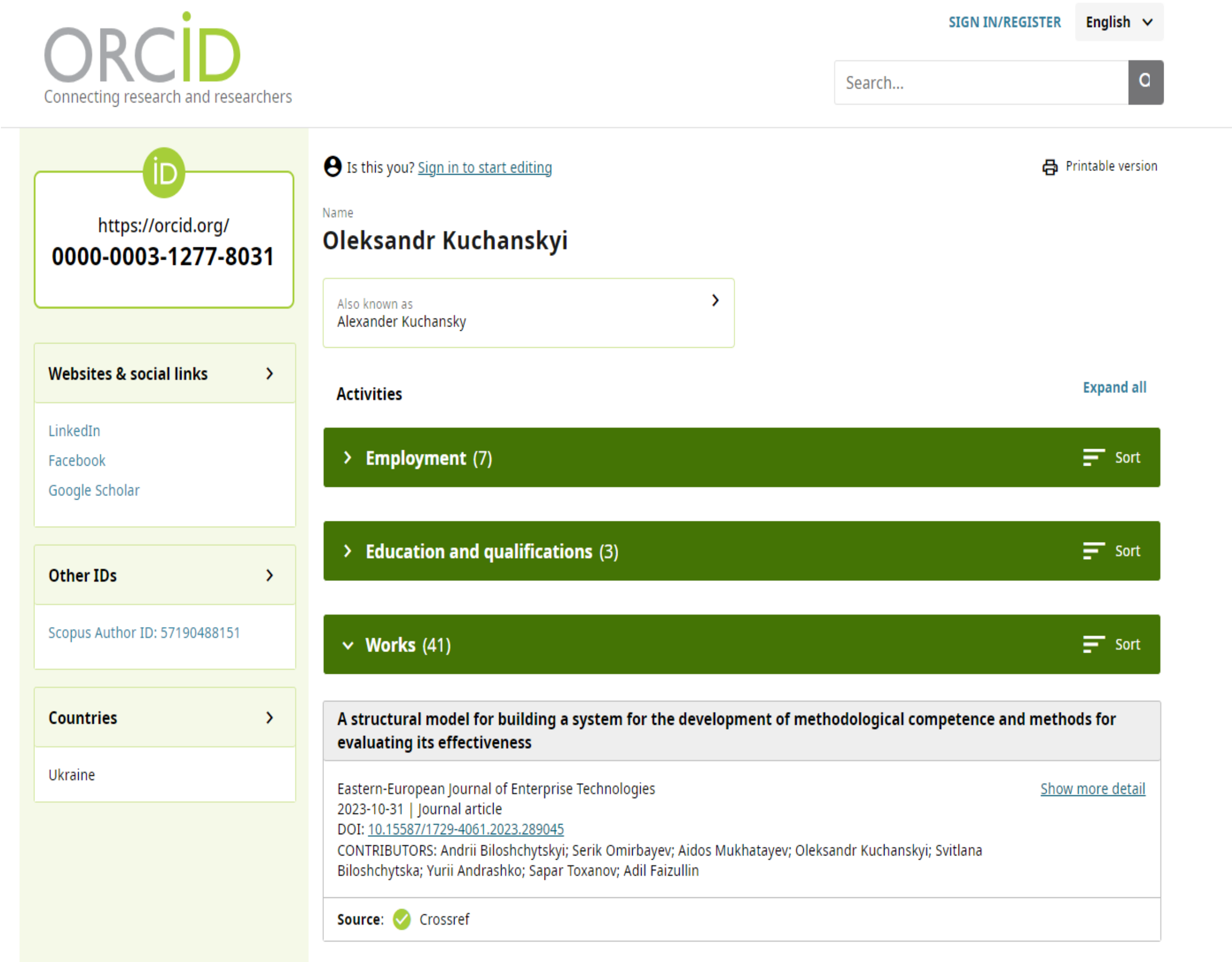

Figure 4.1 Example of a scientist's profile in the ORCID system

Data presentation in a visual format is carried out at this stage, where the results of analytical processing are transformed into intuitively understandable visualizations, such as diagrams, graphs, cartographic images, or other graphic embodiments. This simplifies the process of interpreting voluminous and complex information and speeds up the user's comprehension of relationships and conclusions of the research.

In the context of information systems for selecting project participants, modeling and simulation of various decision-making scenarios are used. This allows evaluating the potential consequences of different strategic options, providing the opportunity for thorough analysis of risks, forecasting outcomes, and forming a more balanced and reasoned approach to selection.

Within the framework of information technology for selecting project executors, a set of tools aimed at optimizing the process of human resource management is implemented. This includes the application of electronic spreadsheets, project management systems, and other digital solutions that facilitate the rationalization of work procedures, automation of individual tasks, and improvement of communication between project participants.

We analyze the initial stages of developing information technologies considering the competence of executors, which is considered in two aspects:

Evaluation of executor's knowledge: Includes analysis of the presence of professional certificates (e.g., a Cisco certificate for tasks related to networks and data transmission or an Oracle certificate for database administration work packages), activity in scientific conferences, and publications in specialized journals. The system automatically registers these indicators, but they can be adjusted in the executor's profile.

Evaluation of project execution experience: Considers the number and role in previous projects, evaluated based on the history of completed works.

In the context of information technology for selecting project executors, the integration of a variety of digital tools is crucial for optimizing human resource management in project environments. This approach not only enhances the efficiency of the selection process but also improves the overall management of project resources.

The use of information technology in the selection of project executors represents a comprehensive approach to human resource management in the project environment. By leveraging digital tools and detailed evaluation criteria, organizations can streamline the selection process, ensuring that the right individuals are chosen for specific project roles based on their knowledge, skills, and experience.

Evaluation aspects in the selection process includes evaluation of executor's knowledge by professional certificates checking for relevant certifications like Cisco for network or data transmission tasks or Oracle for database administration. Certificates are indicators of formal training and expertise.

Participation in conferences signifies engagement with the scientific community, knowledge updating, and potential networking.

Publications in Specialized Journals indicates expertise, research capabilities, and contribution to the field. It's a direct reflection of the executor's knowledge depth.

The system automatically registers these indicators, which can be fine-tuned in the executor's profile.

Evaluation of Project Execution Experience includes Analysis of the quantity and nature of previously handled projects. It helps in understanding the executor's practical experience and adaptability to different project roles.

Feedback and Performance Metrics for past performance reviews, feedback from team members or project leaders, and any quantifiable success metrics.

Assessing how the executor has evolved over different projects, learning curves, and adaptability to new challenges or technologies.

The initiating step in creating information technologies is defining the needs and strategic goals of such technology. Considering the universality of these technologies for complex projects, the primary task is to analyze educational projects and define the requirements for executors' skills for effective management of various aspects of work. The general approach to evaluating competencies, described in Chapter 3, involves a detailed assessment of qualifications of executors that correlate with project specifications. Table 4.1 presents a list of relevant indicators.

Table 4.1 Levels of Competency Assessment for Scientific Research Project Executors

Competencies Indices	Competencies Indices
Evaluation of executor's knowledge	Number of certificates in the direction of the work package
	Number of conference reports in the direction of the work package
	Presence of a scientific degree and academic title in the direction of the project theme
	Scientometric index for publications in the direction of the work package
Evaluation of executor's activity	Number of projects in the direction of the work package completed by the executor
	Number of projects in the direction of the work package in which the executor participates
	Colleague evaluation who jointly executed projects

The implementation of information technology will increase the productivity of scientific projects. Using this technology for the selection of participants in scientific projects will facilitate effective team formation and continuous tracking of their competencies throughout the project. This will allow monitoring the development of each participant, evaluating their contribution to the project, and understanding how the improvement of participants' skills affects the overall efficiency of the project. Consequently, progress in the competencies of participants directly contributes to better overall project outcomes.

The issue of data accumulation for determining the level of executors' competencies is one of the key aspects. The critical condition for data selection is their level of reliability. The ideal source is open information published on official websites of universities or other educational institutions, as well as documentary-confirmed data. To determine the level of competencies, different types of data can be used, but based on the indicators mentioned in Figure 4.1, the evaluation of knowledge will be based on specific indicators.

1. Number of certificates: Check the official websites of universities, academic institutions, and professional platforms, where data on certified courses and qualifications are often published.

2. Conference reports: Use conference programs published on relevant sites and scientific databases containing information about authors and their presentations.

3. Scientific degree and academic title: Official websites of educational institutions often provide information about the academic titles and degrees of their employees and teachers.

4. Scientometric index: Databases like Google Scholar, Scopus, or Web of Science provide information about scientific publications, citations, and researchers' indices.

5. Number of completed projects: Review the profiles of executors on professional platforms or institutional websites, which usually include information about completed projects.

6. Number of current projects: Similarly, check profiles on professional networks or university websites describing participants' current projects.

7. Colleague evaluation: Surveys among colleagues who have previously collaborated with the executor can be organized using questionnaires and feedback collection tools.

One of the methods for assessing professional skills and character traits of participants in educational projects involves the use of the Occupational Personality Questionnaire (OPQ). OPQ is a well-known psychometric tool designed to analyze personal characteristics and qualifications of an individual in view of the specific requirements and goals of the project. OPQ assesses a range of different personality traits, divided into several categories such as relationships with others, thinking, and emotions. This tool helps to better understand how a person's personality can affect their work behavior and interaction with colleagues, as well as their potential for different roles or career development. OPQ is widely recognized and used worldwide for professional assessment, career planning, and staff development.

Typical groups of questions in the OPQ cover aspects such as (Fig. 4.2):

Figure. 4.2 OPQ questions

1. Interpersonal Skills: Ability to communicate, collaborate, interact with others.
2. Thinking Style: Analytical abilities, strategic thinking, creativity.
3. Emotional Resilience: Orderliness, emotional control, stress resistance.
4. Motivation: Ambition, initiative, drive to achieve.
5. Social Adaptability: Flexibility, social sensitivity, openness to change.
6. Organizational Skills: Planning, organization, attention to detail.

7. Leadership Qualities: Influence, ability to inspire, leadership.

8. Risk-Taking/Conservatism: Propensity to take risks, caution, conservative approaches.

Each of these categories contains specific questions aimed at identifying various aspects of behavior and personal characteristics.

When an information system is designed as a web service rather than a desktop application, it offers several distinct advantages, particularly in the context of selecting project executors and managing human resources in project environments. Here are some of these advantages:

1. Accessibility and Mobility.
2. Ease of Maintenance and Updates.
3. Cross-Platform Compatibility.
4. Scalability.
5. Reduced IT Infrastructure and Costs.
6. Real-Time Collaboration and Integration.
7. Security and Data Backup.
8. User Experience and Interface Consistency:

Web services can be accessed from anywhere with an internet connection, providing greater flexibility for users who need to access the system remotely or on the go. Unlike desktop applications, which are typically tied to a single computer, web services can be used on multiple devices, including laptops, tablets, and smartphones.

Web services centralize the maintenance and updating process. When an update is made to the web service, it's immediately available to all users without requiring individual updates on each user's machine. This ensures that all users are always working with the latest version of the software, which can be crucial for security and functionality.

Web services are generally platform-independent and can be used across different operating systems (Windows, MacOS, Linux) without compatibility issues. There's no need to develop and maintain different versions of the application for different operating systems.

Web services are more scalable compared to desktop applications. They can be easily scaled up or down based on the number of users or the level of data processing required.

This is particularly advantageous for projects that may experience fluctuations in team size or data volume.

Web services typically require less client-side computing power and storage capacity, as the heavy lifting is done server-side. This can reduce the cost and complexity of user hardware requirements and IT infrastructure.

Web services facilitate real-time collaboration among team members, as data is synchronized and updated across all users immediately.

They can be more easily integrated with other web-based tools and services, enhancing data sharing and workflow automation.

Data security can be more robustly managed on web services, with centralized control over user access and encryption. Regular, automated backups can be implemented more efficiently, ensuring data integrity and reducing the risk of data loss.

Web services can offer a more consistent and often more modern user interface compared to desktop applications.

They can be designed to be more intuitive and user-friendly, potentially reducing training time and increasing adoption rates.

In summary, a web-based information system for the selection of project executors combines accessibility, ease of maintenance, scalability, and robust security features, making it an effective tool for managing complex project environments in a dynamic and collaborative manner.

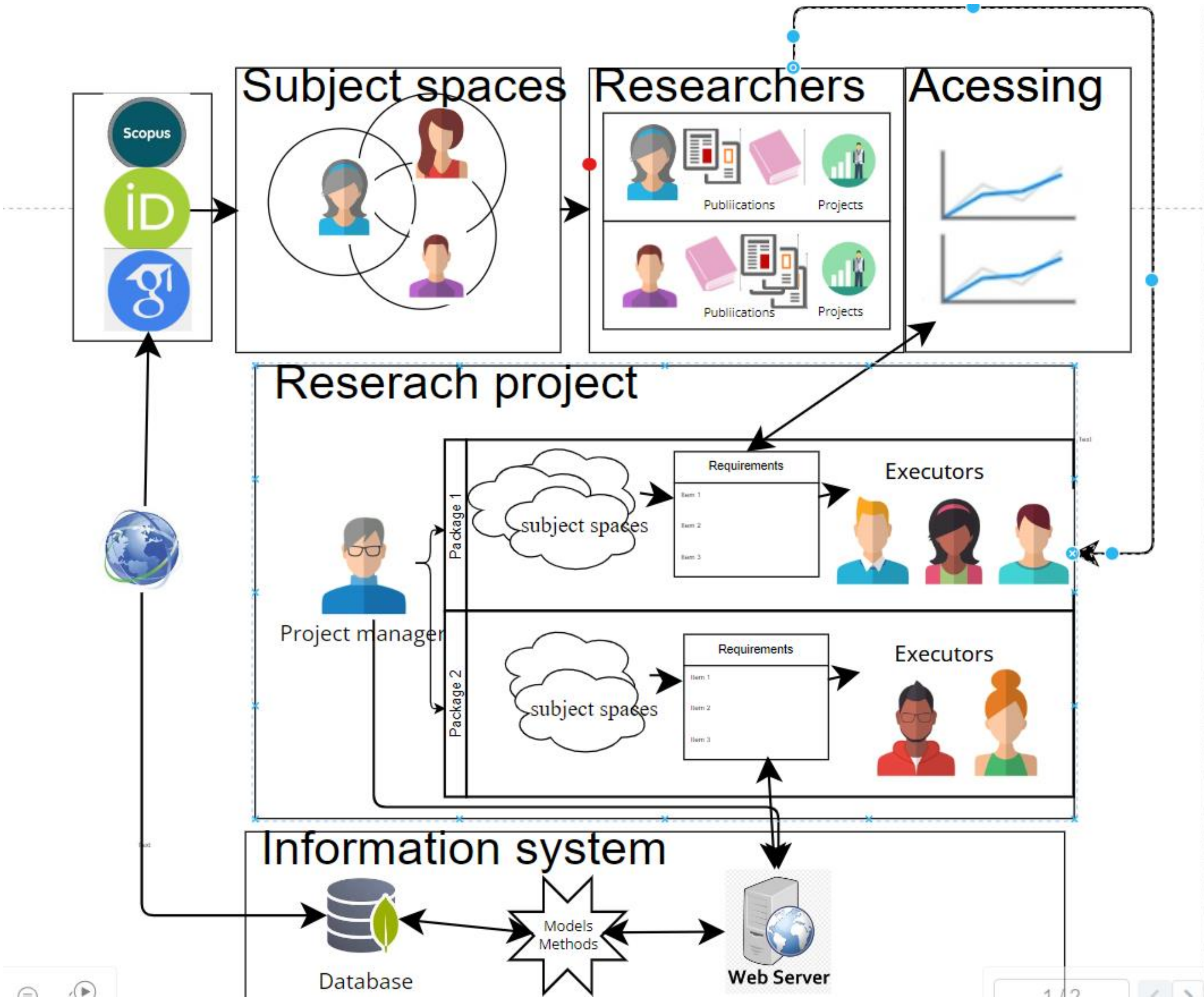

Figure 4.3 conceptual model information system for selecting partners for creating scientific environments of projects

In the context of assessing the personal qualities of project executors, one aspect is mutual evaluation among participants. The initial rating of a newly appointed executor starts at zero value. After a certain period of work in the project, it is planned to conduct a survey among colleagues in the project to assess the effectiveness and professionalism of their contribution. This method involves the use of a structured questionnaire with a clearly defined rating scale to analyze the productivity and competence of project participants.

Processed results are normalized and archived for future use. Preliminary data processing includes:

Data Verification and Cleansing: Involves identifying and correcting errors, detecting and eliminating missing or anomalous values. Corrections can be made by filling in missing data or deleting incorrect entries.

Data Structuring: Involves organizing data into formats and structures suitable for analysis, such as tables, structured databases, or other efficient data representation forms.

MongoDB may be a beneficial choice for partner selection tasks, especially when data are incomplete or have varied structures. Here are some advantages of using MongoDB:

1. Schema Flexibility: MongoDB does not require a rigid data structure, allowing the storage of documents with different data structures.

2. Scalability: MongoDB easily scales, supporting large data volumes and query traffic.

3. High Performance: Fast data access thanks to optimized storage and indexing.

4. Support for Various Data Types: Ability to store different data types, including text, numbers, arrays, etc.

5. Ease of Development: MongoDB offers a simple and understandable interface for developers.

In MongoDB, the absence of rigid schemas provides flexibility in data structuring and storage. Therefore, less effort is needed to adapt the data structure to the non-relational model. In MongoDB, data are stored as documents in a JSON-like format. For the information technology, data were structured as follows:

1. "Executors" Collection: Contains documents with data about executors, such as unique ID, name, contact information. Each executor can have their document.

2. "Ratings" Collection: Stores ratings of knowledge, performance, and personal qualities of executors. Documents in this collection may contain the executor's ID (as a reference to the "Executors" collection) and various ratings.

3. "Projects" Collection: Contains information about educational projects and the work packages of these projects, with possible fields like ID, project name, start and end dates, and requirements for potential executors.

4. "Scientific Subject Spaces" Collection: Stores data on the affiliation of publications to various subject spaces and their characteristics, including sets of keywords and frequency characteristics of texts.

To automate the process of searching and selecting executors for project work packages, an information system has been developed that implements all the components of the proposed information technology.

The information system is designed for access by project managers or HR managers, as well as by scientists who wish to participate in scientific projects as executors, or to find partners for joint scientific research.

Figure 4.4 shows the system's login form. Users who have entered their email address in their profile settings can reset their password, and instructions for recovery are sent to the email address specified in the user's profile.

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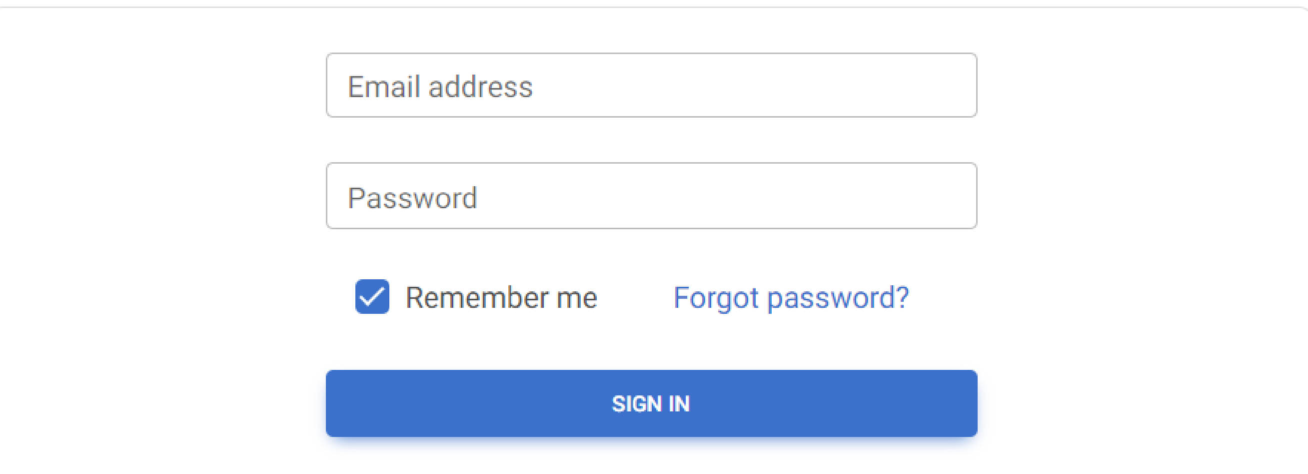

Figure 4.3. Login form of the information system.

The system has several tabs: home, user profile, active projects, requirements for the executors of the project work packages. If you are a project manager or HR manager, you can see which processes are currently active and make adjustments to them, create, edit, and delete project work packages. You can also view the list of active projects add a new research project.

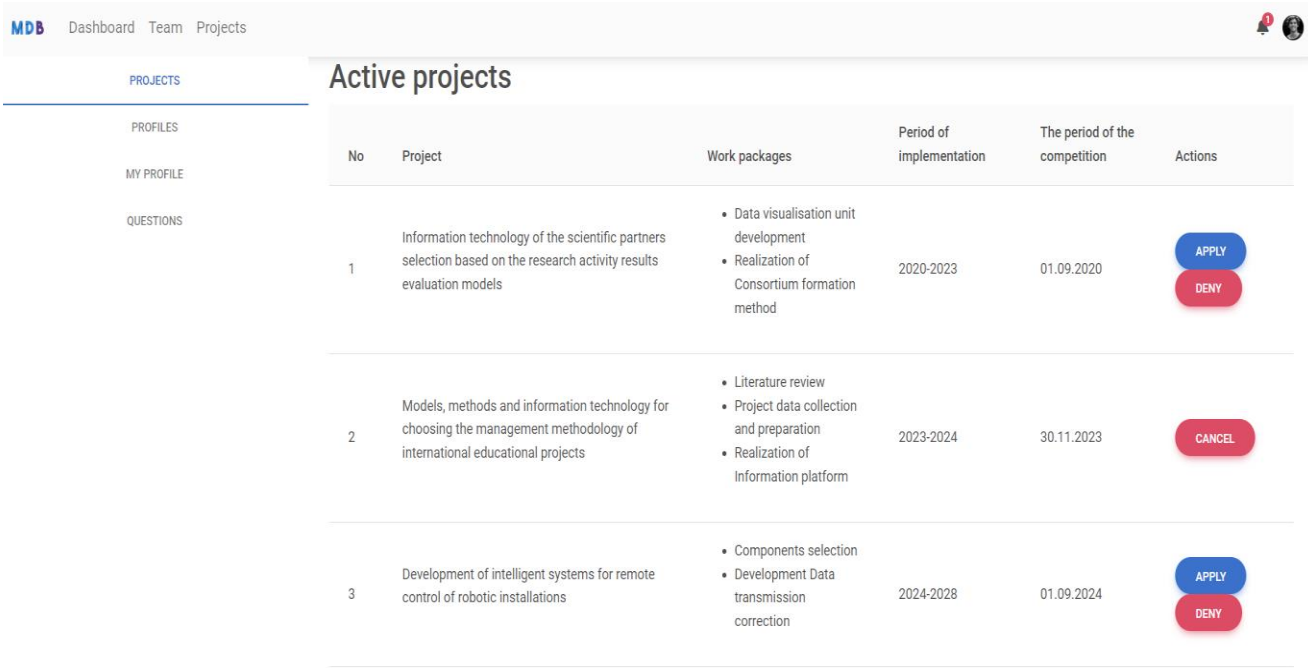

Figure 4.4. Active project list

For each project, its description is displayed, along with a list of work packages for that project, deadlines for completion, and the date by which applications are accepted from those wishing to undertake the project. Here, one can also confirm or cancel their participation in the execution of the project.

Figure 4.5 shows a list of all researchers who are registered in the system and who are considered as potential executors of the project.

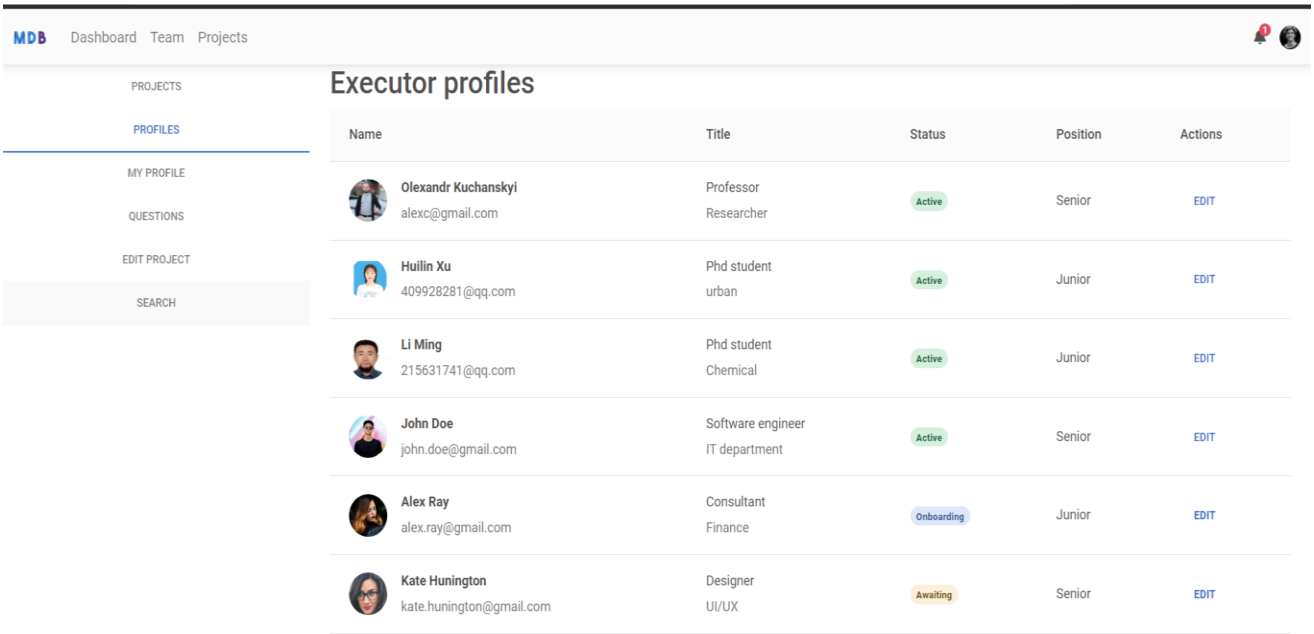

Figure 4.5. Researchers list.

The user profile (Fig 4.6) contains data that the user can modify. In particular, the profile allows viewing the list of the user's publications, as well as a list of work projects where the user is an executor.

Based on the known publications of the user, their affiliation to scientific spaces is calculated.

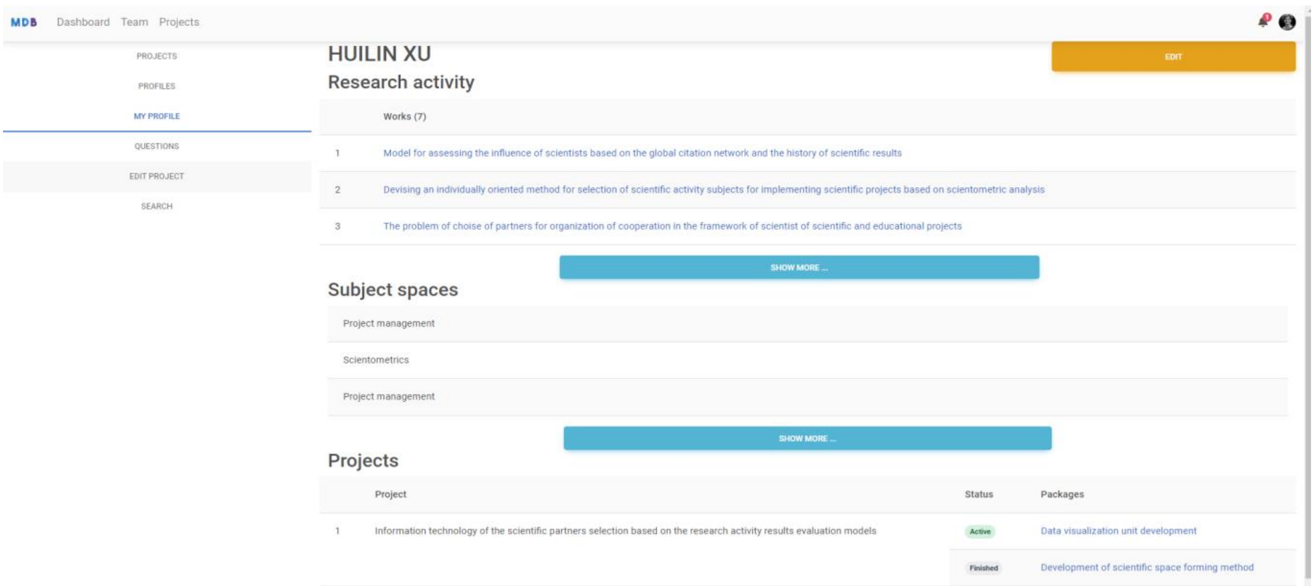

Figure 4.6. User profile

The "project" (Fig. 4.7) tab contains a page with data on the project work packages and requirements for the executors. The "Find Executors" button offers a search and ranking of potential executors. You can also send messages to potential executors via email, view their profile, and appoint a particular scientist as the executor of the selected project work package. The manager uses these recommendations to make operational decisions.

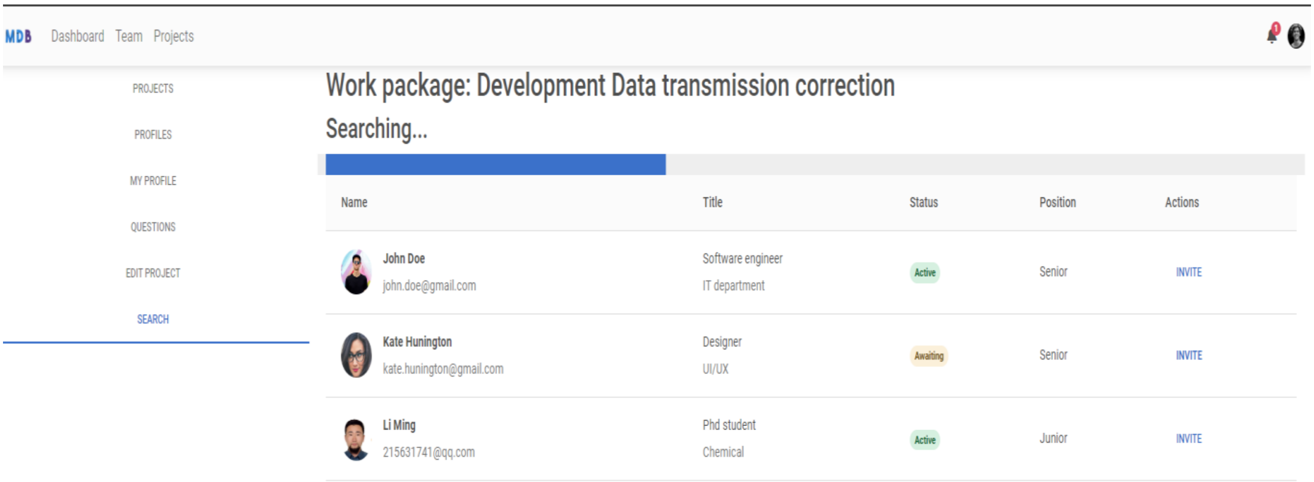

Figure 4.7 Executor for work package searching

In the context of data analysis and collection, the information system performs the following modules:

Data collection and preparation module. This module includes collecting data on the scientific activity results of scientists from various open data sources, cleaning, and processing for further analysis. Data on the scientific activity results of executors are collected through APIs of scientometric databases, websites of scientific and educational institutions where executors are mentioned, and the website of the Ministry of Education. Also, verified links provided by the project manager for checking indicators are used.

Collected data may be incomplete, so they are stored in the database in a loosely structured form. As a result, these data are used as input parameters for the developed models for assessing the influence of scientists through the global citation network, taking into account the age of scientific results.

Data analysis module. This module contains the implementation of the method of forming subject scientific environments and the individually-oriented method of selecting partners-executors for scientific projects based on the analysis of subject scientific environments. In the context of the information system, the level of influence of scientists in the relevant subject spaces is assessed.

Data visualization module helps transform complex numerical data into a graphical form, simplifying their understanding. In the context of the information system, an activity chart is created that displays the system usage statistics, a Gantt chart, scientists' affiliation to subject scientific spaces, their ratings by other executors, etc.

User interface module provides interaction with the system, allows setting project parameters, defining key components of executors' environments, determining publications included in projects.

The system is flexible, as it has a modular structure, which ensures its integration with other systems if necessary. This position is important, as specific university or science department systems are often used in projects, requiring integration to obtain and consider executor data.

In the context of information systems specializing in data analysis and processing, ensuring security and confidentiality is extremely important. The scientific approach to this involves implementing authentication mechanisms, such as password protection and multi-factor authentication, to prevent unauthorized access. The system stores important data, including ratings of potential executors, details of their participation in projects, implementation of project work packages, and affiliation to subject scientific spaces. These data are not confidential, as they are publicly available on the Internet and are mostly quantitative. However, the data may contain sensitive personal information.

To prevent potential threats that could negatively affect the selection of project executors, the search for scientific partners, projects, and call into question the credibility of the obtained results, it is necessary to protect the system from access by third parties.

The information system for automating the process of searching and selecting executors for project work packages is a comprehensive tool that integrates various key components and functionalities. It is tailored to cater to the needs of project managers, HR managers, scientists, and researchers involved in scientific projects.

This information system represents a significant advancement in streamlining the process of managing scientific research projects. It not only facilitates efficient project and personnel management but also enhances the process of forming collaborative research teams based on detailed analysis and visualization of relevant data. The system's flexibility, security measures, and comprehensive data analysis capabilities make it an invaluable tool for academic and research institutions.

4.2. Verification of the information technology for Selecting executors of scientific projects

Verification of the study was carried out at Astana IT University on the example of the formation of applications for scientific research works for 2021. The module consisting of the spiders for scraping the information of international scientometric bases and websites of scientific periodical journals was created. Part of scientometric information was obtained freely to perform scientific research. The database contains information about more than 56 thousand individ-ual subjects of scientific activity and 257 thousand scientific publications and is constantly updated. A set of scientific subject spaces was formed based on cluster analysis of publications of individual subjects of scientific activity and based on latent semantic analysis. Clustering is implemented based on establishing a metric distance between publications of subjects of scientific activity according to the citation graph and taking into consideration the proximity of annotations of scientific publications of subjects of scientific activity using the method of locally sensitive hashing. After clus-tering publications, the clusters were named and scientific subject spaces were constructed. A total of 211 scientific subject spaces were obtained. 4 scientific subject spaces were selected for three project applications (cluster 1 – Project Development, cluster 2 – Professional Competence, Cluster 3 – Educational Process, Cluster 4 – Scientific Activity). Table 1 shows quantitative indicators obtained as a result of the use of the devised method for selecting executors of three research projects. All actual project executors were included in the list of applicants.

Table 4.2. Verification of the study was carried out at Astana IT University

Scientific subject areas	Cluster 1	Cluster 2	Cluster 3
Number of publications	783	609	1140
Total number of scientists in the space	60	41	95
Number of scientists who meet selection criteria	30	17	39
Number of scientists involved in projects	3	4	10
Average position in the orderly list of executors who meet the selection criteria and are actual project executors	22.8	10.9	31.4
Average position in the orderly list of executors selected by the individually oriented method	19.3	12.5	21.4
Average position in the orderly list by the CB criterion	18.1	11.2	20.8
Average position in the orderly list by the QA criterion	19.9	13.6	23.0

For project applications, the actual project groups were compared with the project groups, which were proposed based on the individually oriented method for selecting the executors of scientific projects. They were compared based on the magnitude of the degree of a project executor belong-ing to the relevant scientific subject space (clusters

1–4). In accordance with the calculated magnitudes of belonging, a rating list of potential performers was formed.

The position in the orderly list of executors who meet the selection criteria and are involved in projects indicates that the executors with an average rating in clusters take part in projects. The average percentage of scientists who meet the requirements of project managers for each scientific subject space is 46.55 %. The percentage of those involved in a proj-ect from those who were selected is 24.07 %. The average position in the orderly list of executors who meet the selection criteria (Table 4.2) is higher than the value corresponding to randomly selected scientists from scientific subject spaces. The proposed scientists were compared with actual exec-utors according to the CB and QA criteria described in paper [36] and for which there are enough data. An orderly list of executors was constructed according to the specified criteria and based on the individually oriented method for selecting executors of scientific projects. The use of the developed method makes it possible to obtain a rational list of executors according to all criteria, compared to the projects, in which executors were chosen by another method.

Another verification of the study was conducted at Yancheng Institute of Technology, exemplifying the formation of applications for scientific research for the year 2023. The database was supplemented with data from MathSciNet-dir, collected in project [118], including information about over 391 thousand publications and 873 thousand citations. Detailed characteristics of the data set are provided in Table 4.3

Table 4.3 Characteristics of the MathSciNet-dir data set

Nodes	391.5K
Edges	873.8K
Density	1.13999e-05
Maximum degree	496

Minimum degree	1
Average degree	4
Assortativity	0.122669
Number of triangles	1.8M
Average number of triangles	4
Maximum number of triangles	1.6K
Average clustering coefficient	0.401687
Fraction of closed triangles	0.141333
Maximum k-core	25
Lower bound of Maximum Clique	25

Data visualization of scientific publications was made in the form of a graph, where publications are represented as nodes. It is a powerful way to visualize the relationships and thematic clusters within a scientific field. In this visualization, each publication is a node, and their proximity or connections in the graph represent thematic or conceptual similarities, forming identifiable scientific spaces or clusters. Each node in the graph represents an individual publication. These nodes are numbered for easy identification. Edges represent relationships between publications based on thematic similarities. The length of edges denotes the strength of thematic similarity.

Publications that are closely related in terms of their content, citations, or authors will form clusters in the graph. These clusters represent specific scientific spaces or subfields. The layout of the graph is such that publications belonging to the same scientific space are positioned closer together, forming visually identifiable groups.

Clusters are differentiated by distinct colors, making it easier to distinguish one scientific space from another.

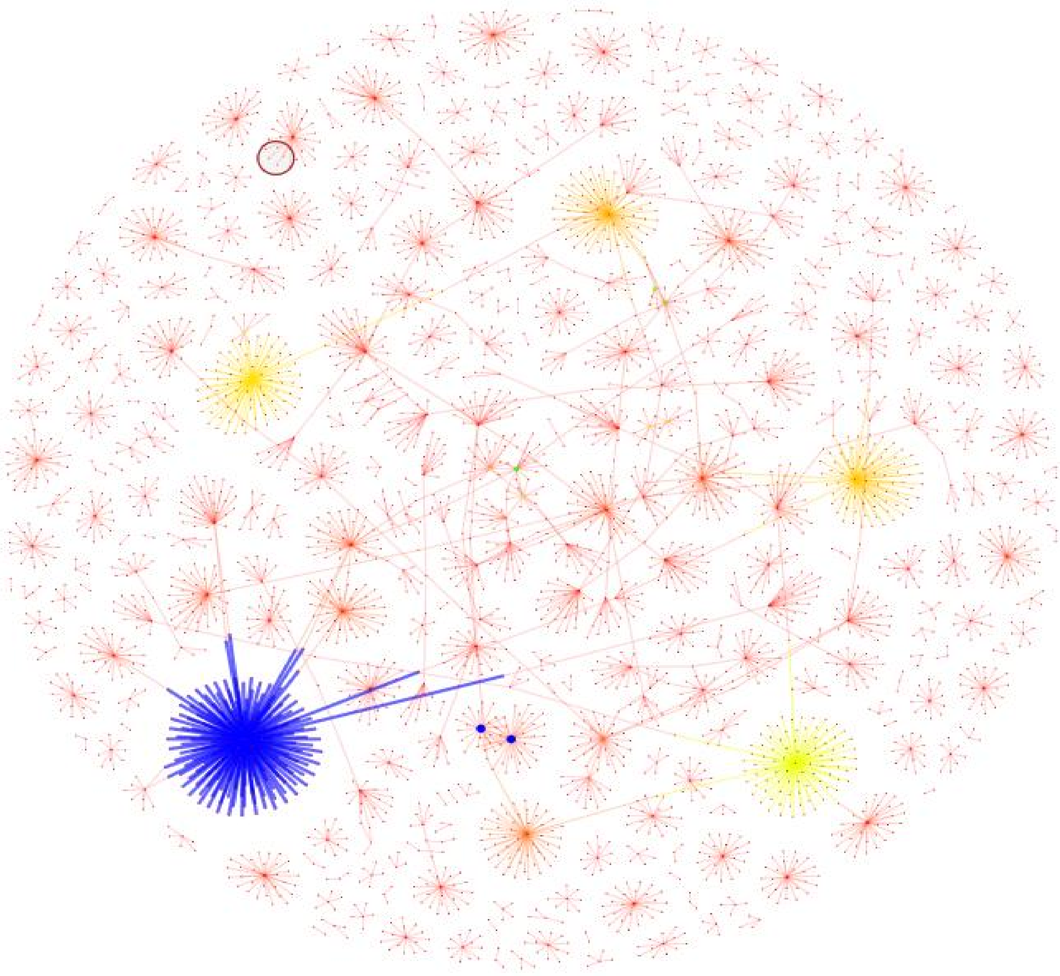

Figure 4.7. Example of forming scientific spaces in the MathSciNet-dir dataset

The set of scientific subject spaces was formed based on cluster analysis of publications. After clustering the publications, the clusters were named and scientific subject spaces were constructed. A total of 496 scientific subject spaces were obtained (Figure 4.8).

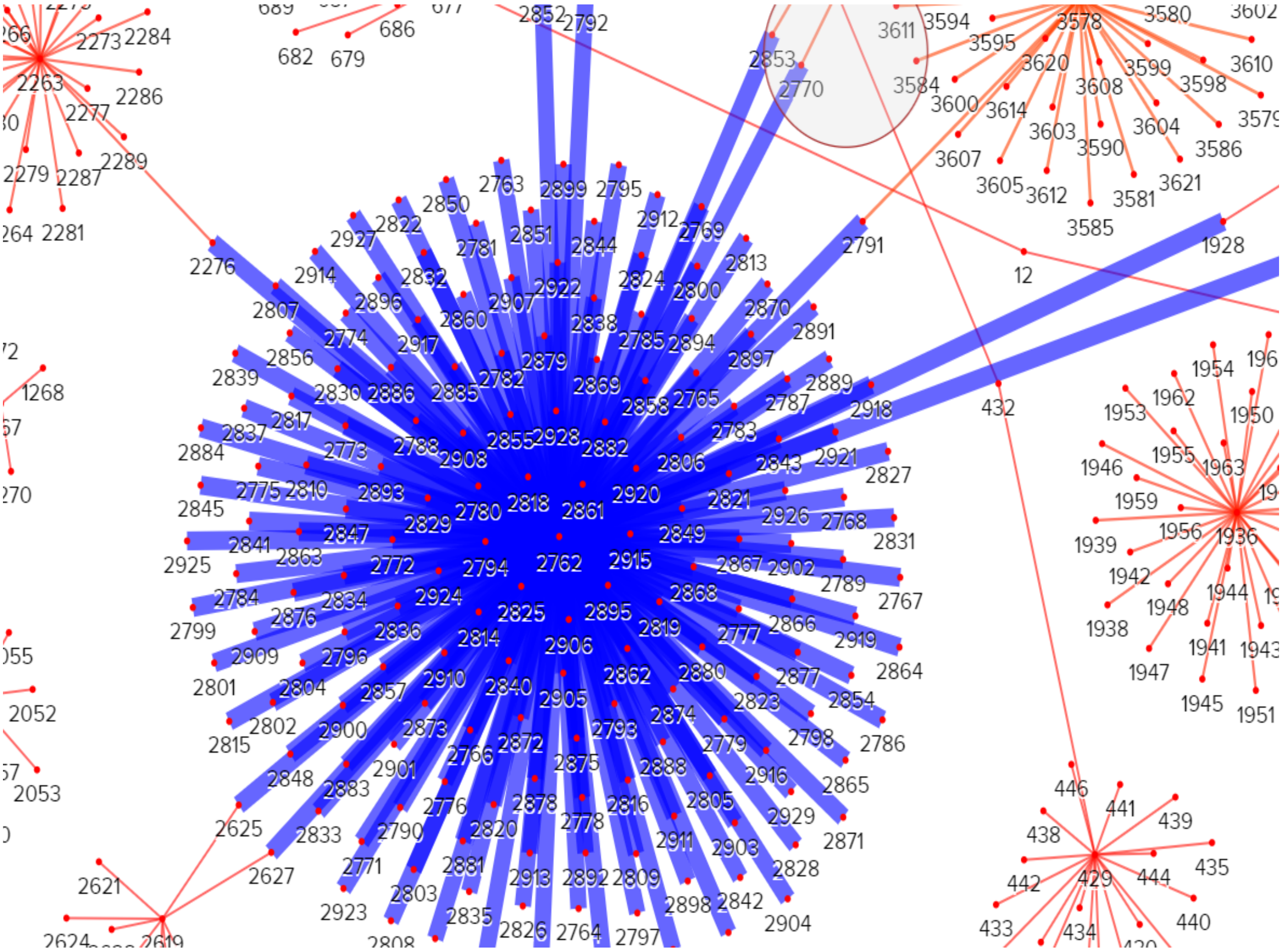

Figure 4.8. Example of a computer science scientific space. The distance from the center is proportional to the affiliation

For three project applications, 4 scientific subject spaces were selected (Cluster 1 - Project Development, Cluster 2 - Professional Competence, Cluster 3 - Educational Process, Cluster 4 - Scientific Activity). Table 4.3 shows the quantitative indicators obtained as a result of using the developed method for selecting executors of three projects."

Table 4.2. Verification of the study was carried out at Yancheng Institute of Technology

Scientific subject areas	Cluster 1	Cluster 2	Cluster 3
Number of publications	1241	768	1540
Total number of scientists in the space	72	48	99

Number of scientists who meet selection criteria	35	19	42
Number of scientists involved in projects	7	6	12
Average position in the orderly list of executors who meet the selection criteria and are actual project executors	22.8	18.7	42.4
Average position in the orderly list of executors selected by the individually oriented method	17.6	16.5	23.4
Average position in the orderly list by the CB criterion	18.4	13.1	25.5
Average position in the orderly list by the QA criterion	22.8	15.2	26.0

For project applications, the actual project groups were compared with the project groups, which were proposed based on the individually oriented method for selecting the executors of scientific projects. They were compared based on the magnitude of the degree of a project executor belong-ing to the relevant scientific subject space (clusters 1–4). In accordance with the calculated magnitudes of belonging, a rating list of potential performers was formed.

The position in the orderly list of executors who meet the selection criteria and are involved in projects indicates that the executors with an average rating in clusters take part in projects. The average percentage of scientists who meet the requirements of project managers for each scientific subject space is 41.85 %. The percentage of those involved in a project from those who were selected is 28.05 %. The average po-sition in the orderly list of executors who meet the selection criteria (Table 4.4) is higher than the value corresponding to randomly selected scientists from scientific subject spaces.The proposed scientists were compared with actual exec-utors according to the CB and QA criteria described in paper [36] and for which there are enough data. An orderly list of executors was constructed according to the specified criteria and based on the individually oriented method for selecting executors of scientific projects. The use of the developed method makes it possible to obtain a rational list of executors according to all criteria, compared to the projects, in which executors were chosen by another method.

4.3. The scientific and practical significance of the developed software

The scientific and practical significance of the developed software for the information system can be divided into separate modules:

1. Scientific Aspect: The development of a module for creating scientific profiles involves formalizing and integrating information about the scientific activity outcomes of potential participants in research projects. This information includes publication activity, evaluation of project participation experience, and assessment of interaction with other participants. Data collection methods include scraping from open Internet sources, manual entry, API integration, verification based on open information sources, and surveys of participants with collaborative experience. The scientific profile of a participant is dynamic and reflects the continuous accumulation of experience and knowledge, impacting the overall assessment. Unstructured data obtained through scraping undergo verification, partial structuring, and are collected in a database. These models characterize participants as dynamic elements, accumulating experience in other projects and contributing to new research initiatives. The models reflect the continuous process of development and transformation of scientific research project participants, demonstrating how this process influences other projects in which they participate.

2. Scientific Context: The developed module for evaluating the suitability of executors to the criteria of project work packages includes a comprehensive assessment of participants' knowledge and experience. Knowledge is assessed through the analysis of publication activity, while experience is determined based on the history of participation in scientific projects. Additionally, the module considers personal characteristics of executors identified through surveys. Information for evaluation is collected using various methods, including data from open and reliable Internet sources,

and formed through surveys. All collected data are systematized in a database, creating a structured scientific profile for each executor.

3. Research of Information Systems: The project monitoring module analyzes and evaluates project work packages, including necessary tasks and expected outcomes. Based on the data generated by this system, personnel managers and project leaders can make operational decisions regarding the modification of participants' contributions to scientific research projects. These decisions aim to increase efficiency and assess the overall results of the project. A key feature of this module is its ability to make quick decisions based on objective, verified, and reliable data, minimizing subjective influence on decision-making.

The practical significance of the results lies in the fact that the developed models and methods for forming scientific spaces and evaluating the influence of scientists in these spaces, considering the results of their scientific activity, form the basis for ensuring the effectiveness of scientific research projects. Using theoretical and practical results will improve the quality of scientific research projects and simplify the management of such projects. The results of the study also help reduce the time and effort required to form a new project team. Developed information system as web technology can be useful for project and personal managers of research projects or for the team leaders.

The practical value is that as a result of the work, an information technology for finding partners for conducting joint scientific research and implementing scientific projects based on a personally-oriented analysis of scientific activity results has been developed and implemented. The necessary mathematical models and software modules of the information system for managing executors of scientific research projects have been developed.

The main scientific provisions of the dissertation have been brought to the level of methodological generalizations and applied tools, enabling the formation of scientific spaces and the selection of executors-partners of scientific projects based on an individually-oriented approach based on the analysis of scientific subject environments.

The main provisions and results of the research have been implemented and applied in the activities of Yancheng Polytechnic College.

The development of the described information system for selecting scientific partners and managing research projects represents a significant advancement in both the scientific and practical realms. The system's design is modular, allowing for specific functionalities to be developed and integrated seamlessly.

The implementation of these research findings and system functionalities at Yancheng Polytechnic College showcases their applicability and effectiveness in a real-world educational and research setting. This comprehensive system demonstrates a significant stride in harnessing technology for optimizing scientific collaborations and project management, catering to the evolving needs of the scientific community.

Conclusions to chapter 4

The information technology is designed to facilitate the selection of scientific partners by implementing models and methods for collecting, storing, and transforming data. This includes algorithms for an individually-oriented method of selecting partners based on the analysis of subject-specific scientific environments. Software implementation is required to integrate these algorithms as modules in the information system. Databases and DBMS are crucial for organizing information about potential partners and projects. Integration with scientific databases and platforms like Scopus, PubMed, ORCID, and Google Scholar is essential for automated access to up-to-date research information. User interfaces should provide easy access and powerful search capabilities. Communication tools, while not mandatory, are beneficial for facilitating discussions and coordination among potential partners.

Centralized data storage in reliable databases is critical for accessible and protected information. Automation of data collection and updating is important to reduce human errors and maintain data quality. Advanced data analysis is utilized to identify trends and connections between researchers and projects. Regular data updating and integration with external scientific databases ensure the timeliness and completeness of information. Scalability and adaptability of the information system are vital to accommodate growing data volumes and changing requirements. Effective communication tools and automation of repetitive tasks improve the efficiency of the partner selection process. Organizational support includes defining strategic goals, developing policies, establishing procedures and standards, and providing training and resources. Regular updates, maintenance, and user feedback are necessary for the system's long-term relevance and effectiveness.

The application of these technical, software, informational, and organizational tools significantly enhance the quality and efficiency of selecting scientific partners. This optimization leads to better resource management, time-saving, and improved effectiveness in scientific research and project implementation.

According to the results of experimental verification of the individually oriented method of selection of subjects of scientific activity as a part of the information technology, it was shown that the average percentage of scientists who meet the requirements of project managers for each scientific subject space is about 46.55 %. The per-centage of those involved in the project among the selected ones is about 24.07 %. The probability of cooperation is higher among those who have an average H-index. The effectiveness of the selected participants in research projects can be discussed upon their completion or according to the results of reporting. The proposed scientists were compared with actual executors according to three criteria. The use of the devised method makes it possible to get a rational list of executors according to all criteria.

Purpose and Phases of Information Technology: The technology is aimed at enhancing the effectiveness of scientific research implementation by compiling, preserving, and analyzing data. It includes phases from identifying needs to strategically implementing tools for selecting project participants.

Development and Functionality: The system's development starts with assessing the need for tracking competencies of scientific project executors, involving detailed user requirement analysis and task definition. It then moves to accumulate and analytically process information from multiple sources, including scientometric databases and academic profiles.

Information technology streamlines the process of selecting scientific project participants by leveraging advanced data analysis, visualization tools, and strategic modeling, significantly boosting the efficiency and productivity of scientific research projects.

CONCLUSIONS

This work addresses the important task of developing mathematical models to evaluate the scientific activity outcomes of researchers dynamically, identifying their suitability to the requirements of executors of complex structured scientific research projects, as well as decision-making models for effective personnel management of scientific research projects (scientific component). It also involves developing an information technology for selecting scientific partners based on the models of evaluating scientific activity outcomes, automating the processes of data collection and processing about candidates (practical component).

The practical significance of the obtained results is that the developed models and methods for forming scientific spaces and assessing the influence of scientists in these spaces, considering their scientific activity outcomes, form the basis for ensuring the effectiveness of scientific research projects. The use of these theoretical and practical results will improve the quality and simplify the management of such projects. The research results also help reduce the time and effort required to form a new project team.

The practical value is that, as a result of the work, information technology for searching partners for conducting joint scientific research and implementing scientific projects based on personally-oriented analysis of scientific activity outcomes was developed and implemented. Necessary mathematical models and software modules of the information system for managing executors of scientific research projects were developed.

The research conducted leads to several conclusions:

1. The general theoretical foundations for selecting partners-executors of scientific projects and factors influencing the choice of potential executors in scientific projects were analyzed. The changes in scientific collaboration were considered, focusing on the globalization of scientific networks. The section highlights how the globalization of collaboration networks promotes interdisciplinary and transnational approaches to scientific research, involving experts from various fields to work on complex problems. The importance of international research consortia, conferences, symposia, joint

research centers of universities, and publications in specialized journals is shown. The complexity of global scientific collaboration in terms of forming teams for joint research is emphasized. It was established that the task of assessing the competencies of executors based on the results of scientific activity and their correspondence to the work packages of a scientific research project is not fully resolved. To ensure effective management of executors of a scientific research project, it is appropriate to develop new or improve known models of evaluating the results of scientific activity and build an information technology of selecting scientific partners based on these models.

2. A conceptual scheme of research with the assessment of the influence of scientists and their selection as partners-executors of a scientific project was constructed. Within this scheme, a mathematical model for assessing the influence of scientists through the global citation network considering the age of scientific results was considered. Factors influencing the choice of potential executors for scientific projects were analyzed. It was determined that the correspondence of the experience and competencies of the executors to the research direction is extremely important in selecting partners-executors of a scientific project. It is proposed to assess the correspondence of experience and competencies of the executors to the research direction, taking into account the affiliation of the scientific research project and the scientist to certain subject scientific environments. A method for forming subject scientific environments for scientists, scientific institutions, and scientific projects was proposed.

3. Models for assessing the influence of scientists through the global citation network were improved, taking into account the age of scientific results. The significance of the project structure and dynamics of scientific productivity in relevant subject spaces for choosing subjects of scientific activity were established. An individually oriented method for choosing scientific partners was devised, considering the project structure: the choice of executors for each project package separately, according to the performance estimates of executors in subject spaces corresponding to the package area. The use of this method allows reducing the subjective impact on

decision-making, guided only by open sources of information about the performance, competence, etc., of potential performers. This approach is rational in terms of achieving maximum quality and effectiveness of the implemented scientific project.

4. Models for assessing the influence of scientists were refined to consider the affiliation of publications to subject scientific spaces to more accurately assess scientists in the context of selecting partners-executors of scientific projects.

5. Methods for forming subject-specific scientific environments have been improved. The proposed method includes 3 stages. The first stage involves clustering of publications. In the second stage, the proximity of publications is determined. The third stage involves the alignment between researchers and scientific spaces. Analysis shows that the application of BERT methods for the second stage has several advantages

6. An individually-oriented method for selecting partners-executors of scientific projects based on the analysis of subject scientific environments was developed, enabling effective management of executors of a scientific research project and their correspondence to the work packages of the project. The main advantages of the method are high accuracy in choosing partners thanks to a detailed analysis of their competencies and experience, allowing the formation of effective teams based on complementary competencies that can adapt to the specific requirements of the project thanks to an individual approach to selecting each partner.

7. The information technology designed for selecting scientific partners streamlines the process by using models and algorithms to analyze and manage data. Key components include software integration of these algorithms, databases for organizing partner and project information, and interfaces with scientific databases for current data. User-friendly interfaces and optional communication tools aid in partner selection and coordination. The system emphasizes reliable data storage, automated data handling, and advanced analysis to identify research trends and connections. Regular updates and integration with external databases ensure information accuracy and completeness. Scalability, adaptability, and effective communication tools enhance the efficiency of the selection process. Organizational support, such as strategic goal setting,

policy development, and training, along with regular system updates and user feedback, maintain the system's long-term effectiveness. Overall, these measures significantly improve the quality and efficiency of selecting scientific partners, optimizing resources, and boosting research productivity.

8. Information technology streamlines the process of selecting scientific project participants by leveraging advanced data analysis, visualization tools, and strategic modeling, significantly boosting the efficiency and productivity of scientific research projects.

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APPENDIX A. ACT OF IMPLEMENTATION

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ACT OF IMPLEMENTATION

The act of implementing the results of the dissertation work of PhD student **Huilin Xu** «INFORMATION TECHNOLOGY OF THE SCIENTIFIC PARTNERS' SELECTION BASED ON THE RESEARCH ACTIVITY RESULTS EVALUATION MODELS»

The commission considered in detail the results of **Huilin Xu** dissertation research, «Information technology of the scientific partners' selection based on the research activity results evaluation models» and established:

While writing his dissertation, Huilin Xu fruitfully cooperated with our company and implemented research results for several years.

1. The Commission believes that **Huilin Xu** dissertation reflects in his work the management paradigm of scientific research project work package executors through the prism of their development in subject spaces. This is realized through an individually oriented method of selecting partners-executors for scientific projects based on the analysis of subject scientific spaces, which allows improving the quality of scientific research projects' implementation and simplifying the management of their executors' teams.

2. The work employs a method of forming subject scientific spaces for the formalized description of researchers' correspondence to the requirements of executors of work packages in scientific research projects. This approach enables accurate modeling of the life cycle of such projects and timely evaluation of the effectiveness of the executors for their institutional participants and leaders.

3. From a practical standpoint, the work introduced information technology for selecting scientific partners based on models for evaluating scientific activity outcomes. This facilitated the development of an information system for selecting scientific partners to find executors for the implementation of international scientific research projects.

We believe that the practical implementation of **Huilin Xu** research work in the practice of enterprise activity is an important reason to believe that Huilin Xu deserves to be awarded the scientific degree of Doctor of Philosophy in specialty 126 - "Information systems and technologies".

Yancheng Polytechnic College
Vice-chancellor **WANG SHUDONG**
10 August 2023

APPENDIX B. LIST OF THE APPLICANT'S PUBLICATIONS ON THE THEME OF THE DISSERTATION AND INFORMATION ON THE APPROVAL OF THE RESULTS OF THE DISSERTATION

Articles in professional publications of Ukraine (included in the list of the Ministry of Education and Science of Ukraine)

1. **Xu, H.,** & Kuchansky, A. (2019). The problem of choise of partners for organization of cooperation in the framework of scientist of scientific and educational projects. Scientific Bulletin of Uzhhorod University. Series of Mathematics and Informatics, 2(35), 134–142. https://doi.org/10.24144/2616-7700.2019.2(35).134-142 [category «B»]
2. **Xu, H.** (2019). Review of methods of evaluation of scientific and research activity for the choice of selection of scientific partners. *Management of development of complex systems,* 38, 156–160. https://doi.org/10.6084/m9.figshare.9788654 [category «B»]
3. **Xu, H.**, & Andrashko Yu. (2019) The problem of partnership choices for scientific projects cooperation. *Management of development of complex systems,* 37. 111–115. https://doi.org/10.6084/m9.figshare.9783086 [category «B»]
4. **Xu, H**., Kuchansky, A., & Gladka, M. (2021). Devising an individually oriented method for selection of scientific activity subjects for implementing scientific projects based on scientometric analysis. *Eastern-European Journal of Enterprise Technologies*, 6(3(114)), 93–100**.** https://doi.org/10.15587/1729-4061.2021.248040 [**Scopus, Q3,** category «A»]
5. Xu, H. (2023). Model for assessing the influence of scientists based on the global citation network and the history of scientific results. *Management of Development of Complex Systems,* 54, 90–94. https://doi.org/10.32347/2412-9933.2023.54.90-94 [category «B»]

Articles in professional publications of Ukraine

(not included in the list of the Ministry of Education and Science of Ukraine)

1. **Xu, H**. (2020). The Problem Of Choosing Partners For Scientific Cooperation. *Science Journal Innovation Technologies Transfer,* 4, 35-39. https://doi.org/10.36381/iamsti.4.2020.35-39 .

Approbation works:

1. **Xu, H.** (November 20-21, 2018). Information technology of scientific partners selection. *International Scientific and Practical Conference "Information Technologies and Interactions" (IT&I-2018),* Kyiv, Ukraine, 68–69.

2. **Xu, H.** (2019). The problem of formating of scientific communities. *I International Scientific and Practical Conference (IMTCK2019)*, Chernivtsi, Ukraine, 111-113

3. **Xu, H.** (December 20, 2019). The problem of partners selection for scientific projects. *VI International Scientific and Practical Conference "Information Technologies and Interactions" (IT&I-2019)*, Kyiv, Ukraine, 104-106.

4. **Сюй Х.** (25-26 March 2020) Задача вибору партнерів для наукової співпраці. *Seventh international scientific practical conference «Management of the development of technologies»*, Kyiv, Ukraine, 135-136.

5. **Xu, H.**, Kuchansky, A., Biloshchytska, S., & Tsiutsiura ,M. (2021). A Conceptual Research Model for the Partner Selection Problem. *2021 IEEE International Conference on Smart Information Systems and Technologies (SIST),* Astana, Republik of Kazakhstan, 1-6. https://doi.org/10.1109/SIST50301.2021.9465931 [abstracts **Scopus, Web of Science**]

6. Кучанський, О.Ю., Гладка, М.В., & **Сюй, Х.** (2021). Індивідуально-орієнтований метод вибору суб’єктів наукової діяльності. *X Наукова конференція «Наукові підсумки 2021 року»*, Харків: Технологічний Центр, 17.

7. **Xu, H.**, (2021). The problem of foundind partners for the formation of a scientific consortium. *International Scientific and Practical Conference "Information Technologies and Interactions" (IT&I-2021)*, Kyiv, Ukraine, 30-31.