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**PHD THESIS**

# MODELS, METHODS AND INFORMATION TECHNOLOGY FOR CHOOSING THE MANAGEMENT METHODOLOGY OF INTERNATIONAL EDUCATIONAL PROJECTS

122 Computer Science

12 Information Technology

Applying for the Doctor of Philosophy degree

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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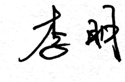



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## SUMMARY

**Li Ming. Models, methods and information technology for choosing the management methodology of international educational projects. –** *Qualifying scientific work as a manuscript.*

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**Abstract content**. The dissertation is devoted to the construction of a model and method of choosing a software project management approach based on vague ideas, the development of architecture, analytical hardware and software tools for the operation of an information platform for choosing and structuring an approach to project management.

Today, information technologies are experiencing a rapid phase of development under conditions of economic crisis, especially in the fields of research, education, industry, etc. The key resources of modern organizations are human resources, which include a number of productive knowledge and various human abilities. In some areas of information development, there is a partial or complete loss of skills and competencies acquired over the years. This affects the terms of implementation of current projects within the framework of contractual agreements.

The realities of modern innovative social, educational and business processes reveal not only the aging of production technologies, but also the passive participation of enterprises in the implementation of these plans. Today, there are many systems that solve tasks that do not require special human abilities to make management decisions. Traditional methods do not always provide the necessary target functionality of the software product, as well as the degree of complexity of the modeled project, this determines the need for a professional level of programmer, taking into account the human factor in the choice of technical means, which can lead to errors in modeling, planning, execution, monitoring and, in turn, to an increase in time and material costs.

A scientifically based solution to the specified range of scientific-methodical, calculation-analytical and applied problems through the development of a multi-component information platform and a structured approach to project management is a necessary prerequisite for identifying shortcomings at the pre-project stage, which will reduce the risk of choosing a development methodology unsuitable for the project.

In this work, an important task is solved, namely: the development of models and methods based on vague ideas that form the basis of modeling the decision-making system in the management of an international project in conditions of uncertainty and the adaptation of scientific and methodological foundations and practical recommendations for the qualitative assessment of the project management model as components information platform.

**The object** of research is software project management processes and mechanisms in information and communication technologies.

**The research subject** is models and methods and information and communication technologies regarding the selection and structuring of the approach to project management.

**Research methods.** The general-methodological basis of the research presented in the dissertation is analytical approaches, logical laws of building an organizational structure of management, general scientific and special methods of cognition, which is directly determined by the set goal and tasks of the research: a classification-analytical approach and grouping, models and methods of evaluating project selection are proposed; the method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies; theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics; methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic; application of the basic principles of construction of computer numerical methods; simple iteration methods for solving systems of nonlinear equations. Empirical conclusions of the thesis are based on the use of statistical methods, forecasting, methods of mathematical programming and correlation-regression analysis, as well as the use of special packages of data processing programs.

**The study aims** to develop of conceptual provisions of models and methods and information technologies based on vague ideas that form the basis of modeling the decision-making system in the management of an international project under conditions of uncertainty and the adaptation of scientific and methodological principles and practical recommendations for the qualitative assessment of the project management model as components of the information platform.

**The scientific novelty of the obtained results** lies in the development of models and methods and evaluation information technologies regarding the selection and structuring of the project management approach in conditions of fuzzy logic based on the Agile methodological platform.

In the dissertation, the author obtained the following results:

• For the first time, a generalized model of the choice of evaluation options for management decisions of the project justification was investigated, taking into account organizational, analytical, informational and communicative processes, taking into account fuzzy logic based on the Agile methodological platform.

• For the first time, the use of flexible methodology and automated assessment indicators for the implementation of international joint projects, during the implementation of educational and scientific projects, was investigated.

• The method of building a system for selecting options for management solutions based on the established principles of management, teamwork, control, verification and evaluation of the results of integrated information platforms has been improved.

• The method of forming the choice of a project approach, assessment of technical and economic activity, determination of business opportunities, time and work to complete the project has been improved.

• The model for choosing a project management methodology has been improved, which allows you to reflect existing risks and make management decisions on methodological development.

• The conceptual and methodological principles of the formation of management decisions within the organizational structure of management, which was carried out through the justification of institutional, operational-analytical, investment and organizational-administrative through the combination of matrix-structured divisions of the organization, received further development.

• Methodological and analytical principles regarding the development of client-service architecture, hardware, organizational, and analytical software for the functioning of an automated system of options for management decision-making were further developed.

• The methods of organizing the implementation of international educational projects on the basis of Agile methodology, which takes into account the management deficiencies present in the project at the pre-project stage, were further developed.

**The first chapter** of the dissertation contains an analysis of existing theoretical and practical research on the modeling of organizational and information technology methods and models in project management. The analysis proved significant scientific and analytical advantages of using flexible management of international educational and scientific projects as a progressive and iterative methodological platform. This platform is suitable for use in such conditions of the project microenvironment, when at the initiation of the project there is no proper certainty about what the life cycle of the project and its final product should be. The section contains a justification of the feasibility of using the flexible Agile methodology for the needs of developing a multi-component information educational and scientific platform, which should ensure successful structuring, administrative support and implementation of international projects in conditions of insufficient certainty.

**The second chapter** of the thesis describes the models and mechanisms of application of flexible methodology for joint international projects. As part of the study of the main approaches and models of the application of flexible modeling of the management of international projects with clear goals and transparency, it was found that the Agile methodological platform allows in the circumstances of insufficient certainty and an improperly prepared communicative space (at the beginning of the project cycle) to cover the content of large-scale and complex projects, and then to phase them structure, make adjustments and work to ensure a growing level of satisfaction with the project product among stakeholders and project team members.

For the needs of information and communication support, office and analytical preparation and implementation of international projects on the basis of Agile, this section describes a unique scientific and methodological background, the components of which are: classification and analytical approach and grouping, models and methods of evaluating project selection; the method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies; theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics; methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic.

**In the third chapter** of the dissertation, a mathematical model and a method for choosing an approach to project management based on vague ideas about the applicability of existing standards, guidelines, and project management methodologies are proposed. The developed model and method allow you to choose the best approach to project management for a specific project from such popular approaches as the PMVOK management, Scrum methodologies, and Kanban. A number of parameters of the project and its environment that affect the choice of approach are identified, such as the number of people participating in the project, the experience of the customer with this project team, the experience of the project team in this field, and others. The above method is illustrated by an example of its application for choosing an approach to managing a software development project.

A method of forming an approach to project management has been developed, the advantage of which is the complex application of the Cynefin model and the method of fuzzy representations. The method is applied to the project dedicated to the development of gas cleaning equipment.

The section contains a description of the improved algorithm for applying the QFD method within the framework of the Scrum technological system when implementing a project on the basis of a project management platform to solve the problem of developing specific recommendations for ensuring the quality of separate components of the specified complexes. The success or failure of each stage of the technological process of project implementation is simulated using the Monte Carlo method, and the final results of the statistical accumulation of simulation results are processed using the MathCAD package.

**The fourth chapter** describes the architecture, analytical hardware and software tools of the functioning of the information platform for the selection and structuring of the approach to the management of international educational and scientific techno-projects. The scientific-methodical and information-analytical research results were integrated into the complex of application programs "IPPM - international platform for project management", which made it possible to test the proposed models and methods of the international educational-scientific and information-technical project management system. The components of the platform for choosing and structuring the approach to project management allow you to create and evaluate alternative specialized approaches to project management, choose the best of them from the point of view of cost and effort of management, as well as the risks accompanying the application of the approach.

**Practical significance of the obtained results.** The main scientific provisions of the dissertation are brought to the level of methodical generalizations and applied tools, which enables effective monitoring, structuring and maneuvering of project management, which allows to reduce the risk of closing the project due to increased financial requirements or non-fulfillment of obligations to the customer. Approbation of the methodological platform adapted to practical use made it possible to adjust the opinions of the customer and competent specialists when deciding on the choice of development methodology.

The obtained results of both a theoretical and practical nature are the basis for further research aimed at improving and ensuring the sustainability of the development of higher education institutions, which meets the requirements of international systems for monitoring their activities, taking into account changes in the competences of executors of educational projects that are carried out in these institutions of higher education .

**Keywords:** Agile methodology, information technologies for choosing a management methodology; integrated project management platform; joint international project; management knowledge; system dynamic modeling; methodology selection model; project management methodology; fuzzy set analysis.

## LIST OF PUBLICATIONS OF THE APPLICANT BY PHD THESIS TOPIC

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**Approbation works**

1. **Li Ming.** (2018). SCRUM for implementing educational projects based. V international scientific and practical conference "Information technologies and interactions", 61-62.

2. **Li Ming.** (2019). Competitiveness of foreign university in Chinese education process. "Management of projects in the development of society", 36-37.

3. **Li Ming.** (2019). Competitiveness of foreign university in chinese education process. I international scientific-practical conference, Chernivtsi IMTSK-2019 (Information Modeling Technologies, Systems and Complexes), 115-116.

4. **Li Ming.** (2020). Інтегрована платформи для управління науковим проектом. Seventh international scientific-practical conference «Management of the development

of technologies» Topic: "Information technology development of educational content» Kyiv, 25 – 26 March 2020, 137-138.

## АНОТАЦІЯ

**Лі Мінг. Моделі, методи та інформаційні технології вибору методології управління міжнародними освітніми проектами. –** *Кваліфікаційна наукова праця на правах рукопису.*

Дисертація на здобуття наукового ступеня доктора філософії за спеціальністю 122 «Комп'ютерні науки» – Київський національний університет імені Тараса Шевченка, Київ, 2023.

**Зміст анотації.** Дисертація присвячена побудові моделі і методу вибору підходу управління програмним проектом на основі нечітких уявлень, розробці архітектуру, аналітичним апаратним та програмним засобам функціонування інформаційної платформи вибору та структурування підходу до управління проектом.

Сьогодні інформаційні технології переживають бурхливу фазу розвитку за умов економічної кризи, особливо у сферах досліджень, освіти, промисловості тощо. Ключовими ресурсами сучасних організацій є людські ресурси, які охоплюють низку продуктивних знань та різних здібностей людини. У деяких галузях інформаційного розвитку відбувається часткова чи повна втрата навичок та компетенцій, набутих роками. Це впливає терміни реалізації поточних проектів у рамках контрактних угод.

Реалії сучасних інноваційно-соціальних, освітніх та бізнес-процесів оголюють не лише старіння виробничих технологій, а й пасивну участь підприємств у реалізації цих планів. На сьогоднішній день існує безліч систем, що вирішують завдання, що не потребують особливих здібностей людини для ухвалення управлінських рішень.Традиційні методи не завжди забезпечують необхідну цільову функціональність програмного продукту, а також за ступенем складності

проекту що моделюється, це обумовлює необхідністю професійного рівня програміста, враховуючи людський фактор вибору технічних засобів, що може призвести до помилок при моделюванні, плануванні, виконанні, моніторингу та в свою чергу до збільшення часових та матеріальних витрат.

Науково-обґрунтоване вирішення зазначеного кола науково-методичних, розрахунково-аналітичних та прикладних проблем шляхом розробки багатокомпонентної інформаційної платформи та структурованого підходу до управління проектом є необхідною передумовою виявлення недоліків ще на передпроєктному етапі, яка дозволить знизити ризик вибору непридатної для проекту методології розробки.

В даній роботі вирішується важливе завдання, а саме: розробка моделей та методів на основі нечітких уявлень, що становлять основу моделювання системи прийняття рішень при управлінні міжнародним проектом в умовах невизначеності та адаптації науково-методичних основ і практичних рекомендацій щодо якісної оцінки моделі управління проектом як компоненти інформаційної платформи.

**Об'єктом дослідження** є процеси управління програмним проектом та механізми в інформаційно-комунікаційних технологіях.

**Предметом дослідження** є моделі та методи та інформаційно-комунікаційні технології щодо вибору та структурування підходу до управління проектом.

**Методи дослідження**. Загально-методичне підґрунтя представлених в дисертації досліджень аналітичних підходів, логічних законів побудови організаційної структури управління, загальнонаукових і спеціальних методів пізнання, що безпосередньо зумовлено поставленою метою та завданнями дослідження: запропоновано класифікаційно-аналітичний підхід та групування, моделі та методи оцінювання вибору проектів; метод експертних оцінок і комплексний підхід – для визначення комплексних показників вибору інформаційно-комунікативних технологій; теорію прийняття управлінських рішень, теорії імітаційного експерименту, та методи математичної статистики;

методи багатокритеріальної оцінки управлінський рішень в умовах нечіткої логіки; застосування основних принципів побудови комп'ютерних чисельних методів; методи простої ітерації для розв'язування систем нелінійних рівнянь. Емпіричні висновки дисертації ґрунтуються на використанні статистичних методів, прогнозуванні, методах математичного програмування та кореляційно-регресійного аналізу, а також використання спеціальних пакетів програм обробки даних.

**Метою дослідження є** розробка концептуальних положень моделей та методів та інформаційних технологій на основі нечітких уявлень які складають основу моделювання системи прийняття рішень при управлінні міжнародним проєктом в умовах невизначеності та адаптація науково-методичних засад та практичних рекомендацій щодо якісної оцінки моделі управління проектом як компоненти інформаційної платформи.

**Наукова новизна** одержаних результатів полягає в розробці моделей та методів та інформаційних технологій оцінювання щодо вибору та структурування підходу управління проектом в умовах нечіткої логіки на основі методологічної платформи Agile.

У дисертаційній роботі автором отримані наступні результати:

- Вперше досліджена узагальнена модель варіанти вибору оцінювання управлінських рішень обґрунтування проекту з урахуванням організаційних, аналітичних, інформаційно-комунікативних процесів з врахуванням нечіткої логіки на основі методологічної платформи Agile.

- Вперше досліджено застосування гнучкої методології і показників автоматизованої оцінки для реалізації міжнародних спільних проектах, при виконання освітніми і науковими проектами.

- Удосконалено метод побудови системи вибору варіантів управлінських рішень встановленим принципам управління, командної роботи, форми контролю, перевірки та оцінки результату діяльності інтегрованих інформаційних платформ.

- Удосконалено метод формування вибору проектного підходу, оцінку техніко-економічної діяльності, визначення бізнес-можливостей, час та роботу для завершення проекту.
- Удосконалено модель вибору методології управління проектом що дозволяє відобразити наявні ризики та прийняття управлінських рішень методологічної розробки.
- Отримали подальший розвиток концептуально-методичні засади формування управлінських рішень в межах організаційної структури управління яке здійснено через обґрунтування інституційних, операційно-аналітичних, інвестиційних та організаційно-адміністративних через сполучення матрично-структурованих підрозділів організації.
- Отримали подальший розвиток  методологічні та аналітичні засади щодо розробки клієнт-сервісу архітектуру, апаратних, організаційних, аналітичних програмних засобів функціонування автоматизованої системи варіантів вибору прийняття управлінських рішень.
- Отримали подальший розвиток методи організації впровадження міжнародних освітніх проектів на основі методології Agile яка враховує недоліки управління, наявні в проекті на передпроєктному етапі.

**Перший розділ** дисертації містить аналіз існуючих теоретичних та практичних досліджень щодо моделювання організаційних та інформаційних технологій методів та моделей при управлінні проектами. Аналіз засвідчив значні науково-аналітичні переваги застосування гнучкого управління міжнародними освітньо-науковими проектами як поступальної та ітеративної методологічної платформи. Ця платформа доцільна до застосування в таких умовах проектного мікросередовища, коли при ініціації проекту немає належної достовірної визначеності стосовно того, яким має бути життєвий цикл проекту та його кінцевий продукт. Розділ містить обґрунтування доцільності застосування гнучкої методології Agile для потреб розробки багатокомпонентної інформаційної освітньо-наукової платформи, яка має забезпечити успішну структуризацію, адміністративний супровід та впровадження міжнародних проектів в умовах неналежної визначеності.

**В другому розділі** дисертації описані моделі та механізми застосування гнучкої методології для спільних міжнародних проектів. В рамках дослідження основних підходів та моделей застосування гнучкого моделювання управління міжнародними проектами проектом у чітких цілях та прозорості виявлено що методологічна платформа Agile дозволяє в обставинах недостатньої визначеності та неналежно підготовленого комунікативного простору (на початку циклу проекту) охопити зміст масштабних та складних проектів, далі їх поетапно структурувати, вносити корективи та працювати на забезпечення зростання рівня задоволеності продуктом проекту між стейкхолдерами та членами команди проекту.

Для потреб інформаційно-комунікативного забезпечення, офісно-аналітичної підготовки та впровадження міжнародних проектів на ґрунті Agile вданому розділі описано унікальне науково-методичне підґрунтя, компонентами якого є: класифікаційно-аналітичний підхід та групування, моделі та методи оцінювання вибору проектів; метод експертних оцінок і комплексний підхід – для визначення комплексних показників вибору інформаційно-комунікативних технологій; теорію прийняття управлінських рішень, теорії імітаційного експерименту, та методи математичної статистики; методи багатокритеріальної оцінки управлінський рішень в умовах нечіткої логіки.

**У третьому розділі** дисертаційної роботи запропоновано математичну модель та метод вибору підходу до управління проєктами на основі нечітких уявлень щодо застосовності існуючих стандартів, керівництв, методологій управління проєктами. Розроблені модель та метод дозволяють обрати найкращий підхід до управління проєктом для конкретного проєкту з таких популярних підходів, як керівництво PMBOK, методології Scrum, та Kanban. Визначено ряд параметрів проєкту та його середовища, які впливають на вибір підходу, таких як кількість людей, які беруть участь у проєкті, досвід замовника з цією командою проєкту, досвід роботи команди проєкту в цій галузі та інші. Вищевказаний метод проілюстрований на прикладі його застосування для вибору підходу до управління проєктом з розробки програмного забезпечення.

Розроблено метод формування підходу до управління проєктом, перевагою якого є комплексне застосування моделі Cynefin та методу нечітких уявлень. Метод застосовано до проєкту, присвяченого розробці газоочисного обладнання.

Розділ містить опис удосконаленого алгоритму застосування QFD-методу в рамках технологічної системи Scrum при реалізації проєкту на базі платформи управління проєктами для вирішення задачі вироблення конкретизованих рекомендацій щодо забезпечення якості відокремлених компонентів зазначених комплексів. Факт успішності чи не успішності виконання кожного з етапів технологічного процесу реалізації проєкту моделюється з використанням методу Монте-Карло, а підсумкові результати статистичного накопичення підсумків моделювання опрацьовані із застосуванням пакету MathCAD.

**В четвертому розділі** описано архітектуру, аналітичні апаратні та програмні засоби функціонування інформаційної платформи вибору та структурування підходу до управління міжнародними освітньо-науковими техно- проектами. Інтегровано науково-методичні та інформаційно-аналітичні результати дослідження в комплекс прикладних програм “IPPM - international platform for project management”, що дозволило провести апробацію запропонованих моделей та методів системи управління міжнародними освітньо-науковими та інформаційно-технічними проектом. Компоненти платформи вибору та структурування підходу до управління проєктом дозволяють створювати і оцінювати альтернативні спеціалізовані підходи до управління проєктом, вибирати найкращий з них з точки зору вартості і трудомісткості управління, а також ризиків, що супроводжують застосування підходу.

**Практичне значення одержаних результатів.** Основні наукові положення дисертації доведені до рівня методичних узагальнень і прикладного інструментарію, що дає змогу здійснювати ефективний моніторинг, структуризацію та маневрування управління проектом що дозволяє знизити ризик закриття проекту через збільшені фінансові вимоги або невиконання зобов'язань перед замовником. Апробація адаптованого до практичного використання методологічної платформи дали можливість скоригувати думки замовника та компетентних фахівців при прийнятті рішення про вибір методології розробки.

Отримані результати як теоретичного, так і практичного характеру, є підґрунтям для подальших досліджень, спрямованих на удосконалення та забезпечення сталості розвитку закладів вищої освіти, що відповідає вимогам міжнародних систем моніторингу їх діяльності з урахуванням зміни компетентностей виконавців освітніх проєктів, які виконуються в цих закладах вищої оствіти.

**Ключові слова:** методологія Agile, інформаційні технології вибору методології управління; інтегрована платформа управління проєктом; спільний міжнародний проєкт; управлінське пізнання; системне динамічне моделювання; модель вибору методології; методологія управління проєктом; нечіткомножинний аналіз.

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## CONTENT

# INTRODUCTION

Today, information technology is going through a turbulent stage of its development in the conditions of the economic crisis, especially in scientific research, education, industry, thermal energy and other areas. The key resource of modern organizations is human resource, which includes a set of productive knowledge and various human abilities. There is a problem of partial or complete loss of skills and competencies acquired over the years in certain areas of information development. This affects the timelines of current projects under existing contractual arrangements.

Modern realities of innovative and social, educational and business processes have revealed not only the problem of the obsolescence of production technologies and the passive participation of enterprises in the implementation of these programs. Today there are many systems that solve the problem of making management decisions without special human abilities. Traditional methods do not always provide the necessary target functionality of the software product, as well as the degree of complexity of the modeled project, this requires the professional level of the programmer, taking into account the human factor in the choice of technical means, which can lead to errors in modeling, planning, execution, monitoring and in its queue to increase time and material costs.

In the scientific and educational sense, the design and modeling process is an important study, especially at the stage of initiation and planning of the management project management system. The analysis of the latest research and publications in the scientific community regarding the methodology of a flexible approach to system design is described by domestic scientists such as V. I. Bobrytska, S. B. Belikov, O. V. Klymov, D. V. Pavlenko, D. V. Tkach, A. Biloshchytskyi. O., Biloschytska S.V., Bushuev S.D., Chupryna H.M., Batenko L.P., Bugakov, I.A. Vaisman, V.A., Voznyy A.M. and foreign O'Reilly T, Lurye B, Kaster K, Itegov D, Gudvin, G, Dail G, Arnott D, et al. Despite the significance of the scientific and applied contribution of these specialists, it is necessary to determine that the existing approaches and developments do not provide adequate justification for the flexible methodology of non-software projects.

Today, there are many information technologies that solve the problem of organizing educational learning processes. Such information systems require significant resource costs if they are developed from scratch or large costs if a decision is made to purchase licenses for already existing solutions. They are available to large enterprises that have already occupied their niche in the market and have the resources to develop project management strategies and purchase such services. The financial capabilities of small organizations or startups are limited during development, which greatly complicates or makes it impossible to purchase a ready-made solution.

The need for a scientifically based solution to the specified range of scientific-methodical, calculation-analytical and applied problems regarding the development of a multi-component information platform and a structured approach to project management as a necessary prerequisite for the formation of shortcomings at the pre-project stage and to reduce the risk of choosing a development methodology unsuitable for the project, which determines the relevance of the research topic .

In this work, an important task is solved, namely: the development of models and methods based on vague ideas that form the basis of modeling the decision-making system in the management of an international project in conditions of uncertainty and the adaptation of scientific and methodological foundations and practical recommendations for the qualitative assessment of the project management model as components information platform.

The dissertation work was carried out at the Faculty of Information Technologies of Taras Shevchenko National University of Kyiv in accordance with the national strategy for the development of education in Ukraine for 2011-2027 and in accordance with the plan of research works of Taras Shevchenko National University of Kyiv, in particular the topic "Information technologies of analysis and forecasting of processes , invariant to the subject area", No. 0123U101621.

**The object** of research is software project management processes and mechanisms in information and communication technologies.

**The research subject** is models and methods and information and communication technologies regarding the selection and structuring of the approach to project management.

**Research methods.** The general-methodological basis of the research presented in the dissertation is analytical approaches, logical laws of building an organizational structure of management, general scientific and special methods of cognition, which is directly determined by the set goal and tasks of the research: a classification-analytical approach and grouping, models and methods of evaluating project selection are proposed; the method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies; theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics; methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic; application of the basic principles of construction of computer numerical methods; simple iteration methods for solving systems of nonlinear equations. Empirical conclusions of the thesis are based on the use of statistical methods, forecasting, methods of mathematical programming and correlation-regression analysis, as well as the use of special packages of data processing programs.

**The study aims** to develop of conceptual provisions of models and methods and information technologies based on vague ideas that form the basis of modeling the decision-making system in the management of an international project under conditions of uncertainty and the adaptation of scientific and methodological principles and practical recommendations for the qualitative assessment of the project management model as components of the information platform.

The defined purpose of the study determined the need to solve the research tasks according to the following list:

- To conduct an analysis of existing theoretical and practical research on the modeling of organizational and information technology methods and models in project management.

- Identify the relevance of modern methodological approaches and analytical tools that do not belong to software.

- To investigate the main approaches of the model and methods of complex solutions of flexible modeling of project management with clear goals and transparency.

-E the organizational and functional structure of project management and diagnose trends in changes in their structure;

- To form a model for the selection of organizational structures necessary for project managers to effectively achieve the goal.

- To propose methods and parameters for choosing the project approach of international project management methodology.

- Develop and justify a model of decision-making in the management of an international project under conditions of uncertainty.

- Build and apply a software project management model and approach selection methods based on fuzzy representations.

- Develop the architecture, analytical hardware and software tools for the functioning of the information platform for choosing and structuring the project management approach.

- Test the proposed models and methods of the project management system as components of the information platform and its application.

**The scientific novelty of the obtained results** lies in the development of models and methods and evaluation information technologies regarding the selection and structuring of the project management approach in conditions of fuzzy logic based on the Agile methodological platform.

In the dissertation, the author obtained the following results:

• For the first time, a generalized model of the choice of evaluation options for management decisions of the project justification was investigated, taking into account organizational, analytical, informational and communicative processes, taking into account fuzzy logic based on the Agile methodological platform.

• For the first time, the use of flexible methodology and automated assessment indicators for the implementation of international joint projects, during the implementation of educational and scientific projects, was investigated.

• The method of building a system for selecting options for management solutions based on the established principles of management, teamwork, control, verification and evaluation of the results of integrated information platforms has been improved.

• The method of forming the choice of a project approach, assessment of technical and economic activity, determination of business opportunities, time and work to complete the project has been improved.

• The model for choosing a project management methodology has been improved, which allows you to reflect existing risks and make management decisions on methodological development.

• The conceptual and methodological principles of the formation of management decisions within the organizational structure of management, which was carried out through the justification of institutional, operational-analytical, investment and organizational-administrative through the combination of matrix-structured divisions of the organization, received further development.

• Methodological and analytical principles regarding the development of client-service architecture, hardware, organizational, and analytical software for the functioning of an automated system of options for management decision-making were further developed.

• The methods of organizing the implementation of international educational projects on the basis of Agile methodology, which takes into account the management deficiencies present in the project at the pre-project stage, were further developed.

In order to solve the problems of the dissertation research, the first section of the work describes the analysis of existing theoretical and practical studies on the modeling of organizational and information technologies, methods and models in project management. The analysis proved significant scientific and analytical advantages of using flexible management of international educational and scientific projects as a progressive and iterative methodological platform. This platform is suitable for use in such conditions of the project microenvironment, when at the initiation of the project there is no proper certainty about what the life cycle of the project and its final product should be. The section contains a justification of the feasibility of using the flexible Agile methodology for the needs of developing a multi-component information educational and scientific platform, which should ensure successful structuring, administrative support and implementation of international projects in conditions of insufficient certainty.

**The second chapter** of the thesis describes the models and mechanisms of application of flexible methodology for joint international projects. As part of the study of the main approaches and models of the application of flexible modeling of the management of international projects with clear goals and transparency, it was found that the Agile methodological platform allows in the circumstances of insufficient certainty and an improperly prepared communicative space (at the beginning of the project cycle) to cover the content of large-scale and complex projects, and then to phase them structure, make adjustments and work to ensure a growing level of satisfaction with the project product among stakeholders and project team members.

For the needs of information and communication support, office and analytical preparation and implementation of international projects on the basis of Agile, this section describes a unique scientific and methodological background, the components of which are: classification and analytical approach and grouping, models and methods of evaluating project selection; the method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies; theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics; methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic.

**In the third chapter** of the dissertation, a mathematical model and a method for choosing an approach to project management based on vague ideas about the applicability of existing standards, guidelines, and project management methodologies are proposed. The developed model and method allow you to choose the best approach to project management for a specific project from such popular approaches as the PMVOK management, Scrum methodologies, and Kanban. A number of parameters of the project and its environment that affect the choice of approach are identified, such as the number of people participating in the project, the experience of the customer with this project team, the experience of the project team in this field, and others. The above method is illustrated by an example of its application for choosing an approach to managing a software development project.

A method of forming an approach to project management has been developed, the advantage of which is the complex application of the Cynefin model and the method of fuzzy representations. The method is applied to the project dedicated to the development of gas cleaning equipment.

The section contains a description of the improved algorithm for applying the QFD method within the framework of the Scrum technological system when implementing a project on the basis of a project management platform to solve the problem of developing specific recommendations for ensuring the quality of separate components of the specified complexes. The success or failure of each stage of the technological process of project implementation is simulated using the Monte Carlo method, and the final results of the statistical accumulation of simulation results are processed using the MathCAD package.

**The fourth chapter** describes the architecture, analytical hardware and software tools of the functioning of the information platform for the selection and structuring of the approach to the management of international educational and scientific techno-projects. The scientific-methodical and information-analytical research results were integrated into the complex of application programs "IPPM - international platform for project management", which made it possible to test the proposed models and methods of the international educational-scientific and information-technical project management system. The components of the platform for choosing and structuring the approach to project management allow you to create and evaluate alternative specialized approaches to project management, choose the best of them from the point of view of cost and effort of management, as well as the risks accompanying the application of the approach.

**Practical significance of the obtained results.** The main scientific provisions of the dissertation are brought to the level of methodical generalizations and applied tools, which enables effective monitoring, structuring and maneuvering of project management, which allows to reduce the risk of closing the project due to increased financial requirements or non-fulfillment of obligations to the customer. Approbation of the methodological platform adapted to practical use made it possible to adjust the opinions of the customer and competent specialists when deciding on the choice of development methodology.

The practical value lies in the fact that the architecture, analytical hardware and software for the functioning of the information platform for the selection and structuring of the approach to the management of international educational-scientific techno-projects have been developed as the defining scientific and applied results of the work. An important aspect in the development of the method is that solving the task is complicated by the vagueness of existing recommendations regarding the applicability of different management approaches in different cases and conditions, in particular for the development of projects that do not relate to software development and have an international direction. The results of the research in aggregate use significantly reduce project risks, allowing them to be minimized at the initial stages of the project cycle.

The introduction of theoretical and applied results of the dissertation work into the practice of administration of international and educational-scientific projects based on the AGILE methodology proved that the scientific-applied approach and set of programs introduced for the researched projects allows for successful adaptation to the complex-structured, digitally-adapted environment of projects, contributes significant increase in transparency and effectiveness of communications between interested parties (contractors, customers, consumers).

The main provisions and results of the research have been implemented and applied in Zhajiang ACME Information Technology Co. LTD.

**Personal contribution of the acquirer.** All scientific results presented in the dissertation were obtained by the author personally. In the scientific works published in co-authorship, only those ideas and provisions that are the result of the personal work of the recipient are used in the dissertation. The work [1] describes the proposed method of using an integrated platform for project management, the implementation of which made it possible to minimize the time for coordinating backlogs and eliminate delays in the work of teams in different parts of the world, which makes the implementation of such projects competitive on the international market of research services. The work [2] describes the use of a predictive and simulation dynamic model of competitiveness indicators for the study of alternative approaches to the development of educational institutions and the selection of optimal situations of their market behavior. The obtained results of the experiments, during which the problem of inverse modeling is solved, make it possible to evaluate (within the limits established by some criterion or a set of criteria) different strategies that ensure the functioning of this system. In work [3], a model developed on the basis of fuzzy-multiple analysis is proposed for the creation of decision-making support tools when choosing a project management methodology, the use of which fully ensures the consideration of project metrics when choosing a project management methodology. In work [4] based on the concept of a risk assessment tool, a method of choosing a project approach using the "Cynefin" model was developed. The proposed method makes it possible to effectively choose a project management methodology, taking into account factors influencing international projects. The work [5] describes the advantages of using the Agile methodology for project management in conditions of international disagreements and for finding project executors in different countries, in particular when performing joint scientific research for customer enterprises. Materials of international conferences were also published, which reveal more detailed provisions dissertation work [7-10].

**Approbation of the results of the dissertation.** The main results of the work were reported, discussed and received a positive evaluation at the international conferences "Information Technologies and Interactions", Kyiv (2018), "Project Management in the Development of Society", Kyiv (2019), "Information Modeling Technologies, Systems and Complexes", Chernivtsi (2019), "Management of the development of technologies", Kyiv (2020).

**Publications.** Based on the dissertation materials, 10 scientific works were published, of which: 5 scientific articles in specialized publications of Ukraine, 1 article in a publication that is not included in the list of the Ministry of Education and Culture, 4 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 that are the result of 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 225 pages, of which the main part is 200 pages, including 67 figures, 25 tables, a bibliography of 244 titles and 2 appendices.

## LIST OF TERMS

AM - academic mobility

IHE - institution of higher education

PWMD - a person who makes decisions

IMES - International market of educational services

RDW - research and development works

SRW - Scientific research work

ESIC - educational and scientific innovation complex

UCM uncertain computing models

S - Software

OECD - Organization for Economic Cooperation and Development

EP - educational program

ES - educational system

SCE DSS- system of continuous education

DSS - decision support system

KMS - knowledge management system

UIT - universal information technology

JUST - Jiangsu University of Science and Technology

GCM - generalized computational model

PM - project management

EPM - education project management

IPMS - international project management system

## CHAPTER 1.

## ANALYSIS OF RECENT ACHIEVEMENTS IN THE APPLICATION OF FLEXIBLE METHODOLOGY FOR NON-SOFTWARE PROJECTS

### 1.1 Ability to manage projects

Regardless of the industry, project management has proven to be an important element of a company's performance and eventual success. In fact, projects are typically 2.5 times more successful when proven project management practices are used [11].

As defined by Gartner, project management is "the application of knowledge, skills, tools and methods of designing activities to meet project requirements" [12]. As an integral part of the software engineering process, as well as business analysis and requirements specification, design, programming and testing, project management has been the subject of considerable debate over the years.

Regardless of the scope, any project must follow a sequence of actions that must be controlled and managed. According to the Project Management Institute (PMI), a typical project management process includes the following steps:

1. The beginning;
2. Planning;
3. Implementation;
4. Execution/monitoring;
5. Closing the project.

Used as a roadmap for specific tasks, these phases define the project management lifecycle.

But this structure is too general. A project usually has a number of internal stages within each phase. They can vary greatly depending on the scope of work, the team, the industry and the project itself.

In an attempt to find a universal approach to managing any project, mankind has developed a significant number of PM methods and methodologies.

## 1.2 Traditional methodologies of project management

Based on the classical basis described above, traditional methodologies implement a step-by-step approach to project implementation. Thus, the project goes through initiation, planning, execution, monitoring right to its closure in successive stages.

Often called cascading, this approach includes a number of internal phases that are sequential and performed in chronological order (Fig. 1.1).

Applied most often to the construction or manufacturing industry, where little or no change is required at each stage, traditional project management has also found its application in software engineering.

Known as the waterfall model, it has been the dominant software development methodology since the early 1970s, when it was formally described by Winston W. Royce:

There are two important steps common to all computer program development, regardless of size or complexity. There is a first step of analysis followed by a second step of coding. This very simple implementation is really all that is needed if it is small enough and if the end product is to be managed by those who developed it - as is usually done with computer programs for internal use.

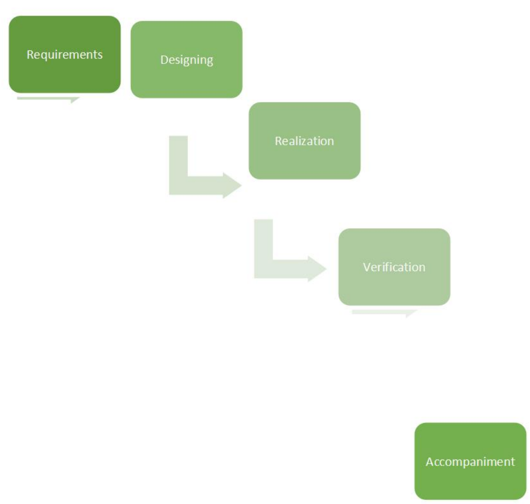



Fig. 1.1 Waterfall (cascade) project management model

The waterfall model has a strong emphasis on planning and specification development:

it is believed to take up to 40% of the project's time and budget. Another main principle of this approach is the strict order of project stages. A new project stage does not begin until the previous project is completed.

The method works well for well-defined projects with a single deliverable and deadline. A waterfall approach requires careful planning, extensive design documentation, and tight control over the development process.

In theory, this should lead to on-time, on-budget delivery, low project risk and predictable results.

However, when applied to a real software development process, the cascade method proves to be slow, expensive, and inflexible due to numerous limitations. In many cases, his inability to adapt the product to changes in market demands often results in a huge waste of resources and possible failure of the project.

### 1.3 Flexible methodology for project management (Agile)

In contrast to traditional methodologies, the agile approach was introduced as an attempt to make software engineering more flexible and efficient. In 2015, 94% of organizations practice Agile [13], making this methodology the standard for project management.

The history of Agile can be traced back to 1957, when Bernie Dimsdale, John Von Neumann, Herb Jacobs, and Gerald Weinberg were using incremental development methods (now known as Agile) to build software for IBM and Motorola. Although not sure how to categorize the approach they practiced, they all clearly understood that it differed in many ways from the Waterfall Model [14].

However, the modern agile approach was introduced in 2001, when a group of 17 software development professionals met to discuss alternative project management methodologies. With a clear vision of a flexible, lightweight, and team-oriented approach to software development, they captured it in the Agile Software Development Manifesto.

The manifesto, aimed at "revealing better ways of developing software", clearly defines the main principles of the new approach:

Complemented by the Twelve Principles of Agile Software, the philosophy has become a universal and effective new way of project management.

Flexible methodologies use an iterative approach to software development (Fig. 1.2). In contrast to the straight-line cascade model, flexible projects consist of several smaller cycles - a sprint. Each of them is a project in miniature: it has a backlog and consists of stages of design, implementation, testing and deployment within a predetermined scope of work.

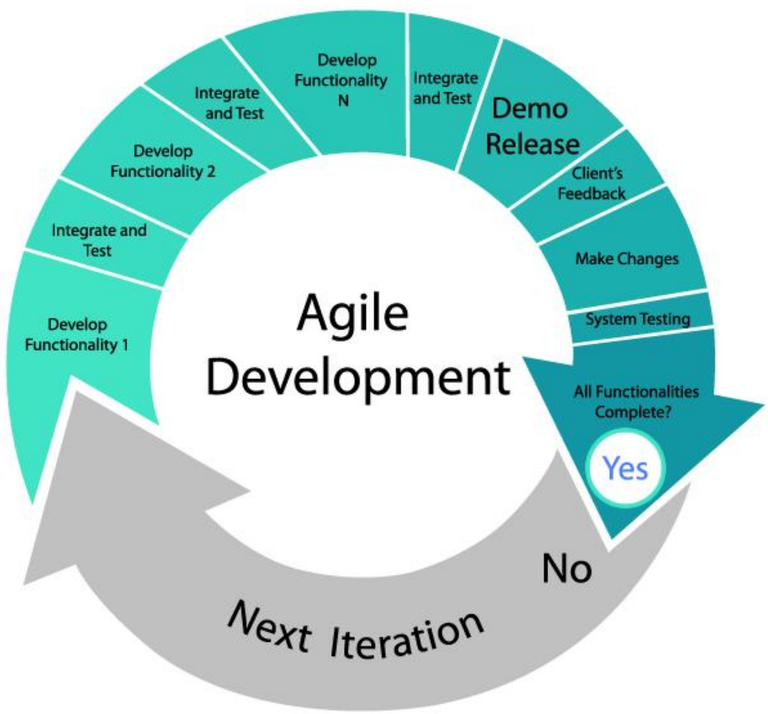



Fig. 1.2. Flexible project management methodology

At the end of each sprint, a potentially incremental product increment is delivered. Thus, with each iteration, new features are added to the product, resulting in a gradual growth of the project. Because capabilities are tested so early in the development process, the chances of delivering a potentially failed product are much lower.

Given the priority of availability and quick turnaround, an agile approach provides the following benefits, according to recent studies:

• Ability to manage changing priorities (87%)

• Increased team productivity due to daily assignment of tasks (84%)

• Better visibility of the project due to a simple planning system (82%) [13]

### 1.4 Agile Frameworks

Agile is an umbrella term for a large variety of methodologies and methods that share the principles and values described above. Each of them has its own areas of use and distinctive features.

#### 1.4.1 Scrum: Roles, Sprints and Artifacts

Scrum is the dominant agile methodology. It is used exclusively by 42% of organizations, and another 54% of companies combine it with other methods [16]. First described in 1986 by Hirotaka Takeuchi and Ikujiro Nonaka in New Product Development, this approach is based on systematic interactions between three main roles: Scrum Master, Product Owner and Team.

• The Scrum Master is the central figure in the project. His main responsibility is to eliminate all the obstacles that can interfere with the work of the team.

• The Product Owner, typically the customer or other stakeholder, is actively involved throughout the project, communicating the global vision of the product and providing timely performance feedback after each sprint.

• The Scrum team is a group of people responsible for the implementation of the product. It should consist of no more than 7 team members in order to remain flexible and productive.

The main unit of work in Scrum is a sprint (Fig. 1.3). This is a short development cycle that is necessary to ensure the growth of the product under development. Sprints are usually between 1 and 4 weeks long: longer iterations lack the predictability and affordability that are the fundamentals of Scrum. With no standard duration (as long as it's less than 4 weeks), all sprints within a project must have a specified length. This makes it easier to plan and track progress.

Scrum relies on three main artifacts used to manage requirements and track progress - the product backlog, the sprint backlog, and the sprint deployment schedule. The process is formalized through a series of recurring meetings such as daily Scrum (Standup), sprint planning, review and retrospective meetings.

By setting customer needs and on-time, on-budget delivery as the highest priority, Scrum has an overall project success rate of 62% [6]. Thus, the list of companies using this approach is impressive. In fact, there is a public table with such organizations, including Microsoft, IBM, Yahoo and Google.

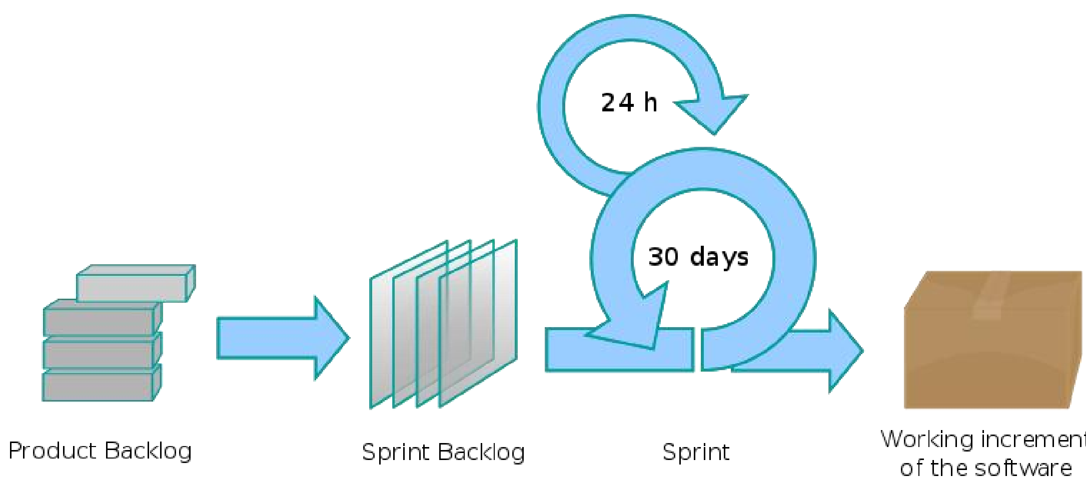



Fig. 1.3 Scrum project management methodology

### 1.4.2. Kanban: a comprehensive solution to work in progress

The other most common project management structure is Kanban. In some cases, it is used by 43% of organizations that have chosen flexible modeling [6]. Based on the visual card system used in Toyota manufacturing as a production management method, Kanban is a very simple but powerful approach to developing software products.

Kanban prioritizes work-in-progress (WIP), limiting its scope to effectively match the team's capabilities. Once the task is completed, the team can take the next item. Thus, the development process has a higher priority in planning, faster turnover, clear objectives and transparency.

Unlike Scrum, Kanban does not require standard procedures or fixed iterations. Project development is based on team work. Visualization takes place through the Kanban board (Fig. 1.4). A whiteboard is usually represented by sticky notes on an unmarked surface or online tools such as Trello.

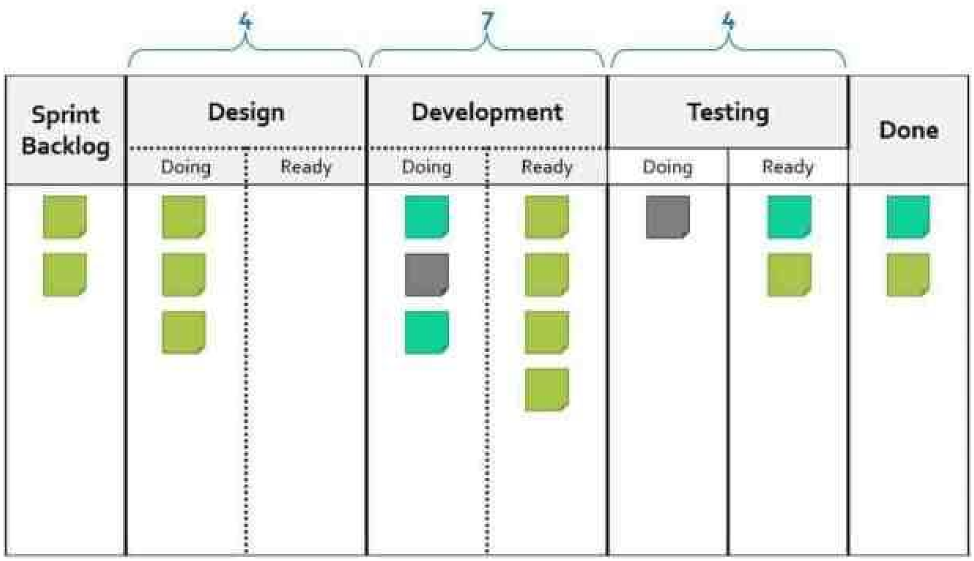



Fig. 1.4 Kanban board for project management

Companies like Spotify and Wooga (a leading mobile game development company) have been using this approach successfully for years. However, 43% of organizations combine Scrum with Kanban methods, using Scrumban rather than the original methodology [16].

### 1.4.3 Lean: eliminating costs in software development

Lean is the third most widely used flexible approach, adopted by 21% of organizations [16]. Having the same origins as Kanban, the approach began as a technological process applied to physical production. Toyota is credited with pioneering this approach. The production system as a management approach aims to "make the vehicles ordered by customers in the fastest and most efficient way to deliver the vehicles as quickly as possible" [17].

The application of Lean principles to software development was originally introduced by Mary and Tom Poppendick in their book Lean Software Development: Agile Toolkit. It includes 7 main principles:

- Eliminate waste
- Improve learning and create new knowledge
- Make decisions as late as possible
- Ship as soon as possible
- Strengthen the team
- Increase integrity / quality
- See the full picture [18]

These fundamentals perfectly describe the Lean philosophy: its goal is to achieve greater value through less cost, investment and time. From a project perspective, the term "waste" refers to anything that does not add value to the project and therefore should be eliminated. In software engineering, it can be free time, unnecessary features, or defects.

Lean software development is an iterative and incremental methodology. Therefore, as with any other Agile approach, work product increments are made early in the development process. Further progress depends mainly on feedback from the product owner.

What concerns the Lean approach (Figure 1.5) is that the team is not limited to using any formal processes, such as recurring meetings or prioritization of tasks. However, its principles are often combined with other Agile methods: 21% of teams combine Scrum with Lean [16].

Effectively adopted by a large number of manufacturing companies such as Nike, Ford and Intel, Lean principles are widely used in other industries. Startups and successful companies, e.g. Corbis, PatientKeeper and Xerox apply Lean technologies to software development in their processes.

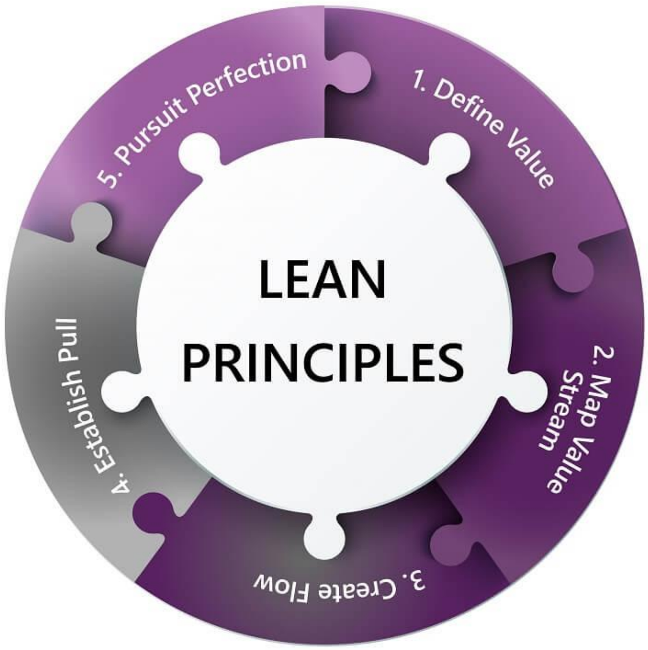



Fig. 1.5. Lean project management methodology

### 1.5. Agile Software Engineering Best Practices: Extreme Programming

Although the techniques listed above mainly focus on the project management process and its formal aspects, there are a large number of flexible methods that are purely technical. Extreme Programming (XP) combines the most important, providing flexible teams with a range of tools to optimize the technological process.

Extreme programming is a set of certain practices applied to software engineering to improve its quality and adaptability to changing requirements. Kent Beck, an early signer of the Agile Manifesto, was the first to document the practice in his book Extreme Programming Explained: Embrace Change.

The most frequently used XP practices are:

• Development using tests (TDD),

• Refactoring,

• Continuous integration,

• Pair programming.

Test-Driven Development is an advanced engineering technique that uses automated block tests to advance the software design process. Unlike the normal development cycle, where tests are written after the code (or not written at all), TDD takes a first approach. This means that unit tests are written to the code itself.

According to this approach, the test should first fail until there is no code to execute the function. After that, engineers write code focusing on functionality to make the test pass. Once this is done, it is necessary to improve the source code to pass all the tests. These three steps are often called the red-green refactoring cycle [19].

TDD has found the following benefits:

1. Tests are used to detect any defects or errors in the code, providing constant feedback on the state of each software component. Thus, the quality of the final product becomes increasingly high.

2. Block tests can be used as modern project documentation that changes as the project develops.

3. Being deeply involved in the development of the product, the team must be able to critically analyze it and anticipate the intended results in order to properly test it. This allows you to motivate and engage the team, contributing to the quality of the products.

4. With thorough initial testing, debugging time is minimal.

In addition to being used in the TDD cycle, code refactoring is a common practice in agile software development. Basically, it is a process of continuously improving the code by simplifying and clarifying it. The process is purely technical and does not involve any changes in the behavior of the software.

By expanding the source codes with each iteration, agile teams use refactoring as a way to avoid code clutter and duplication. This helps prevent software obsolescence by preserving and maintaining and extending the code.

Continuous integration (CI) is another practice that uses agile teams to manage common code and software testing. Tools like CruiseControl or Jenkins are used to test software quality and automate its deployment. In addition to this, CI helps maintain shared code by eliminating integration issues. Thus, the product pipeline is reliable and clean and can be quickly deployed if necessary.

Pair programming, or "coupling", is considered a highly controversial agile practice. This technique involves the joint work of two engineers. While one of them actually writes the code, the other actively participates as an observer, making suggestions and guiding the process.

Focused on both code and more abstract technical tasks, this team of two should be more efficient, creating better software designs and making fewer mistakes. Another advantage of this approach is the dissemination of knowledge about the project among team members.

However, this practice is often blamed for having a negative impact on short-term team performance. Studies show that each task typically requires more than 15-60% of the time [20], which is the main drawback of the approach. However, there is an opinion that the additional time is easily compensated in the long run due to the higher quality of the software [21].

An agile approach is often mistaken for a single methodology. However, there are dozens of methodologies and certain practices that were not covered in this study.

Regardless of the exact methodologies and techniques they use, Agile teams have been shown to grow profits 37% faster and generate 30% more revenue than non-agile companies [22]. The higher speed, flexibility and productivity achieved through this approach are key factors driving more and more organizations to move to Agile.

Software engineering, being an extremely fast-paced industry, calls for accessibility and agility in all aspects of project development. Flexible methodologies allow us to provide state-of-the-art products and develop innovative experiences while keeping the product in sync with market trends and user requirements.

However, there is always room for variety. Depending on your business requirements and goals, you can still use the waterfall model or a combination of the two.

### 1.6 Applying agile methodology to non-software projects

Active project management methods have become one of the fastest growing and most popular aspects of IT project management. Using agile methods in software development can make the difference between a project that has a low chance of completion and one that will deliver results very quickly and continue to deliver results over time. However, agile thinking was never meant to be limited to software development alone. The application of this concept of project management to processes and other types of projects was foreseen from the very beginning [23].

One of the key challenges in an enterprise project is the depth of change it can cause in an organization. A common mistake is to create a comprehensive plan and then rush to deploy the entire plan at once. Applying agile thinking to change management projects is excellent.

Agile project management forces us to think about a project first in terms of big goals at a strategic level, and then at a tactical level we think in terms of delivering finished production results.

An enterprise project is one that affects the operations of the enterprise. Enterprise projects can be system projects. Replacing the organization's financial system would certainly be acceptable. The financial system does not only affect accounting. This may affect how we buy, how we sell, how we track our customers, how we sell, and how we maintain our inventory or deliver our products. But the enterprise project does not need software. The transition of the headquarters of the organization from one building to another can certainly be considered as such a project. A corporate merger/acquisition also fits this classification. The creation of a project management office (PMO) is almost always suitable for an enterprise project.

A key feature of the enterprise project is culture change. It is expected that the project will lead to a change in the behavior of people in the organization.

Problems of the project of the enterprise

There are several challenges that are so common for enterprise projects that we must mention here.

Enterprise projects are almost always underestimated

Regardless of how detailed such a project is, the complexity of an enterprise project is almost always underestimated. The very nature of the project makes this almost inevitable. When a project leads to changes in behavior, it is clear that as the project develops, those who participate in it will see it from the perspective of change. Just like the old joke about someone asking for directions and being told, "You can't get there," enterprise projects can almost never be fully appreciated until they're done.

As a result, estimates that seem quite reasonable up to the starting point change views on what is really required of the system. This can have serious consequences at the end of the project as the schedule and budget are under pressure.

Moving office? This means we need to move all the laptops. Wouldn't it be great then to use this opportunity to change all laptops?

No it is not.

Changing the financial system? This would mean that the delivery department would have to change its procedures. Wouldn't it be a great time to replace all our trucks?

No it is not.

Enterprise projects can take a lot of time and a large percentage of the corporate budget. This makes it an obvious target for those trying to complete their projects.

Whatever the problem, it can be solved with the help of technology

In our modern age, we are so dependent on technology that it can be all too easy to think that there has to be a technological answer to what is a business challenge.

Worse, if technology is involved in an enterprise project, the project can quickly become a technology rather than a project-engineered solution.

Thus, changing the financial system becomes an Oracle or SAP project. Moving to a centralized project management office becomes a Microsoft Project Server or Primavera or Clarity project [23].

It is generally accepted for the executive sponsor to underestimate the impact of the enterprise's project. As a result, management may not understand that you will be changing the corporate culture and that this may lead to disruption. It makes no sense to assume that management has a full understanding of how many will be needed at key points in the project to help keep staff on the job. This can be most difficult in a culture where management by consensus is the rule. The consensus of one big happy family, which pleases the enterprise project as it develops, is not a common phenomenon.

The more the enterprise influences the organization, the more risky this path is. Each day the project is incomplete, it looms on the horizon like a storm approaching those affected. This puts the project at enormous risk. Every day he progresses, something can happen to him. Sponsor may change. The company can be sold. A company may acquire another company. The industry can change. The economy can change. During all this time, the benefits of the project are only theoretical

### 1.7 Experience in applying flexible methodology at enterprises

Many IT organizations use agile methodologies as their primary method of managing development projects. In most organizations, a hybrid environment of more traditional planning and project management collaborates with agile methods that are more likely to be applied at the tactical level.

The most notable benefit for organizations using this approach is the iterative release of useful functionality. The client begins to see the development gains as each part is completed and as the project progresses, the depth and value of the product increases.

A less visible but much more important aspect of these environments is that customers naturally become an integral part of the process, working with the development team more and more as the project progresses, and they can see and comment on what they're getting.

We can use this in almost any project if we apply the same mindset.

Even in software-only project management offices, conventional project management methods almost always coexist with agile methods.

Implementing an agile method means that you will not abandon existing project management processes, but the nature of project execution may ultimately change dramatically [23].

Choosing which aspects of Agile to apply in other contexts

Below are some of the most popular best practices that can be applied to enterprise projects:

• Backlogs

Backlogs are functions and features that will become part of the final project. They can be thought of as a large collection of items that have been described in terms of what they will mean to end users. These items are designed to resource a small collection of work in a very short amount of time, called a sprint.

• Sprint

A sprint is a short mini-project in just a few days. All tasks (backlog items) entered into a sprint are expected to be completed within the duration of the sprint. The work is tightly managed within the sprint itself, the team feels they have a lot of freedom. In addition, there is a structural tension in the practice to complete the entire work. People tend to work hard in these environments to avoid being the only one on the team whose work isn't done by the end of the sprint. And it's generally better to manage shorter tasks.

• Cross-functional team

The concept of cross-functional teams in agile methodologies is easily transferred to other types of projects. In some projects, teams will work in departments that pass through and only go out to work with each other at specific times. The problem software developers have found with this is that at these designated moments, teams are forced to believe that their work is at cross-purposes with the thinking of other teams, or that some work has been over-replicated by other teams. A cross-functional team works with increased efficiency and has a more distinctive focus.

It is easy to imagine such a structure that works well in a company reorganization project or in a corporate merger project or in a company office relocation project.

• Continuous integration

Project elements from different groups should be brought together on an ongoing basis so that no project element becomes a silo. Let's take, for example, a project of an enterprise to relocate an office for 1,000 people. One group might work on interior office furniture, while another group works on office computer networks. In traditional project management thinking, it's easy to imagine a situation where these groups compare their work only after completion, leading to conflicts. Involving this kind of collaboration during project development is usually much more efficient.

• Iterative and gradual development

This is one of the fundamental aspects of flexibility models that is most useful for all types of business projects. An enterprise project is often characterized by the fact that it is difficult to predict precisely in advance. Some areas of activity later in the project are almost impossible to evaluate before the project participants have seen the decisions and designs made earlier. As a result, trying to be predictive on a large scale is often high risk for such projects. Instead, an adaptive approach of developing the early stages and coming back to improve the project again and again can be much more effective. Returning to the concept of traveling wave planning as described in the PMBOK® Guide [24] has the potential for tremendous benefit.

• Scrum meetings

Scrum meetings are meetings where cross-functional teams meet with a facilitator (called the ScrumMaster). The group updates the progress of the last sprint of tasks and regroups for the next sprint. The focus is on backlogs of the best features, tasks, and issues that have been accepted by team members who take on certain tasks for the next short period of the current or future sprint.

A great thing about a Scrum meeting is the way the meetings are conducted. First, they are almost always fast. Since the project has been broken down into cohesive sprints, it is much easier to focus. And finally, the standard for a facilitator is not to be a participant. This means that observers who are not involved in the project can promote the project. Even the commitments people make are to a small number of items over the next few short days. The end of the sprint is always in sight, even on the first day, and this keeps the project velocity at a very high level.

Unlike a traditional schedule, where it's easy to get complacent and think there's an unlimited amount of time, in a sprint you work more efficiently because the project only has a few short days.

• Timebox

Timeboxing is a term very familiar to those interested in traditional project management. He takes a wide range of work and invests it in the schedule - time boxing. Those familiar with the traditional critical path methodology for scheduling take this schedule by default. Those raised in a more agile project management environment consider this to be the exception rather than the rule. However, it is important not to abandon traditional methods of project management. No matter how far you go in adopting agile practices for your non-software projects, there will always be a place to ensure the on-time and on-budget use of methods and practices that have become dogmatic in the project management industry.

• Use case

A flexible use case is a very commonly used method of describing what someone will do to perform a function. This technique is extremely useful in almost any process project. Project managers will often have a process that is described by a name and content, but with a use case description, the steps to be completed are listed one by one, with the end result being the completion of the process. By describing the process in this way, many potential pitfalls in predictive practice can be eliminated. It's easy to imagine how useful this would be in a corporate reorganization or office move or any corporate process change.

When this kind of technique is not used, there is great potential for a process to be implemented only to learn about a procedure that is about something fundamental and critical to the organization. In this case, there is a high risk of delay or failure of the project.

• User history

Where a use case describes a process and the steps required to complete that process, a user story is a description of a business problem. Very often this type of documentation is missing in a non-aggressive project, but it is critically useful. The user story outlines the purpose for which the changes are made. Unfortunately, it is all too common to see a project in which a solution is implemented without a fundamental understanding of the problem.

When you create a user story, you describe in simple language what the problem is and how it can be solved. This is an obvious requirement if you wish to manage the completion of the project. What could be more important for a project manager?

Many organizations have already started using agile methods in project management in non-IT areas. This experience can be used in international educational and scientific projects. As with any change in corporate culture, it is more effective to recognize which methods to adopt and how quickly to adopt them.

**Conclusions to chapter 1**

Chapter of the dissertation contains an analysis of existing theoretical and practical research on the modeling of organizational and information technology methods and models in project management. The analysis proved significant scientific and analytical advantages of using flexible management of international educational and scientific projects as a progressive and iterative methodological platform. This platform is suitable for use in such conditions of the project microenvironment, when at the initiation of the project there is no proper certainty about what the life cycle of the project and its final product should be. The section contains a justification of the feasibility of using the flexible Agile methodology for the needs of developing a multi-component information educational and scientific platform, which should ensure successful structuring, administrative support and implementation of international projects in conditions of insufficient certainty.

# CHAPTER 2.
# MODELS AND MECHANISMS OF APPLICATION OF FLEXIBLE METHODOLOGY FOR JOINT INTERNATIONAL PROJECTS

One of the components of the decision support system (DSS) in AM management is the knowledge management system (KMS), which ensures the availability of heterogeneous information necessary for decision-making in AM management.

A knowledge management system is a set of interacting and interdependent elements related to knowledge management (processes, databases, software, organizational structures, etc.), which ensures the achievement of set goals. To manage knowledge means to systematically, accurately and thoughtfully form, update and apply it in order to maximize the effectiveness of management [69]. The knowledge management system is the organization of management actions based on all information resources [139].

The knowledge management system allows combining two types of information [92]:

1) material - data and knowledge that are reflected in documents, letters, audio and video recordings, etc. For example, the rules of participation in the AM program, information from university websites, signed educational agreements;

2) hidden knowledge is personal knowledge inextricably linked to individual experience. For example, the experience of participants who returned after AM, the experience of AM organizers from other universities.

The life cycle of the knowledge management system includes several stages [70, 92, 93].

Accumulation is the stage of unsystematic accumulation of information, which begins with the search for sources of data, information and ready-made knowledge.

Removal is one of the most difficult and time-consuming stages, the further viability of the system depends on its success. In the process of acquiring knowledge, interaction can take place in the form of direct live communication. Removing knowledge from texts is formulated as the task of understanding and extracting the content of the text. The text in natural language is only a guide to the content, and the author's intention lies in the secondary structure, which is adjusted over the natural text [70].

*Structuring.* At this stage, the main concepts of the subject area are revealed; the structure of the information in the KMS and its architecture are being developed; terminology, a list of basic concepts and their properties, the relationship between concepts, the structure of input and output information are defined; decision-making strategy. Knowledge structuring is the process of developing an informal description of knowledge about the subject area in the form of a graph, table, diagram or text, which reflects the main concepts and relationships between the concepts of the subject area, clearly demonstrates where the sources of knowledge and data are located [70].

*Formalization.* At this stage, formal models for presenting knowledge are developed.

*System design – development of architecture and specifications for software implementation of KMS.*

*Software implementation – software development.*

*Maintenance – updating data and knowledge, filtering to find information needed by users.*

## 2.1 Models of knowledge presentation

The formalization of knowledge consists in the development of a knowledge base based on knowledge presentation models that correspond to the structure of the knowledge field, which allows later implementation of the system prototype [144].

The following basic methods are used to present structured knowledge [111, 143, 144]:

• formal logical models;

- production models (rules);
- semantic networks;
- frames;
- neural networks;
- genetic algorithms;
- object-oriented languages that use the structure of classes and subclasses;
- hybrid models (a combination of the above methods).

A logical model is a formal system, namely some logical calculation. All knowledge about the subject area is described in the form of a set of formulas and axioms of this calculation or derivation rules. The main disadvantages of this presentation include:

- bulky records;
- ease of making mistakes when creating records;
- complex search;
- lack of visibility [144].

The production model is based on rules that allow knowledge to be presented in the form of propositions: "IF a condition, THEN an action." Formally, the production model can be given in the following form [143]:

$$N = <A, U, C, I, R>, \qquad (1.1.)$$

where $N$ is the product name; $A$ – product application area; $U$ – product applicability condition; $C$ - product core; $I$ – product networks, which are actualized in case of positive sales of products; $R$ – comment, informal explanation (justification) of products, time of entry into the knowledge base.

Rules provide a natural way of describing processes. The main advantages of production models are related to the simplicity of presenting knowledge, organizing logical conclusions and making additional changes. Disadvantages of production models include: departure from human knowledge structures; ambiguity of the rules' mutual relations; low efficiency of knowledge processing [143, 144].

Semantic model of knowledge presentation. A semantic network is a directed graph whose arcs correspond to relations between objects, and vertices correspond to concepts and objects. The network can be represented in the following mathematical expression [143]:

$$H = \langle I, C, G \rangle, \quad (1.2.)$$

where $I$ is a set of information units; $C$ is a set of types of connections between information units; $G$ is a mapping specifying specific relations from the available $C$ types between the elements of $I$.

The following three types of relations are necessarily present in semantic networks:

1) class – class element;

2) property-value;

3) an example of a class element.

The most frequently used types of relations:

• "part-whole";

• functional;

• quantitative;

• spatial;

• temporary;

• attributive;

• logical;

• linguistic.

The problem of finding a solution in a knowledge base of the semantic network type is reduced to the task of finding a fragment of the network that corresponds to some area that reflects the query to the database. Disadvantages of knowledge presentation include: ambiguity, heterogeneity of connections [143].

The frame model is a systematized psychological model of human memory and consciousness. A frame is a data structure for presenting some conceptual object [143].

A distinction is made between sample frames (prototypes) stored in the knowledge base and instance frames created to describe real situations.

The main types of frames include:

• frames-structures;

• frames-roles;

• frames-scenarios.

The structure of the frames is uniform and consists of standard units - slots, which contain a name and their meaning. The advantage of presenting knowledge with frames is the representation of the conceptual basis of the organization of human memory by a model. The frame is displayed in the form of a chain [144]:

Frame name = <slot 1> <slot 2> … <slot M>.

Neural networks are mathematical models that are built according to the principle of organization and functioning of biological neural networks. A neural network consists of a set of interconnected neurons and operates according to fixed transfer functions and variable weights [144].

Genetic algorithms are a common model of evolution based on the principles of genetic inheritance and natural selection. The genetic algorithm copies population evolution as a renewable process of crossing, mutation, generational change and survival of individuals that better adapt to the environment [148].

Hybrid models. Different models of knowledge presentation have their advantages and disadvantages. The most frequently used knowledge representation models: production model, semantic networks and frames. At the end of the 1980s, there was a tendency to create hybrid (combined) models that have the advantages of component models [144].

To monitor AM, advise students on AM programs, analyze educational programs, when forming an educational agreement and an individual curriculum, knowledge presentation models in the form of production models and semantic networks have been developed.

Knowledge presentation models in DSS, the information model is the basis of the database schemes, knowledge base and information support.

The purpose of information support is to display information that characterizes the characteristics of the managed object and serves as a basis for making management decisions. Information support consists of a set of indicators, information flows, document flow options; system of unified documentation and various arrays of information (files) that are systematically stored on electronic media.

## 2.2. Project management organizational forms

There is a wide variety of organizational forms of project management, depending on who acts as the project manager and on the accepted division of functions between project participants. Nevertheless, existing organizational forms are subject to classification, albeit very conditional.

A number of project implementation functions are constantly performed by certain project participants. These include: construction, financing, licensing measures, installation, commissioning, equipment start-up, operation, etc. However, part of the functions may be redistributed between organizations, participants from one project to another. These include, first of all, design, supply and project management. The main options for the distribution of functions between project participants are as follows:

• "Basic" system. The project manager is a representative of the customer and bears no financial responsibility for the decisions made. In this case, the project manager can be any company participating in the project. In this case, the project manager is only responsible for coordinating and managing the development and implementation of the project. He is not in contractual relations with other project participants except the customer. The positive sides of this form of relationship are the objectivity of the manager, and the disadvantage is that the risk for the fate of the project lies exclusively with the customer.

• "Extended management" system. The project manager assumes responsibility for the project within the defined funding (estimated price). The manager provides management and coordination of the project management processes by agreement between him and other project participants. The project manager can be a contracting, consulting or engineering firm that manages the project, coordinates deliveries and all work.The risk also rests with her.

• System of "accelerated construction" ("turnkey"). The project manager is a design and construction organization with which the customer concludes a turnkey contract with a fixed price and the cost of the works.

In any of the options considered, the use of project management systems involves the creation of a special group that becomes an independent participant in the project (or is structurally included in one of these participants) and manages the investment process within the project. This group is created for the duration of the project and is dissolved after its completion. The relationship between project participants within such a group, which is created for project management, is revealed by its organizational structure.

Thanks to this form of management, increased responsibility of each participant is achieved, "bottlenecks" are quickly identified and issues related to their elimination are effectively resolved.

There are two main principles of forming groups for project management.

1. The leading participants of the project - the customer and the contractor (in addition to them there may be other participants) create their own groups, which are headed by the project managers, respectively, from the customer and the contractor. These managers report to a single project manager.

Depending on the organizational form of project implementation, the manager from the customer or from the contractor can be the manager of the entire project. In all cases, the project manager has his own team of employees who coordinate the activities of all project participants.

2. A single group headed by the project manager is created to manage the project. The group includes authorized representatives of all project participants to perform functions in accordance with the accepted division of responsibility areas.

When it comes to structures used for project management, there are several types of such structures: functional, matrix, and project structures.

### 2.2.1. Functional structure of management

In the functional structure, management is carried out by a line manager through a group of functional managers subordinate to him, each of whom has the right to manage subordinate units within the limits of the functions assigned to him. The functional specialization of the management apparatus within the framework of this structure significantly increases its efficiency due to the deepening of the professional specialization of management employees. However, at the same time, the problem of interfunctional coordination arises, the solution of which becomes possible only at the highest level of management. Due to the heavy workload, senior managers are not always able to carry out such coordination. Therefore, if this type of structure is used in project management, then, as a rule, one or more coordinators are appointed to communicate between functional units (Fig. 2.1).

These coordinators may report to managers at different levels and coordinate work related to one or more projects, working together with line managers. The coordinator's efforts do not always achieve the goal due to the lack of his direct participation in solving everyday tasks that arise during the implementation of the project.

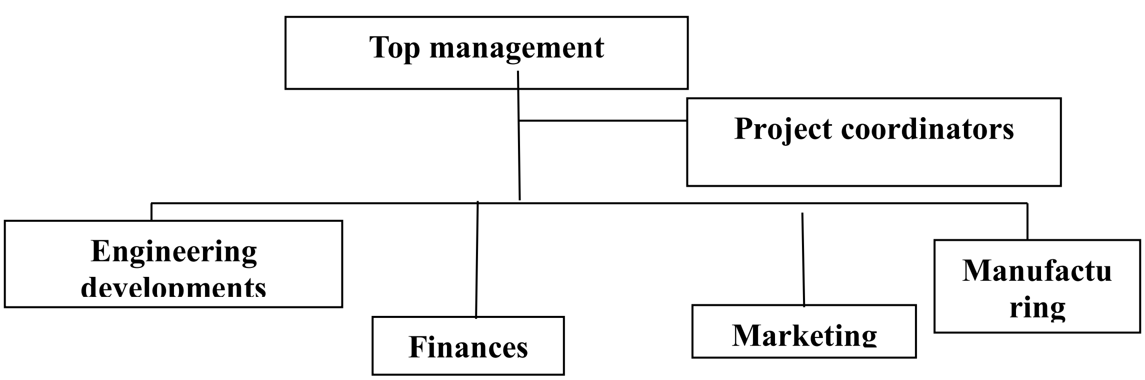


Fig. 2.1 Functional management structure

This type of structures is used, as a rule, in those organizations that are characterized by a stable mode of operation, relatively low dependence on the external environment, an unchanged nature of production specialization, and a uniform pace of development. However, if any of the mentioned conditions are violated, for example, with a change in specialization, a sharp increase in the volume of work, with the transition to a new production technology, etc., such a structure turns out to be ineffective.

### 2.2.2 Matrix management structure

The matrix structure is created on the basis of the functional structure, the relations in which are based on direct vertical relations of management-subordination. Temporary project groups headed by project managers are created to solve specific problems. Groups are formed from specialists of relevant functional departments located at different levels of the management hierarchy. Interaction of project managers with functional departments is carried out horizontally, and these relationships are superimposed on traditional vertical leadership-subordination relationships, which forms an interaction matrix (Fig. 2.2). The matrix structure makes it possible to flexibly maneuver human resources by redistributing them between projects, but on the condition that they remain administratively owned by the relevant functional departments.

Attracting highly qualified specialists to work on the project, ensuring high quality of work with the maximum speed of its execution and minimum costs - this is its main advantage.

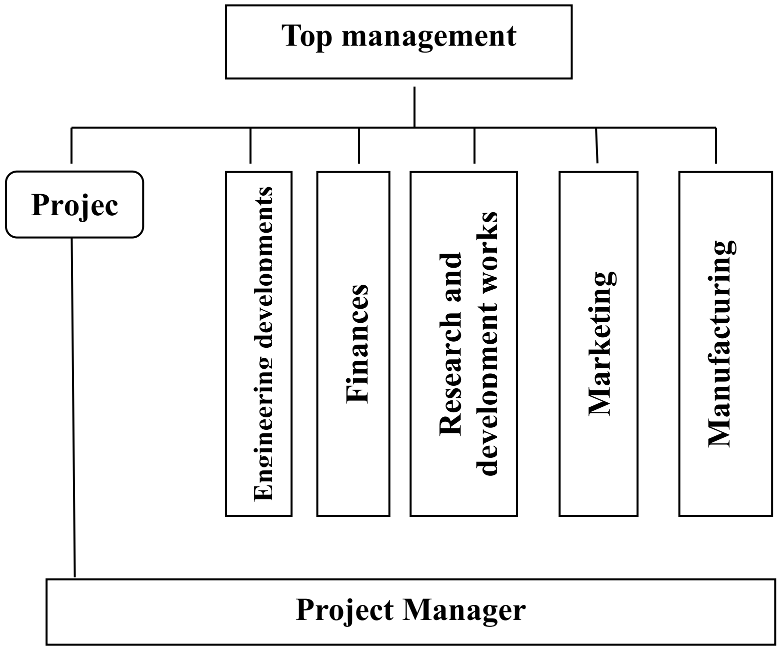


Fig. 2.2 Matrix management structure

A feature of the matrix management structure is that the project manager has no control over the personnel employed in the project. The project manager determines what needs to be done and when, and the functional manager decides who will do the work and how. Thus, the project manager is responsible for all the final results of the project work, including production costs, time consumption and project quality, but, in contrast to managers of functional departments, the project manager must achieve his goals without having direct administrative authority over the members of his project team. groups He is obliged to:

• To demand from the departments participating in the project, the fulfillment of their tasks according to the project;

• Ensure that the work of the departments is conducted strictly taking into account the specification, time and budget of the project;

• Identify difficulties, errors, lack of resources in a timely manner;

• Take corrective actions, if necessary, with the help of higher-level managers;

• Inform all managers related to the implementation of the project about the progress of work;

• Inform the customer about the progress of the project, negotiate with him about making changes to the project.

One of the main problems of matrix organizational structures is the overloading of functional divisions. When there is an imbalance between the amount of work that needs to be done for different projects and the capabilities, i.e. human resources, conflicts arise in the respective functional units. However, this problem is solved with the help of better planning of loading of employees in units. A matrix organizational chart cannot work effectively without a strategic matrix plan with prioritization of tasks and a matrix budget with resource allocation. The matrix budget is the resources allocated to the project manager for the performance of services provided by the functional units during the implementation of the project. Drawing up such a budget requires careful work with long-term and annual planning.

As a rule, the project manager, after agreeing the specification with the customer and concluding the contracts, determines the costs for the project, which is the basis for calculating the cost of the project and its execution time. Time is determined by the project manager based on calculations provided by various departments regarding the work they perform. By accepting or rejecting department estimates, the project manager ensures that they meet the terms of the contract and specifications. After drawing up the time budget, a matrix plan is developed, which is agreed with the relevant departments. For the project manager, the following elements of this plan serve as important management tools:

• Structure of distribution of tasks;

• Work time schedule;

• Calendar schedule of works;

• Distribution of employees.

The selection of personnel to perform the necessary tasks during working hours is coordinated by the head of the department with the project manager. Specialists must be allocated for a certain calendar period. Heads of departments may not assign any other temporary or permanent tasks to assigned employees without the approval of the project manager.

When using a matrix structure, there should be a well-organized system of control over the progress of work on the project, the quality of execution, costs and deadlines. It is necessary to constantly monitor that the actual indicators correspond to the planned ones. The project manager must have at his disposal detailed information about the entire project, and the heads of departments - about the work performed by their departments. On the basis of this data, reports are compiled, which are discussed by project managers with their groups. Discussions can be held weekly, and in critical situations - daily.

The matrix type of management structure can be used in the implementation of small and medium-sized projects. When implementing large projects, it is ineffective, as in this case the complexity of the communication network increases dramatically, and this leads to a significant slowdown in management decision-making processes.

### 2.2.3 Project management

When solving problematic tasks related to the reorientation of the organization's goals or changing the ways to achieve them, the most effective form is the so-called project management. In this organizational form, the requirements of a systemic approach to management are implemented to a greater extent, according to which the entire set of works that provide a solution to a certain problem or the achievement of a final goal is considered not from the standpoint of an established hierarchy of subordination, but from the standpoint of achieving this particular goal or solving the specified problem. To manage the development of specific projects and programs, complex bodies are created, endowed with all the necessary powers. These bodies are called to:

• Increase responsibility for the final result of work;

• Provide a mobile mechanism for simultaneous implementation of several projects;

• Ensure the priority of general, global goals of the organization over private, local goals of a functional nature;

• Decentralize the solution of operational tasks, ensuring a flexible and prompt response to changes in external and internal conditions.

At the beginning, this organizational form was considered as a temporary structural entity and was used within the framework of the existing linear functional management structure. The duration of the life cycle of such an organizational form was determined by the time of achievement of the goals and tasks set before the organization. However, in the process of functioning of this organizational form, a special organizational mechanism began to work out, which initiated a qualitatively new scheme of interaction between units and individual performers. This led to the need for scientific and methodical substantiation of a new organizational form - project management. At the same time, project management is understood as the overall management of all labor, financial, material and energy resources required to ensure the processes of design and construction of the object within the specified period, within the planned estimated cost and with the specified quality.

In the project structure (Fig. 2.3.), a special working group is created to solve a specific task, for example, design and construction of an object, which is dissolved after the completion of work on the project.

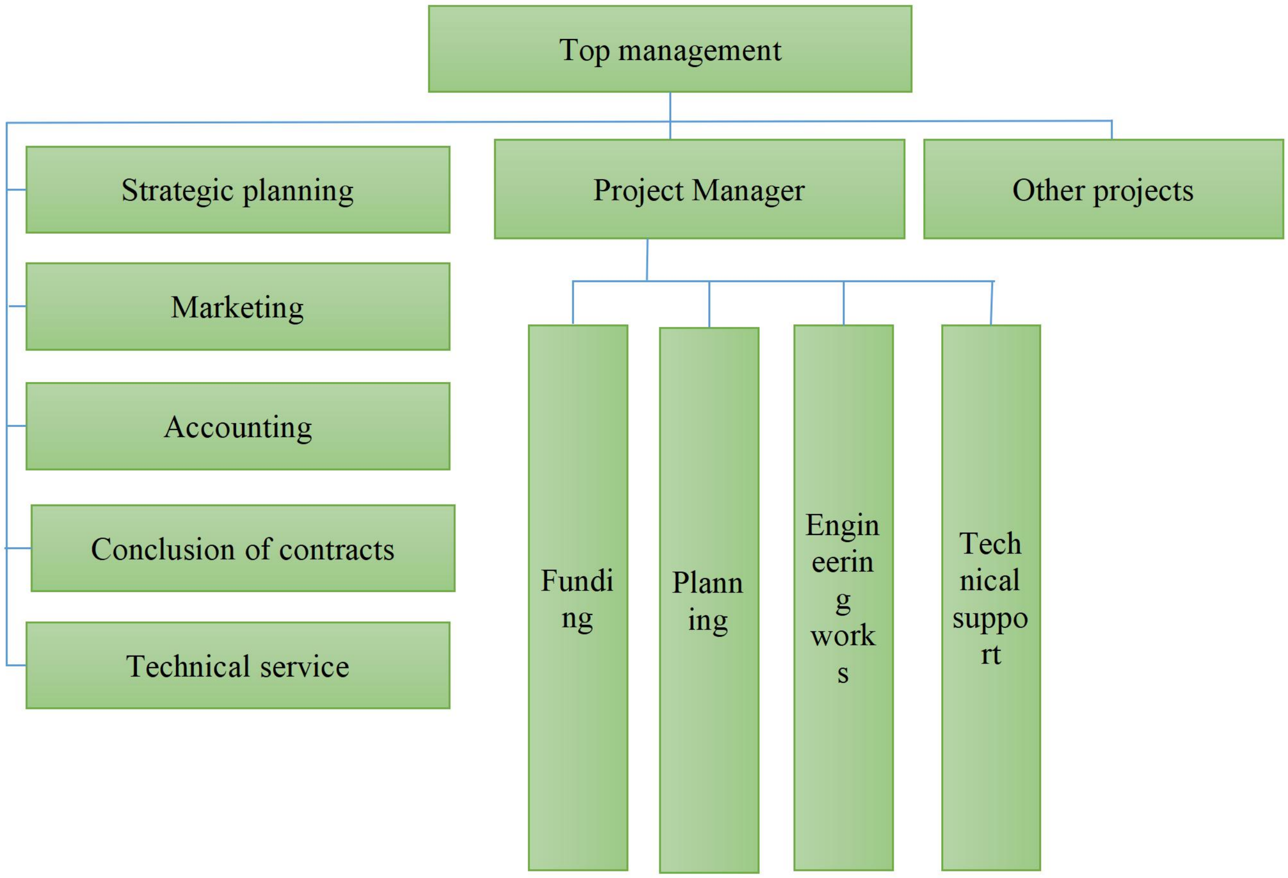



Fig. 2.3 Structure of project management

At the same time, the relevant personnel and resources, previously involved in the work, are returned to specialized units. In order to solve the problems of long-term development, a special division is created within the company, which deals exclusively with strategy issues, and project managers focus their attention on the implementation of specific tasks. One of the important problems that arise in organizational structures built on the principle of project management is the distribution of functions between the so-called project and organizational levels of management, in other words, the question of which part of management can be transferred down by the center without harming the business needs to be resolved. to the project level, and the performance of which functions remains at a higher level.

Conflict situations between the center and the project group arise mainly for the following reasons:

• Existence of issues for which both levels of management are responsible;

• A significant degree of uncertainty that accompanies many decisions at both the organizational and project management levels.

At the organizational level:

• projects are selected;

• deadlines for the completion of their development and implementation are established;

• resources are distributed between projects.

The selection of projects and the establishment of their completion dates are strategic tasks, the solution of which requires a wide range of knowledge in many fields of technology, economics, sociology and other sciences. At the project level of management, as a rule, project solutions are prepared for their further transfer to the organizational level of management. Interaction between these levels of management takes place through the transfer of instructional information from top to bottom, current data about the project from bottom to top. At the same time, sufficiently aggregated information is transferred to the organizational level. To check the activity of the project groups, a periodic evaluation of their work is carried out according to the completed stages.

One of the important problems, the solution of which depends on the effectiveness of project management as a whole, is the problem of evaluating the performance of the functional executor in the project management system. Most project management systems are characterized by the fact that the functional executor is subordinate to at least two managers: the functional manager and the project manager. If the executor is permanently subordinated to the functional manager, then to the project manager - temporarily, for the period of performance of works related to the implementation of this project. In many cases, the executor simultaneously participates in several projects, in connection with which his subordination is carried out simultaneously by many managers. In this case, there is a problem of evaluating the results of activities and the potential of individual performers when the project ends or when the project manager is going to promote the employee.

Project management systems focused on the ultimate goal of project implementation contribute to:

• Shortening the terms of its execution;

• Increasing the efficiency of solving current issues related to the progress of project implementation;

• A more balanced connection of the work program with the resource capabilities of the contracting firm;

• Savings of resources, as well as a more objective assessment of the activities of individual specialists.

- This type of management structures is widely used in the implementation of large construction programs and projects that require the involvement of a wide range of specialists of various profiles. In this regard, one may get the impression that project management as an organizational form of management is used only for these types of projects. In fact, all the basic principles of the formation and operation of project management systems are quite suitable for the management of small projects. The head of the project in these structures is included in the work already at the pre-project stage during the technical and economic justification of the project, participates in the evaluation of the most rational version of the project, in the selection of contractors, organization of financing, signing of the contract, and this allows him to familiarize himself with the project in detail.

- Project management methods depend on the type of project, the nature of the organizational structure, and the specialization of the firm. Despite the variety of project management methods, it is possible to identify rather general principles characteristic of these management systems, such as:

- The necessity of subordinating each member of the project group to only one manager of a higher management level;

- Adherence to the norms of manageability, i.e. the standard number of subordinates that can be effectively managed by the manager (the rational norm of manageability for project management systems is accepted within 6 - 8 people);
- Open discussion of new ideas and proposals;

• Rational distribution of responsibility between levels of the management hierarchy, as well as between managers and executors at each level of the project management hierarchy. The nature of the project manager's interaction with project team members largely depends on the size of the project. When performing small projects, a project group consisting of 6 - 8 people is created. In such groups, interaction is usually carried out in a prescribed manner, without documented instructions and orders. At the same time, the small size of the project allows the manager to interact directly with each member of the project team. The internal structure of the project team in small projects usually has two levels. For the implementation of medium-sized projects, for example, the construction of a freeway, project groups with a three-level structure are created, and for large projects, project groups are created with an even more complex hierarchical structure, in which managers of intermediate links can be specialized:

• By functional feature (for example, by functions of design, planning);

• By subject (special sections of the project or special types of works);

• By territorial feature (parts of the facility located in different areas during the construction of such facilities as highways, oil and gas pipelines, power lines, etc.).

Interaction of the project manager with subordinates in such groups is carried out on the basis of documented information in the form of orders, instructions and assignments. An important task of increasing the effectiveness of project management systems is to maintain effective interaction and microclimate within groups, which are closely related to the factor of the duration of the group's existence. The experience of the operation of project groups shows that the optimal period of its effective work is a period of 18 - 24 months, after which a decline in efficiency is observed. In this connection, there is a problem of maintaining the effectiveness of the work of the project team. One of these measures is the periodic return of a number of specialists from the project group back to the relevant functional unit.

Table 2.1 presents an analysis of the advantages and disadvantages of project and matrix structures.

Table 2.1. Advantages and disadvantages of project and matrix management structures

| The main factors | Matrix structure | Project structure |
|---|---|---|
| Planning and reporting system requirements | It is necessary to have a strategic matrix plan | Since the team works in one location, the planning and reporting system can be quite simple |
| Project implementation control | Control is carried out through heads of functional units | All group members are under control. It is easier for the project manager and the customer to control all issues related to the project |
| Effective use of working time | The use of time, from the point of view of division of work, is efficient | Inevitably, backup time occurs |
| Making changes to the project | Inevitably, difficulties arise when making changes, since there are many structural divisions involved in the work on the project | The process of making changes is simple because everyone works in one place, actively interacting with each other |
| Requirements for the manager | Must be a good coordinator, agitator and | The project manager must be not only a technically |

| | | |
|---|---|---|
| | able to influence project participants | competent specialist, but also a good leader |
| The role of informal relationships | Huge | There is a place, but not as much as with a matrix organization |
| Impact on existing structure | The impact is minimal | Requires reorganization of the existing structure |
| Quality of performed works | Maximum strict control | Less stringent quality control |

### 2.2.4 Selection of organizational management structures

In order to choose an organizational structure for the given conditions of a specific project, you can use the criteria listed in Table 2.2.

For example, an organization engaged in the development of numerous but small projects with standard technology will most likely prefer a functional structure. On the other hand, a firm engaged in a long-term, large, complex and important project will prefer an organizational structure built according to the project scheme. But a firm, for example, in the pharmaceutical industry, which works on numerous complex technologies, will most likely choose a matrix tour structure.

It is also possible to use all three named structures in the same firm for different projects. All these three structures can also be used within the same project at different levels and phases of project management.

However, before making a final decision, it is necessary to take into account the following additional factors:

• How are the organizational structure, skills of the project manager and the planning and reporting documentation system related to each other in the project?

• Is it possible to improve coordination and accountability in a functional structure without moving to a project and matrix structure?

• What are the variants of the matrix structure and what are the advantages of each variant?

Table 2.2. Criteria for decision-making when choosing an organizational structure

| Evaluation criteria | Functional | Matrix | Project |
|---|---|---|---|
| Uncertainty of the terms of the project implementation | low | high | high |
| Project technology | standard | difficult | new |
| The complexity of the project | low | medium | high |
| Project cycle duration | short | medium | grand |
| The size of the project | small | medium | grand |
| The importance of the project | not very important | of medium importance | longer valid |
| Interdependence and relationship between individual parts of the project | low | medium | high |
| Time criticality (obligations of the organization in terms of completion of work) | low | medium | high |
| Interconnection and interdependence of the project with higher level systems | low | medium | low |

It is impossible to decide on an organizational structure without also deciding who will be chosen as the project manager and what scheme we would like to choose for the planning and reporting systems. These solutions are closely related. So, for example, with a project structure, it is necessary that the project manager has broad management skills in general. In order to manage a project team, he must combine technical knowledge in the relevant field with managerial skills. If such a project manager cannot be found, it makes no sense to choose an organizational structure according to the project scheme.

The planning and reporting system in the project structure is quite simple, as the team works in close cooperation. Conversely, the system becomes more complicated if project management is carried out within a functional structure. Information in the form of plans, schedules, budgets, and reports is the basis of an integrated union of separate divisions of the functional organizational structure that participate in the implementation of a specific project. In this regard, a functional organization requires a more complex planning and reporting system than an organization operating within a project structure.

Organizations usually use project and matrix structures when the usual functional structure is unsuitable for a number of projects. Before abandoning the functional organization, you should analyze the possibility of implementing the project in this structure and see if it cannot be applied before carrying out the reorganization. This is, first of all, an opportunity to implement end-to-end plans, budgets, schedules and conduct operational meetings. An important role is played by direct contacts between the relevant managers and informal connections. These are the unifying mechanisms that allow not to bring the case to the introduction of matrix and project structures.

Considering the three main organizational forms used in project management - functional, matrix, and project-based, we see that the matrix form is located, as it were, in the middle and has a large number of modifications, from the so-called weakly matrix-based and almost functional to strongly matrix-based and almost project-based. This is determined by the percentage of full-time employees working in functional divisions to the total number of employees fully employed in the project team. With a functional organization, the project team does not have its own full-time employees at all. The dividing line between the functional and matrix schemes is the one where at least one person is appointed to the role of a partially occupied coordinator of works performed by functional units on a specific project.

### 2.3. Integrated platform of project management for the development of gas cleaning devices for ventilation systems

One of the main challenges for project managers using the Agile methodology is to consider human factors, focusing on the talents and skills of individuals. If the people in the project are skilled enough, they can use different approaches to complete the task. Agile is aimed at teamwork, with maximum use of individual talents to effectively achieve the goal [25].

For agile methodology, it is practiced to use the work cycle visualization tool to display the status of project tasks. The Odoo complex is used for joint projects between Ukrainian research institutions and Yanchen Polytechnic Institute. Odoo is an open source software suite that covers all the needs of a company: CRM, e-commerce, accounting, warehouse, point of sale, project management and more. The uniqueness of Odoo lies in its ease of use and full integration [26].

Figure 2.4 shows the menu for creating project tasks in the Odoo system, which is used to implement the common scientific topic "Development of a gas cleaning device for ventilation systems of industrial premises". The tasks are detailed in the specialized menu, which is presented in Figure 2.5.

The Kanban board of the general scientific topic "Development of a gas cleaning device for ventilation systems of industrial premises" is presented in Figure 2.6.

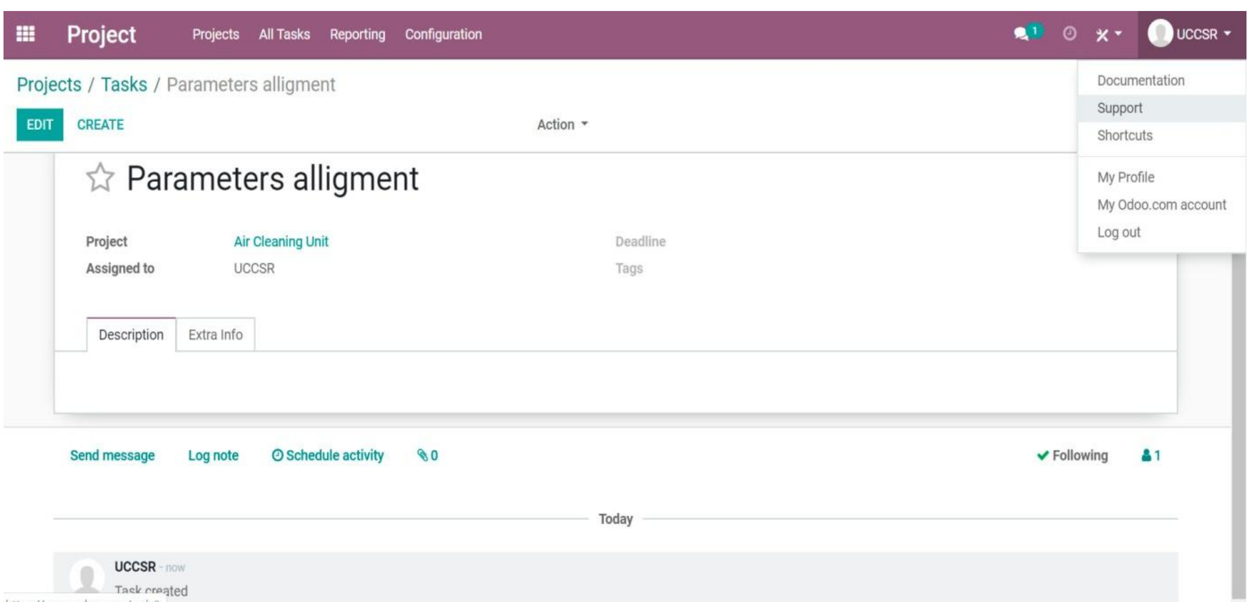



Fig. 2.4 Menu for creating project tasks in the Odoo system

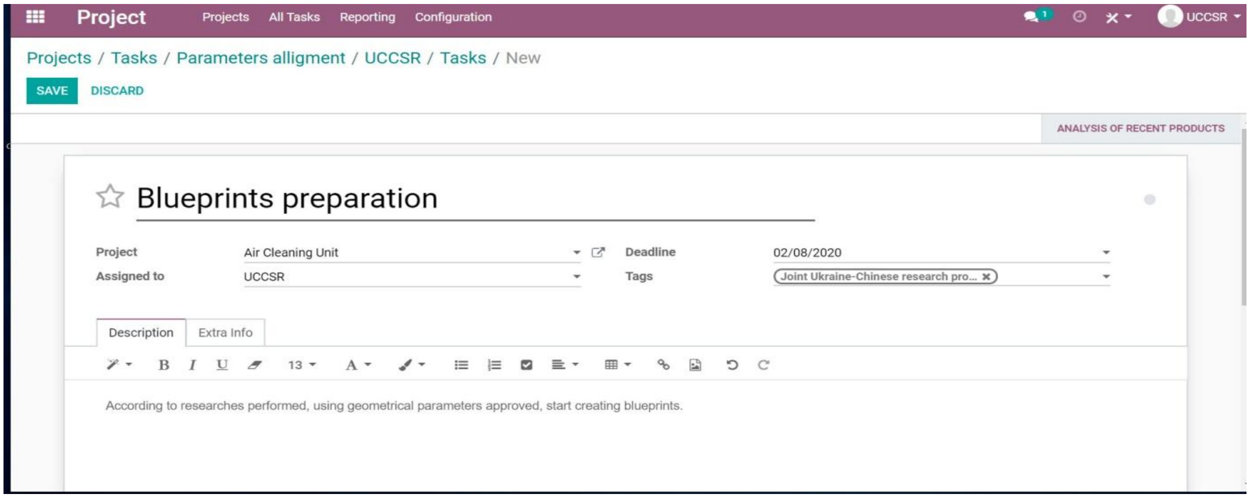



Fig. 2.5 Menu with a detailed description of project tasks in the Odoo system

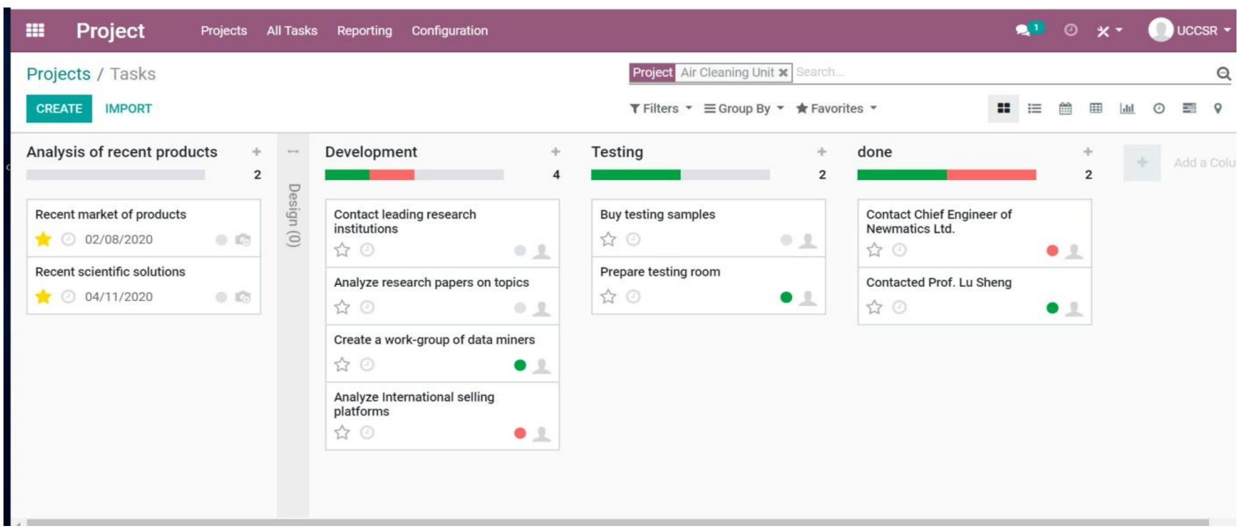



Fig. 2.6. Kanban menu of a joint international scientific topic

As an example, a task board is presented for the implementation of the joint scientific topic "Development of a gas purification device for ventilation systems of industrial premises", which was carried out on the order of a Chinese company. The main performers are two parties - Chinese and Ukrainian. The customer is directly involved in the project as a party with whom each sprint result is a backlog.

Using an integrated project management platform minimizes backlog approval time. Work on the project by teams in different parts of the world takes place without delay, which makes the implementation of such projects competitive in the international market of research services.

Many organizations have already started using Agile methods in project management in non-IT areas. This experience can be used in international educational and research projects. As with any change in corporate culture, it is more effective to recognize which practices to adopt and how to adopt them quickly.

Yanchen Polytechnic Institute, which integrates the latest achievements in project and program management with educational and scientific processes, is no exception.

Agile mechanism - iterative and gradual development - is widely used for the implementation of international joint projects. This approach is very important in the context of ethnic differences and the location of project implementers in different countries. In particular, when performing joint research for customer companies.

There is a project management structure - Kanban. As an example, the task of implementing the general scientific topic "Development of a gas cleaning device for ventilation systems of industrial premises", which is carried out on the order of a Chinese company (Table 2.3).

Table 2.3. Kanban project with a Chinese enterprise

| **Back to the sprint** | **Participants of performers** | **Designing** | | **Development** | | **Testing** | | **Done** |
|---|---|---|---|---|---|---|---|---|
| | | **become** | **done** | **become** | **done** | **become** | **done** | |
| Preparation of the technical task | Chinese side | | Initial technical characteristics | Clarification of technical characteristics | | Coordination with the customer | | |
| | Ukrainian side | | Initial documentation | Preparation of accompanying documentation | | Coordination with the customer | | |
| Carrying out mathematical modeling of the gas | Chinese side | Integration of the specified technical | | | | Coordination with the customer | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| dynamics of the process | | characteristics | | | | | | |
| | Ukrainian side | Construction of a mathematical model<br><br>Simulation of gas flow dynamics | | Refinement of the mathematical model<br><br>Adjustment of geometric characteristics depending on the simulation results | | Coordination with the customer | | |
| Production of drawings | Chinese side | Working design | | Working design | | Coordination with the customer | | |
| | Ukrainian side | Sketch design | | Sketch design | | Coordination with the customer | | |
| Prototype construction | Chinese side | Preparation of details | | Preparation of details | | Coordination with the customer | | |
| | Ukrainian side | Prototype assembly | | Prototype assembly | | Coordination with the customer | | |
| Conducting experimental research | Chinese side | Prototype assembly | | Prototype assembly | | The customer participates in testing | | |
| | Ukrainian | Experim | | Experim | | The | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | side | ents | | ents | | customer participates in testing | | |

As can be seen from table 2.3, the main performers are two parties - Chinese and Ukrainian. And the customer, as foreseen by the Agile methodology, takes a direct part in the project as a party with whom every result of the sprint is a backlog.

**Conclusions to chapter 2**

As part of the study of the main approaches and models of the application of flexible modeling of the management of international projects with clear goals and transparency, it was found that the AGILE methodological platform allows in the circumstances of insufficient certainty and improperly prepared communicative space (at the beginning of the project cycle) to cover the content of large-scale and complex projects, further structure them step by step, make adjustments and work to ensure an increase in the level of satisfaction with the project product among stakeholders and project team members.

4. For the needs of information and communication support, office and analytical preparation and implementation of international projects on the basis of AGILE, a unique scientific and methodological foundation has been built, the components of which are:

- classification and analytical approach and grouping, models and methods of evaluation of project selection;
- method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies;
- theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics;
- methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic;

- application of the basic principles of construction of computer numerical methods;

- simple iteration methods for solving systems of nonlinear equations.

Such a structure of the methodological basis of the research made it possible to build a successful criterion-parametric basis for the implementation of a flexible, AGILE-adapted approach in the administration of international projects.

# CHAPTER 3.
# MODELS AND METHODS OF CHOOSING AN APPROACH TO PROJECT MANAGEMENT BASED ON FUZZY IMAGES, APPLICATION OF THE METHOD

There are a large number of different project management methodologies that have been developed to meet the needs of various industries and organizations [12, 13]. Today, project management methodology is studied by researchers as a separate branch [14-17], it is a standardization of project management and determines how the team will work and interact. The effectiveness of the methodology primarily depends significantly on the specifics of the project and the established principles of management, teamwork, the form of control, verification and evaluation of the result. Also, the quality of project planning and execution depends on the management methodology [18-21]. Having the right methodology in place will allow the project team to get started quickly, standardize results, and accelerate decision-making. However, there is no single method or organizational structure that can be used to choose an international project management methodology [22, 23].

The work [25] is devoted to the selection of methodologies for software development projects using the Potentially All Pairwise RanKings of all possible Alternatives method. This method is based on users expressing their views on the relative importance of project criteria or attributes that are of interest for decision-making or choice, then the selection of project parameters takes place by pairwise ranking of alternatives [26].

The work [26] describes the process of developing and approving a tool for choosing a software development methodology using the random forest machine learning method and taking into account the most significant metrics for choosing a project development methodology.

The work [28] presents a method of choosing a project management methodology based on vague ideas. In the method, a questionnaire was developed that describes the project in terms of the number of people involved, the experience of the customer's work with the team, the assessment of the project team's competence by the project manager, reporting on the project, and the probability of occurrence of risk events. The next step of the method is to determine the membership functions of all considered project management methodologies by means of a survey of experts. For all the considered methodologies, their total weighted distances from the project evaluation according to the questionnaire are calculated using linear metrics and Euclidean metrics. The approach for which the calculated distances are minimal is chosen [26].

But in the end, a wide range of methodological and instrumental approaches to the selection of project management methodologies does not provide a reliable solution to the leading problem - none of the specified approaches and tools in autonomous use provide the appropriate objectivity of such a choice. This prompts the search for an artificial toolkit that correlates the characteristics and format of all researched methodologies with the specifics of the project environment.

In this section, a subsystem has been developed, which, based on the TT, determines whether it is necessary to apply an iterative and flexible process that divides the large project life cycle into short achievable phases.

## 3.1. The method of choosing a project approach based on the "Cynefin" model

### 3.1.1. Conceptual description of the model for choosing a project management method.

In the first stage of the agile software development life cycle, the team defines and prioritizes projects. Some teams may work on multiple projects simultaneously depending on the organization of the department. For each concept, you need to define the business opportunity and determine the time and work that will be required to complete the project. Based on this information, it is possible to assess technical and economic feasibility and decide which projects should be implemented.

Choosing the wrong way to manage an international project can lead to misunderstandings between the customer and the team, and create many other problems.

When choosing a management method, project managers usually focus not on how well the conditions for the product are defined, but how well the team understands how to implement the project, that is, which technology stack to choose.

In the project management guide in PMBOK [29], the following scheme is indicated:

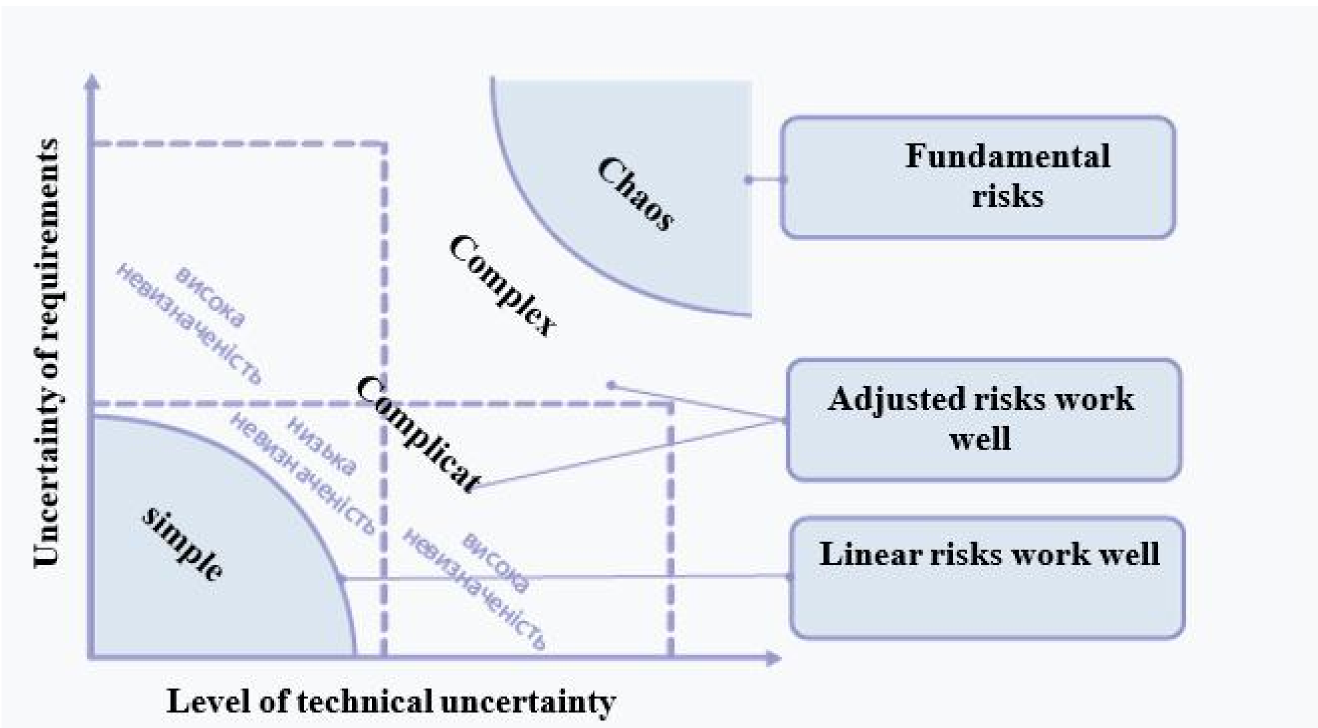



Fig. 3.1. System classification scheme [29]

This diagram (Fig. 3.1.) helps to navigate when choosing a project management approach: the Y axis shows whether it is clear what needs to be done, the X axis - how to achieve it.

In table 3.1. several situations that arise when choosing a management approach for international projects and examples of their application in the IT sphere are given.

Table 3.1. Analysis of situations that arise when choosing a management approach for international projects

| Situation | Approach | Example |
|---|---|---|
| *Low requirement uncertainty and low technical uncertainty*<br>*The presence of a detailed technical task, the requirements for the project are defined and fixed, their change is unlikely. the team clearly understands how to implement the project, what stages to divide the work into, and what set of technologies to use.* | For management, we choose a classic approach. This will allow you to divide the project into stages, plan their implementation dates and determine the result of each of them. | Operation of a software-based IT system with a standard set of functions with minimal changes. |
| Average requirement | Flexible Agile approaches are suitable for project | Development of a corporate website. |

| | | |
|---|---|---|
| uncertainty and average technical uncertainty The requirements are clear and relatively stable. The technical tasks are clear, the team can plan and manage the project. With increasing uncertainty in the project, the probability of making changes and revisions may increase. | management. Iterative work and the creation of a certain working increment will allow testing the product in the early stages and making adjustments in a timely manner. This approach allows you to reduce the volume of losses and revisions, as the team receives regular feedback. | |
| Uncertainty of requirements and technical uncertainty is high | The project can become "chaotic". To avoid project chaos, the team must reduce uncertainty. In this case, it is necessary to use the practice of pre-project research and implement a system prototype. This will help to understand whether the team has enough technical expertise and tools to | Creating an application for a mobile device with a radio signal reader unit. Recognition of the dimensions and other parameters of the object of the shooting taken by the device. During the pre-project research, it was possible to test the |

| | | |
|---|---|---|
| | solve such tasks.<br>You can also start a project with the Lean Startup concept, which will allow you to test a hypothesis, create a prototype with minimal investment, determine whether the product is interesting to the target audience, and outline a plan for its development. | hypothesis about the possibility of introducing the machine learning algorithm into the application and test the functionality of reading radio signals in field conditions. The team ensured that the task had a clear technical solution, thereby reducing the level of technical uncertainty. |

The analysis of existing organizational forms of management carried out in the second chapter and existing methods of choosing a management approach to international projects showed that even at the pre-project stage it is important to determine the key factors that influence the choice of a flexible management approach and to develop a formalized method of choosing a project approach. At the same time, it must be taken into account that the solution to the task is complicated by the vagueness of the existing recommendations regarding the applicability of different approaches in different cases and conditions.

In this section, the author's method of choosing a project approach is proposed, which was developed taking into account the peculiarities of the organization of international projects that are not related to software development projects.

The first stage of this method determines the level of complexity of the system. Usually, the project manager assesses the situation under the influence of the acquired experience, since economic and political fluctuations, the atmosphere in the team, and the non-trivial nature of the task are difficult to formalize. This type of thinking does not provide a reliable guarantee of choosing a project approach, especially if the project does not belong to software. Therefore, it is proposed to use the structure of the Cynefin model proposed in 1999 by Dave Snowden, which is a conceptual framework used to assist in decision-making [31]. Cynefin Framework is used in almost many sectors: strategy, policing, international development, public policy, security, energy, health care, sales or education [32].

The term Cynefin (English "environment" or "place") is used to explain the evolutionary nature of any complex system. On the basis of the "Cynefin" model, tactics of behavior are created in a certain, most often problematic environment (work of the project team, production, activities of the department of interaction with suppliers, activities of the company as a whole). Systems have their own regularities, so it is difficult to determine the logic of flow from one state of the system to another. Importantly, the control methods work only when the system is in the appropriate state. The "Cynefin" model allows you to determine in what state the system exists, and therefore it becomes possible to choose the right management model that will optimally correlate the team's competence.

The "Cynefin" model divides systems into five categories (fig.): ordered simple, ordered complex, complex, chaotic and the last - undefined, which must be abandoned as soon as possible.

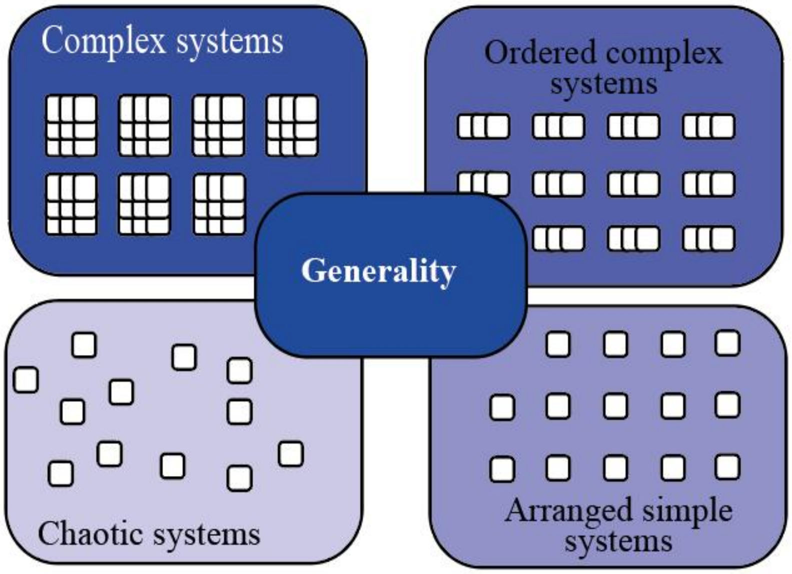



Fig. 3.2. Classification of system categories defined in the Cynefin model.

Table 3.2. Characteristics of system categories according to the "Cynefin" model

| System name | Description | Decision-making formula: | Method | Risks |
|---|---|---|---|---|
| Ordered simple systems | The systems are clear, and the team has the experience to solve them. Already at the start, it is clear what the result will be, for what money and in what terms. | We identify – We classify – We react. | Operational management, Waterfall and other best practices. | 1. Satisfaction and comfort<br>2. Desire to simplify complex problems<br>3. There is no doubt about the correctness of the information received<br>4. Excessive improvement with best practices, even if the situation changes significantly (transition to another environment/context) |
| Ordered complex systems | And here it is not clear in advance how to solve the problem. The task is not unique, but the team has no experience in this direction. | We determine - Analyze - React. | PMI and PMBoK approaches. | 1. Experts confident in their overall decisions or the effectiveness of past decisions<br>2. Complex analysis<br>3. Decision-making depends on expert groups<br>4. The opinions of non-experts are excluded from the analysis |
| Disordered complex systems | If you design a system for a task, then it is an incomprehensible task, but at the same time, the team has encountered a similar problem and | We measure – We determine – We react. | Method: Agile, specifically Scrum. Kanban etc. | 1. The desire to return to the usual mode of setting tasks and control<br>2. Willingness to act before the hypothesis is tested |

| | | | | |
|---|---|---|---|---|
| | has experience in solving it. | | | |
| Chaotic systems | An experimental approach works well here. Chaotic - completely new tasks that no one has ever solved before. Trying to figure out such a system is the way to innovation. Any method of solution (stabilization of the system) will be new. Sometimes it is necessary to act contrary to traditional methods of management. | We act - Determine - React. | new | 1. Applying manual control longer than necessary<br>2. The cult of the leader<br>3. Reduction of opportunities for innovation<br>4. Chaos does not decrease |
| Uncertainty | This is the state companies are in for most of their life cycle. | The goals of the "Cynefin" model:<br>• help to get out of this zone;<br>• determine what industry you are in;<br>• choose the right tactics. | - | - |

The border between idle and chaotic systems is characterized by maximum risks. Being in the zone of stability, and relying only on accumulated experience and knowledge, you can miss the moment when the system plunges into a crisis.

Each category has its own characteristics: in the field of complexity, cause-and-effect relationships are not visible. Therefore, it is necessary to act by the method of trial and error, to constantly "probe" the environment. When identifying favorable types of behavior, it is necessary to create restrictions to ensure their repetition. It can be processes organized in a certain way, new recommendations for management and employees, etc. With the introduction of restrictions, the project moves into the area of complex or even ordered simple systems. The danger is that if there are too many constraints, processes become rigid and lose their ability to adapt to changing conditions. In this case, the project can "fall" into chaos. Fortunately, this state cannot be long-lasting, as it requires a huge expenditure of energy. After that, you find yourself back in a more natural area of complexity, when you can and should try and create again. Debates with people who have different experiences, skills, and views will help you understand what zone you are in. For companies, learning new things will always take place through a flexible approach, but with sufficient accumulated experience and expertise, you can move to project management and translate projects and processes into operational activities.

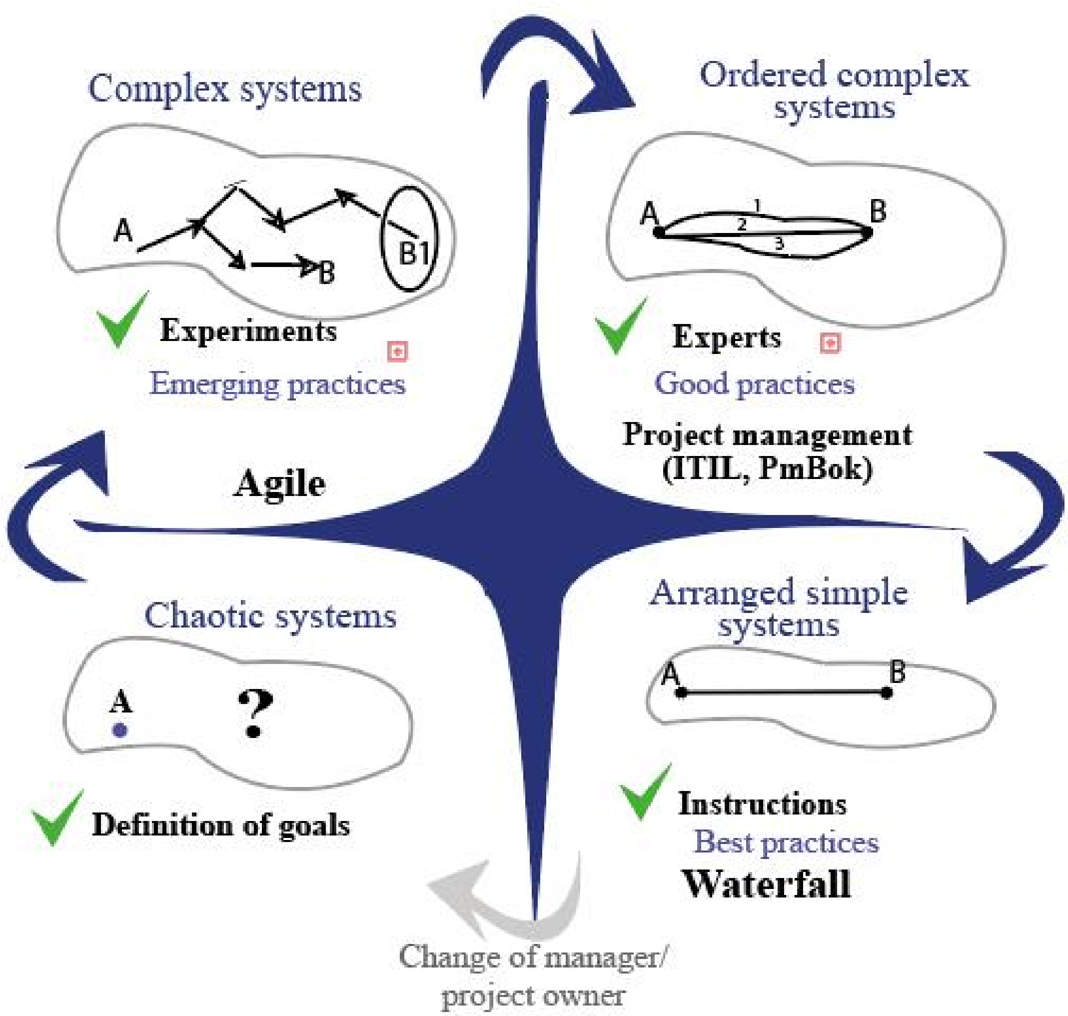



Fig. 3.3. Changing the state of the system in certain situations.

In fig. 3.3 shows how the state of the system can change under certain conditions. Sometimes, after conducting a detailed analysis and forming specific goals and objectives, a chaotic system can become confusing.

Likewise, all other systems can become more certain. On the other hand, with more, sometimes a simple system can become chaotic.

The Cynefin concept perfectly fits and describes the field of software development. All development projects can be presented as one of the proposed systems or considered through their projections. But in the case when the project does not relate to the development of software for international projects, a logical question arises: how to determine to which system this or that project can be attributed. After all, the Cynefin concept is obviously compared with software development methodologies (Fig. 3). A simple system - a world of instructions - fully fits the description of the Waterfall development model. A complex system - a world of experts - the use of accumulated practices, for example, project management using ITIL. A tangled system – a world of experiments – is a perfect description of an agile development methodology. As for the chaotic system, it is necessary to carry out analytical work and transfer the project to a system with a greater degree of certainty.

The modern development of the field of software development methodologies also determines that in the event that a project is compared with a specific system, it is necessary to unambiguously use a certain management methodology. Regarding projects that are not related to software development, it cannot be said that a certain methodology will always solve the task of building the development process of a certain type of project better than others. One way or another, it is necessary to take into account the private characteristics of international projects not aimed at software development and the risks of each project, and for different teams or companies these characteristics and risks can differ significantly. The intuitive-empirical approach common among managers of project teams and project activities causes great risks that the entire development process will be misplaced, which can cost great temporal and economic losses or break cooperation with the customer. This determines the importance of the task of finding a tool for collective and transparent decision-making regarding the use of one or another methodology.

The software development methodology selection model proposed in this article is based on the concept of the Risk Assessment Framework for the Enterprise Services Planning approach. The model for choosing a project management methodology is a coordinate system, the axes of which are project parameters. All axes are built from a single origin point. Project characteristics are applied to the axis, the number of axes depends on the project parameters, which are advisable to use. The characteristics are located on the axes in such a way that the closer to the point of origin of coordinates - the lower the risks associated with such a parameter, the further from the point of origin of coordinates - the higher the risks. For each parameter, it is necessary to select the characteristics that it can have and that affect the project activity process to the greatest extent.

International experts and the customer determine and agree on the number and characteristics of the

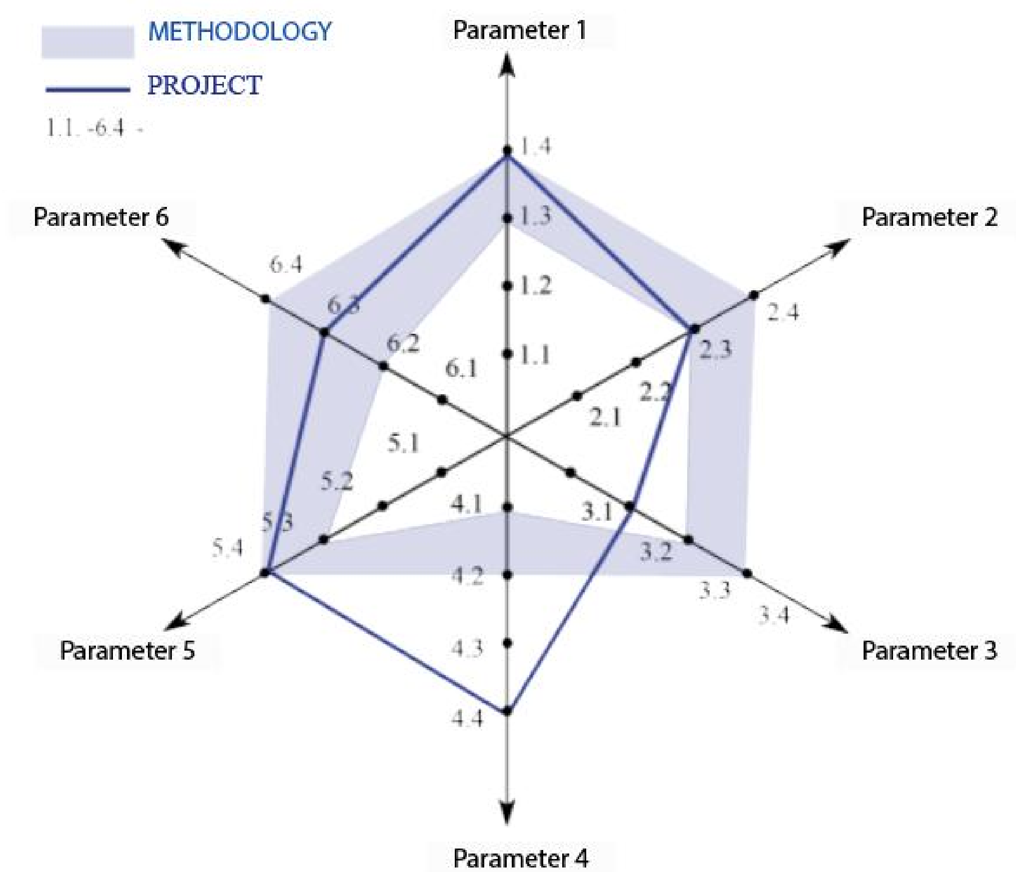



Fig. 3.4. A model for choosing a project management methodology. Developed by the author

The diagram clearly demonstrates that the Project complies with the "Methodology" in all parameters, except for "Parameter 3" and "Parameter 4". The model allows you to discuss the existing risks and make a decision on choosing one or another development methodology. If one of the parameters becomes irrelevant or its use is impractical, it can be excluded. If there is doubt about the choice of parameter values or their location on the axes, the model also allows you to change their number and location to more indicative ones.

### 3.1.2. Selection of parameters of the model for choosing the management methodology of the international project on the development of gas cleaning devices for ventilation systems

The first stage of the model begins with the construction of a diagram of project parameters. Experts are invited to participate in the process of project activity and to conduct an analysis of possible parameters and their values. The group of experts consists of the product owner, product manager, project manager, technical director of the company, project manager, business analysts, technical specialists, developers, testers.

As a rule, the project manager is a specialist who is responsible for the project or the product that is the result of the project, and he is the person who makes the decisions. This expert must have extensive information about the project or product itself and the risks associated with it;

The business analyst is responsible for identifying and forming requirements when communicating directly with the customer. This expert thoroughly studies and deeply immerses himself in the subject area, the specifics of the project/product, therefore he has knowledge of all possible "pitfalls";

Developers and engineers are directly responsible for the technical implementation of the project, for its functionality and compliance of the result with the customer's expectations. The number of competent specialists participating in the meeting, the depth of their immersion in a certain field of the project increase the objectivity of the analysis result, since the choice of parameters and their meaning depends on the completeness of the agreement of experts on the account of one or another parameter.

The following specialists are included in the expert group of the international project on the development of gas cleaning devices for ventilation systems (tab. 3.3.)

Table 3.3. Participants of the expert group of the international project on the development of gas cleaning devices for ventilation systems.

| Expert | Area of responsibility |
|---|---|
| technical director of the company | Designer, main developer |
| Project managers | Responsible for the organizational component of the project, communication with the customer, formation of requirements and documentation, partly development. |
| Business analyst | Immersion in the subject area of the customer. Responsible for gathering and developing requirements, developing and maintaining documentation, communication between the development team and the customer. |
| Developers, engineers, technical specialists | Direct product development and testing |

Based on the experience of working with customers and the practices of developing gas cleaning devices for ventilation systems accumulated in the company, the expert group identified the following specific project parameters, presented in table 3.4. The considered parameters have a special impact on the design process in the international project on the development of gas cleaning devices for ventilation systems, the riskiness of one or another characteristic of the parameter increases as the value in the "Risk" column increases.

Table 3.4. Parameters of the international project on the development of gas cleaning devices for ventilation systems

| Parameter | Risks | Characteristics of the parameter |
|---|---|---|
| Requirements | 1 | Requirements provided and recorded |
| | 2 | The requirements are known, but may change |
| | 3 | The requirements are partially formulated and will be formed during the development process |

| | | |
|---|---|---|
| | 4 | The requirements are unknown, will be formed during the development process |
| Budget | 1 | The budget is fixed |
| | 2 | The budget can expand |
| | 3 | The budget can expand |
| | 4 | Time&Material budget |
| Cooperation with the customer | 1 | Minimal |
| | 2 | If possible |
| | 3 | On key processes |
| | 4 | Maximum |
| Terms of product creation/installation | 1 | Not Urgent |
| | 2 | The given date |
| | 3 | Periodic deliveries/works |
| | 4 | Urgently |
| Technical risks | 1 | Template work |
| | 2 | There is experience in creating such a product/such work |
| | 3 | There are analogues made by other teams |
| | 4 | No experience, no solution |
| Project risks | 1 | Controlled |
| | 2 | Partially uncontrolled |
| | 3 | Mostly uncontrolled |
| | 4 | Risks are difficult to define |

The obtained parameters and their values are plotted on the diagram, Figure 3.5.

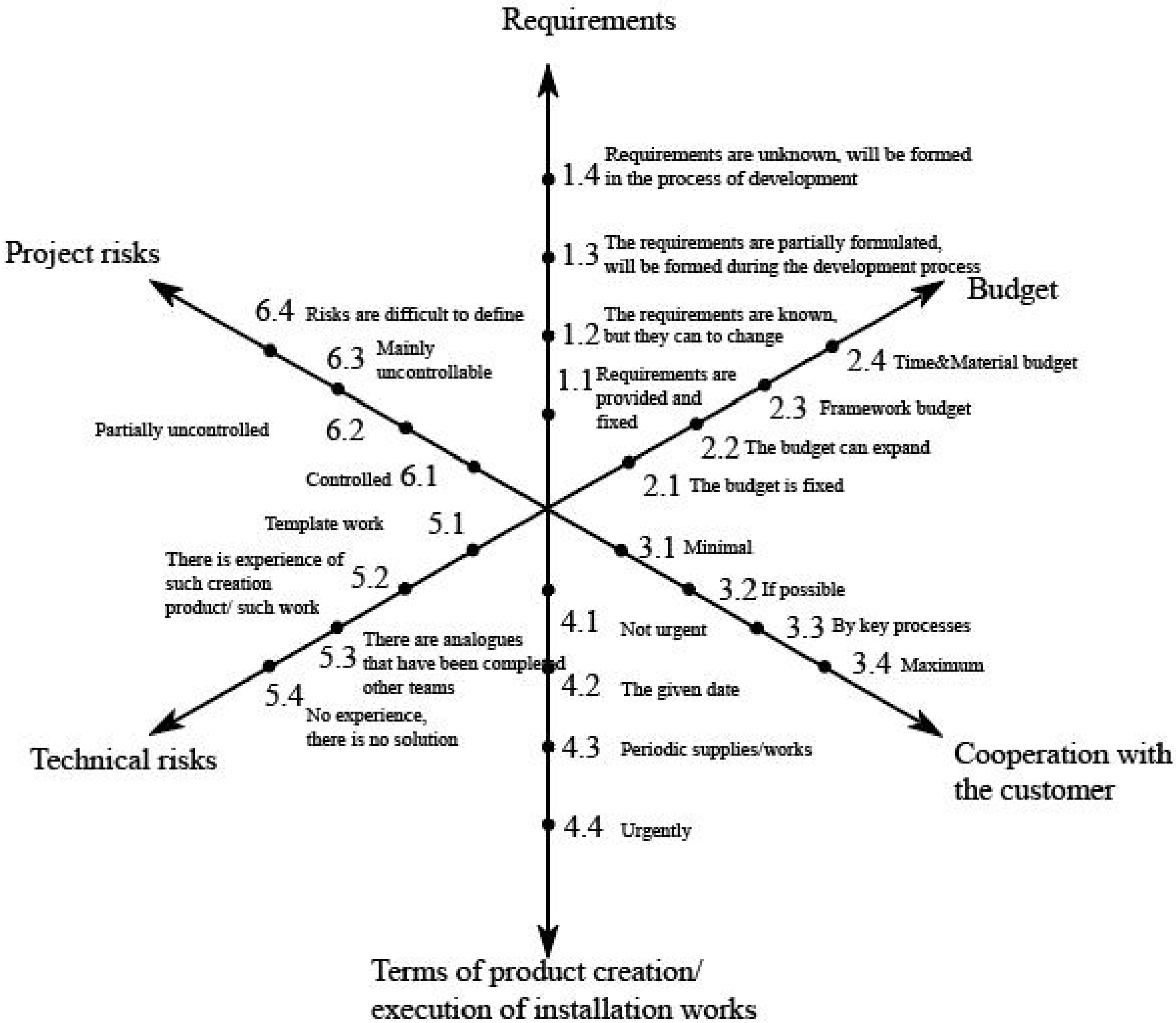



Fig. 3.5. Diagram of project parameters for the development of gas cleaning devices for ventilation systems. Developed by the author

As a result, the "Project Parameters Diagram" is obtained, which is used to evaluate projects with the possibility of their classification.

The next stage of creating a control metrology selection model involves plotting the parameters of all possible management methodologies for the development of gas cleaning devices for ventilation systems on the project parameters diagram.

Let's consider all the methodologies discussed in the second section of this study, such as cascade (Waterfall); spiral (Spiral); Scrum; Kanban.

The cascade model is used in small projects (less than six months), when the customer knows exactly what he wants, and the developers know how to do it. In this methodology, analysis and design are the most important processes, because the error made at these stages will have the most expensive cost. The parameters of the cascade model, plotted on the diagram of the project parameters, are presented in fig. 3.6.

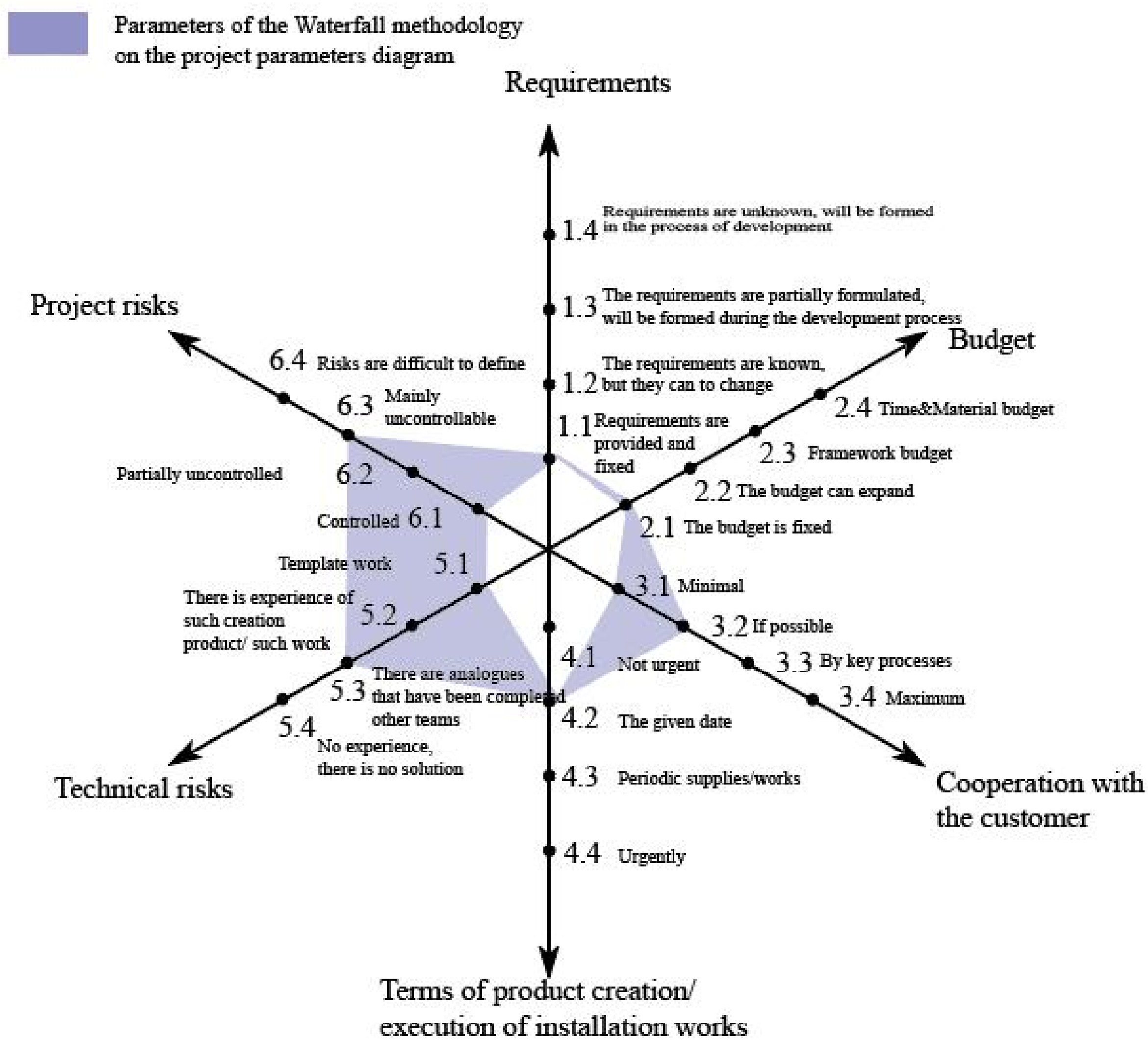



Fig. 3.6. Diagram of the Waterfall model on the diagram of the parameters of the project of gas cleaning devices for ventilation systems. Developed by the author

The spiral model is used in complex or experimental projects when there is no clear understanding of the result or high risks of not realizing the product. It allows you to control the project process in detail and adjust it during execution. The parameters of the spiral model plotted on the diagram of project parameters are presented in fig. 3.7.

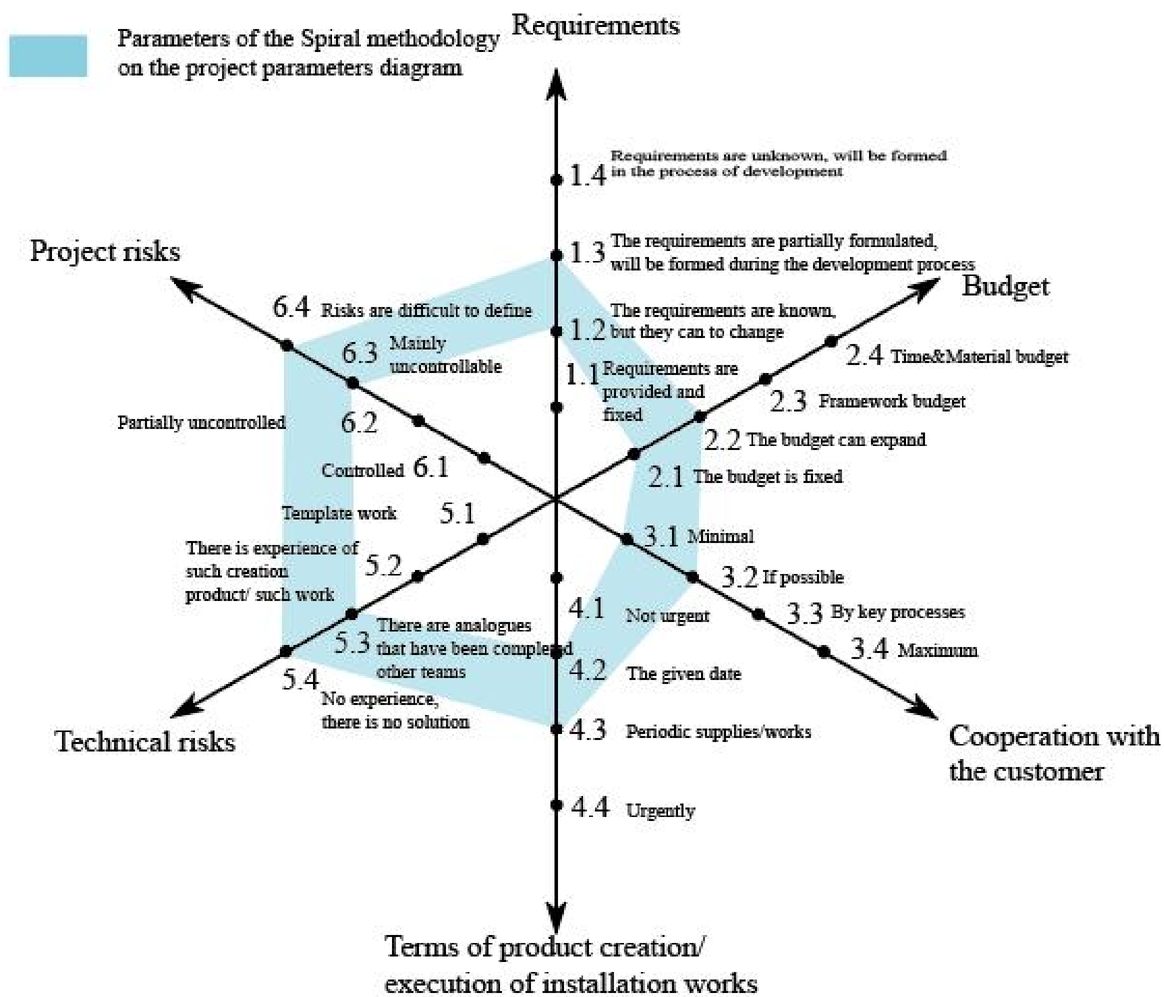



Fig. 3.7. Characteristics of the Spiral model on the diagram of the parameters of the development project of gas cleaning devices for ventilation systems. Developed by the author

To use the mechanisms and principles of agile development, and even more so all the practices united under the Scrum methodology, three conditions must be met. 1. The customer cannot influence the composition of the sprint backlog and the development process. It can only shape and prioritize the top-level backlog, but the developers themselves choose the tasks to be included in the sprint; 2. The temporary and budget boundaries may be changed in the project, and the customer must cover the costs; 3. The existence of a permanent, self-organized scrum team consisting of a scrum master, analysts and developers. The team is collectively responsible for the development process. When these conditions are fulfilled, the use of Scrum becomes possible.

The parameters of the Scrum methodology plotted on the diagram of the project parameters are presented in Fig. 3.8

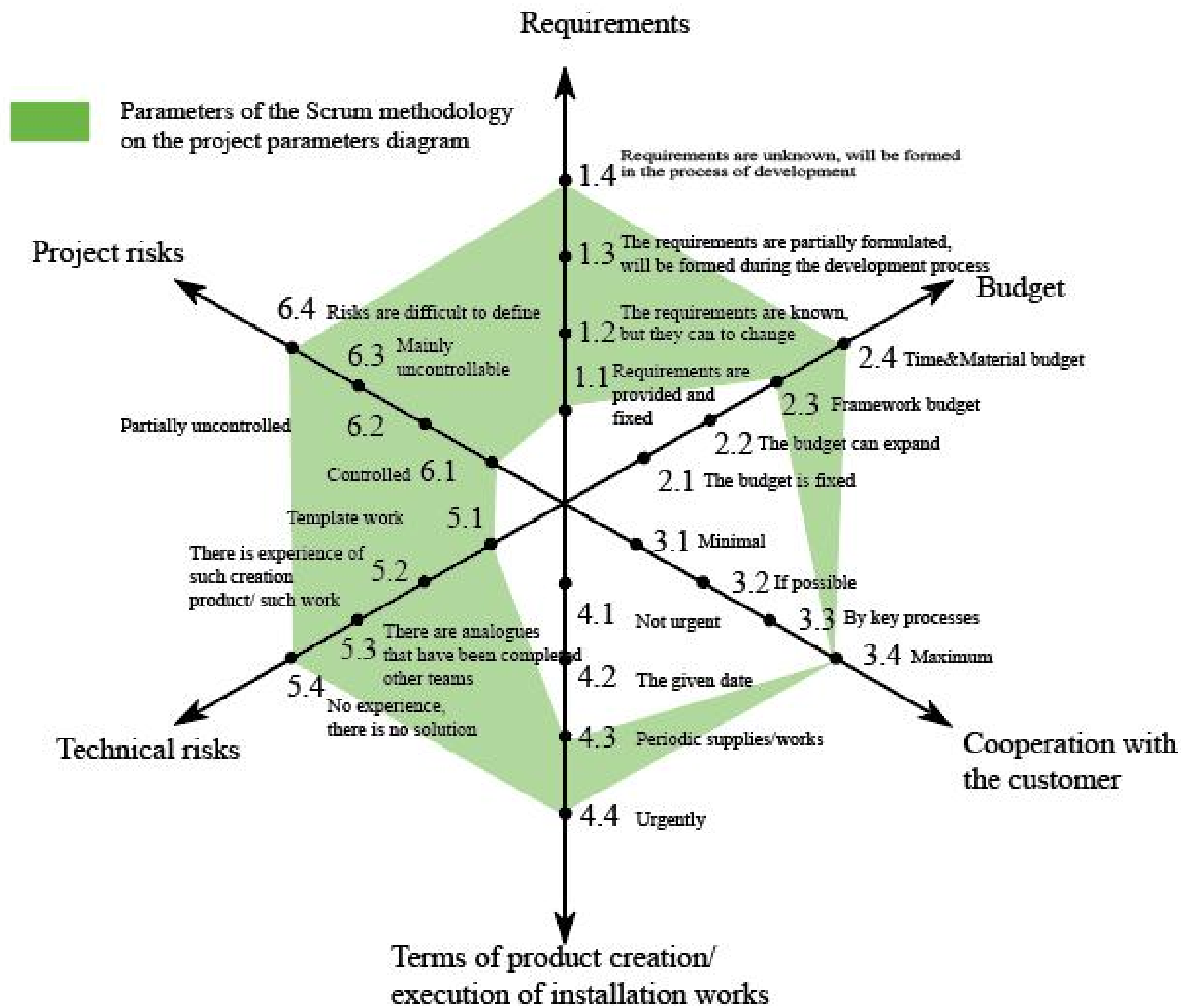



Fig. 3.8. Parameters of the Scrum methodology on the diagram of the parameters of the project for the development of gas cleaning devices for ventilation systems. Developed by the author

The Kanban methodology is used for projects for customers with whom there is already work experience and established project processes from both sides.

The customer is satisfied with the cooperation with the company and is interested in performance, most often this type of cooperation can be called outsourcing. There is a catalog of prioritized white-label tasks compiled by the customer. The development team "pulls" tasks from the catalog and concentrates on the current work, when the work task is completed, the team takes the next one from the top of the backlog. This limitation is necessary to control the speed of production, and even the speed of response to changes in the plan. The parameters of the Kanban methodology, plotted on the diagram of the project parameters, are presented in Fig. 3.9.

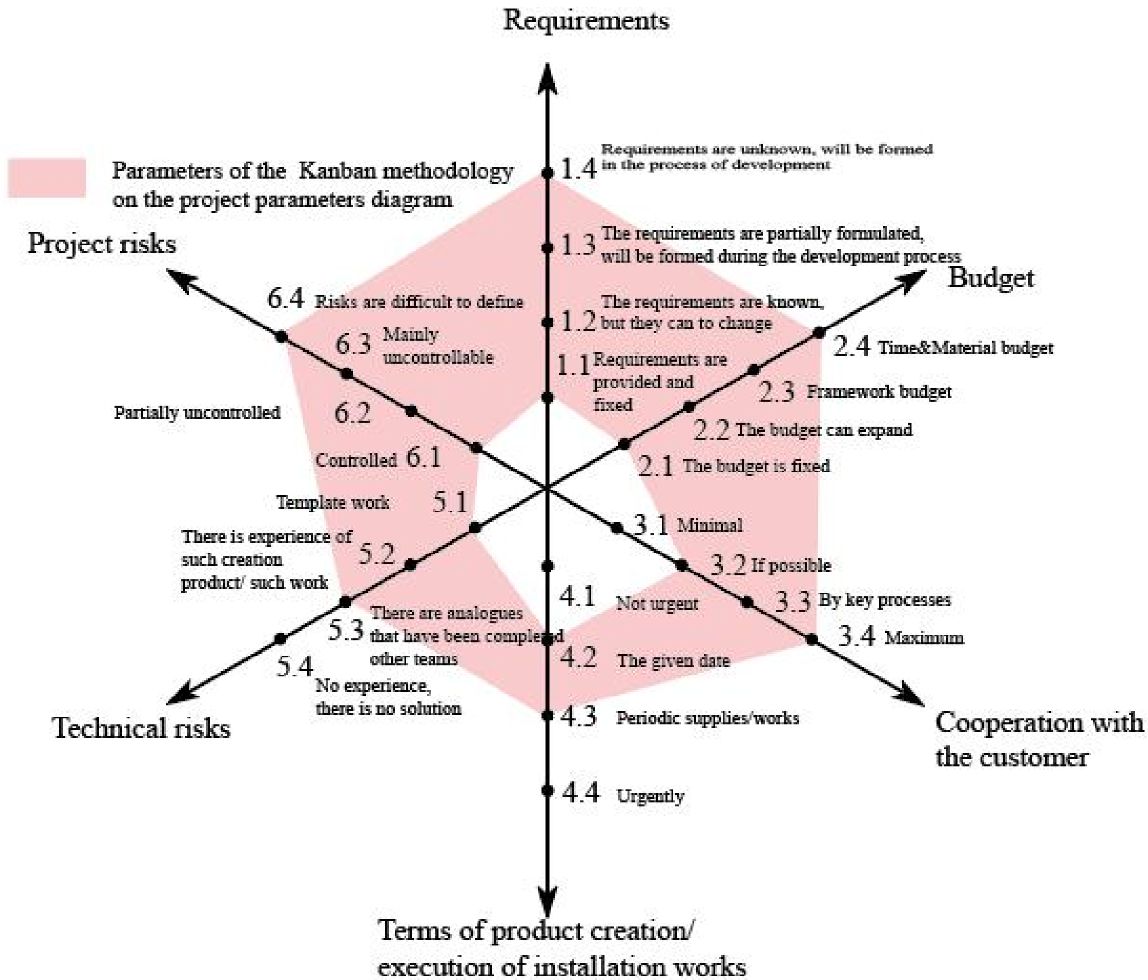



Fig. 3.9. Parameters of the Kanban methodology on the diagram of the parameters of the project for the development of gas cleaning devices for ventilation systems. Developed by the author

A model of the characteristics of methodologies on the diagram of project parameters has been created. For clarity, the parameters of the four projects are combined on one diagram (Fig. 3.10).

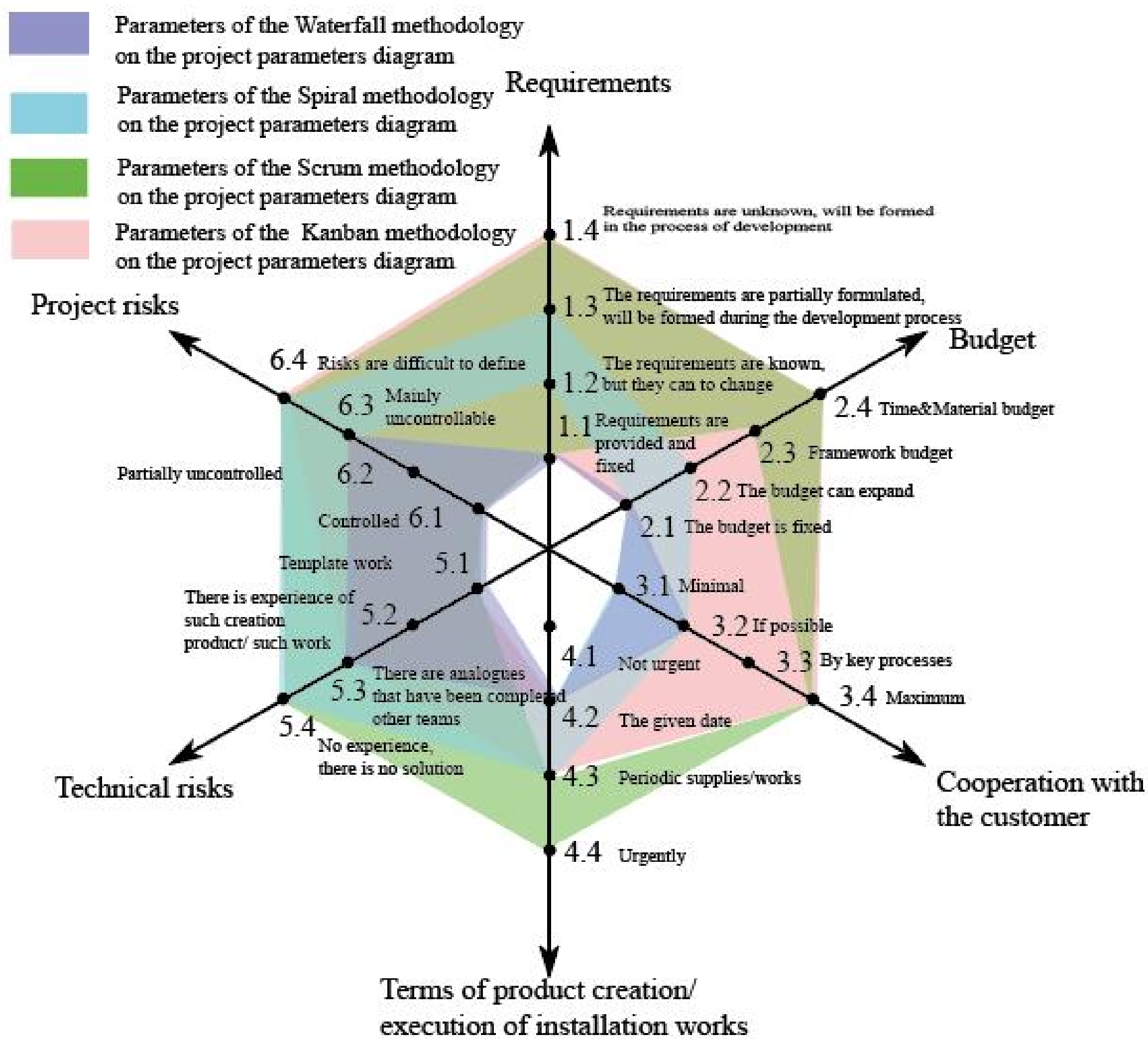



Fig. 3.10. Summary diagram of methodologies on project parameters for the development of gas cleaning devices for ventilation systems. Developed by the author

The choice of an inappropriate project management methodology entails, at a minimum, the risk of disruption of project deadlines, and at the maximum risk of closing the project due to increased financial requirements or non-fulfillment of obligations to the customer. In addition, the choice of an inappropriate methodology can significantly complicate and slow down the processes of work on the project.

### 3.2. A model of decision-making in the management of an international project under conditions of uncertainty

### 3.2.1. Development of a model and a method of choosing an approach to project management based on vague ideas

According to the results of the analysis of modern methods for choosing an approach to project management, at the pre-project stage it is important to determine the key factors that influence the choice of the methodology that will be used for project management. Having identified the factors, it is necessary to develop a formalized method for choosing a management approach.

At the initial stage, we will describe the method of choosing an international project management methodology based on fuzzy multiple analysis in the form of an algorithm (Fig. 3.8):

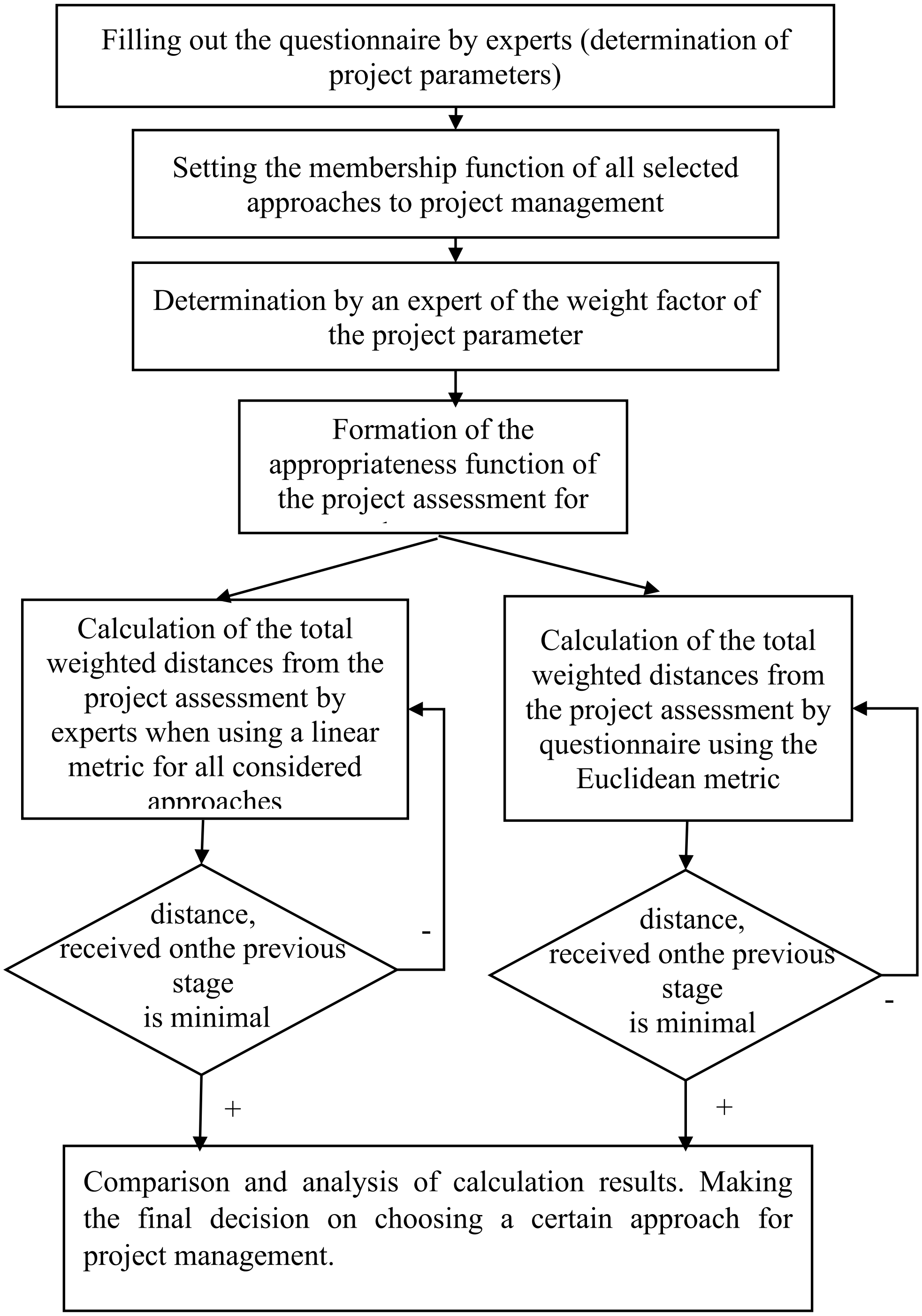



Fig. 3.8. Algorithm for choosing an international project management methodology based on fuzzy multiple analysis

An important aspect in the development of the method is that solving the task is complicated by the vagueness of existing recommendations regarding the applicability of different management approaches in different cases and conditions, in particular for the development of projects that do not relate to software development and have an international direction. It is proposed to solve this task by using questionnaires (table 3.5). Questionnaires reflect information about the project, communications, team and all possible risks in a structured way. An important condition is that the questionnaires should be filled out not only by the project manager, but also by the involved experts, specifically in our case, experts on the development of gas cleaning devices for ventilation systems.

Table 3.5. Fragment of the project data questionnaire

| **Project parameters and requirements** | | | | |
|---|---|---|---|---|
| **Parameter 1** | Project cost A1 | | | |
| **Options** | Less than 100 thousand monetary units | From 100 to 500 thousand monetary units | From 500 thousand to 1 million monetary units | More than 1 million monetary units |
| **Poin** | 10 | 20 | 30 | 40 |
| **Parameter 2** | Project product quality requirements, A2 | | | |
| **Options** | Requirements of the local market | National requirements | International requirements | Higher international requirements |
| **Poin** | 10 | 20 | 30 | 40 |
| ……… | | | | |
| **Parameter 9** | Frequency of reports to the customer during the project implementation, A9 | | | |
| **Options** | A report on each operation | Report on the execution of the work package | Report on the readiness of the product component of the project | Project readiness report |
| **Poin** | 10 | 20 | 30 | 40 |
| **Project risk assessment** | | | | |

| | | | | |
|---|---|---|---|---|
| **Parameter 10** | Probability of risk events related to project management (poor planning, controlling, communication problems, etc.), A10 | | | |
| **Options** | Risk event may occur, 10-50% | A risk event is likely to occur 50-75% | A risk event is likely to occur 50-75% | A risk event is most likely to occur,75-100% |
| **Poin** | 10 | 20 | 30 | 40 |
| ……… | | | | |
| **Parameter 13** | Probability of external risks (disruption of work by contractors, unfavorable political and economic situation in the country, market changes), A13 | | | |
| **Options** | A risk event may manifest, 10-50% | A risk event is likely to occur 50-75% | A risk event is likely to occur, 50-75% | A risk event is most likely to occur, 75-100% |
| **Poin** | 10 | 20 | 30 | 40 |
| ***Command options*** | | | | |
| **Parameter** 14 | The number of people involved in the project, *A15* | | | |
| **Options** | > 12 persons | ≤12>50 | ≤50>100 | ≤100 |
| **Poin** | 10 | 20 | 30 | 40 |
| **Parameter** 16 | Work experience in international projects, *A16* | | | |
| **Options** | They do not have experience working in international projects | They have up to 2 years of experience in international projects | They have more than 2 to 5 years of experience in international projects | They have more than 5 years of experience in international projects |
| **Poin** | 10 | 20 | 30 | 40 |
| ……… | | | | |
| **Parameter** 25 | Competence of the chief engineer, *A22* | | | |
| **Options** | High level of competence in this field, is an inventor | A high level of competence in this field can improve | Worked on the creation of ventilation systems for gas | Theoretical training, little experience |

| | | | | |
|---|---|---|---|---|
| | | ventilation systems of gas cleaning devices | cleaning devices | |
| **Poin** | 10 | 20 | 30 | 40 |

We will consider each parameter that describes the project in the questionnaire as An, n=(1,m) where n is the serial number of the parameter in the questionnaire, m is the number of questions. For this project m = 25.

$$\text{Then } A_n = \{a_{1n}, a_{2n} ... a_{in},\} \tag{3.1}$$

will be the set of possible values of the nth parameter. The score corresponding to the i-th option on the n-th parameter of the questionnaire $a_{in}$, $where\ i = \overline{1,k}$ , $k$ – the number of possible options for the nth parameter. In this project, k=4 for all parameters. Alternatives to the project methodology are marked as

$$M_n = \{M_1, M_2 ... M_p,\} \tag{3.2}$$

where $M_p$ , $p = \overline{1,P}$ - approach to project management, P - the number of project approaches. Among the alternatives of project approaches, we will select the following 4 approaches: cascade Waterfall Methodology (in PMBOK) ($M_1$), Spiral model ($M_2$), methodology Scrum ($M_3$), i Kanban ($M_4$). We will consider each methodology from the point of view of its application to specific options for answering questionnaire questions. However, there is a need to solve the problem of formalization of information for the given approaches to project management, which necessitates the use of the mathematical apparatus of fuzzy sets. The fuzzy set M on the set A = (a) is defined as [23]:

$$\text{M}=\{\langle a, \mu, (a)\rangle \ / a \in A\} \tag{3.3}$$

where $\mu_M(a) \in [0,1]$ is a function of belonging to the fuzzy set M.

So, applying the p-th approach to each of the possible options corresponding to the values $a_{in}$, where $i = \overline{1,k}$, n-th parameter

$An = \{a_{1n}, a_{2n} ... a_{in},\}$, will be considered as a fuzzy set $M_p$, $p = \overline{1,P}$, such that

$$M_{pn}=\left\{\langle a_{1n}, \mu_{M_{pn}}(a_{1n})\rangle, \langle a_{2n}, \mu_{M_{pn}}(a_{2n})\rangle, ..., \langle a_{kn}, \mu_{M_{pn}}(a_{kn})\rangle\right\} \quad (3.4)$$

Therefore, the membership function $\mu_{M_{pn}}, (a_{1n}), i = \overline{1, k}$ will determine the degree of applicability of the p-th approach to the parameter corresponding to the i-th variant of the answer to the n-th question given in the questionnaire. An expert commission was chosen to determine the appropriateness functions of all the mentioned approaches. A fragment of the given values is given in table 3.6.

Table 3.6. A fragment of the table of values of functions belonging to approaches

| Parameter $An$ | Valuation $a_{1n}$ | Waterfall $\mu_{M_{1n}}, (a_{in})$ | Spiral $\mu_{M_{2n}}, (a_{in})$ | Scrum $\mu_{M_{3n}}, (a_{in})$ | Kanban $\mu_{M_{4n}}, (a_{in})$ |
|---|---|---|---|---|---|
| $A1$ | 1 | 1 | 1 | 0 | 0 |
| | 2 | 1 | 1 | 0,25 | 0 |
| | 3 | 0,5 | 0,5 | 0,75 | 0,25 |
| | 4 | 0,5 | 0,25 | 1 | 1 |
| $A2$ | 1 | 1 | 1 | 0,25 | 0 |
| | 2 | 1 | 1 | 0,5 | 0,25 |
| | 3 | 0,25 | 0,25 | 0,75 | 0,5 |
| | 4 | 0,1 | 0,15 | 10 | 1 |
| $A3$ | 1 | 1 | 1 | 0 | 0 |
| | 2 | 0,5 | 0,5 | 0,5 | 0,5 |
| | 3 | 0,15 | 0 | 1 | 1 |
| | 4 | 0 | 0 | 1 | 1 |
| … | … | … | … | … | … |
| $A25$ | 1 | 1 | 1 | 0 | 0 |
| | 2 | 1 | 0,75 | 0 | 0 |
| | 3 | 0,25 | 0,25 | 0,75 | 0 |
| | 4 | 0 | 0 | 1 | 1 |

A graphical presentation of functions for parameter A1 (number of people involved in the project) for all methodologies is presented in Figure 3.9.

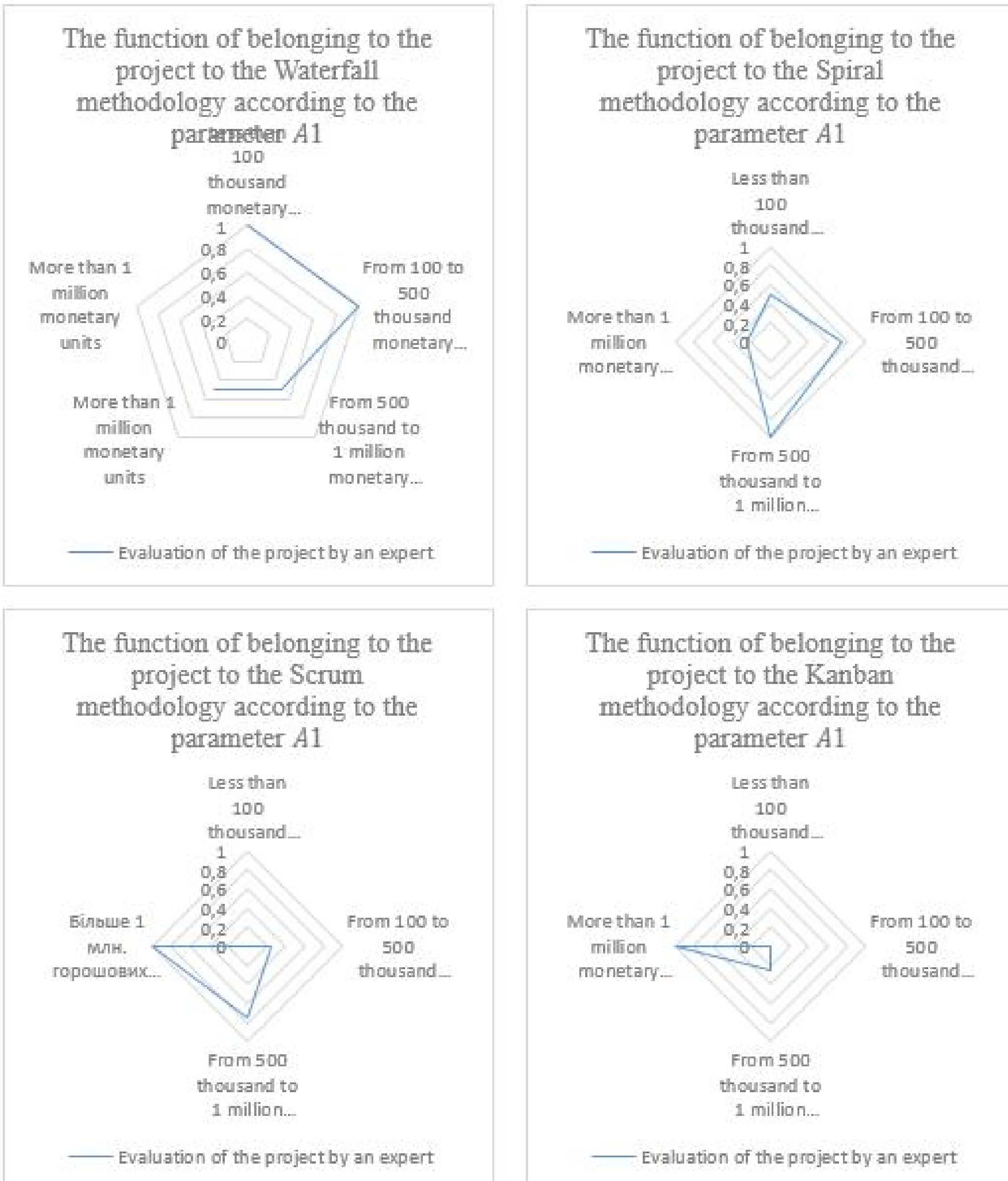



Fig. 3.9. Functions of the project belonging to the methodology according to the parameter $A1$

Approach to project management $M_p$, $p = \overline{1, P}$, characterized by the possibility of its application to each variant of all P parameters of the questionnaire. That is to say, $M_p = \{M_{p1}, M_{p2} ... M_{pP},\}$.

$$E=\{E_1,E_2,...,E_N\} \tag{3.5}$$

$E_n$, $n = \overline{1,N}$ - a fuzzy set that determines the correspondence of a project to the variants corresponding to the values $a_{in,\,i}$, $i = \overline{1,k}$ $n-$th parameter to the project $A_k=\{a_{1n},a_{2n},...,a_{kn}\}$, that is,

$$E_n=\{\langle a_{1n}, \mu_{E_n}(a_{1n})\rangle, \langle a_{2n}, \mu_{E_n}(a_{2n})\rangle, ..., \langle a_{kn}, \mu_{E_n}(a_{kn})\rangle\} \quad (3.6)$$

Then function $\mu_{E_n}(a_{in})$, $i = \overline{1,k}$ reflects the level of belonging of the project to the option that corresponds to the i-th option of the situation of the n-th parameter of the questionnaire. To determine the management approach that is most suitable for this project, we will estimate the distance from the project estimate $E=\{E_1,E_2,...,E_N\}$ to each of the considered approaches to project management $M_p = \{M_{p1}, M_{p2}...M_{pP},\}$ where $p = \overline{1,P}$.

There are many ways to determine the distances between fuzzy sets. The choice of one or another distance depends on the nature of the problem under consideration. Each of these distances has its advantages and disadvantages, which become certain during applications. Such distances between fuzzy sets M, E on the set are most often used $A = \{a_1, a_2...a_n,\}$ [23]:

- Euclidean metric e(M, E):

$$d(M,E) = \sqrt{\sum_{i=1}^{n} (\mu_M(a_i) - \mu_E(a_i))^2} \quad (3.7)$$

Although Euclidean distance is a general measure of distance, it does not scale in the variant, which means that the calculated distances can be distorted depending on the units of the features. Typically, data must be normalized before using this distance measure.

- Linear metric d(M, E):

$$d(M,E) = \sum_{i=1}^{k} \left| \mu_M(a_i) - \mu_E(a_i) \right| \quad (3.8)$$

The linear metric is difficult to use unless the two vectors are of the same length.

Moreover, it does not take into account the actual value if they are different or equal. Therefore, the linear metric is not recommended when magnitude is an important measure.

Manhattan metrics: $d(M,E) = \sum_{i=1}^{k} \left| M_i - E_i \right|$ (3.9)

The Manhattan metric works well for multidimensional data. But there is a possibility that the fault will give a higher distance value than the Euclidean distance because it is not the shortest possible path.

Cosine similarity:

$$d(M,E) = \cos(\Theta) = \frac{ME}{\|M\|\|E\|} \quad (3.10)$$

An important disadvantage of cosine similarity is that only their direction is taken into account, and the magnitude of the vectors is not taken into account. This means that differences in values are not fully taken into account.

Chebyshev metric

$$d(M,E) = \max_i(|M_i - E_i|) \quad (3.11)$$

The Chebyshev metric is usually used in very specific cases, making it difficult to use as a universal metric such as Euclidean distance or cosine similarity. Therefore, it is recommended to use it only when you are absolutely sure that it is suitable for your use case.

Thus, let's choose two universal metrics for this study, such as linear and Euclidean metrics.

Formulas (3.7 and 3.8) do not fully reflect the specifics of the problem under consideration. After all, in our problem, if the value of the membership function for the approach exceeds the value of the membership function for the project or coincides with it, then the distance between these coordinates should be considered zero. Therefore, the membership function for the project is covered by the membership function for the management approach. There is also an option when the approach fully meets the requirements of the project. Therefore, for the application of linear or Euclidean metrics, the distance according to the i-th value of the n-th parameter between the considered approach $M_p$ where $p = \overline{1, P}$ and the project estimate E is defined as follows: $0\ if\ \left(\left(\mu_{M_{in}}(a_{in})\right) - \left(\mu_{E_n}(a_{in})\right)\right) \geq 0$ , otherwise $\left(\mu_{M_{pn}}(a_{in}) - \left(\mu_{E_n}(a_{in}) \geq 0\right)\right.$ then the total distance between the approach M and the evaluation of the project E according to the n parameters when using the linear metric $d(M_p, E)$ is:

$$d_{in}(M_p, E) = \sum_{n=1}^{N} \sum_{i=1}^{K} \left|d_{in}(M_p, E)\right| \qquad (3.12)$$

You also need to consider that not all parameters $A_n, i = \overline{1, k}$ when solving the task of choosing an approach to project management are equivalent. To display the level of influence of the nth parameter on the result of the problem solution, weighting factors $m_n, n = \overline{1, N}$ are given in table 3.

Table 3.7. Value of weighting coefficients $m_n$, $n = \overline{1, N}$

| Parameter, $A_n$ | A1 | A2 | A3 | A4 | …. | A20 | A21 | A22 | A23 | A24 | A25 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighting coefficient, $m_n$ | 0,07 | 0,07 | 0,05 | 0,03 | …. | 0,04 | 0,03 | 0,03 | 3,03 | 0,03 | 0,05 |

Let's impose the following restrictions on them: $\sum_{n=1}^{N} m_n = 1\ at\ 0 \leq m_n \leq 1.$

Total distance between approaches $M_p$, and the evaluation of the project E according to N parameters, taking into account the entered weighting factors $m_n$, $n = \overline{1, N}$ when using Euclidean distance $d_m(M_p, E)$ we will find as:

$$d(M_p, E) = \sum_{n=1}^{N} m_n \sqrt{\sum_{i=1}^{K} (\mathrm{d}_{in}(\mathrm{Mp}, \mathrm{E}))^2} \qquad (3.13)$$

An approach for which the total distance from the estimate of project B and taking into account the weighting factors $m_n$, $n = \overline{1, N}$ when using the Euclidean metric is minimal and will be considered the best:

$$M = \arg min\{\mathrm{dn}(\mathrm{M_p}, \mathrm{E})\} \qquad (3.14)$$

Taking into account weighting factors, the total distance between approaches $M_p$ and the evaluation of project E by parameters N $d_m(M_p,E)$ when using a linear metric, will be determined as follows: $d_m(M_p,E)=\sum_{n=1}^{N} m_n \sum_{i=1}^{K} |\mathrm{dn}(\mathrm{Mp},\mathrm{E})|$

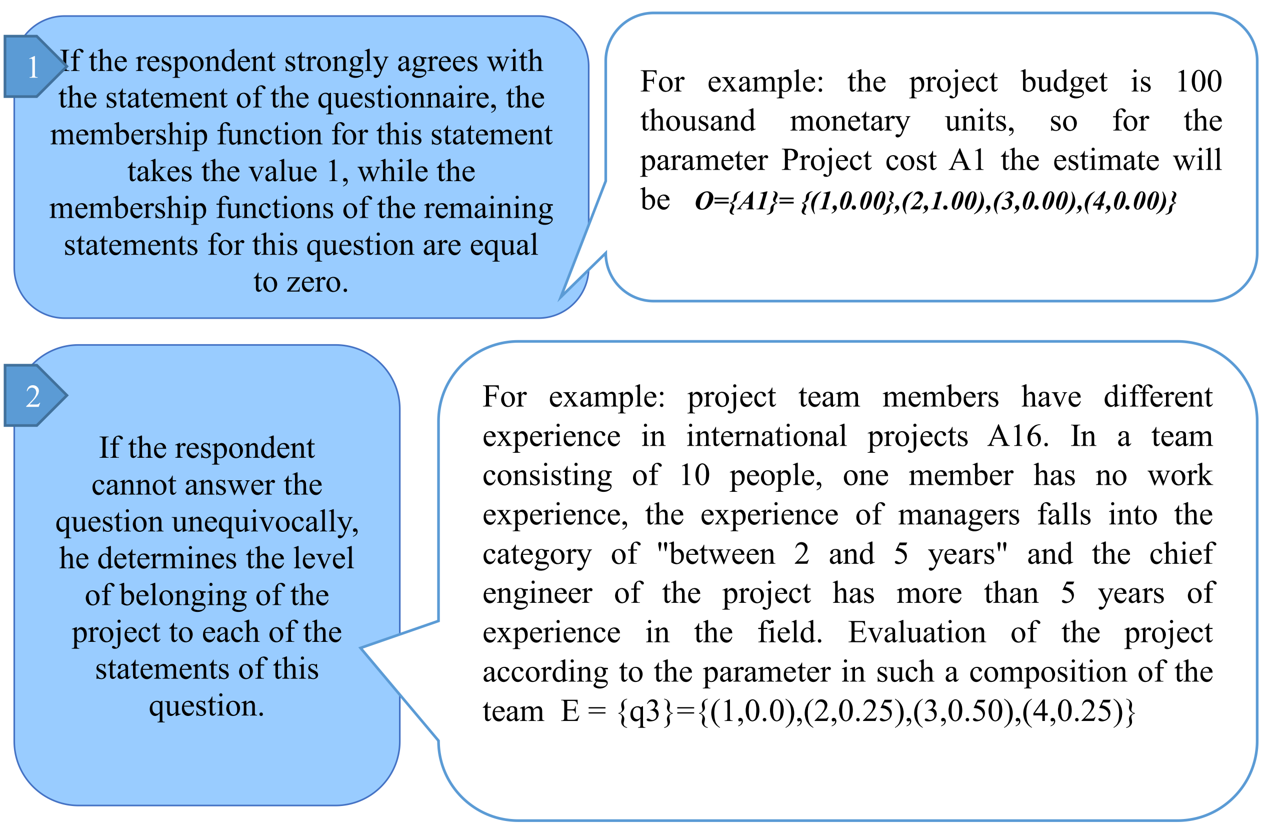
$$M = \arg min\{\mathrm{dn}(\mathrm{Mp},\mathrm{E})\} \qquad (3.15)$$

We will consider the optimal approach, for which the distance from the project estimate E, taking into account the weighting factors $m_n$, $n = \overline{1,N}$ when using the linear metric is minimal.

**3.2.2. Application of the project management model based on vague ideas for choosing an approach to software project management**

The application of the project management methodology selection method based on fuzzy multiple analysis is proposed on the example of a project dedicated to the development of gas cleaning devices for ventilation systems.

A questionnaire is created for the respondent, in which the appropriateness function of the project assessment (E) according to the selected parameters is specified. The evaluation options are shown in Figure 3.10. Values of the appropriateness function of



the project assessment according to all considered parameters are given in table 3.8.

Fig. 3.10. Evaluation options

Table 3.8. The value of the appropriateness functions of the project assessment, B

| Parameter, A1 | | Parameter, A2 | | Parameter, A3 | | Parameter, A4 | |
|---|---|---|---|---|---|---|---|
| Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ |
| 1 | 0,00 | 1 | 0,00 | 1 | 0,00 | 1 | 0,00 |
| 2 | 0,00 | 2 | 0,00 | 2 | 0,00 | 2 | 0,00 |
| 3 | 0,00 | 3 | 1,00 | 3 | 1,00 | 3 | 1,00 |
| 4 | 1,00 | 4 | 0,00 | 4 | 0,00 | 4 | 0,00 |
| Parameter, A5 | | Parameter, A6 | | Parameter, A7 | | Parameter, A8 | |
| Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ |
| 1 | 0,00 | 1 | 0,00 | 1 | 0,00 | 1 | 0,00 |
| 2 | 0,00 | 2 | 0,00 | 2 | 0,00 | 2 | 0,00 |
| 3 | 1,00 | 3 | 1,00 | 3 | 1,00 | 3 | 0,00 |
| 4 | 0,00 | 4 | 0,00 | 4 | 0,00 | 4 | 1,00 |
| ………… | | | | | | | |
| Parameter, | | Parameter, A23 | | Parameter, A24 | | Parameter, A25 | |

| A22 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ | Amount of points, $a_{ik}$ | Value $\mu_{E_n}(a_{in})$ |
| 1 | 0,00 | 1 | 0,00 | 1 | 0,00 | 1 | 0,00 |
| 2 | 1,00 | 2 | 0,25 | 2 | 0,00 | 2 | 0,00 |
| 3 | 1,00 | 3 | 0,75 | 3 | 1,00 | 3 | 1,00 |
| 4 | 0,00 | 4 | 0,00 | 4 | 0,00 | 4 | 0,00 |

Using a linear metric, we will calculate the total weighted distances between project estimates and each approach:

$$d_m(M_1,E)=\sum_{n=1}^{N} m_n \sum_{i=1}^{K} \mathrm{dn}(M_1, E)= 0{,}703 \text{ Waterfall Methodology } (M_1) \quad (3.16)$$

$$d_m(M_2,E)=\sum_{n=1}^{N} m_n \sum_{i=1}^{K} \mathrm{dn}(M_2, E) = 0{,}732 \text{ Spiral model } (M_2) \quad (3.17)$$

$$d_m(M_3,E)=\sum_{n=1}^{N} m_n \sum_{i=1}^{K} \mathrm{dn}(M_3, E) = 0{,}112 \text{ Methodology Scrum } (M_3) \quad (3.18)$$

$$d_m(M_4,E)=\sum_{n=1}^{N} m_n \sum_{i=1}^{K} \mathrm{dn}(M_4, E) = 0{,}345 \text{ Kanban } (M_4) \quad (3.19)$$

We choose the approach according to (3.8):

$$M = arg\,min\{\mathrm{d_n}(\mathrm{Mp}, \mathrm{E})\} = argmin\begin{Bmatrix} 0{,}703 & 0{,}732 \\ 0{,}112 & 0{,}345 \end{Bmatrix} \text{argmin } (0{,}012) \quad (3.20)$$

The result of calculating the distances between the considered approaches and project evaluation using linear metrics, it is recommended to use the Scrum methodology to manage the project on the development of gas cleaning devices for ventilation systems. Let's calculate the total weighted distances for the same indicators using the Euclidean metric:

$$d_m(M_1, E) = \sum_{n=1}^{N} m_n \sqrt{\sum_{i=1}^{K} \mathrm{d}_{in}(\mathrm{Mp}, \mathrm{E})}{=}0{,}703 \quad (3.21)$$

$$d_m(M_2, E) = \sum_{n=1}^{N} m_n \sqrt{\sum_{i=1}^{K} \mathrm{d}_{in}(\mathrm{Mp}, \mathrm{E})}{=}0{,}725 \quad (3.22)$$

$$d_m(M_3, E) = \sum_{n=1}^{N} m_n \sqrt{\sum_{i=1}^{K} \mathrm{d}_{in}(\mathrm{Mp, E})}=0{,}110 \quad (3.23)$$

$$d_m(M_4, E) = \sum_{n=1}^{N} m_n \sqrt{\sum_{i=1}^{K} \mathrm{d}_{in}(\mathrm{Mp, E})}=0{,}308 \quad (3.24)$$

We choose the approach according to (15):

$$M = arg\,min\{\mathrm{d_n}(\mathrm{Mp, E})\} = argmin\begin{Bmatrix} 0{,}700 & 0{,}725 \\ 0{,}110 & 0{,}308 \end{Bmatrix} = \mathrm{argmin}(0{,}110) \quad (3.25)$$

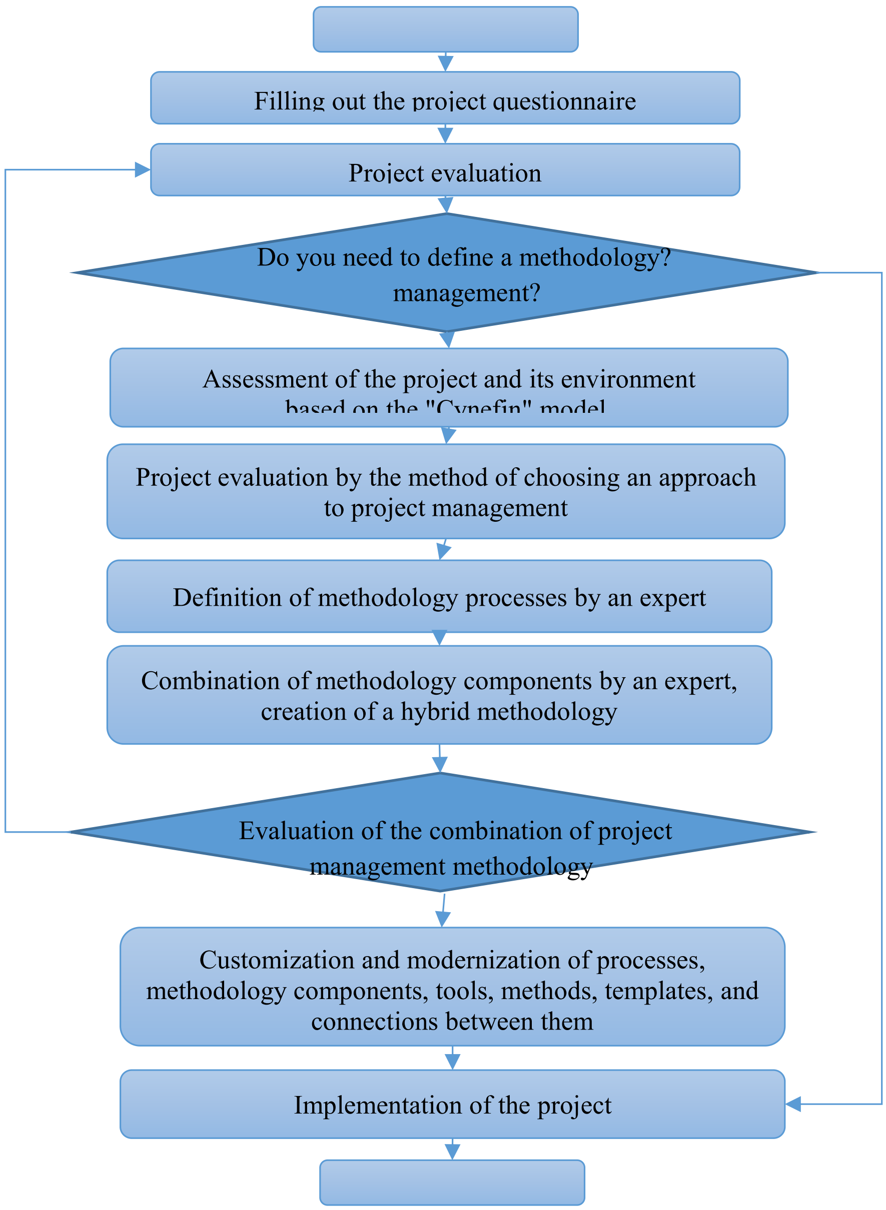
So, the result obtained by calculating the Euclidean metric regarding the choice of project management methodology is similar to the previous result. Thus, we can conclude that the Scrum methodology is best suited for project management with such initial conditions.

To determine the management approach that is most suitable for a given project, we estimate the distance from the project assessment to the methodology assessment. Of all the ways to determine the distances between fuzzy sets, the system chooses one or another metric, depending on the nature of the problem under consideration. Each of these metrics has its advantages and disadvantages. It is possible to use several metrics to compare results.

On the basis of the developed model, in chapter 4 of the dissertation, an effective and flexible software tool for choosing an international project management methodology is proposed in the form of the "Methodology Selection" module, which allows you to automatically choose the optimal international project management methodology for this project.

## 3.3 A method of selecting and structuring an approach to project management

An integrated method of forming the component composition of the project management methodology based on the Agile methodology is proposed. "Agile methodology" is a system of principles and values, processes, tools, practices, organizational structure, and roles that ensure successful project management [94]. It is proposed to divide the method of forming an approach to project management based on




the Agile methodology into stages, Fig. 3.9.

Fig. 3.9. The main stages of the method of forming an approach to project management

The first stage of the algorithm is filling out a questionnaire that characterizes the project by all interested parties of the given project. The questionnaire contains questions related to: the basic requirements for the project, the customer's work experience with the team, the number of people involved in the project, the level of competence of the project team, the manager's area of responsibility, the possibility of risk events.

The second stage is the assessment of the project and its surroundings by the developed method of choosing a project approach based on the "Cynefin" model (presented in subsection 3.1.)

The third stage is the assessment of the project and its environment using the developed method of choosing an approach to project management based on fuzzy sets (presented in clause 3.2.1), the selection of project management methodologies from those that are popular in the world. This methodology is further used as a basis for the synthesis of an individual methodology for the considered project.

The chosen methodology is supplemented by an expert for better consistency with the project. An expert is a person who knows the peculiarities of values and standards of methodologies. The expert has the opportunity to choose other principles and values, processes, practices, life cycle and organizational structure of the project for the considered project, to carry out the distribution of roles and responsibilities in the project. The expert has the opportunity to add, replace or change the components of the methodology, the combination of which best implements the project.

The next step is the expert's determination of the methodology processes, which allow to assign the methods and tools of their implementation, as well as the corresponding templates, which as a result become the basis of alternative project management models.

During the implementation of the project, periodic adjustment and modernization of processes, methodology components, tools, methods, templates, and connections between them is carried out. The proposed method can be applied to a portfolio of projects, taking into account the diversity of the organization's projects that are not related to IT projects. Projects can be classified at the second stage, if the basic methodologies for several projects are the same, they can be combined into a group. The method can be applied to any non-IT projects.

### 3.3.1 Solving the problem of practical application of the integrated method of selection and formation of an approach to project management

The proposed method was applied in practice to manage the project for the development of gas cleaning equipment. The product of the project is a gas purification system. The expected duration of the project is 2 months. The cost of project management should not exceed 1,500 monetary units.

At the first stage of project evaluation, the method of choosing a project approach based on the "Cynefin" model is used. At the same time, interested parties evaluate the project by filling out a special questionnaire. The evaluation of the gas cleaning equipment development project received from the project manager is shown in Table 3.9.

Table. 3.9. Evaluation of the parameters of the gas cleaning equipment disassembly project

| ***Project parameters and requirements*** | | | | |
|---|---|---|---|---|
| *Parameter 1* | *The cost of the project A1* | | | |
| Options | Less than 100 thousand monetary units | From 100 to 500 thousand monetary units | From 500 thousand to 1 million monetary units | More than 1 million monetary units |
| Poin | | | 30 | |
| *Parameter 2* | *Project product quality requirements, A2* | | | |
| Options | Requirements of the local market | National requirements | International requirements | Higher international requirements |
| Poin | | | 30 | |
| ……… | | | | |
| Parameter 9 | The frequency of reports to the customer in the process of project implementation, *A9* | | | |
| Options | A report on each operation | Report on the execution of the work package | Report on the readiness of the product component of the project | Project readiness report |

| | | | | |
|---|---|---|---|---|
| Poin | 10 | | | |
| ***<u>Project risk assessment</u>*** | | | | |
| Parameter 10 | The probability of risk events related to project management (poor planning, controlling, communication problems, etc.), *A10* | | | |
| Options | Risk event may occur, 10-50% | A risk event is likely to occur 50-75% | A risk event is likely to occur 50-75% | A risk event is most likely to occur, 75-100% |
| Poin | | | | 40 |
| ……… | | | | |
| Parameter 13 | Probability of manifestation of external risks (disruption of work by contractors, unfavorable political and economic situation in the country, market changes), A13 | | | |
| Options | Risk event may occur, 10-50% | A risk event is likely to occur 50-75% | A risk event is likely to occur 50-75% | A risk event is most likely to occur, 75-100% |
| Poin | | | | 40 |
| ***<u>Command options</u>*** | | | | |
| Parameter 14 | Number of people involved in the project, A15 | | | |
| Options | > 12 persons | ≤12>50 persons | ≤50>100 persons | ≤100 persons |
| Poin | | 20 | | |
| Parameter 16 | Work experience in international projects, *A16* | | | |
| Options | They do not have experience working in international projects | They have up to 2 years of experience in international projects | Have experience of working in international projects for more than 2 to 5 years | They have more than 5 years of experience in international projects |
| Poin | | | 30 | |
| ……… | | | | |
| Parameter 25 | Competence of the chief engineer, *A22* | | | |
| Options | High level of | A high level of | Worked on the | Theoretical |

| | | | | |
|---|---|---|---|---|
| | competence in this field, is an inventor | competence in this field can improve the ventilation systems of gas cleaning devices | creation of ventilation systems for gas cleaning devices | training, little experience |
| Poin | | 20 | | |

The next stage of the method allows you to determine which methodology is more appropriate for the project (traditional, plan-oriented or flexible, or perhaps it is necessary to form a hybrid approach based on the conditions of the project). The project assessment obtained at the first stage and the method of choosing an approach to project management based on vague ideas are used. In this way, an approach to project management is selected that most closely matches the specifics of the project. Formulas for calculating the total distances of linear and total Euclid distances, as well as the calculation results, are given in Table 3.10.

Table. 3.10. Calculation of total weighted linear and Euclidean distances for choosing an approach to the management of the gas treatment equipment development project

| The name of the approach | $d(M,E) = \sum_{i=1}^{k} \left| \mu_M(a_i) - \mu_E(a_i) \right|$ | $d(M,E) = \sqrt{\sum_{i=1}^{n} (\mu_M(a_i) - \mu_E(a_i))^2}$ |
|---|---|---|
| Waterfall | 0,701 | 0,688 |
| Spiral model | 0,676 | 0,667 |
| Scrum | 0,325 | 0,322 |
| Kanban | 0,412 | 0,406 |

According to the calculation results (table 3.10), the minimum distance from the project assessment, both by the linear metric and by the Euclid method, is achieved for the Scrum project management methodology, which can be recommended as a basis for the further formation of the approach. The next, close methodology is Kanban. Therefore, it can be concluded that for this project, flexible approaches to project management are more appropriate than other approaches under consideration (Waterfall, Spiral model).

Taking into account the results obtained at the 2nd stage, the expert forms two alternative specialized methodologies for the project of developing gas cleaning devices. The expert is a manager who has comprehensive knowledge of project management methodologies. The first methodology was created by modifying the Scrum project management methodology (basic approach). For the second alternative, the expert chose another methodology from the family of flexible approaches - Kanban as a basis, and supplemented it with components of the Scrum methodology. The component composition of both specialized methodologies involves the presence of values and principles of project management, project life cycle, organizational structure, roles and responsibilities, as well as processes and practices of project management (table 3.11). Values and principles in project management. The four core values of the Agile Manifesto underlie both the first and second alternative methodologies. Next to them, the first methodology is based on the six principles of Scrum, and the second is based on the four principles of the Kanban methodology (table 3.11).

Table 3.11. Component composition of specialized alternative methodologies

| | Basic Scrum approach | Kanban + components of Scrum. |
|---|---|---|
| Values and principles of project management | - People and collaboration are more important than processes and tools - A working product is more important than comprehensive documentation - Collaboration with the customer is more important than negotiating the terms of the contract - Readiness for change is more important than following the plan | |

| | | |
|---|---|---|
| | - Empirical process control - Self-organization - - Collaboration Value-based prioritization Time-boxing - Iterative development | Focus on business needs - Leave on time - Collaborate -- Never compromise quality -- build incrementally and only on a solid foundation - Develop iteratively - Communicate continuously and clearly - Demonstrate control |
| Life cycle of the project | Adaptive | Hybrid |
| Organizational structure in project management | Project-oriented organizational structure | |
| Roles and responsibilities in project management | - Scrum master - Product owner - Scrum team | - Business Sponsor - Business Ambassador - Technical C oordinator - Solution Developer - Solution Tester - Project M anager - Team Leader - Business Analyst |
| Project management processes | - Product development - Creating a prioritized product backlog - Conducting release planning - Creating user stories - Evaluating and | - Identifying previous lessons - Preparing a business case outline - Developing a business case - Developing a prioritized list of requirements - Defining a solution architecture - Defining |

| | | |
|---|---|---|
| | approving user stories - Creating tasks - Estimating tasks - Creating a sprint backlog - Conducting daily meetings - Keeping the product backlog up to date - Sprint demonstration and validation - Sprint retrospective - Delivery of results - Project retrospective | a development approach - Developing a delivery plan - Developing a timebox plan - Updating a prioritized list of requirements - Reviewing the business case - Preparation of the time box review report - Preparation of the project review report - Conducting daily meetings |
| Project management practices | - Workshop with the participation of a facilitator - Iterative development - Time-boxing | |

The first methodology involves the implementation of an adaptive project life cycle. This project life cycle is most consistent with the Scrum methodology. For the second methodology, the expert chose a hybrid project life cycle, which involves the simultaneous use of adaptive and predictive approaches during the project life cycle. This option is typical of a situation where the team gradually moves to agile methodologies and uses some best practices (such as short iterations, daily meetings and retrospectives), but other aspects of the project, such as preliminary estimation, work assignments, progress tracking, remain the same , is performed according to traditional approaches. Organizational structure in project management. For both methodologies, it is advisable to use a project-oriented organizational structure. This structure corresponds as best as possible to the selected flexible values and principles, as well as to the life cycles of the project. Roles and responsibilities in project management. The first methodology involves the application of roles and responsibilities of the Scrum project management methodology. The second methodology assigns team members the roles and responsibilities of a Kanban approach.

For the first methodology, the expert chose 14 processes of the Scrum methodology. The second methodology was formed using the processes of the Kanban and Scrum methodologies. Table 3.11 provides a complete list of project management processes, methodologies and practices. Both methodologies involve the same set of project management practices, the sources of which are the Kanban and FDD methodologies (Table 3.11).

The ultimate goal of choosing an approach to project management is to improve the quality of management. In our case, the quality of project management is the level at which the set of project management characteristics meets the established requirements. As a set of such characteristics, respectively:

- complexity of project management;
- cost of project management;
- project management risks.

At the same time, under the "cost of project management" we will understand the total cost of performing all project management processes that are part of the formed approach. Similarly, "labor intensity of project management" represents the overall labor intensity of performing all management processes of the established approach. By "risks of project management" we will understand systemic risks, which are accompanied by the application of the established approach to project management. To determine the approach to project management, the characteristics of which best satisfy the established requirements, we will solve the problem of multi-criteria optimization with unclear initial data according to the criteria of labor intensity, cost of project management and risks associated with the application of the approach. Solving such a problem is possible by applying the *minmax* method in combination with a complete selection of solutions, which allows choosing the best alternative as safely as possible.

### 3.3.2. Assessment of methodology

Evaluation of the methodology involves the determination of three main indicators related to its implementation, fig.


Fig. 3.11. The main indicators of methodology evaluation.

To calculate indicators of labor intensity and cost of project management, it is necessary to determine all executors of project management processes, their hourly rate and, approximately, how long they can be involved in the implementation of processes. Table 3.12 presents all team members required to implement the first methodology and their hourly rates. The role and responsibilities of the product owner are transferred to the customer's representative. Table 3.13 shows the roles and hourly rates assigned to team members. The customer of the project acts as a business sponsor; the customer's representative performs the role of business ambassador and strategic director at the same time.

Table 3.12. Composition of the project team and hourly rates of team members (for the first methodology)

| | Position | Rate, monetary unit/hour |
|---|---|---|
| Team members | Product Owner | 7 |
| | Scram master | 8 |
| Team | Chief Engineer | 8 |
| | Technician | 7 |
| | Designer | 5 |
| | Mechanic | 4 |

Table 3.13. Composition of the project team and hourly rates of team members (for the second methodology)

| | Position | Rate, monetary unit/hour |
|---|---|---|
| Team members | Bisiner Ambassador | 7 |
| | Project Manager | 8 |
| Team | Lead engineer | 8 |
| | Technical Manager | 7 |
| | Design Manager | 4.5 |
| | Engineer | 3,5 |

In table 3.14. selected management processes, their planned executors and approximate labor intensity estimates are listed. According to the methodology synthesis method [16], labor intensity is presented in the form of triangular fuzzy numbers. The cost estimate for the performer is the result of multiplying the estimate of the performer's labor intensity by his hourly rate. The total labor intensity of the process is equal to the sum of the labor intensity estimates of all its executors. The cost of the process is equal to the sum of all cost estimates for the executors.

Tables 3.14. Assessment of labor intensity and cost of project management (first methodology)

| Process | Performer | Labor intensity estimate, T, people/hour. | Hourly rate, monetary unit | Cost estimate (T*Hourly rate), K, money unit |
|---|---|---|---|---|
| 1 | 3 | 3 | 4 | 5 |
| 3.5. development | Product Owner | 3, 4, 3 | 7 | 21, 28, 21 |
| | Scram master | 2, 1.5, 2 | 8 | 16, 12, 16 |
| | Chief Engineer | 1, 1.5, 2 | 8 | 8, 12, 16 |
| | Technician | 1, 1.5, 2 | 7 | 7, 10.5, 14 |
| | Designer | 1, 1.5, 3 | 5 | 5, 7.5, 15 |
| | Mechanic | 1, 1.5, 3 | 4 | 4, 6, 12 |
| | | ...... | | |
| 5.1. Creating a prioritized product backlog | Product Owner | 2, 2, 3 | 7 | 14, 14, 21 |
| | Scram master | 2, 3, 4 | 8 | 16, 24, 32 |
| | Chief Engineer | 2, 3, 4 | 8 | 16,24, 32 |
| | Technician | 2, 3, 4 | 7 | 14, 21, 28 |
| | Designer | 2, 3, 4 | 5 | 10, 15, 20 |
| | Mechanic | 2, 3, 4 | 4 | 8, 12, 16 |
| | | ...... | | |
| 6.6 Conducting release planning | Product Owner | 1, 1.5, 2 | 7 | 7, 10.5, 14 |
| | Scram master | 1, 1.5, 2 | 8 | 8, 12, 16 |
| | Chief Engineer | 1, 1.5, 2 | 8 | 8, 12, 16 |
| | Technician | 1, 1.5, 2 | 7 | 7, 10.5, 14 |
| | Designer | 1, 1.5, 2 | 5 | 5, 7.5, 10 |
| | Mechanic | 1, 1.5, 2 | 4 | 4, 6, 8 |
| | | ...... | | |
| 7.1. Creating user stories | Product Owner | 6, 8, 8 | 7 | 42, 56, 56 |
| | Scram master | 6, 8, 8 | 8 | 48,64, 64 |
| | Chief Engineer | 6, 8, 8 | 8 | 48,64, 64 |
| | Technician | 6, 8, 8 | 7 | 42, 56, 56 |
| | Designer | 6, 8, 8 | 5 | 30,40, 40 |
| | Mechanic | 6, 8, 8 | 4 | 24,32,32 |

| | | | | |
|---|---|---|---|---|
| 8.3. Conducting daily stand-up | Product Owner | 1.5, 1.5, 2.5 | 7 | 10.5, 10.5, 17.5 |
| | Scrum Master | 1.5, 1.5, 2.5 | 8 | 12, 12,20 |
| | Chief Engineer | 1.5, 1.5, 2.5 | 8 | 12, 12, 20 |
| | Technician | 1.5, 1.5, 2.5 | 7 | 10.5, 10.5, 17.5 |
| | Designer | 1.5, 1.5, 2.5 | 5 | 7.5, 7.5, 12.5 |
| | Mechanic | 1.5, 1.5, 2.5 | 4 | 6, 6, 10 |
| | | ...... | | |
| 9.3 Development | Product Owner | 3, 4, 6 | 7 | 21, 24 ,42 |
| | Scrum Master | 3, 4, 6 | 8 | 18, 27, 36 |
| | Chief Engineer | 3, 4, 6 | 8 | 24, 32, 48 |
| | Technician | 3, 4, 6 | 7 | 21, 24 ,42 |
| | Designer | 3, 4, 6 | 5 | 15, 20, 30 |
| | | ...... | | |
| 9.4 Assessment of tasks | Product Owner | 1.5, 2, 2.5 | 7 | 10.5, 14, 17.5 |
| | Scram-мастер | 1.5, 2, 2.5 | 8 | 12, 16, 20 |
| | Chief Engineer | 1.5, 2, 2.5 | 8 | 12, 16, 20 |
| | Technician | 1.5, 2, 2.5 | 7 | 10.5, 14, 17.5 |
| | Designer | 1.5, 2, 2.5 | 5 | 7.5, 10, 12.5 |
| | Mechanic | 1.5, 2, 2.5 | 4 | 6, 8, 10.5 |
| | | ...... | | |
| 9.7 Creation of the sprint backlog | Product Owner | 3,4, 4 | 7 | 21, 28,28 |
| | Scrum Master | 3,4, 4 | 8 | 24, 32,32 |
| | Chief Engineer | 3,4, 4 | 8 | 24, 32,32 |
| | Technician | 3,4, 4 | 7 | 21, 28, 28 |
| | Designer | 3,4, 4 | 5 | 15,20,20 |
| | Mechanic | 3,4, 4 | 4 | 12,16,16 |
| | | ...... | | |
| *Total according to the methodology* | | *114,145,200* | - | *745,976, 1182.5* |

The final labor intensity of project management represents the total labor intensity of all processes, while its final cost is equal to the sum of costs of all processes, respectively. The labor intensity of project management according to the first methodology is equal to man-hours, its cost is in monetary units.

The scale for assessing the consequences of risk events is shown in Fig. 3.12. Risk events associated with the application of the methodology, as well as their assessments, are presented in Table 3.15.

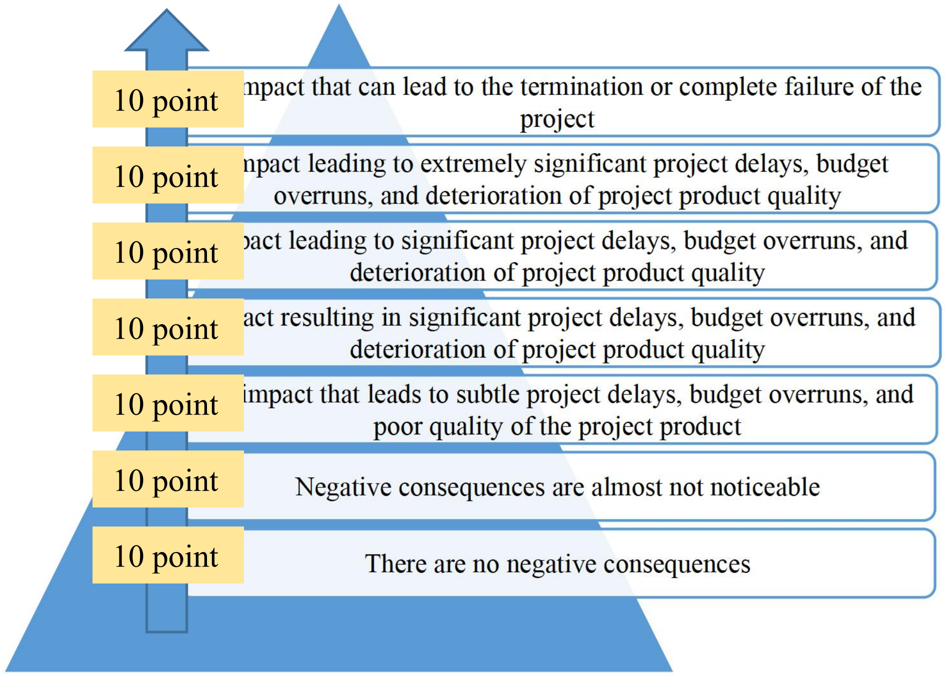



Fig. 3.12. The scale for evaluating the negative consequences of risk events

Table 3.15. Assessment of risks associated with the application of the first methodology.

| Risk | Probability of occurrence, M | Consequences of manifestation, K, score | Risk assessment, R = M*K, score |
|---|---|---|---|
| The project participants do not accept the values and principles of Scrum | 0.3, 0.3, 0.3 | 7, 8, 8 | 2,1, 2,4, 2,4 |
| Team members do not understand / do not accept the roles and responsibilities assigned to them by the Scrum methodology | 0.05, 0.1, 0.15 | 5, 6, 8 | 0.25, 0.6, 1.2 |
| Lack of work experience of a customer representative as a product owner | 0.2, 0.2, 0.2 | 10, 10, 12 | 2, 2, 2.4 |
| Contradictions between the standards and rules of the contracting and / or executive organization and the methodology | 0.4, 0.4, 0.4 | 5, 6, 7 | 2, 2.4, 2.8 |
| Involvement of the product owner in the project is not enough for the optimal development of | 0.35, 0.35, 0.35 | 5, 5, 6 | 1.75, 1.75, 2.1 |
| The project team's ability to self-organize and self-coordinate is not sufficient for effective Scrum implementation | 0.1, 0.1, 0.1 | 7, 8, 8 | 0.7, 0.8, 0.8 |
| Incorrect prioritization of the product backlog | 0.5, 0.5, 0.5 | 7, 8, 9 | 3.5, 4, 4.5 |
| Inefficient sprint planning | 0.3, 0.3, 0.3 | 7, 8, 8 | 2.1, 2.4, 2.4 |
| Inefficiency of the product due to insufficient pre-project research | 0.05, 0.05, 0.05 | 7, 8, 8 | 0.35, 0.4, 0.4 |
| *Final risk assessment* | | | *14.75,16.75,19* |

The risk assessment for the first methodology is 14.75, 16.5, 19.

The second methodology assigns its own roles to project participants.

Table 3.16 lists the management processes of the second methodology, their executors, labor intensity and cost. The labor intensity of project management according to the second methodology is man-hours, its cost is in monetary units.

Table 3.16. Assessment of labor intensity and cost of project management (second methodology)

| Process | Performer | Labor intensity estimate, T, people/hour. | Hourly rate, monetary unit | Cost estimate (T*Hourly rate), K, грош.одиниця |
|---|---|---|---|---|
| 4.1. Development of an approach to defining the solution architecture | Project Manager | 2, 3, 4 | 5 | 10, 5, 20 |
| | Lead engineer | 0.5, 1, 2 | 4 | 2, 4,8 |
| | Technical Manager | 3, 4, 6 | 7 | 21, 28, 42 |
| 4.5 Defining the development approach | Project Manager | 2, 3, 4 | 7 | 14, 21,28 |
| | Lead engineer | 5, 5, 1 0 | 6 | 30, 30, 60 |
| 4.3 Viewing the prioritized list of requirements | Bisiner Ambassador | 6, 9, 12 | 4 | 24, 36, 48 |
| | Project Manager | 6, 9, 12 | 6 | 36, 54,72 |
| | Lead engineer | 10, 15, 20 | 6 | 60, 90, 120 |
| | | | - | |
| 5.2 Business case development | Bisiner Ambassador | 6, 6, 8 | 5 | 30, 30, 40 |
| | Project Manager | 2, 4, 4 | 4 | 8, 16, 16 |
| | | | - | |
| 5.3 Development of a prioritized list of requirements | Bisiner Ambassador | 4, 4, 5 | 5 | 20, 20, 25 |
| | Project Manager | 4, 4, 5 | 4 | 16, 16, 20 |
| 6.1 Creating a business case | Bisiner Ambassador | 4, 6, 6 | 5 | 20, 30, 30 |
| | Project Manager | 2, 4, 4 | 4 | 8, 16, 16 |
| 7.2. Project review report | Bisiner Ambassador | 1,2, 3 | 5 | 5, 10, 15 |
| | Project Manager | 1,2, 3 | 6 | 6, 12, 18 |
| | Lead engineer | 1,2, 3 | 7 | 7, 14, 21 |
| | Technical Manager | 1,2, 3 | 4 | 4, 8, 12 |
| | Design Manager | 1,2, 3 | 5 | 5, 10, 15 |
| | Designer | 1,2, 3 | 2 | 2, 5, 6 |
| 8.2 Проведення щоденних стендапів | Bisiner Ambassador | 7, 8, 9 | 6 | 42,48, 54 |
| | Project Manager | 7, 8, 9 | 7 | 49, 56, 63 |
| | Lead engineer | 7, 8, 9 | 4 | 28, 32, 36 |
| | Technical Manager | 7, 8, 9 | 5 | 35, 40, 45 |
| | Design Manager | 7, 8, 9 | 2 | 14, 16, 18 |
| 95 Preparation of basic business regulations | Bisiner Ambassador | 3, 4, 5 | 5 | 10, 20, 25 |
| | Project Manager | 1, 2, 2 | 4 | 4, 8, 4 |
| *Total according to the methodology* | | *101.5, 135, 172* | | *510,687,877* |

Risks associated with the application of the methodology, as well as their assessments, are presented in Table 3.17.

Table 3.17. Assessment of the risks associated with the use of the second methodology

| Risk | The probability of occurrence, M | Consequences of manifestation, K, score | Risk assessment, R = M*K, score |
|---|---|---|---|
| Conflicts between team standards and rules and methodology | 0.1, 0.15, 0.2 | 4, 6, 8 | 0.4, 0.9, 1.6 |
| The project team's ability to self-organize and self-coordinate is insufficient for effective implementation | 0.1, 0.2, 0.25 | 7, 8, 8 | 0.7, 1.6, 2 |
| Team members do not understand / do not accept the roles and responsibilities assigned to them by the methodology | 0.35, 0.4, 0.45 | 7, 8, 8 | 2.45, 3.2, 3.6 |
| Lack of work experience of the customer / representative of the customer as a Business Ambassador | 0.1, 0.5, 0.2 | 5, 5, 6 | 0,5, 1, 1.2 |
| Project participants do not accept values and principles | 0.2, 0.4, 0.45 | 7, 8, 8 | 1.4, 3.2, 3.6 |
| Problems with assigning multiple roles to one team member | 0.5, 0.5, 0.6 | 5, 6, 6 | 2.5, 3, 3.6 |
| The involvement of the Business Ambassador in the project is not enough for the optimal development of the solution | 0.15, 0.2, 0.2 | 7, 8, 8 | 1.05, 1.6, 1.6 |
| Final risk assessment | | | 9,14.5,16.84 |

A comparative chart of labor intensity, cost of project management for alternative methodologies, and associated project risks is shown in fig. 3.13.

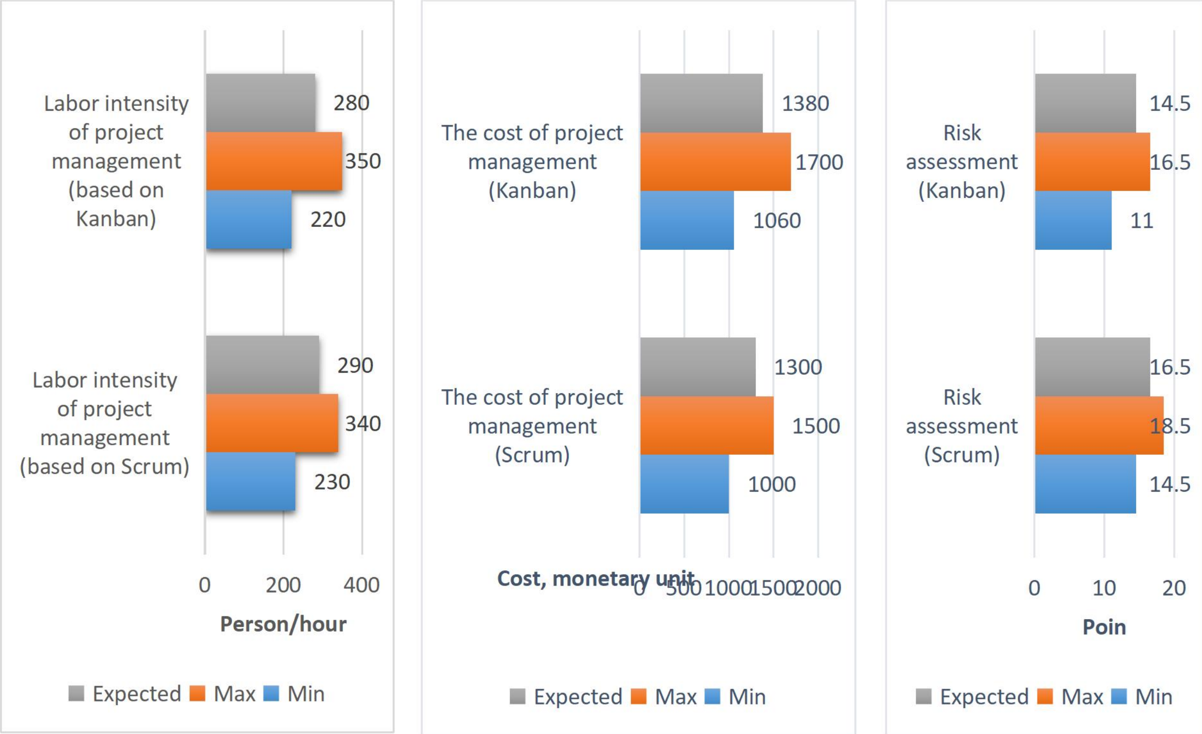



Fig. 3.13. Comparison of project management effort, project management cost, and risks associated with the use of established methodologies (in the format of fuzzy triangular numbers).

The next step is to choose the methodology most suitable for the project, based on a mathematical model. The objective functions have the form:

$$K(X) =< 745,976,1182.5 > x_1 +< \ 510,687,877> x_{2\,\to min} \quad (3.26)$$

$$T(X) =< 114,145,200\ x_1 +< \ \ 101.5, 135, 172\ x_{2\,\to min} \quad (3.27)$$

$$R(X) =< 14.75,16.75,19 > x_1 +< \ 9,14.5,16.84 > x_{2\,\to min} \quad (3.28)$$

Where $X = (x_1, x_2), x_h = \{0,1\}, N = 1,2\ \ \sum_{n=1}^{N} x_n = 1,\ \ x_n = 1$ if applicable n alternate, otherwise $x_n = 0$. The cost of project management should not exceed 1.5 thousand monetary units. That is, the cost limit is $K^{per} = 1500$.:

$$K(1,0) = 745,976,1182.5 < 1500 \quad (3.29)$$

$$K(1,0) = 745,976,1182.5 < 1500 \quad (3.30)$$

All alternatives meet the set limit. To normalize the objective functions for the purpose of their further comparison, it is necessary to solve the problem of single-criterion optimization of each objective function. First of all, it is necessary to carry out the defuzzification procedure to get rid of fuzziness:

$$K^d(1{,}0) = \frac{745+976+1182.5}{3} = 967.8 \quad (3.31)$$

$$K^d(1{,}0) = \frac{510+687+877}{3} = 691.3 \quad (3.32)$$

$$T^d(1{,}0) = \frac{114+145+200}{3} = 153 \quad (3.33)$$

$$T^d(1{,}0) = \frac{101.5+ 135+ 172}{3} = 136.1 \quad (3.34)$$

$$R^d(1{,}0) = \frac{14.75+16.75+19}{3} = 16.8 \quad (3.35)$$

$$R^d(1{,}0) = \frac{9+14.5+16.84}{3} = 13.44 \quad (3.36)$$

$K^d(X), T^d(X), R^d(X)$ - defuzzified values of project management cost, project management effort and risks associated with the application of methodologies, respectively. A comparison of the characteristics of the formed methodologies after getting rid of ambiguity is illustrated in Fig. 3.14.

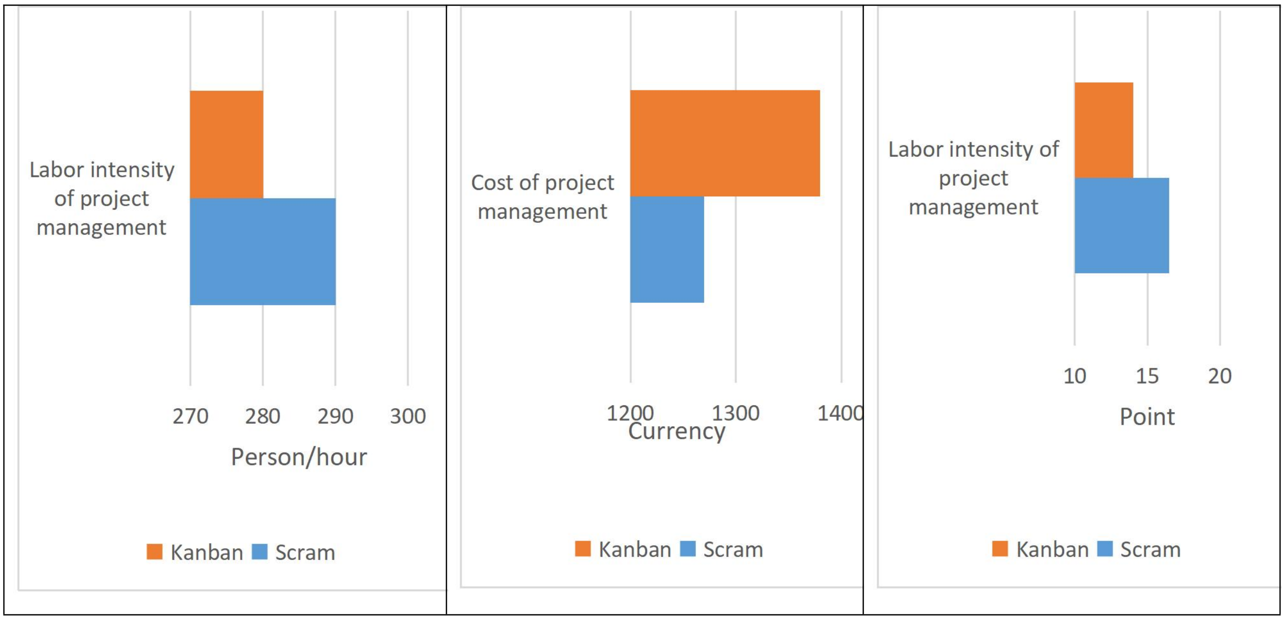



Fig. 3.14. Comparison of labor intensity, cost, risks of project management under the condition of application of established methodologies (in a clear form)

Let's determine the minimum values of the objective functions:

$$K^{opt} = \min\{967.8, 691.3\} = 967.8 \quad (3.37)$$

$$T^{opt} = \min\{153, 136.1\} = 136.1 \quad (3.38)$$

$$R^{opt} = \min\{16.8, 13.44\} = 13.44 \quad (3.39)$$

Based on the obtained results, we will calculate the normalized values:

$$K^{norm}(1{,}0) = \frac{K^d(1{,}0)-K^{opt}}{K^{opt}} = 0 \quad (3.40)$$

$$K^{norm}(1,0) = \frac{K^{d}(1,0)-K^{opt}}{K^{opt}} = 0.399 \quad (3.41)$$

$$T^{norm}(1,0) = \frac{T^{d}(1,0)-T^{opt}}{T^{opt}} = 0.124 \quad (3.42)$$

$$T^{norm}(1,0) = \frac{T^{d}(1,0)-T^{opt}}{T^{opt}} = 0 \quad (3.43)$$

$$R^{norm}(1,0) = \frac{R^{d}(1,0)-R^{opt}}{R^{opt}} = 0{,}25 \quad (3.44)$$

$$R^{norm}(1,0) = \frac{R^{d}(1,0)-R^{opt}}{R^{opt}} = 0 \quad (3.45)$$

According to the minimax criterion:

$$X^{opt} = \arg min = \begin{Bmatrix} max\{K^{norm}(1,0), T^{norm}(1,0), R^{norm}(1,0)\} \\ max\{K^{norm}(1,0), T^{norm}(1,0), R^{norm}(1,0)\} \end{Bmatrix} =$$

$$\begin{Bmatrix} max\{0,0.124,0.25\} \\ max\{0.399,0,0\} \end{Bmatrix} = argmin\{0.124,0.399\} = (0,1) \quad (3.46)$$

Thus, the second methodology, which is a combination of the components of the Kanban and Scrum approaches, is the most suitable for the conditions of the project in the minimax sense. In the case of its application, the cost of project management will be (510, 687, 877) monetary units, the labor intensity of management (101.5, 135, 172 ) - man-hours, the assessment of risks associated with the application of this methodology - (9,14.5,16.84 ). This combination of methodologies turns out to be better, and their application allows to improve such characteristics of project management as the complexity of project management and the risk associated with the application of the approach, without going beyond the limits of the cost of project management. Therefore, the implementation of this hybrid of methodologies increases the level at which the set of project management characteristics meets the requirements and, accordingly, increases its quality.

### 3.4. Informational component of project product quality assurance

For the practical implementation of international projects, a component platform that manages projects within the framework of the Scrum technological system is developed in this work. Therefore, it is important not only to systematically and logically determine the architectural and technological aspects of the quality of project implementation, but also to create specific recommendations for measures to improve quality in the current conditions of the technological processes of the project. The method of creating recommendations for ensuring product quality is aimed at ensuring the specified efficiency, by creating a software component in the project management platform, which in its essence is the correct localization of the method of structuring quality functions (SFC-method or, in the English abbreviation: Quality Function Deployment: QFD-method) for the purpose of implementing a project on the development of gas cleaning equipment within the Scrum technological system.

The specificity of the application of the QFD method as a component of the project management platform affects the objective orientation of the project (the management of which is carried out on the basis of the platform) on the requirements and requests of potential and real customers, dictates the need for constant and continuous integration of the technical capabilities of the multi-component platform being created with the needs that are determined by specialists in the subject field of application of projects, and in our case - projects on the creation of gas cleaning equipment. It is not trivial to use the tools of the QFD-method, the corresponding SFC-methods as a component of the project management platform, and above all within the framework of the SCRUM technological system. The high iterativeness and partial empirical approach to the design and development of project management capabilities within the specified technological system imposes a number of specific features on the application of the QFD method within the Scrum technological system.

Deployment or structuring of project quality functions using the component toolkit of the project management platform is necessary for logically linking the technical and functional capabilities of the implemented project with the expected needs that this project is designed to satisfy. Thus, the structuring of project quality functions, through the development of the Component Toolkit as part of the project management platform, is a process of consistent and entirely determined identification of technical solutions, characteristics, properties and functions of the implemented project, through consistent systematization, specification, localization of the customer's needs and wishes. This process should, in the end, ensure such a quality of project execution that all the significant needs and expectations of the potential consumer will be guaranteed to be satisfied. Detailed principles and main approaches to the practical application of the QFD method are widely described in scientific and practical literature, for example. The basic toolkit of the QFD-method is a multi-tabular diagram called the "house of quality". The central element of the specified tabular diagram is the matrix of connections between the needs, requirements of the potential user and the technical characteristics of the project product. Another important component of the diagram is the correlation matrix, as well as arrays of formalized information, which is separately fixed according to the requirements of potential operators, labor intensity, alternative solutions, etc.

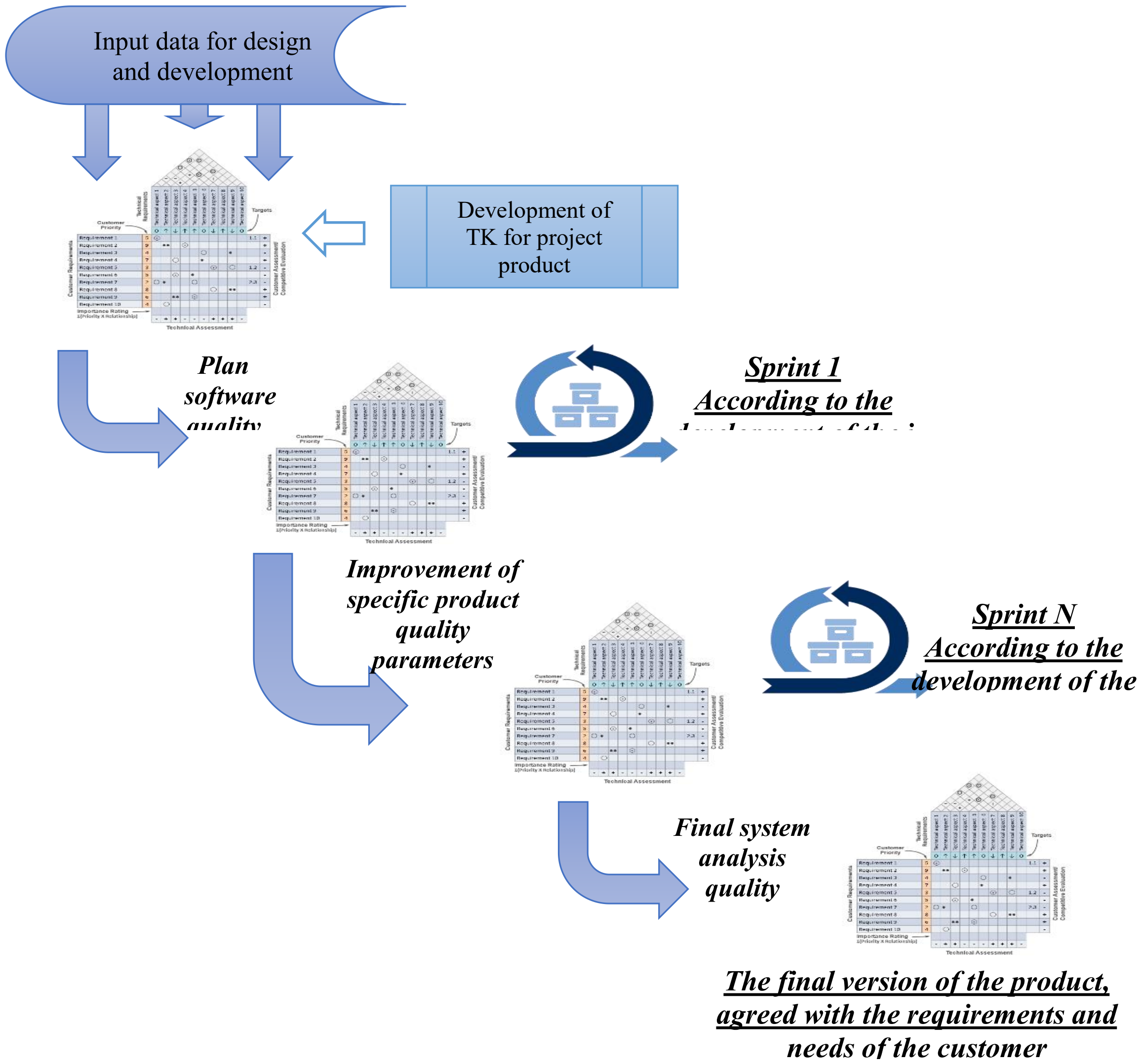



Fig. 3.15.. Stages of application of the multi-table diagram of the QFD method based on the project management component platform

The empirical nature of determining priorities for improving the quality of project implementation within the framework of the Scrum technological system requires the construction of a multi-table diagram of the QFD method at each project implementation sprint. Taking into account the difficulty of forecasting and, as a rule, a large number of sprints N of the development of each project, based on the platform, the practical application of the QFD method within the Scrum technological system in order to develop specific recommendations becomes "heavyweight", time-consuming and ineffective, and in general, has low manufacturability of practical application. (In this case, the manufacturability of the application means the ease of use of the platform component, which enables multiple and simple reproducibility for the needs of development, management and implementation of various projects). This objectively requires the development of highly specialized scientific and methodological tools for the development of recommendations for ensuring the quality of project management, as components of a project management platform based on the QFD method, which takes into account the specifics of the creation of the specified complexes, that is, takes into account the high level of iterative development of their applied functionality. It is the development and localization of the QFD method to the subject area of the project, taking into account the specifics of the development of its main applied functionality within the framework of the Scrum technological system.

Such a scientific and methodological toolkit, which develops qualitative methods for a flexible development methodology, can be used in the future as a methodological basis for the specific methods of systems engineers, quality control specialists in the implementation of projects for the development of gas cleaning equipment. The QFD method has been widely used in the creation of software in various technological development paradigms, but this does not apply to other projects, primarily projects for the development of gas cleaning equipment. The high iterative nature of the technological project management system is not compatible with the high complexity of obtaining a basic multi-table diagram and the methodological complexity of the multi-stage nature of the application of such a diagram, the QFD-method full multi-table diagram. An example of such filling is shown in fig. 3.16.

Due to the large number of project implementation sprints based on the project management platform within the framework of the SCRUM technological system, the total labor intensity of work on the deployment of quality functions, in order to develop recommendations for quality assurance of separate components, becomes comparable to the labor intensity of work on the very development of the software code of the specified components. Thus, the direct application of the QFD method within the framework of the SCRUM technological system to develop recommendations for ensuring the quality of project implementation, in the form of a separate component of the project management platform, is not rational and effective. The algorithm for forming a basic multi-table diagram is "heavyweight" for highly iterative Scrum technology in relation to projects not aimed at software development. This fact indicates the need to modernize (modify) the algorithm for forming the basic multi-table diagram and the general algorithm for applying the QFD method within the framework of the Scrum technological system to solve the private task of developing specific recommendations to ensure the quality of project implementation.

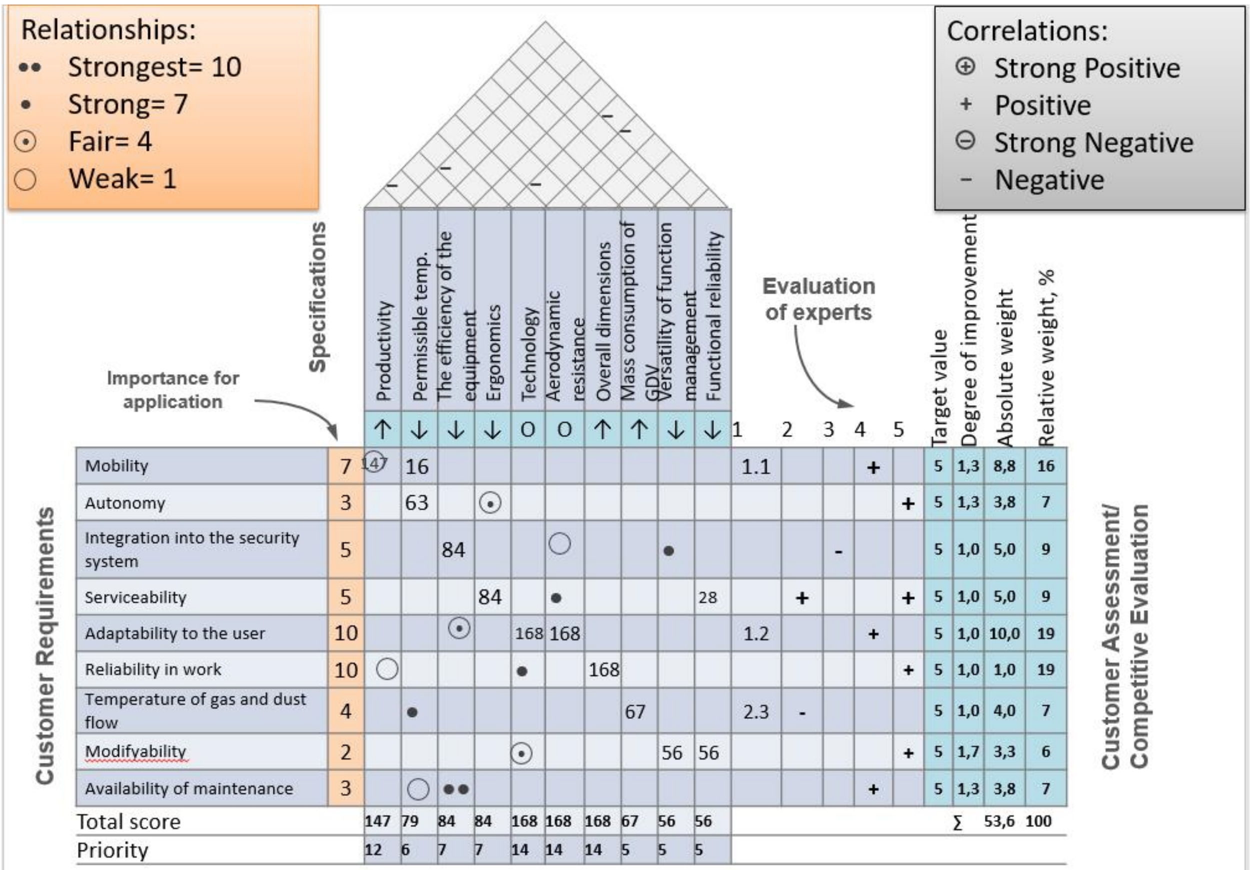



Fig. 3.16. An example of filling in estimated data of a complete multi-table diagram of the QFD method during project implementation (on the example of project management for the development of gas purification equipment)

The purpose of such modernization is to reduce the overall "clumsiness and heavy weight" of the QFD analysis procedures when revealing and detailing the quality requirements for specific technical characteristics of the project by developing specific recommendations. The specified modernization within the framework of the proposed method of developing recommendations for ensuring the quality of project implementation is based on the application of a stratified presentation to the process of structuring and detailing the quality functions of the specified complexes. At the same time, the entire original set of quality functions *F* is considered as a set:

$$F= \langle K, L \rangle \qquad (3.47)$$

where *K* is a subset of all the main applied functions of the implemented project, which are established by examination or within the framework of the relevant technical specifications;

*L* is a subset of logical relations of arrangement (strict order) between the main applied functions of the project.

Analytically describing the set in (3.48), we see that it is the original set of quality functions that is detailed to the final set of all technical characteristics of the project, i.e., it is this set that sets the boundary conditions for the stratification of quality functions:

$$F = X \qquad (3.48)$$

Therefore, the whole set of quality functions, detailing their sub-functions and private characteristics identified in F should, in the end, be reflected in the set of controlled technical characteristics of the implemented project. In this way, the subset of all the basic applied functions of the project includes the strata-description of the corresponding subfunctions, specified properties $\{k_i\}$. In particular, individual quality functions with F can be explained by some detailed data

$$k_i \in \{k_i\} \qquad (3.49)$$

At the same time, $s_i$ correspond to the tasks of more private technical characteristics of the implemented project or its individual components. The final private subfunctions from the set of functions F are indivisible functions, that is, further unstructured subfunctions, specified properties $\{k_i\}$. Therefore, the original set of quality functions can be considered as a multi-level stratified family of structured sets of specific technical characteristics of the project, as well as methods and means of achieving the necessary parameters of the specified technical characteristics. In order to fully implement such consideration, the original set of quality functions F is presented in a stratified form. Analytically, this statement means the possibility of expressing expression (3.47) in the form of a stratified multiple equation:

$$F = \langle \{ki(m_1, m_2, \ldots m_n)\}, L\rangle \quad (3.50)$$

where $\{ki(m_1, m_2, \ldots m_n)\}$ - a subset of the basic applied functions of the project stratified to the technical characteristics;

$n$ - the maximum number of expected strata-technical characteristics;

$L$ is a set of systematized logical ordering relationships (strict order) between the main technical characteristics for the applied functions of the project, as well as methods and means of achieving the necessary parameters of the specified technical characteristics. On the basis of ratios (3.48) and (3.49) for the final set of all technical characteristics of the X project in a stratified presentation, a fair ratio

$$X = \langle \{k_i(g_1, g_2, \ldots g_n)\}, H\rangle \quad (3.51)$$

Thus, the composition of stratified functions and their associated strata-technical characteristics of the main applied functions of the created project $\{k_i\}$, and, accordingly, recommendations for ensuring the quality of separate components of such projects, in the developed method is substantiated by establishing a complete list of methods and means of implementing all quality functions from the set F. Then the development of current recommendations for quality assurance is the choice of $\{k_i\}$ the most effective methods and means of achieving the required quality of the current project sample. The modernization of the algorithm for the application of the QFD method within the framework of the Scrum technological system during the implementation of the project to solve the private task of developing specific recommendations for ensuring the quality of the separated components of the specified complexes is reduced to a bimatrix representation of the multi-table diagram of the developed qualitative method. This means that the multi-table diagram of the QFD method during project implementation is developed only initially, at the first stage of project evaluation, or its important functional component. Further, on its basis, a simplified version of the multi-table QFD-diagram is created, in the framework of which the value of the measure of the intensity of the relationship between user requirements and the technical characteristics of the project is placed in the matrix of connections, but the reference to the corresponding auxiliary connections between the means and methods of improving the corresponding technical characteristics. An example of this version of a multi-table QFD diagram is shown in Fig. 3.17, and an example of one of the auxiliary matrices associated with it is shown in Fig. 3.18.

The proposed multi-table QFD-diagram system is formed in a separate component of the project management platform during the institutional improvement of the Scrum technological system. It is obvious that each new project based on the project management platform inherits certain technical and technological solutions from its predecessors, which constitute the technological style of this or that project. As a rule, innovative solutions in the development of new projects make up 30-40% of the total number of applied solutions. Due to this fact, at the start of a new project, the initial formation of a complete QFD-diagram is carried out, and then for various functionally independent constituent parts, components, a system of multi-table simplified QFD-diagram with the corresponding clarifications is formed.

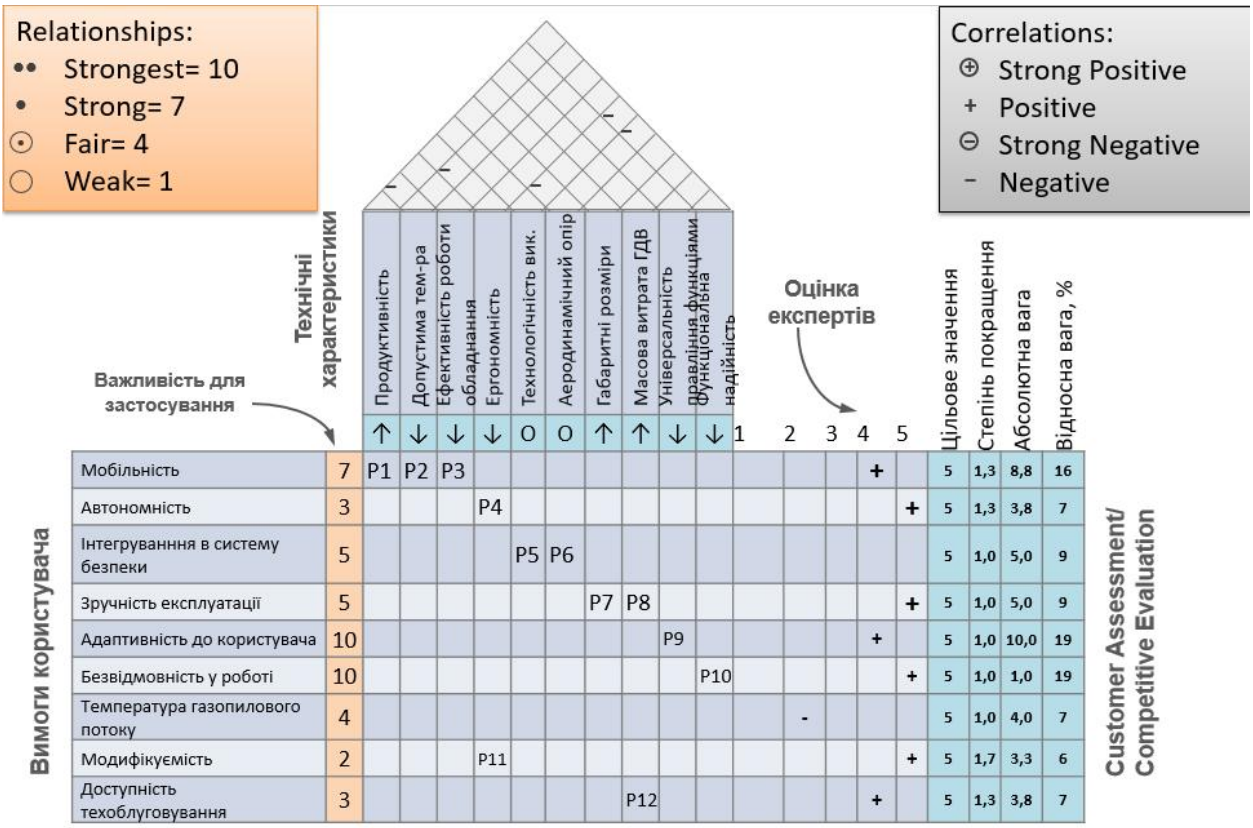



Fig. 3.17. An example of a modified diagram of the QFD method

The simulation model was developed in the AnyLogic graphical modeling environment in the IDEF-Integration Definition for Function Modeling notation. A method of evaluating and identifying the effect of competing options in the modeling process, a detailed criterion of effectiveness.

| | |
|---|---|
| Economy | Cost-effectiveness of project processes, controlled by the project management platform component. Minimizing the probability of inexpediency of labor costs of the current project sprint (the risk of inefficient labor costs during project implementation) |
| Profitability | Practical effectiveness of technology and project implementation. A reduction in the average number of development sprints required for the full implementation of processes embodying one private application function (application task). |
| Productivity | The number of actions (operations) to eliminate errors during the creation and debugging of the project product per unit of time. An increase in the average statistical number of detected and eliminated errors during docking and debugging of project components (per unit of time). |
| Reality | Prevention of malfunctions/failures in the functionality of components when the complexity of the tasks being solved increases. Decreasing the probability of an error occurring with an increase in the percentage of completion of the project project. |
| Conditions of employment | Correctness of architecture; The general usefulness of the derived complex indicators is assessed qualitatively at the level of expert opinions. |
| Innovation | Innovative nature; systematic construction. |

Fig. 3.18. Evaluation parameters and detection of the effect of competing options in the modeling process

The resulting complex indicators are evaluated qualitatively at the level of expert opinions of the Scrum system according to the IDEF notation shown in Fig. 3.19.

The success or failure of each stage of the technological process of project implementation is simulated using the Monte Carlo method (that is, each elementary draw is carried out according to this method using random number generation), and the final results of the statistical accumulation of simulation results are processed using the MathCAD package.

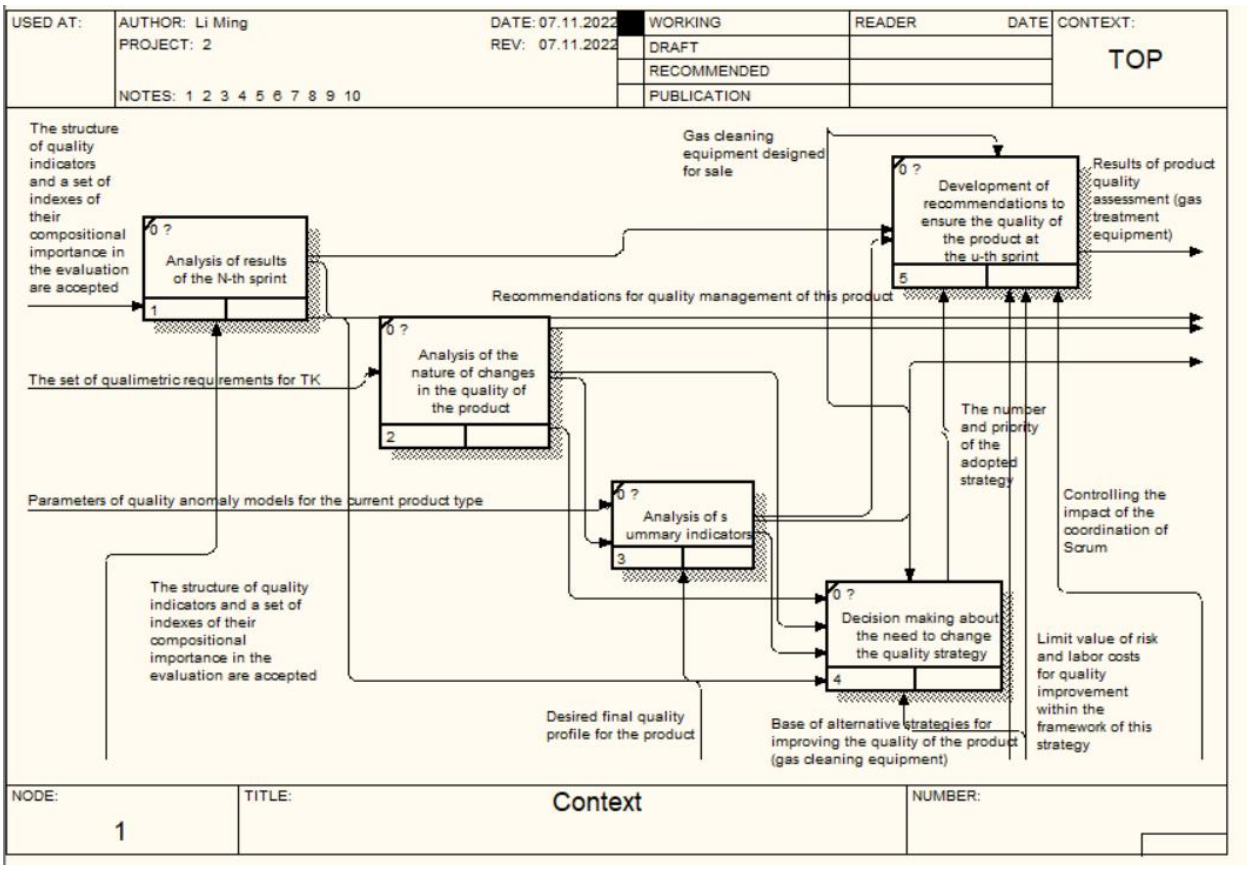



Fig. 3.19. The structure of the simulation model of quality management in the Scrum technological system for the project

On the basis of the specified simulation model of quality management in the SCRUM technological system of project management based on the project management platform, a statistical and computational experiment was carried out, which made it possible to quantitatively assess the effect of the developed methods and methodological tools. The statistical-algebraic essence of the computational experiment consists in carrying out for each of the competing options consecutive acts (at least 10) with the number of 290 trials from 1000 to 10,000 draws of the type: "successful performance of the function/unsuccessful performance of the function" on each element of the structure of the simulation model. As a result of the statistical simulation experiment, the following private tasks were solved:

1. Simulation-statistical modeling of the previously cited competing options based on the simulation model of quality management in the Scrum technological

system of project management based on the project management platform was implemented;

2. A consistent comparison of the relevant performance indicators of the given competing options was made regarding the changing quality assurance capabilities in the technological system of flexible development of software complexes based on the project management platform;

3. The assessment and essential interpretation of the revealed effect from the application of the developed methods and methodological tools is summarized. This made it possible to present summarized conclusions based on the results of the conducted performance assessment. Thus, the evaluation of the effectiveness of the developed methods and methodological means of improving the quality of project implementation was carried out quantitatively using a qualitative interpretation of the effect registered during simulation modeling, according to predetermined indicators of the effectiveness of the technological system of project implementation based on the project management platform.

## Conclusions for the chapter 3

In the third chapter of the dissertation, a mathematical model and a method for choosing an approach to project management based on vague ideas about the applicability of existing standards, guidelines, and project management methodologies are proposed. The developed model and method allow you to choose the best approach to project management for a specific project from such popular approaches as the PMVOK management, Scrum methodologies, and Kanban. A number of parameters of the project and its environment, which affect the choice of the approach, have been determined. It includes: the number of people involved in the project, the customer's experience with this project team, the experience of the project team in this field, and others. For each given parameter, its weight is determined when choosing an approach to project management. The above method is illustrated by an example of its application for choosing an approach to managing a software development project.

A method of choosing and forming an approach to project management is proposed. The method is based on the application of the Cynefin model and the method of fuzzy representations for choosing an approach to project management. The advantage of this method is a comprehensive approach to solving selection problems and forming an approach to project management. At the first stage of the method, the task of choosing the basis for the formation of the approach - one of the existing project management methodologies - is solved. The second stage involves the formation of alternative approaches to project management by modifying the basic approach. To choose the best alternative, it is suggested to use the criteria of labor intensity, cost and risks. The method is applied to the project dedicated to the development of gas cleaning equipment. Scrum was determined as the main project management methodology as a result of the project evaluation according to a special questionnaire. Two alternative methodologies were formed and evaluated by the expert: 1) based on Scrum; 2) based on Kanban+Scram. Both methodologies are flexible. The second alternative turned out to be better according to two criteria: the complexity of project management and the risk associated with its application. Risk played a decisive role in solving the optimization problem. The pre-project stage is of great importance for the project in question, and the comprehensive documentation created at this stage has become the main advantage of Kanban compared to Scrum. The Kanban+Scram methodology was used to manage the project for the development of gas cleaning equipment, which made it possible to improve the quality of the management of this project.

In the practical implementation of projects based on the project management platform within the framework of the Scrum technological system, it is important not only to systematically and logically determine the architectural and technological aspects of the quality of project implementation, but also to effectively develop specific recommendations for quality improvement measures in the current conditions of the technological process. The method of developing recommendations for ensuring the quality of project components through the use of a project management platform, which in its essence is the correct localization of the quality function structuring method (QFD method) to the subject branch of projects aimed at the development of gas cleaning equipment within the framework of technological Scrum systems.

The direct application of the QFD method within the framework of the Scrum technological system to develop recommendations for ensuring the quality of project implementation based on the project management platform is not rational and effective. The algorithm for forming a basic multi-table diagram is "heavyweight" for the highly iterative scrum technology of software development. This fact indicates the need to modernize (modify) the algorithm for forming a basic multi-table diagram and the general algorithm for applying the QFD method within the framework of the Scrum technological system when implementing a project based on a project management platform to solve the private task of developing specific recommendations to ensure the quality of project implementation aimed at development gas cleaning equipment.

Modernization of the algorithm for the application of the QFD method within the framework of the scrum technological system when implementing a project based on a project management platform to solve the private task of developing specific recommendations for ensuring the quality of the separated components of the specified complexes is reduced to a bimatrix representation of a multi-table diagram of the analyzed qualitative method. At the same time, the multi-table diagram of the QFD method for project management is developed only initially, at the first stage of creating the project itself, or its important functional component.

# CHAPTER 4.
# DEVELOPMENT OF THE INFORMATION PLATFORM FOR THE SELECTION AND STRUCTURING OF THE PROJECT MANAGEMENT APPROACH

## 4.1. General characteristics and architecture of the information platform for choosing and structuring the approach to project management

The multi-component information platform for choosing and structuring an approach to project management, proposed in the work, allows you to form an approach to managing a certain project taking into account the specifics of this project and its environment. When solving this problem, great attention is paid to the principles and philosophy of Agile, which aggregates the components of the most common agile methodologies and project management approaches. One of the main limitations of the integration of components in the platform is the complexity of computational operations. In addition, the expansion of the composition of the platform components by mathematical methods, which are non-trivial for project management, complicates interaction with its content. These limitations can be overcome by automating methods of selection and structuring of the approach to project management, as well as storage and interaction with project databases. In order to overcome these limitations, an information platform for selecting and structuring an approach to project management has been developed, which implements the models and methods proposed in Section 3 and provides interaction with the project database.

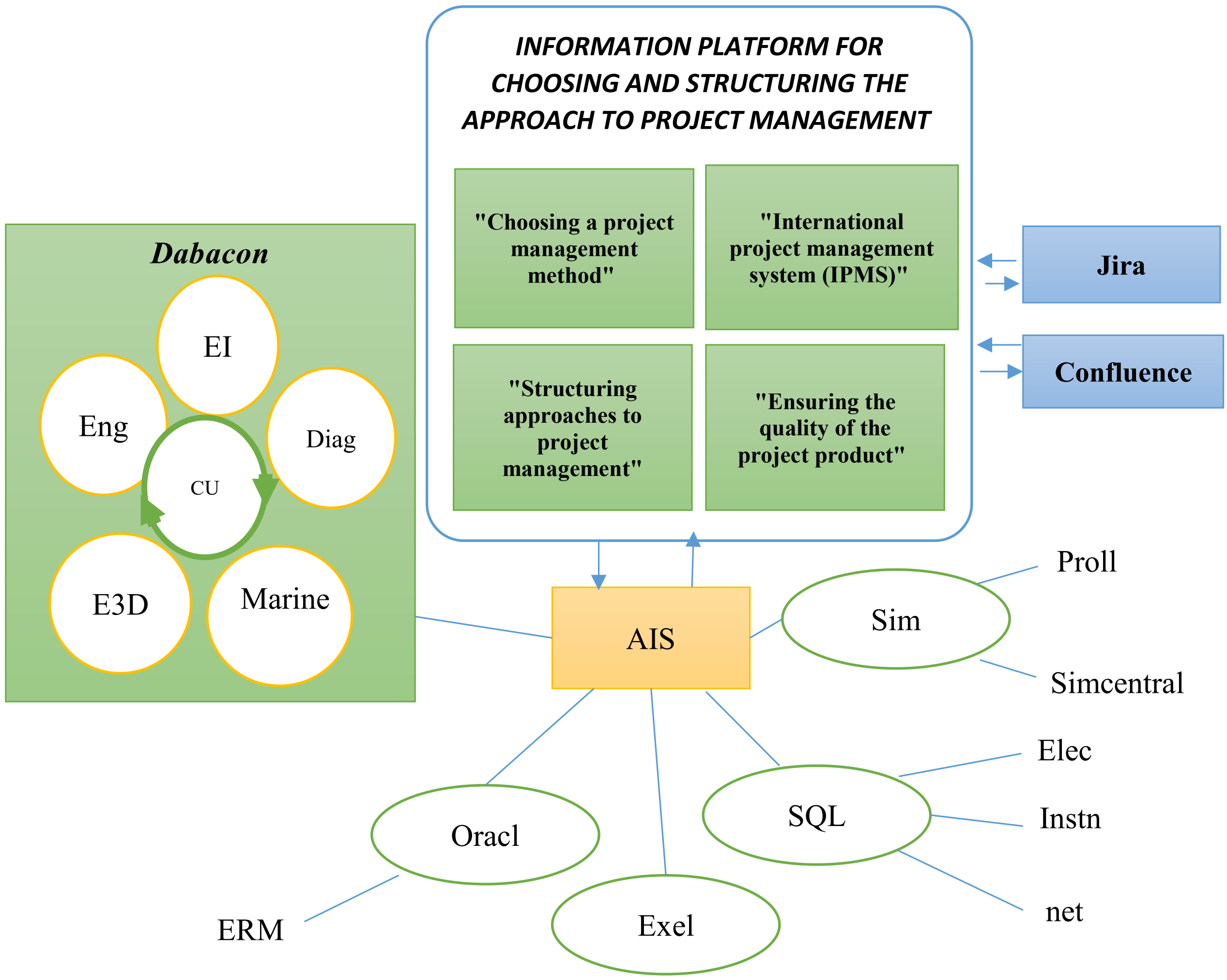



Fig. 4.1. The architecture of a multi-component information platform for choosing and structuring an approach to project management

A graphic description of the business processes automated by the information platform for choosing and structuring the approach to project management is presented in Figures 4.2-4.6

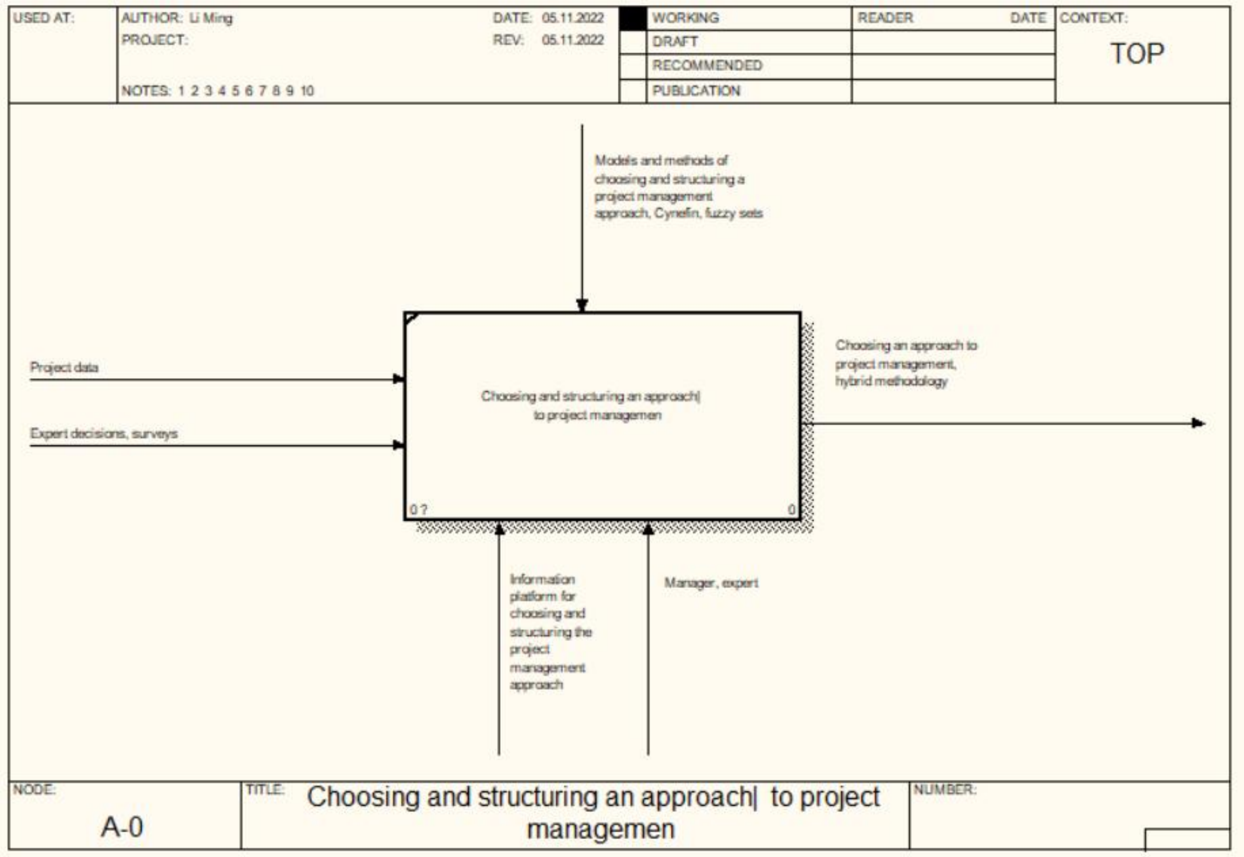



Fig. 4.2. An information platform for choosing and structuring an approach to project management.

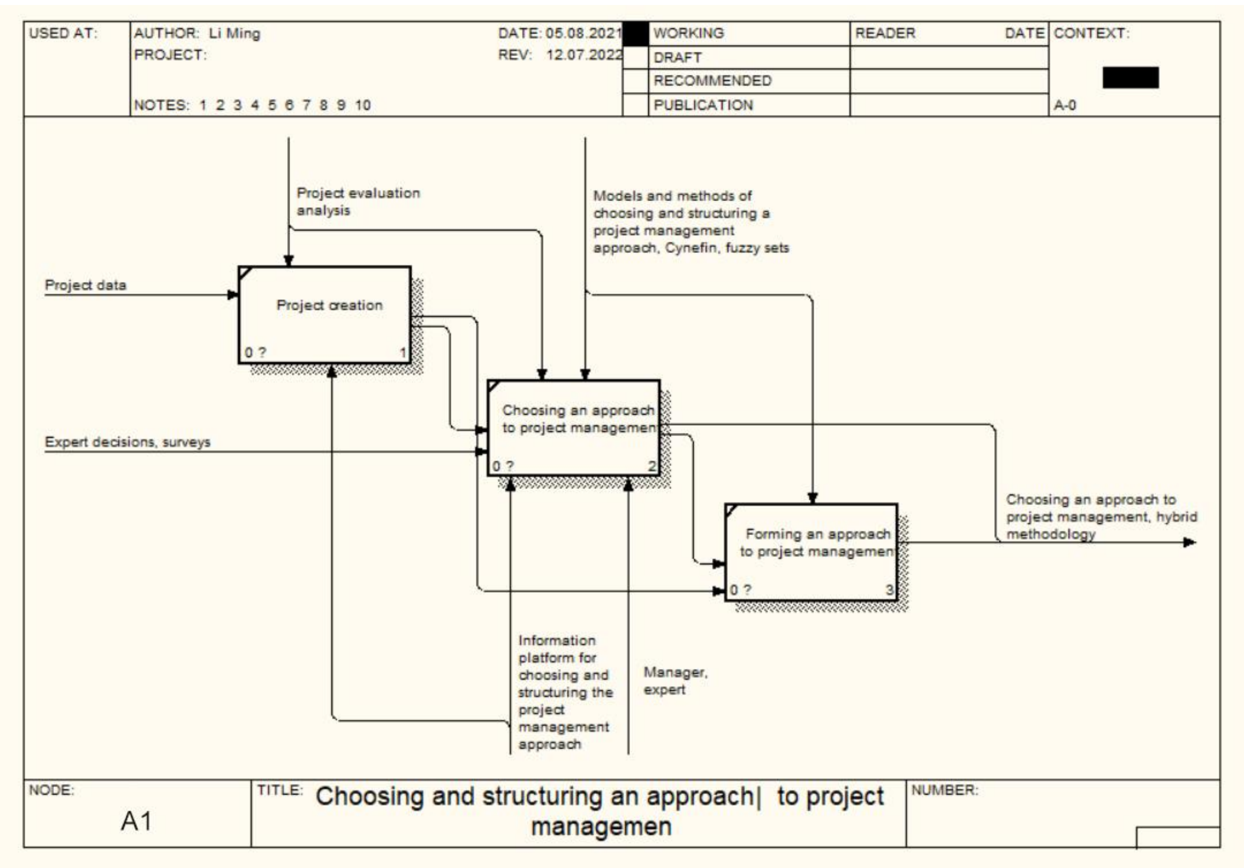


Fig. 4.3. Decomposition of the business process "Choosing and structuring an approach to project management"

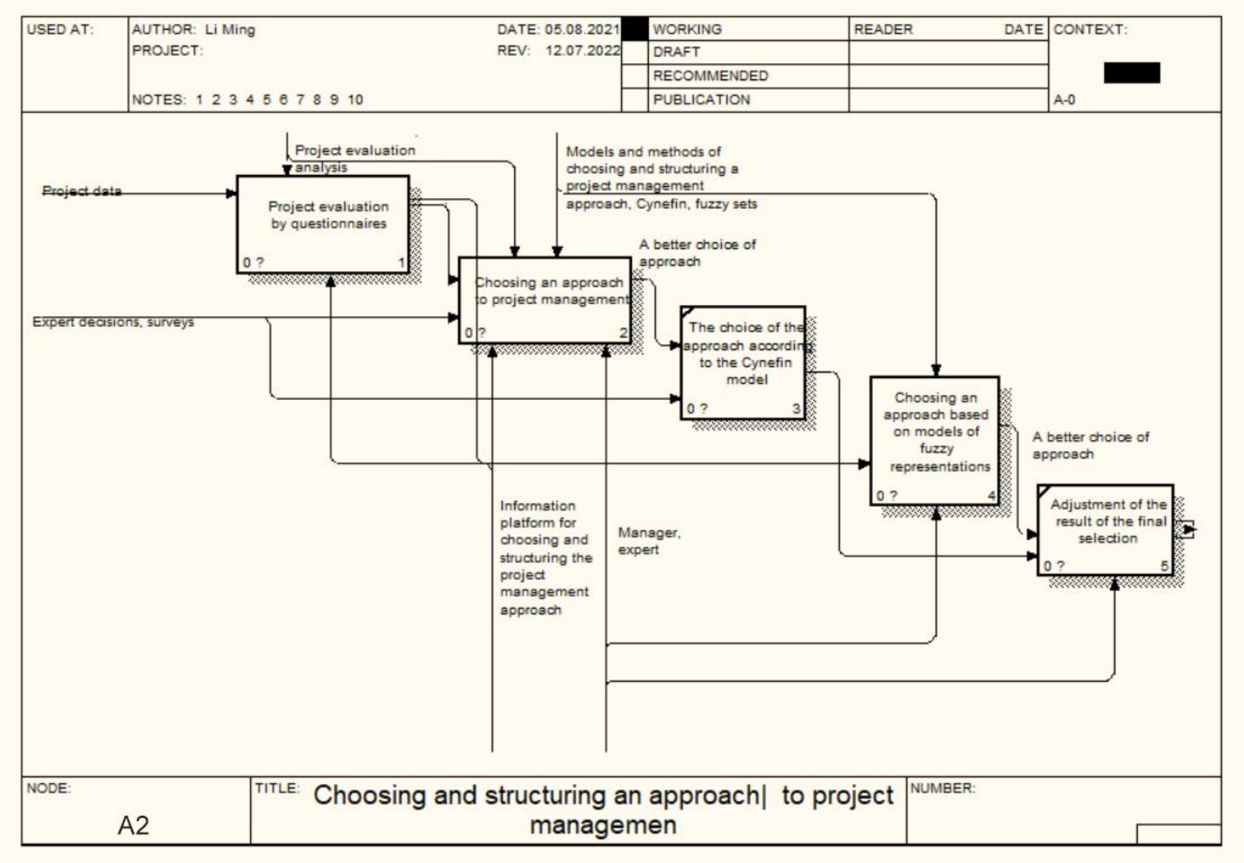



Fig. 4.4. Decomposition of the business process "Choosing an approach to project management" (IDEF0)

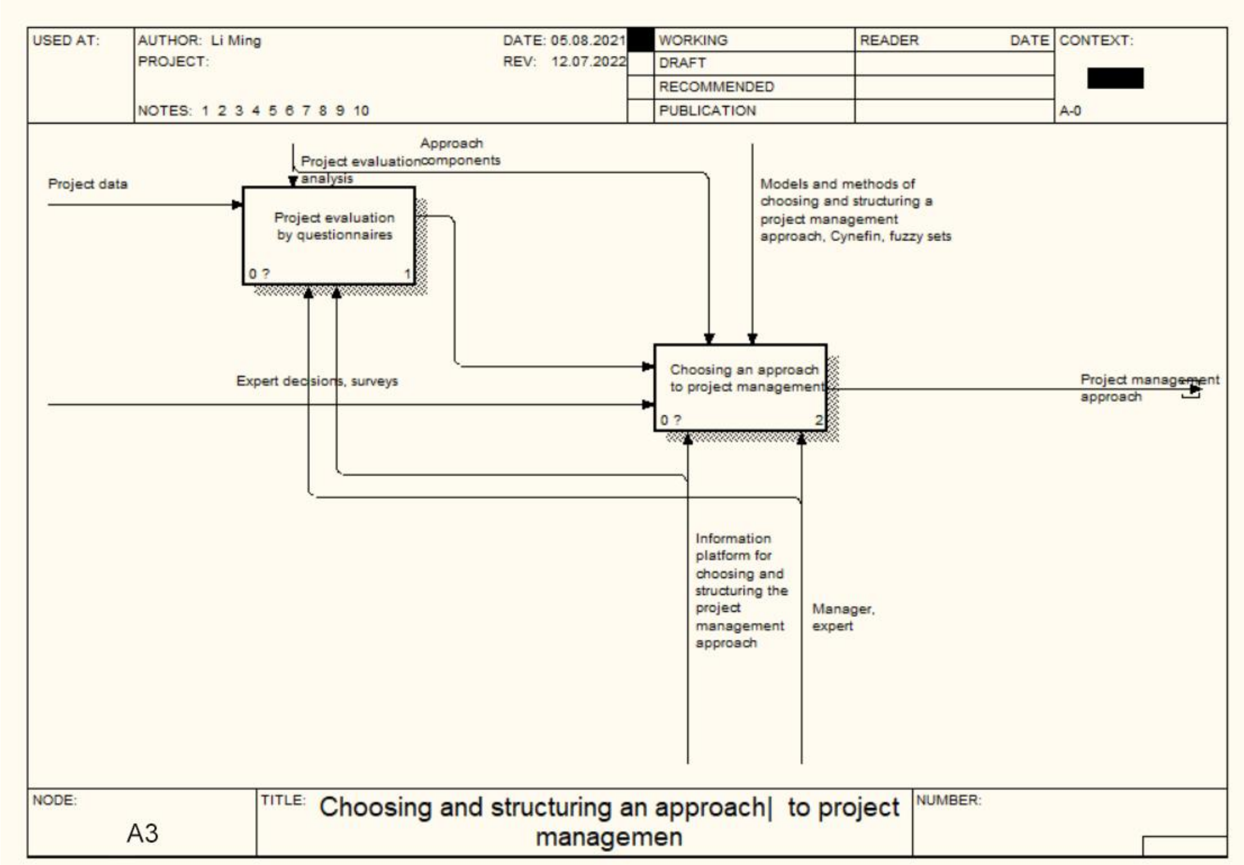



Fig. 4.5. Decomposition of the business process "Structuring the project management approach" (IDEF0)

The information platform for choosing and structuring an approach to project management was designed and implemented as a web application "IPPM - international platform for project management", (in the language of the Russian Federation) using the standardized markup language for web pages on the Internet HTML5, the language of structured queries SQL and a special language used to describe the appearance of pages, CSS.

The following software tools were used for software development: - Windows OpenServer-5.2.8 local web server; - Visual Studio Code integrated source code editor; - MySQ database management system.

The information platform assumes a client-server architecture. The diagram of options for the use of the system, which reflects the high-level requirements for the information system as a whole, is shown in Fig. 4.6. Thus, in order to start working with the system, it is necessary to go through the procedure of registration

(Fig. 4.7) and authorization (Fig. 4.8) in the system. "Choosing a project management method", "Assuring the quality of the project product" are implemented using the corresponding subsystems, access to which is provided by the main page of the web application (Fig. 4.9).

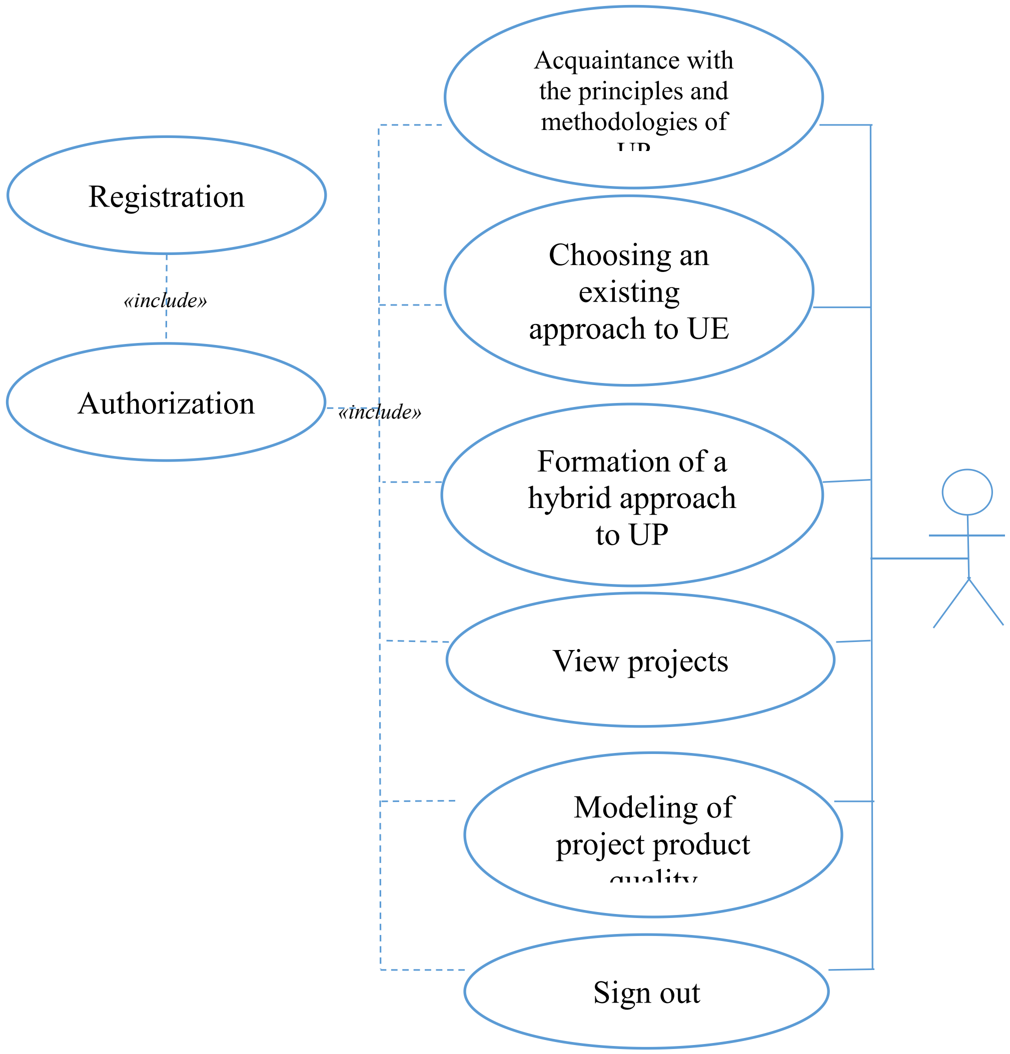



Fig. 4.6. Diagram of options for using a web application for choosing and structuring an approach to project management

After loading the application, we first get to the user authorization window (see Fig. 4.7):

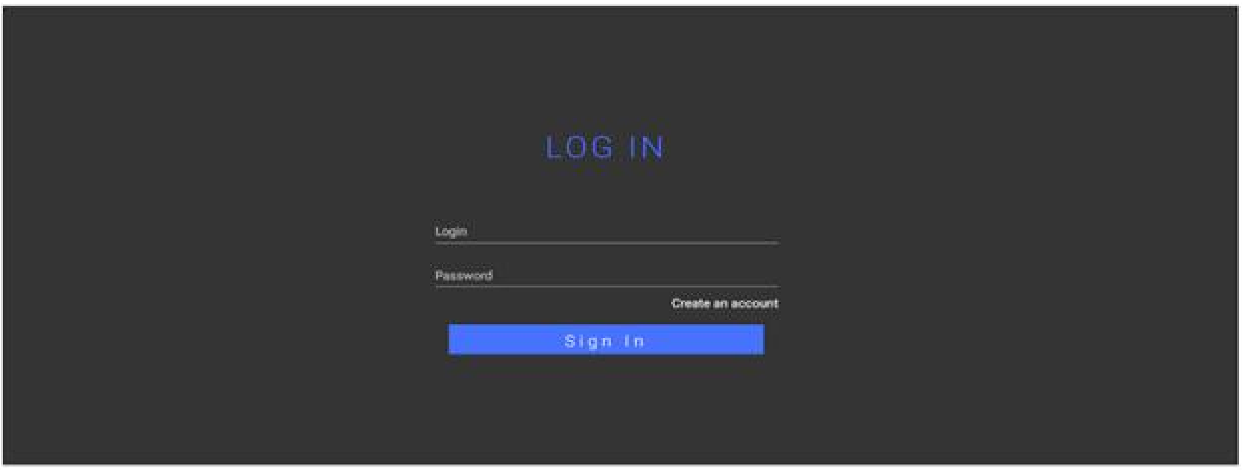



Fig. 4.7. Login page to the "Information platform for choosing and structuring the approach to project management"

Here the user can enter the system from his office or go to the registration page and create a new user (see Fig. 4.8).

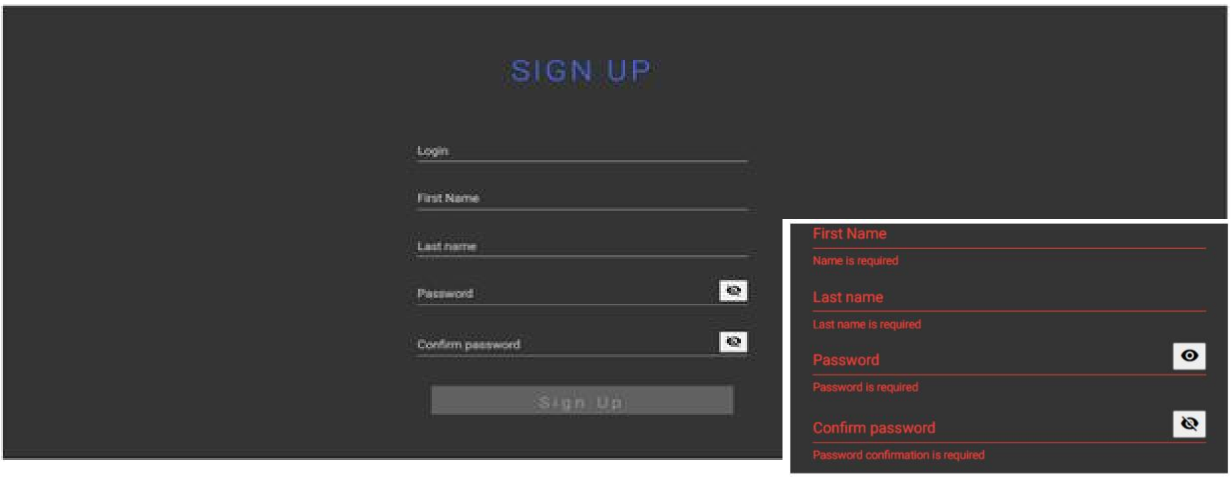



Fig. 4.8. Registration page for "Information platform for choosing and structuring the approach to project management"

The project uses the Angular reactive form validator for all fields, buttons and other elements where the user enters/changes information.

After successful login, the user gets to the main page (see Fig. 4.9).

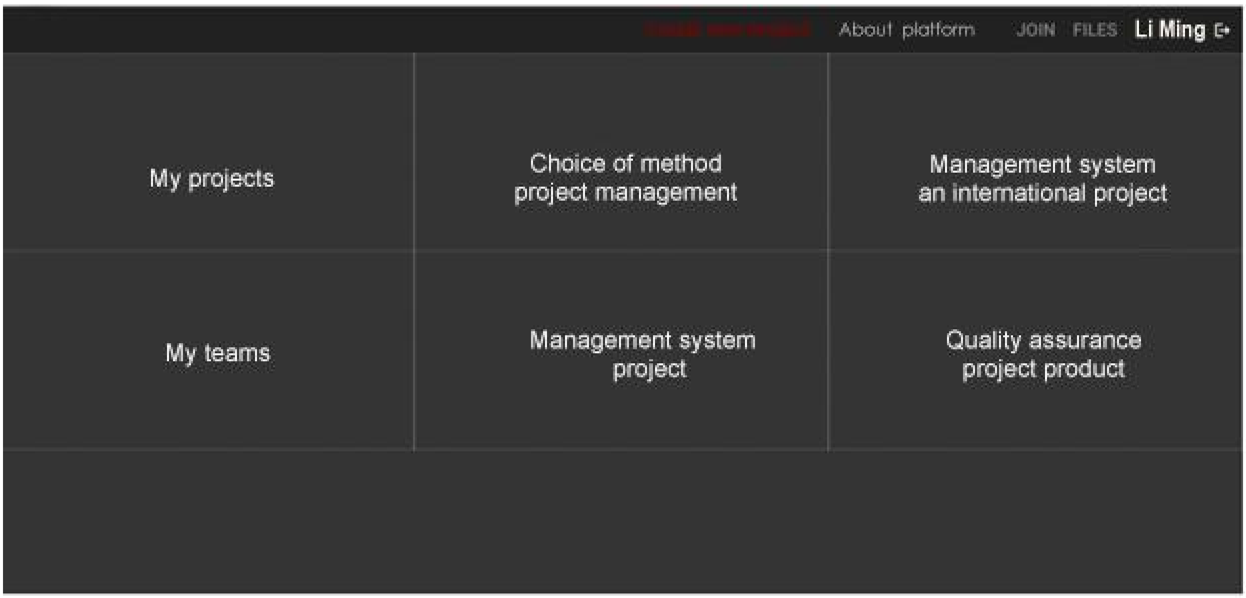



Fig. 4.9. Main page of the Platform

The "My projects" tab contains all user projects, active, completed, experimental.

The tab "My teams" contains access to the teams in which the user is involved, his roles.

The component of the platform "Choosing a project management method" allows you to create projects and evaluate them according to questionnaires specially developed by experts, to choose the approach to project management that is closest to the received project evaluation. This component implements the calculations provided by the method of selecting and structuring the approach to project management, which is based on the method of selecting a project approach based on the "Cynefin" model and the model of project management based on fuzzy representations. The general block diagram of the method, which is the basis of the algorithmic support in the development of the subsystem, is shown in Figure 4.10. The functional capabilities implemented by the subsystem are illustrated with the help of a diagram of options for using this subsystem (Figure 4.11).

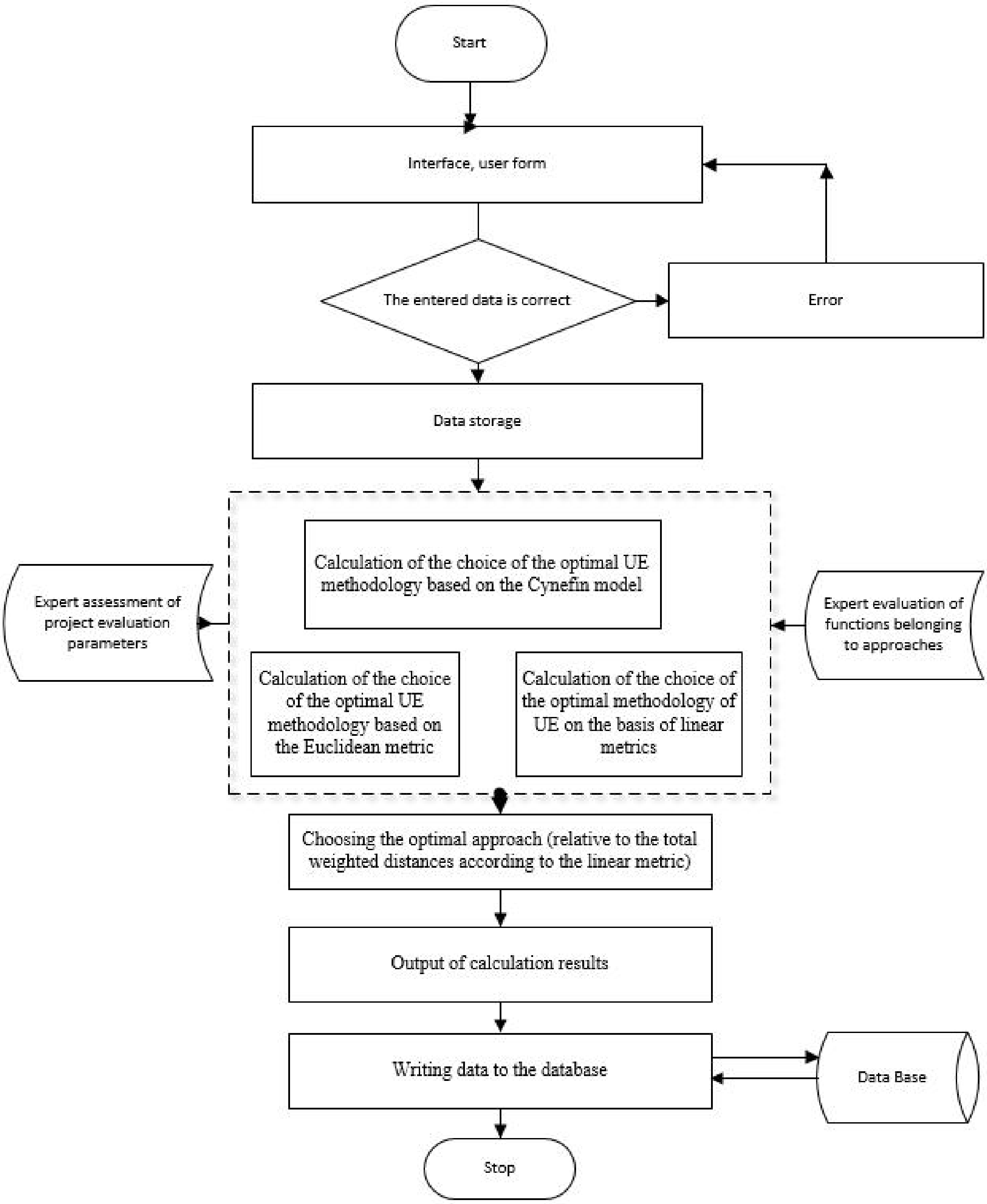



Fig. 4.10. Generalized block diagram of the method of selection and structuring of the project management approach implemented in the "Selection of the project management method" component of the information platform of the selection and structuring of the project management approach.

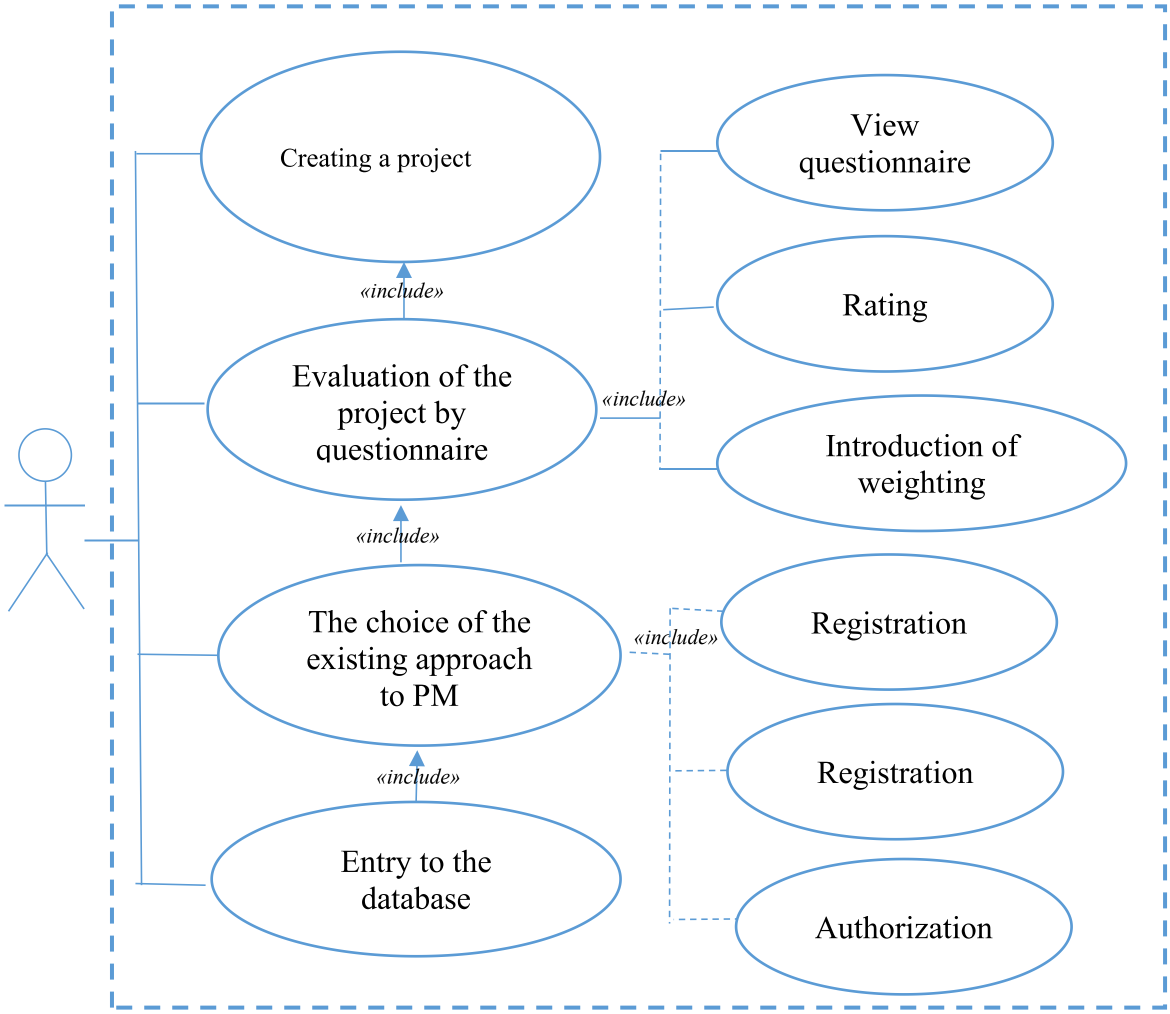



Fig. 4.11. Diagram of options for using the "Choosing a project management method" component of the information platform for choosing and structuring an approach to project management

The "structuring of project management methodology components" component of the project management approach selection and structuring platform allows you to create and evaluate alternative specialized approaches to project management, choose the best one from the point of view of cost and management effort, as well as the risks accompanying the application of the approach. This component implements the calculations provided by the method of selecting and structuring the approach to project management. The general block diagram of the method, which is the basis of the algorithmic support in the development of the component, is shown in Figure 4.12.

The functional capabilities implemented by the component are illustrated with the help of a diagram of options for using this component (Figure 4.13).

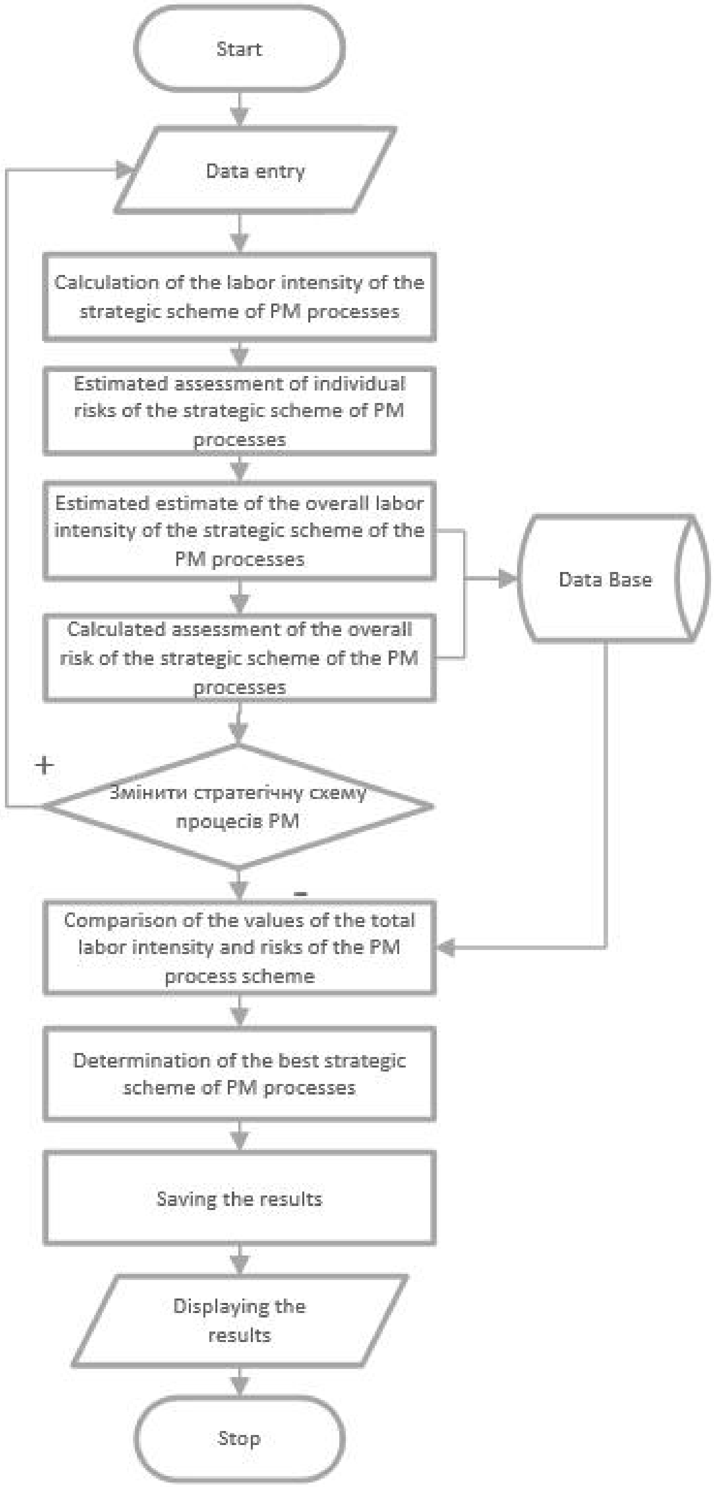



Fig. 4.12. General block diagram of problem solving and structuring of the project management approach

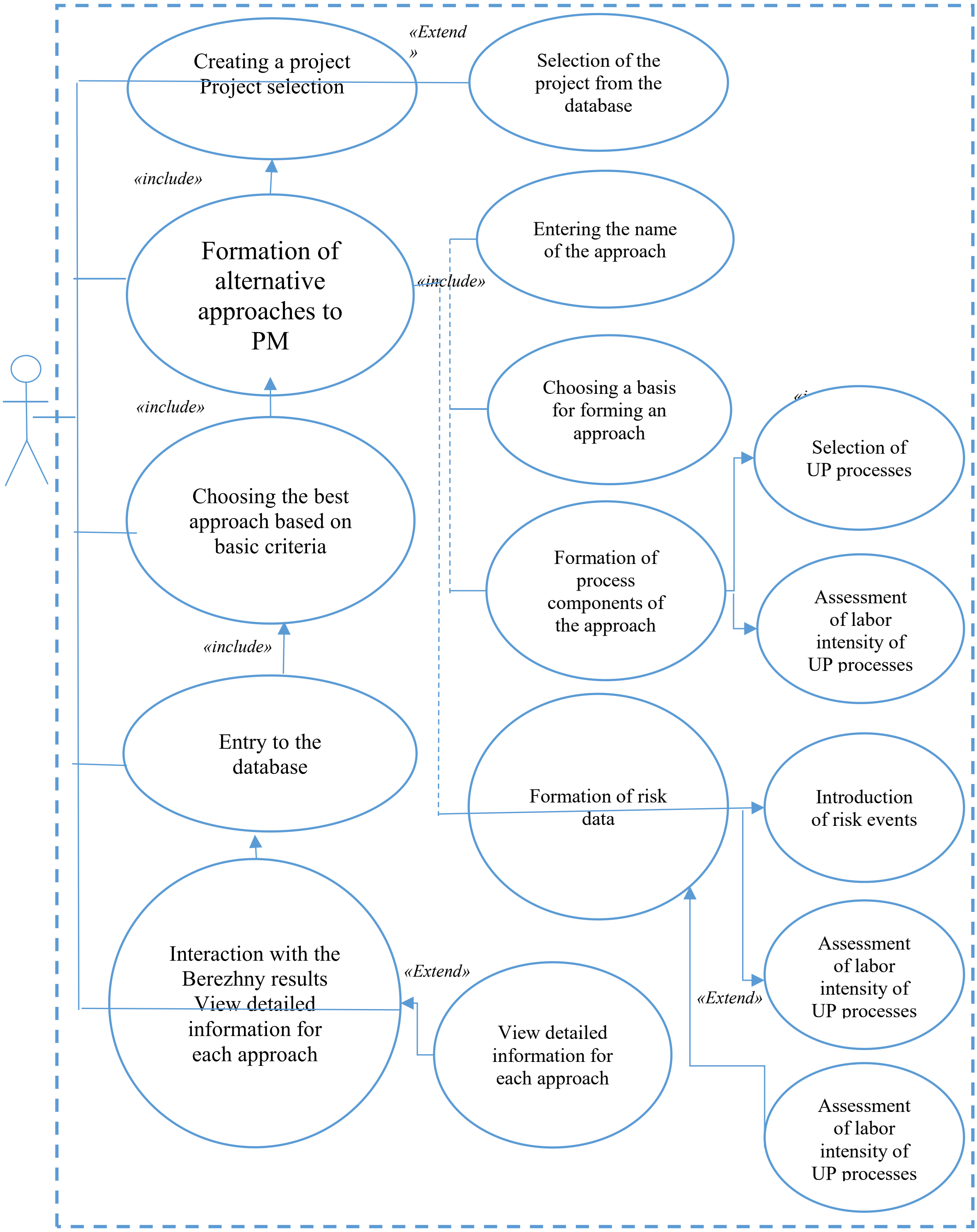



Fig. 4.13. Diagram of options for using the "Structure of approaches to project management" component of the information platform for choosing and structuring an approach to project management

In addition to the functionality of the subsystems, which is discussed in more detail in the following work items, the information platform also allows you to save the created projects and view their list (Figure 4.14). If a management approach was selected for the created projects, this approach will also be displayed in the user's project tableFig. 4.13. Diagram of options for using the "Structure of approaches to project management" component of the information platform for choosing and structuring an approach to project management

In addition to the functionality of the subsystems, which is discussed in more detail in the following work items, the information platform also allows you to save the created projects and view their list (Figure 4.14). If a management approach was selected for the created projects, this approach will also be displayed in the user's project table.

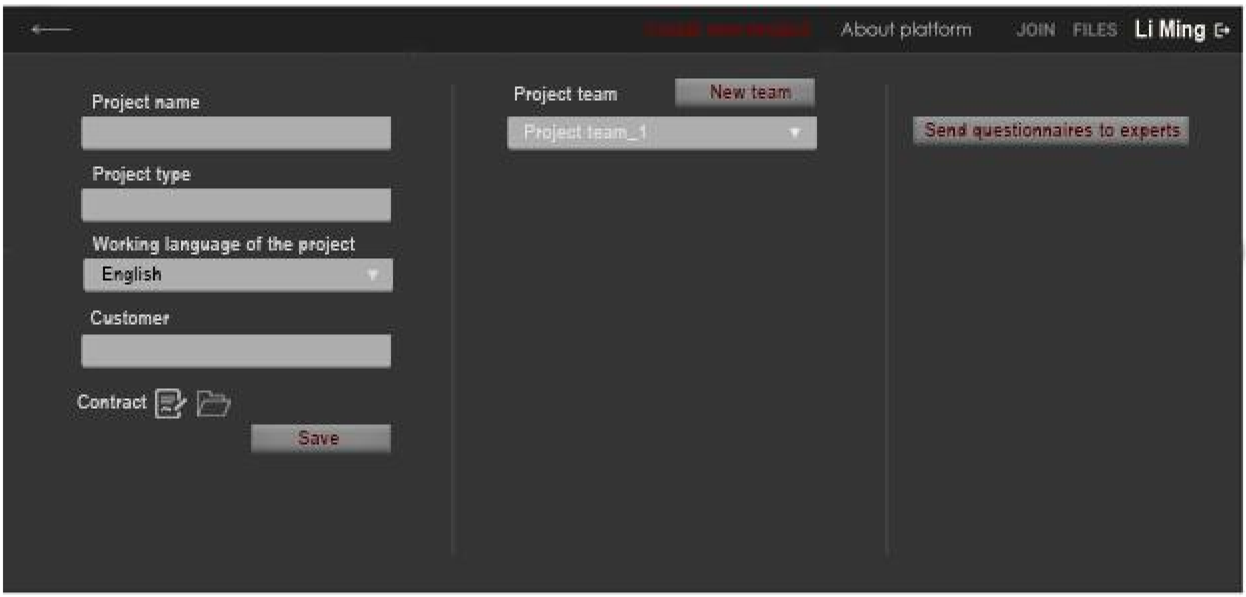



Fig. 4.14. Project creation page

Below is a description of each component of the platform for selecting and structuring an approach to project management

## 4.2 Characteristics of the "Choosing a project management approach" component of the platform for choosing and structuring a project management approach and its application

To solve the task of choosing one of the existing approaches to project management using the "Choosing a project management approach" component of the information platform for choosing and structuring a project management approach, the following sequence of actions must be performed:

1. Register in the system, thereby creating a personal account.
2. Log in to the system to go to your personal account.
3. Create a project.
4. Fill in the project data.
5. Appoint experts.
6. Create project questionnaires
7. Send questionnaires to experts to enter evaluation coefficients.
8. Go to the component "Choosing a project management method" from the main page of the system.
9. Familiarize yourself with the user manual of the module, which explains the technology of calculating the project evaluation

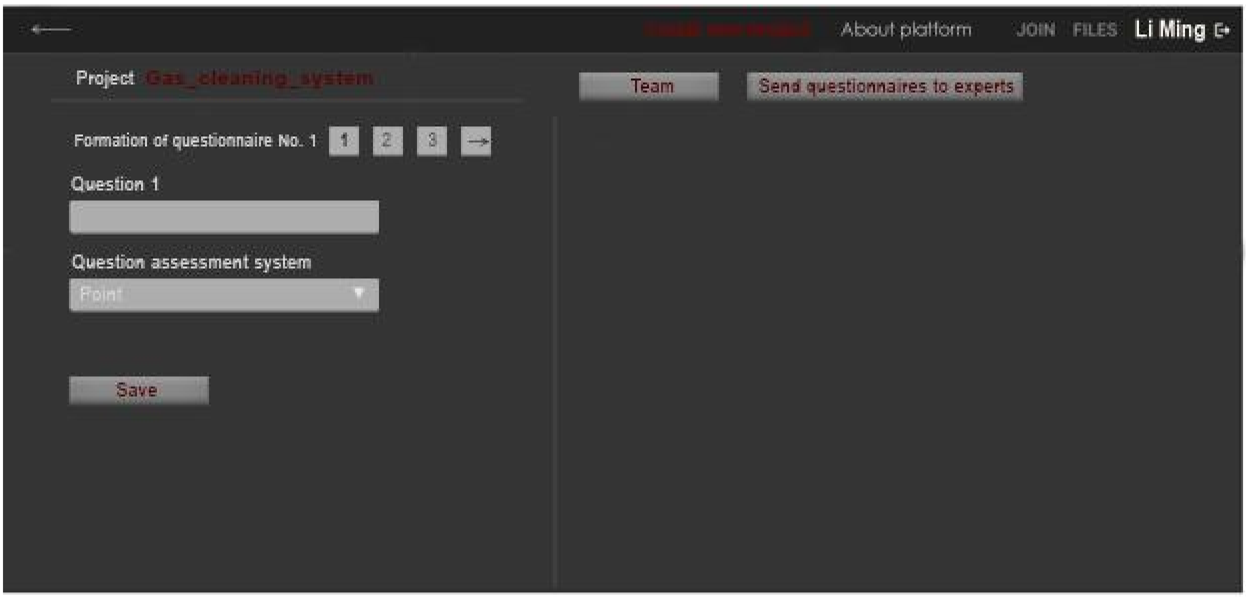



Fig. 4.15. Creating a project questionnaire

Each parameter corresponds to a specific web page. The initial data used to solve the problem of choosing an approach to project management for the development of gas cleaning equipment are given in Tables 3.1-3.6. An example of a web page for the assessment of project parameters by an expert is presented in Figure 4.16.

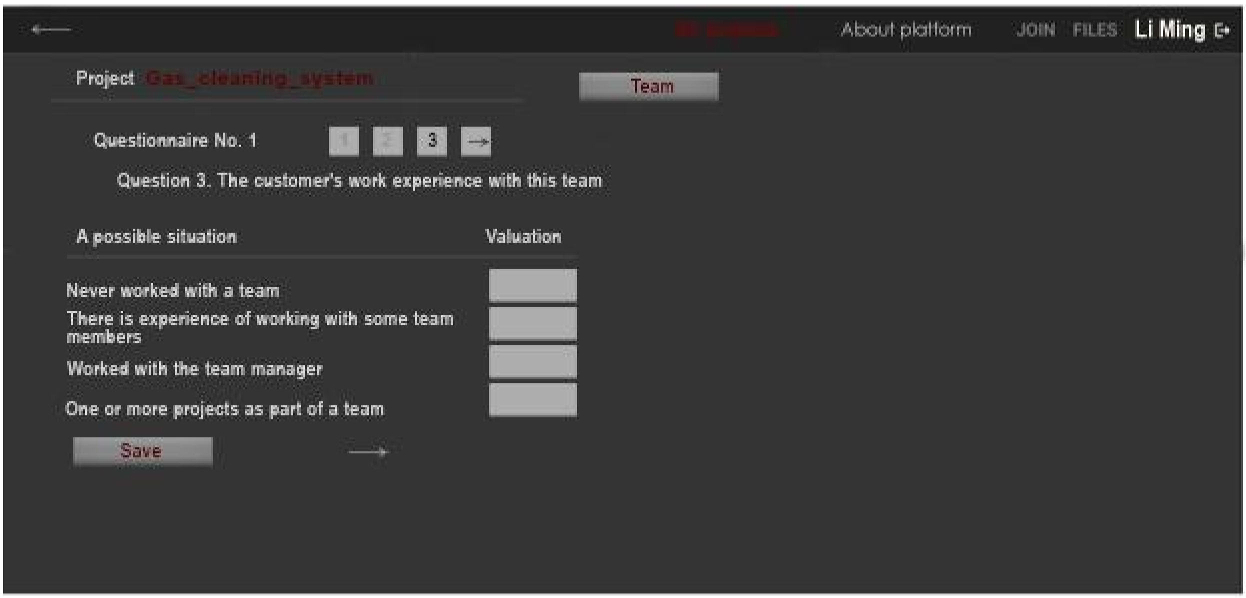



Fig. 4.16. Subsystem "Choice of UP methodology". Filling out the questionnaire by an expert.

The results of the method of the project management model based on vague ideas for choosing an approach to software project management are presented in Fig. 4.17, which shows the results of the calculation of the specified distances for the project that was chosen as an example for model approval - an international project on the development of gas cleaning devices for ventilation systems. This project was chosen for several reasons: at the time of approbation of the model, the project was at the initial stage and the approach to its implementation needs to be determined; it meant the author's personal participation in the project, which allows him to be involved in the process of testing the model's capabilities. The project is aimed at increasing the efficiency of management in the development of air purification units. Project parameters are presented in Fig. 4.17.

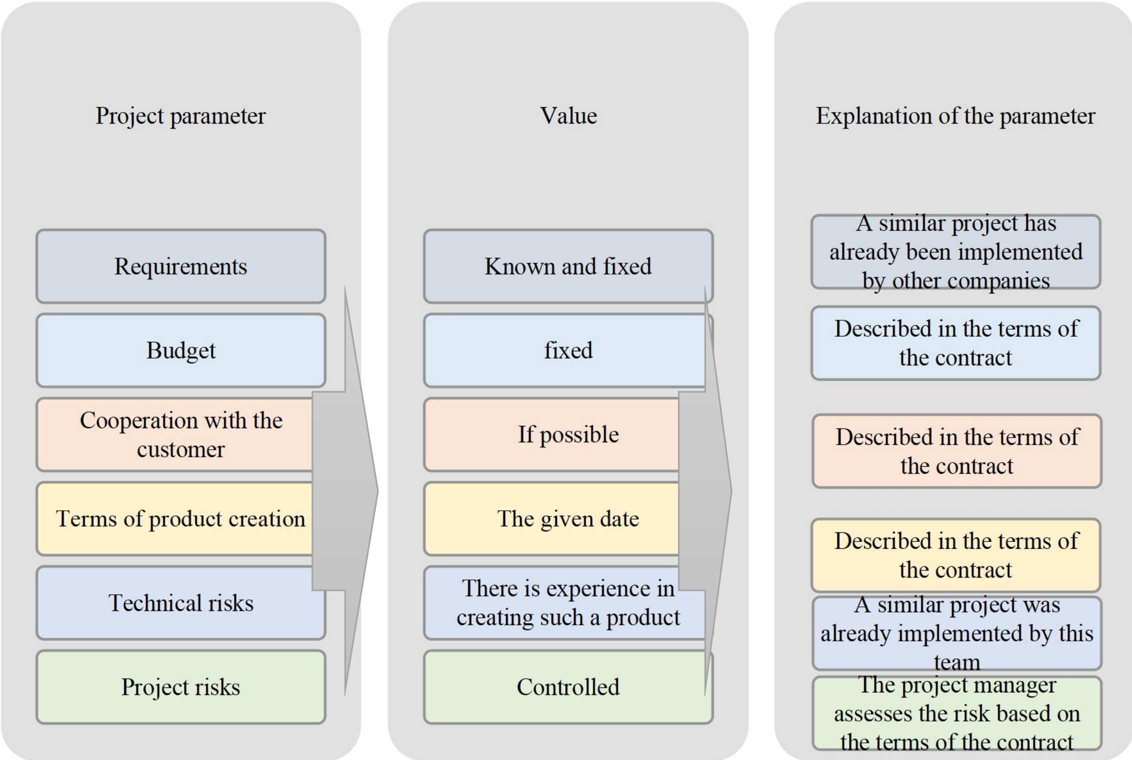



Fig. 4.17. Parameters of the project "Development of gas cleaning devices for ventilation systems"

The project was obtained on a tender basis, so this is the first cooperation with the customer, both parties do not know what to expect from each other.

At the same time, the approaches are displayed in order from the most to the least suitable in the conditions of the specified project.

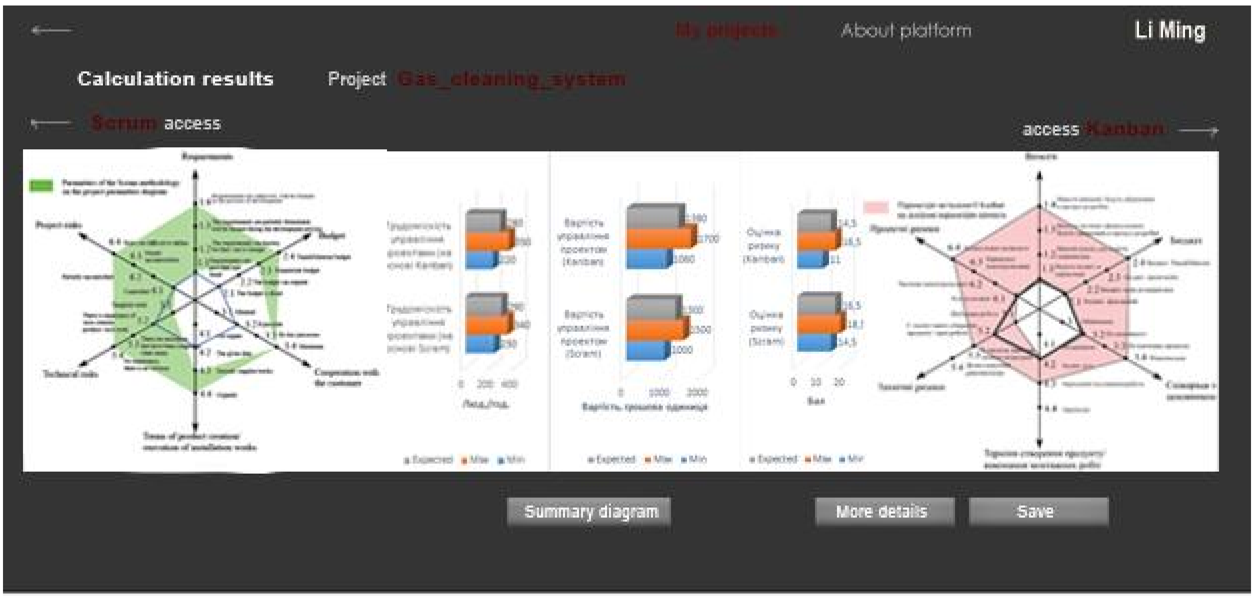


Fig. 4.18. Subsystem "Choosing the UP approach". Output of the results of calculations of the project parameters on the diagram.

The results of the calculation show that the Scrum methodology is the most acceptable in the conditions of this project. The next closest approach to project management is the flexible Kanban methodology, which indicates a higher probability of the effectiveness of using flexible than traditional approaches to managing the project in question.

The result of the calculations implemented in the component, based on the "Cynefin" model, is shown below. Let's transfer the data to the project parameters diagram (Fig. 4.19)

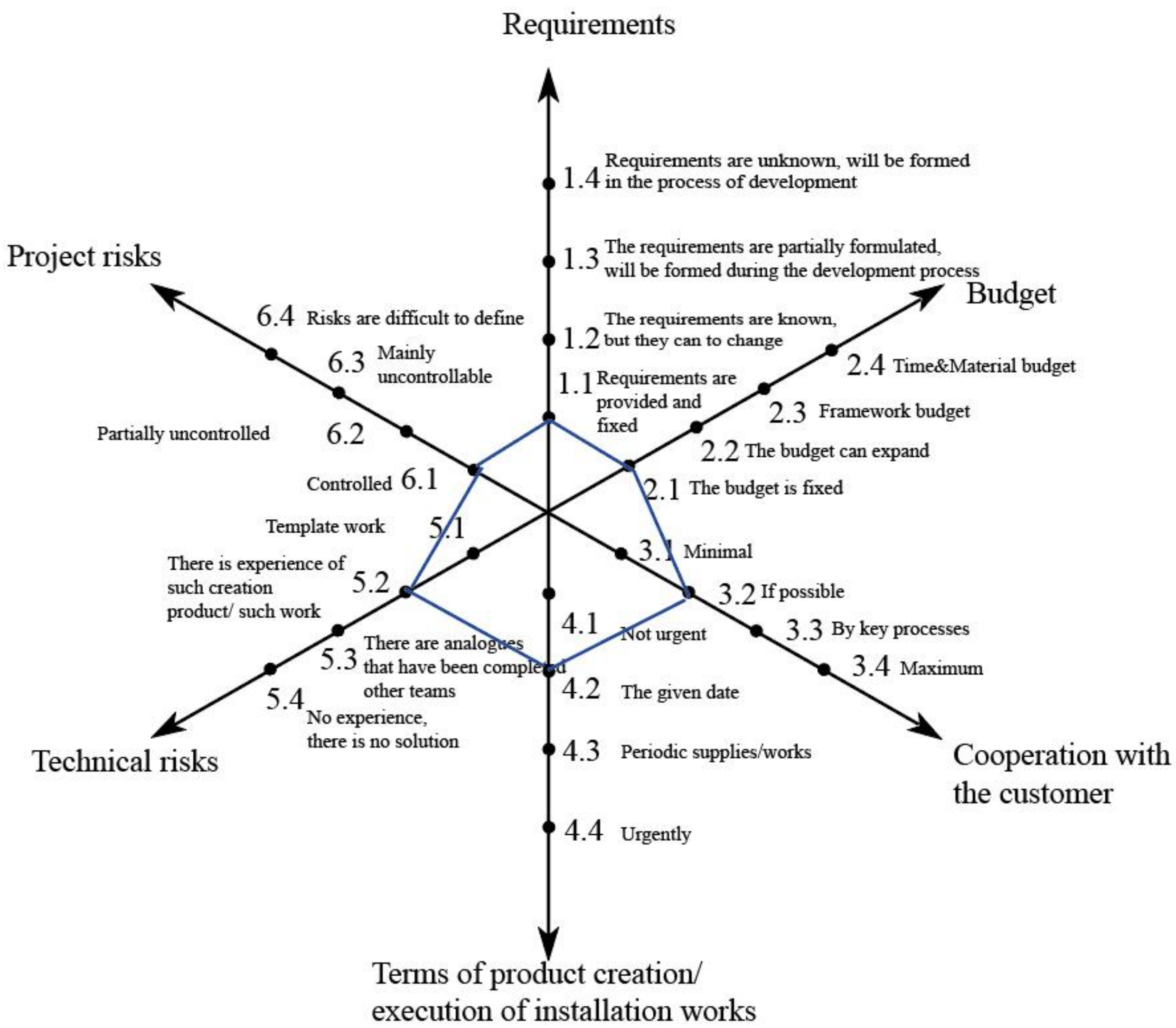



Fig. 4.19. Diagram of the characteristics of the project "Development of gas cleaning devices for ventilation systems"

Thus, the next step is to combine the models of the characteristics of the methodologies and the characteristics of the project and analyze the impact of the characteristics of the project on the characteristics of each of the four methodologies. Figure 12 shows the final model of the selection of the development methodology for the project "Development of gas cleaning devices for ventilation systems".

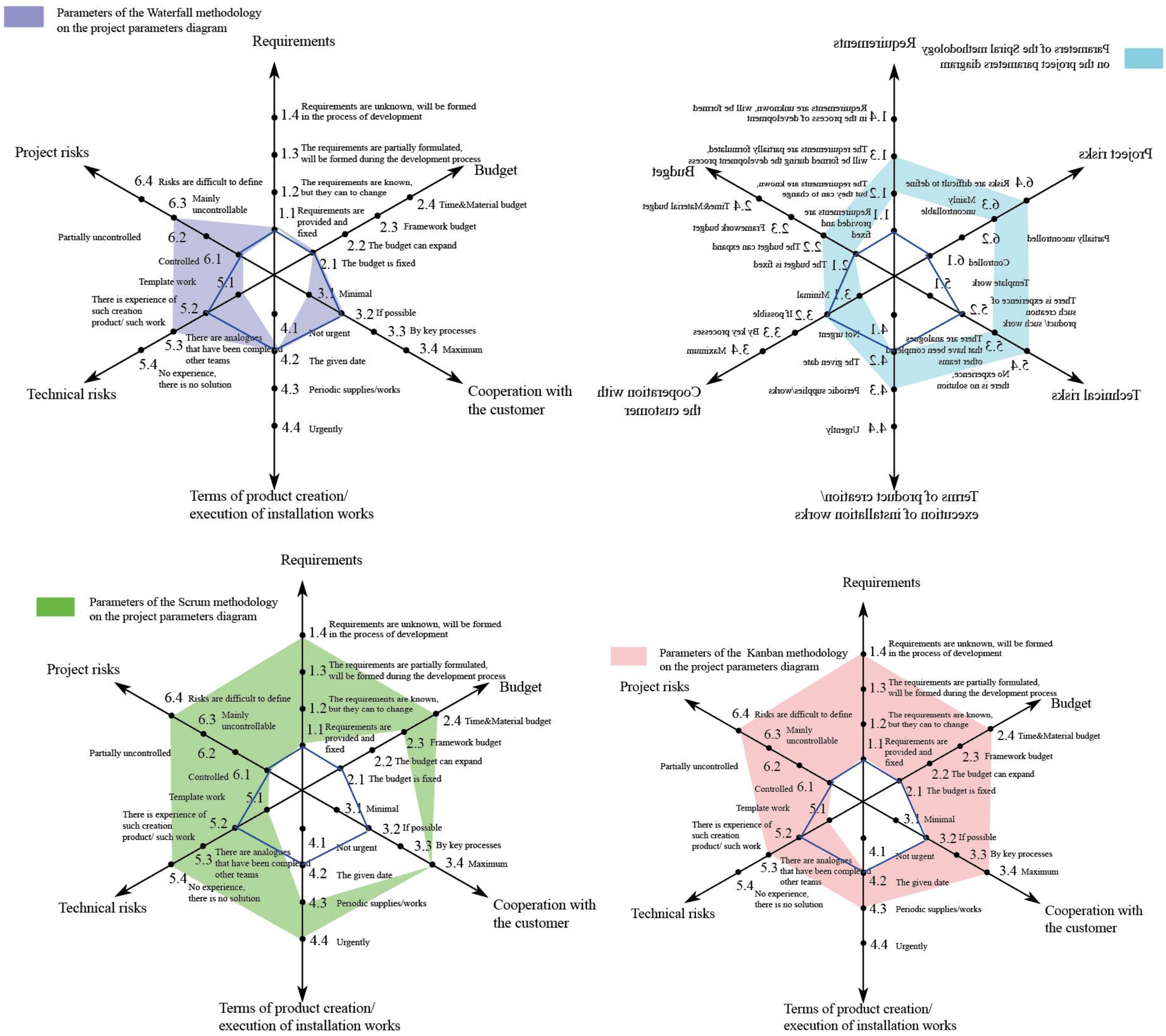



Fig. 4.20. The model for choosing a development methodology for the project "Development of gas cleaning devices for ventilation systems"

The model allows you to visually show the compliance of the project parameters with the parameters of one or another methodology. If you wish, you can combine all the profiles of projects and methodologies on one diagram, but it is necessary to take into account their number and the convenience of such a presentation. A summary model of the selection of software development methodology for the project "Development of gas cleaning devices for ventilation systems" is presented in Fig. 4.21.

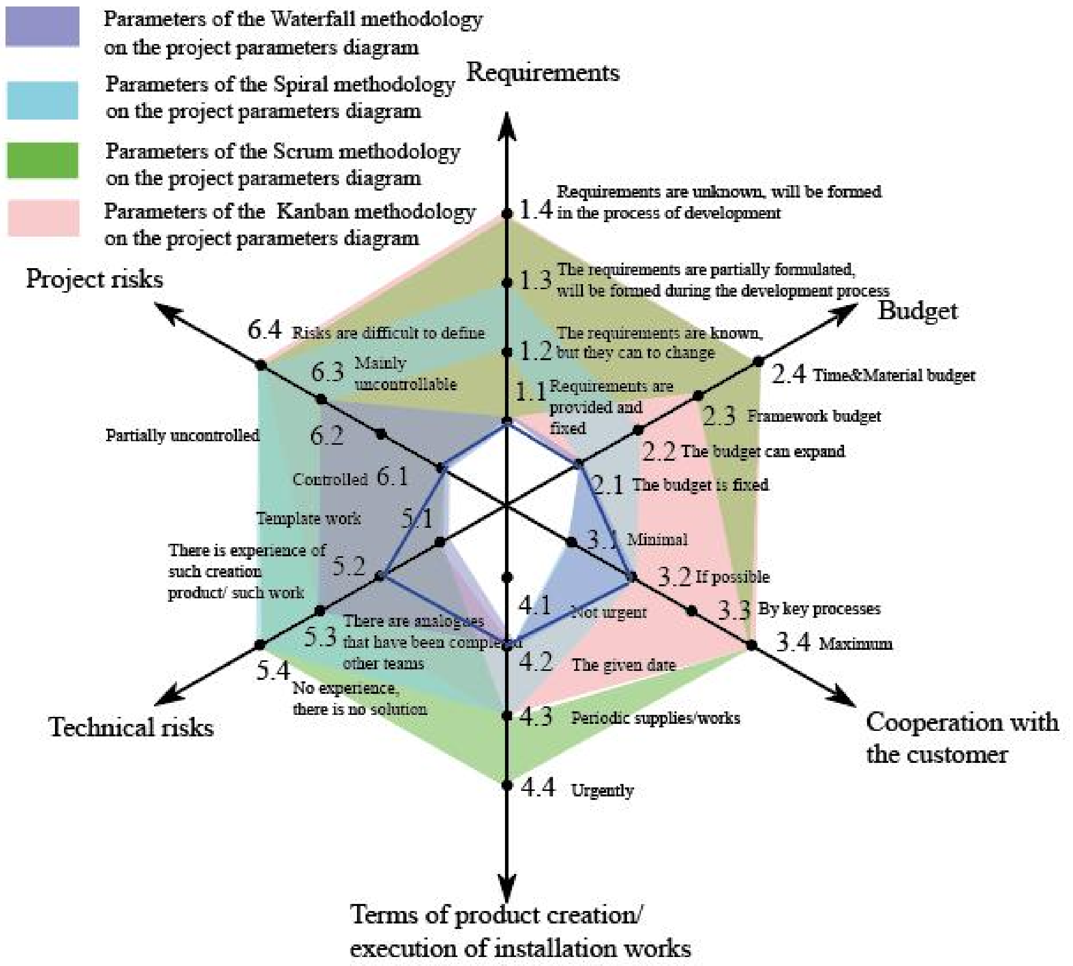



Fig. 4.21. Summary model of software development methodology selection for the project "Development of gas cleaning devices for ventilation systems"

Therefore, the Waterfall model and Kanban methodology are well suited for the project "Development of gas cleaning devices for ventilation systems". Based on the existing model, project managers can make decisions about the choice of these methodologies and defend the decision to senior management. On the example of this project, the cascade model was chosen because the customer had not previously worked with the company and was not familiar with the process of project work using the Kanban methodology. In addition, the contract fixed the requirements, terms and budget, controllable project risks prevailed - it made sense to use an easier-to-use cascade model.

### 4.3. Characteristics of the information component of the "International Project Management System" platform for selecting and structuring an approach to project management

The study of the method of organizing the management of international projects revealed the presence of significant opportunities to improve the efficiency of the project management process. In many ways, the manual management model used in the classics is not entirely adequate to the processes of creating projects carried out by an international team. For the work of the project team, a single information center is necessary, which can be used to solve the following management tasks:

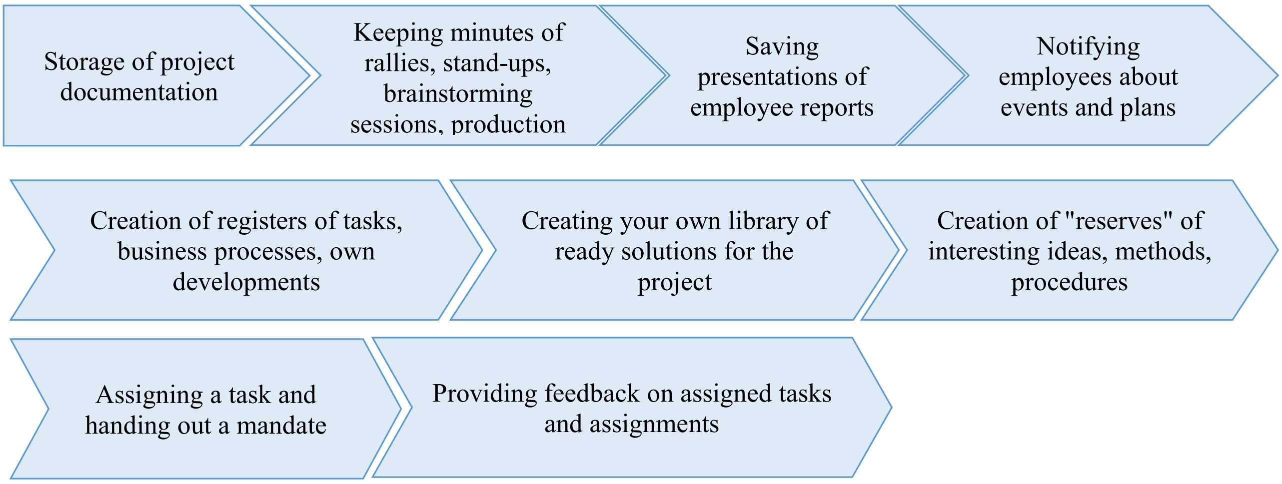



Fig. 4.22. Management tasks of the "International Project Management System"

This subsection contains the proposed model in the form of an international project management information system, which is integrated into the proposed information platform for selecting and structuring the approach to project management, the synergy of which increases the effectiveness of project management, and, therefore, the implementation of the project in general. The analysis of methods and algorithms of the project management process showed that management at the pre-project stage is significantly different from the management process at the implementation stage. The proposed system is based on software products based on the Agile methodology and currently widely used: Jira and Confluence. This product will not replace current systems, but will be integrated into them to automate routine processes. This system is not independent and independent, but is a plugin for the Jira system, therefore it is adapted to work with it. There are the following methods of software adaptation (tab. 4.1.)

Table 4.1. Methods of software adaptation

| Adaptation method | Function | Characteristic |
|---|---|---|
| Parametric adaptation | Related to setting program parameters | This is the easiest way to adapt; it involves changing the values of indicators regulating the program's operation. With the help of parametric adaptation, it is possible to carry out the necessary adjustment of functions and components of the program, and to select behavior strategies from the proposed set of strategies. |
| Functional adaptation | It involves changing the functions of the software within the limits. | Functional adaptation can be performed together with parameters. The structure and organization remain constant. |
| Organizational adaptation | Reconfiguration of flows and processes in the system. | Organizational adaptation means the redistribution of flows and processes of the system as its internal resources, without changing its structure. Can be combined with functional adaptation. |
| Structural adaptation | Changing the structure of the | Using this method of adaptation, modification and replacement of some |

| | | |
|---|---|---|
| | system. | structural elements of the system or algorithmic modules with others is carried out. The adaptive program becomes more adequate to the task being solved. At the same time, it is possible to use all previous types of system adaptation. |
| Reproduction | Generation of similar offspring. | Adaptation by reproduction is an effective method of adaptation. The system produces a similar one, but with the availability of free resources and the ability to change. |
| Development | Directed process of evolution of systems. | The adaptation of software that occurs through development is similar to the processes of evolution of living systems. Adapted software goes through the process of evolution through the accumulation of information about itself, the external environment, and the tasks being solved. Passing through the stages of birth, formation of certain qualities, stable functioning, degradation and death, the system becomes more adapted to solving tasks. |

The proposed project management system is a separate functional unit that is integrated into the Jira and Confluence system, and also interacts with them using their functionality. Thus, the project management system, combining manual and automated, somewhat changes its structure, organization and functions. The functions are applied in the following way. In the "As Is" model, the functions of creating a number of documents and tasks rested with the project team and the project manager. With the help of a plug-in (applied at the pre-project stage), this work is performed automatically, since the algorithm of pre-project research activities is embedded in the proposed system, thanks to which document templates are formed automatically at each stage of the management process; Tasks and assignments are also generated using the new system thanks to the project team action tracking feature.

That allows the To Be system to expand the range of functions used by the team without violating the established limits of changing the functions of the existing management system. The organizational adaptation of the international project management system consists in the fact that the former flows of management information change their trajectory. The interaction between the project manager and all project participants is carried out in a new model through a single Aveva Connect information management center. At the same time, the entry and exit points of organizational flows remain unchanged. The structure of the existing project management system is also slightly changing. Manual management methods cease to be mandatory and a new element appears in the Jira system - a research plugin. This model is developed on the basis of the structural-functional-organizational method of adaptation, and is provided by the following diagrams:

• top-level diagram of the "experimental plugin" ecosystem (Fig. 4.23);

• diagram of To Be management business processes (Fig. 4.24.) depicts the model of interaction of the project management system "To Be" ("How it will be") with the participants of the pre-project stage. As we can see, there is another participant in this model - the research plugin. The processes that were present in the "As Is" model have moved from the project participant pools to the plugin pool, which means that the execution of these processes is taken over by the plugin.

• diagram of precedents (Fig. 4.25);

• ER diagram (Fig. 4.26).

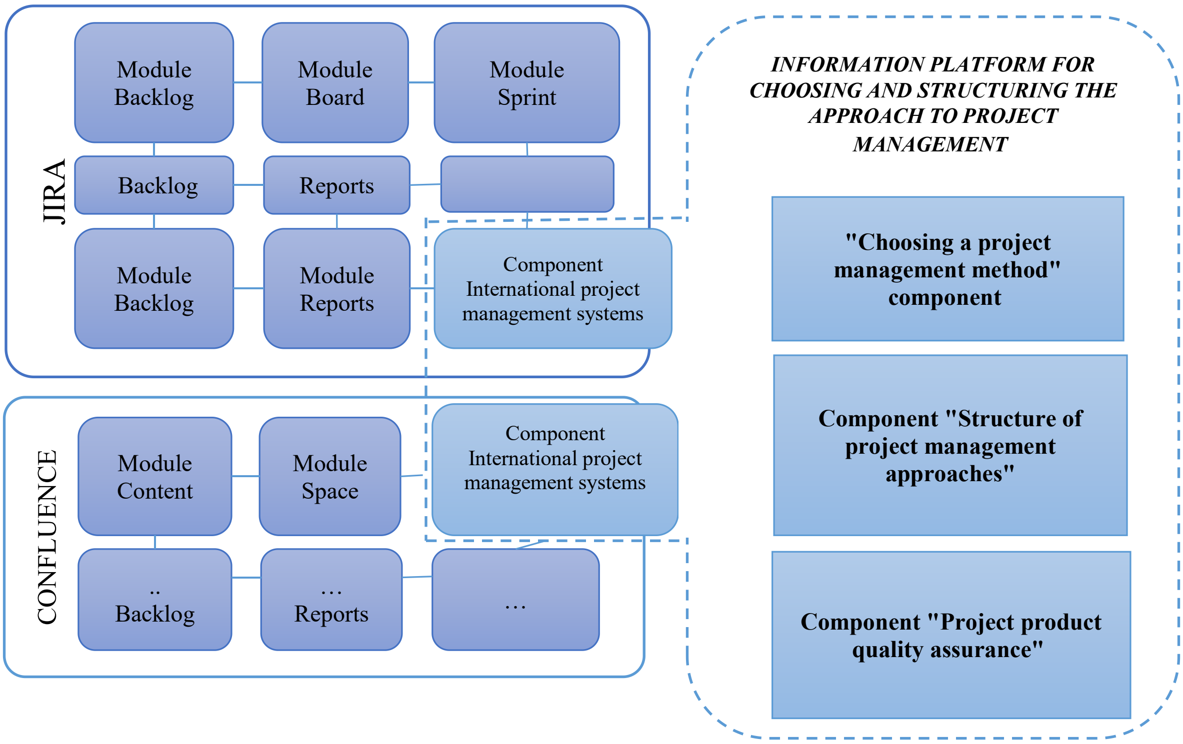



Fig. 4.23. Ecosystem diagram of an embeddable plugin for project management in the research phase

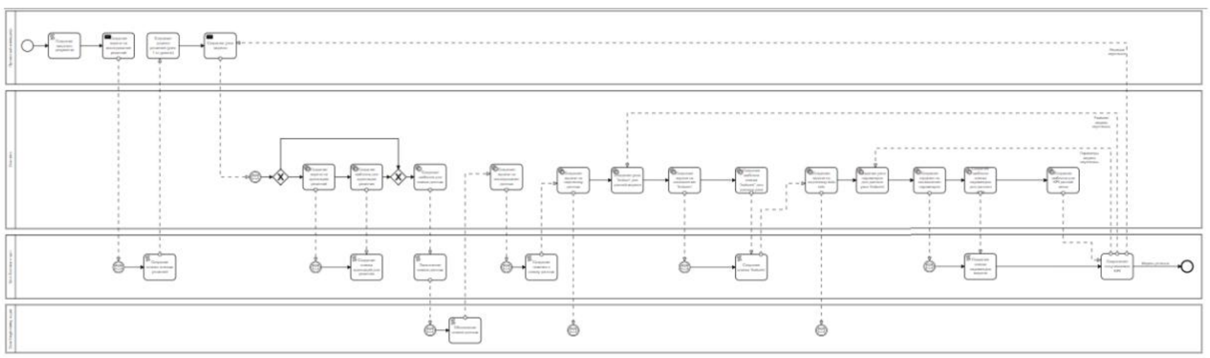


Fig. 4.24. Diagram of business processes of the "To Be" model of project management at the pre-project stage

Taking away some of the responsibilities of other participants in the process, SUMP can significantly reduce the time needed by the project team to create tasks, documentation and track the development process. Let's consider in more detail the proposed diagram of project management business processes at the "To Be" pre-project stage:

Table. 4.2. Algorithm for performing project management business processes at the pre-project stage "To Be":

| | |
|---|---|
| **1. Creation of an input document.** | In order to initiate the creation of a new project by the project manager, SUMP offers him to fill in the input document according to the established template: fill in the list of project goals, fill in the list of business requirements, add a comment to each business requirement - whether the project is created using the I algorithmic approach, and also create a set of KPIs future product. |
| 2) creation of a decision research task. | After the meeting, the PM finishes the work on creating the document, checks the filled-in data and confirms the creation of a new project in the Jira system. The plugin creates a new Jira project, creates a solution research task, and saves the log filled by the PM in the Confluence system. Next, the PM assigns the task to an employee of the Data Science department. The employee who received the task begins its execution; |
| 3) creation of a template list of possible solutions. | The plugin automatically creates a template for the found solutions in the Confluence system. This template will be attached as a link to the task created in clause 2; |
| 4) creating a list of ready solutions. | After point 3, the Data Science employee fills out the list of found solutions in the document. After a meeting where the project team will discuss the solution options, the list creator will mark the priorities of each solution found. Solutions that require adaptation are also indicated |
| 5) creation of a decision tree (node of the 1st level). | On the plugin page, the project manager creates the root node of the future decision tree; |
| 6) creation of a model node. | The project manager initiates the creation of a solution node. ACS creates a decision node in accordance with the priorities selected in point 4 and moves to the next stage; |
| 7) creation of a decision adaptation task. | If the solution corresponding to the node created in point 6 cannot be applied ready-made, the plugin creates a Jira task to adapt the solution. The PM can assign it to a specific employee of the Data Science |

| | |
|---|---|
| | department; |
| 8) creating a solution adaptation template. | If it was done, the plugin creates a template in the Confluence system for the document adaptation of the decision and attaches it with a link to the task created in point 7; |
| 9) creation of a list of adaptations for resolution. | The Data Science employee of the department, who received and completed the task, fills in the list of adaptations and according to the template created in Confluence; |
| 10) creating a data list template. | After the end of point 6, if the solution did not require adaptations, or after point 9, if it did, the plugin creates a template of the list of data required for the current node; |
| 11) creating a list of data. | After choosing a solution option, the project team gathers for a meeting and creates a list of data necessary for work on the project. This item can also be completed by a Data Science employee independently. This list is populated by a template created by Confluence; |
| 12) updating the data list. | An employee of the Data Engineering department prints the document created in clause 7 or opens it in the Confluence mobile application and collects data. The document contains comments about what data was collected and to what extent. After this stage, the CTO of the company notes on the plugin interface that the data collection is finished; |
| 13) creating a data research task. | After completing item 12, the plugin automatically creates a Jira task with an attached link to the Confluence page with a list of data and assigns its execution to the head of the Data Science department; |
| 14) creation of marks to the list of data | The Head of Data Science examines the data and manages the document with a list of data by marking. After completing the task, the head of the Data Science department notes on the plugin interface that the task is finished; |
| 15) creating a data preparation task. | SUMP creates a Jira task for data preparation. The PM can appoint an executor for this task. An employee of the Data Engineering department receives the task together with the document from clause 10.; |
| 16) creation of the "features" node for this model. | After item 15 is completed, the plugin creates a features node; |

| | |
|---|---|
| 17) creation of the "features" compilation task. | After completion of clause 16, the plugin creates a task of compiling the "features" list in Jira. PM can appoint the executor of this task; |
| 18) creating a "features" list template. | As soon as the task described in clause 17 is created, the ACS creates a feature list template for this node. This template as a link to a page in the Confluence system is attached to the task of item 17.; |
| 19) creation of the "features" list. | After creating tags for the data list, employees of the Data Science department hold a meeting to define the "features" list. This list is filled in Confluence by one of the employees of the Data Science department in a pre-created template. After this stage, the head of the Data Science department notes on the plugin interface that the list of "features" has been compiled; |
| 20) creating a Data Sets preparation task. | After completing item 19, the plugin creates a task in the Jira system to prepare Data Sets. The document created in clause 19 is attached to the task. PM can appoint the executor of this task; |
| 21) creating a properties node for this "features" node. | After creating the task described in clause 20, the plugin creates a new node in the system - the parameters node; |
| 22) creation of the task of compiling parameters. | After creating the parameters node, SUMP creates a Jira task to create a list of parameters for the current model variant. PM can appoint the executor of this task; |
| 23) creation of a template list of parameters of this node. | The plugin creates a Confluence parameters list template and attaches a link to this Confluence page to the task described in clause 22.; |
| 24) creating a list of model parameters. | After completing the task set in clause 22, employees of the Data Science department fill in the list of parameters for the current model in the template created by the plugin; The project team is engaged in creating a model according to the given parameters and training it on prepared Data Sets. Once the model is considered trained, the team should analyze its performance in terms of achieving product KPIs. |
| 25) creating a | After executing item 24, the plugin creates a Confluence template for the |

| | |
|---|---|
| template for the KPI of this branch. | list of KPI indicators for this branch; |
| 26) saving the received KPIs. | After completing the training of the model, the employee of the Data Science department fills in the template created in paragraph 25. At the end of clause 26, the project team decides whether the created solution is appropriate and the pre-project stage can be considered completed, or the KPIs are considered not achieved. In the event that the KPIs are considered not achieved, the project team faces a choice of which node to return to: • create other parameters of the model with the same set of features and return to item 21; • create a new set of "features" and return to point 16; • return to the selection of a new decision option and return to point 6. |

The proposed diagram of precedents reflects options for the interaction of the participants of the pre-project stage with the plug-in being modeled.

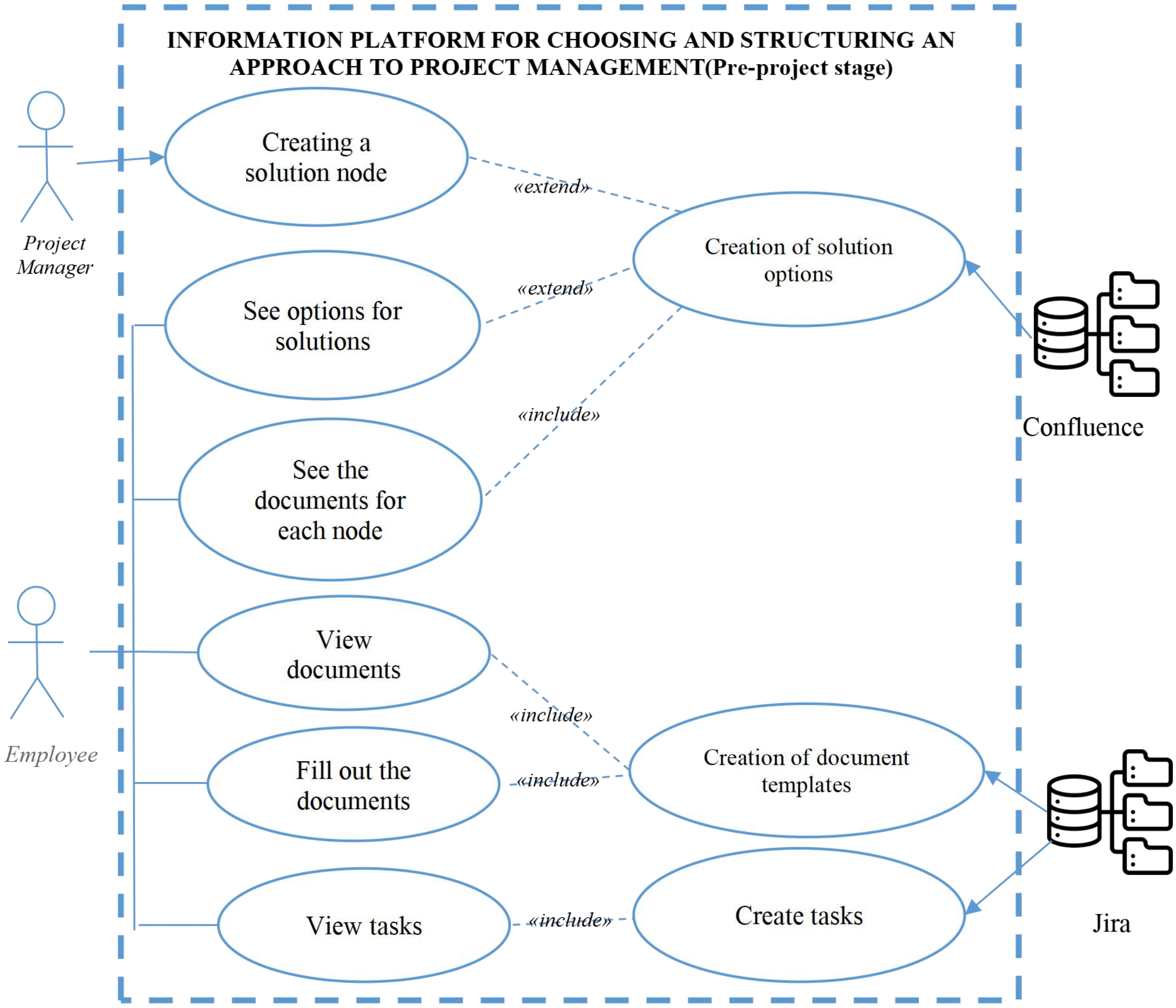


Fig. 4.25. Diagram of precedents for the To Be model of project management at the pre-project stage

A use case diagram allows you to describe the functional purpose of the system and also shows the boundaries of the system. Research Plugin is a system that automates processes that require manual management. IPMS can cover the performance of such functions as creating documents and their structure, creating tasks. These functions are automatic and are performed at the right time based on a system of triggers, which correlates with the algorithm of the pre-project stage embedded in the system. Thanks to the functions of tracking the execution of tasks and the timely creation of templates of the necessary documentation, the system simplifies the process of creating documentation for the project, as well as facilitates the creation of a unified format for it. Also, IPMS allows you to conveniently visualize the phases of the pre-project stage, as well as see the statuses of each phase of the study. For the structural analysis of the modeled system, the entity-relationship modeling method, or ER-diagram, was used. This method allows you to display the objects that will be used in the system, as well as the methods of their interaction. The ER IPMS diagram at the pre-project stage is shown in Fig. 4.26.

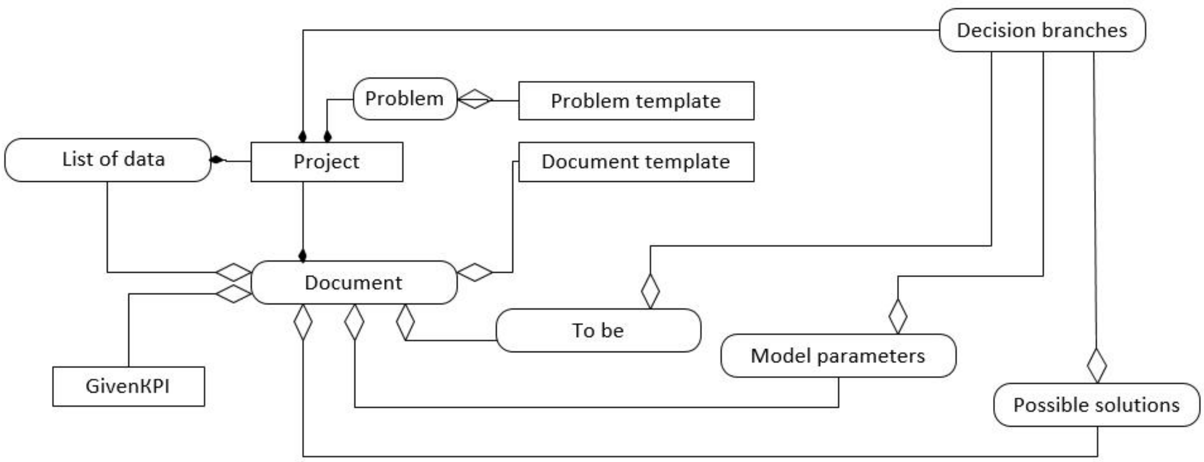



Fig. 4.26. ER-diagram of the "To Be" project management model at the pre-project stage

The ER-diagram reflects the interaction between the key entities of this system (project, documents, tasks and branches of decisions) in statics. The set of described diagrams (ecosystem diagram, business process diagram, precedent diagram and ER diagram) provides a complete description of the "To Be" model of the international project management system at the pre-project stage as components of the information platform for the selection and structuring of the approach to PM.

### 4.4. Qualitative evaluation of the international project management system model as a component of the information platform for the selection and structuring of the management approach

In order to qualitatively evaluate the proposed model of the international project management system, the following methods of assessing the degree of automation of business processes in comparison of As Is and To Be models and the method of expert evaluations were applied. A SWOT analysis was used to analyze the developed IPMS model, identify weaknesses/strengths, as well as the potential for its further development and identify possible risks. To assess the degree of automation, it was necessary to count the number of performed routine or manual actions (As Is model), and the number of the same actions after the possible implementation of IPMS (To Be model) and automation of the management process. Two processes have the most routine actions: creating a task in the Jira system and creating a document in the Confluence system. Creating tasks is a routine activity, because in the pre-project phase tasks are mostly short-term, but there are enough of them that it is sometimes impractical for a project manager to spend time creating and managing tasks in the Jira system.

Creating a document is also time-consuming in itself, since the Confluence system is not the most user-friendly tool. It is also an inconvenience that technical specialists have to create documents due to the specifics of the pre-project stage. Such responsibilities are rarely assigned to project managers, so technical specialists often attach a photo of the same handwritten document instead of creating a full-fledged document, or even completely neglect this task. The degree of automation was assessed based on an ordinal scale of 10 levels of automation (Fig. 4.27). Table 4.3 lists elementary user actions in the process of creating a task and creating an As Is document and gives an assessment of the degree of their automation.

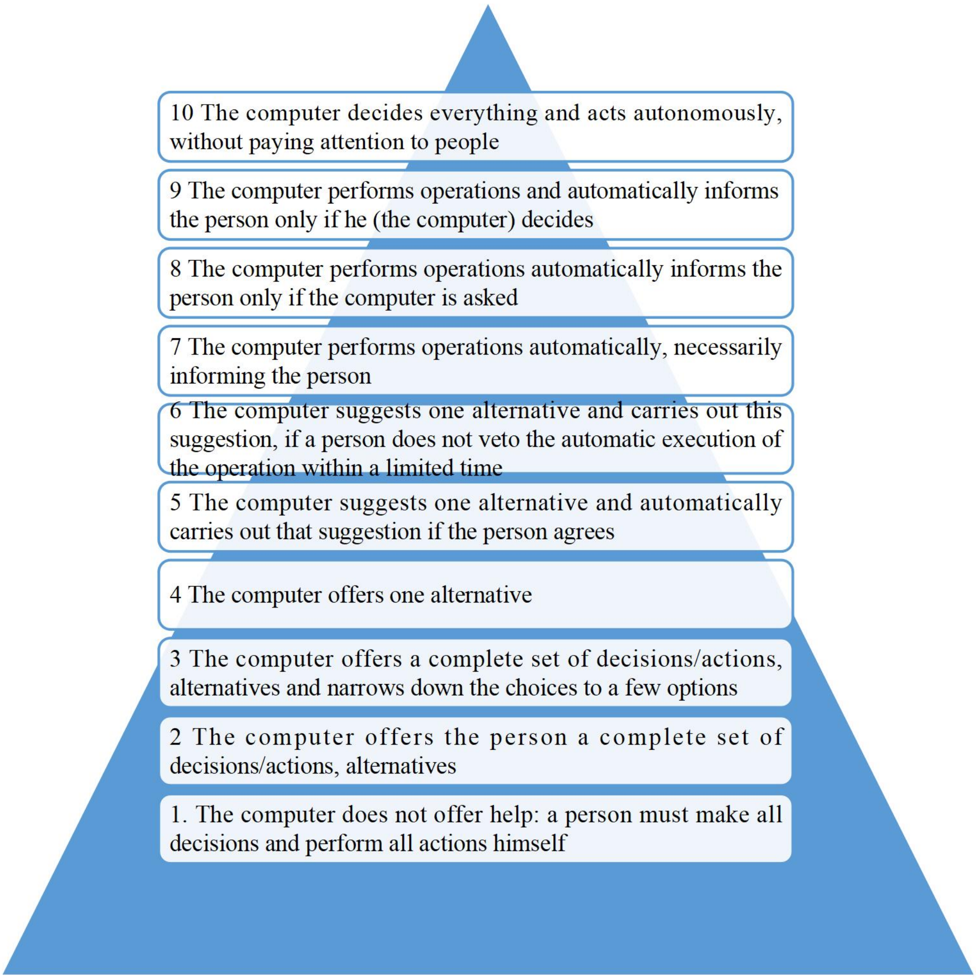



Fig. 4.27. Scale of automation levels

The considered processes (creation of a document and creation of a task) are repeatedly repeated during the entire pre-project stage. Let's find the total number of operations performed by members of the project team on one complete branch of the decision tree. We will also divide these operations into 2 categories - manual (LOA=6) - and find the percentage of content of each of the categories of operations at the R&D stage.

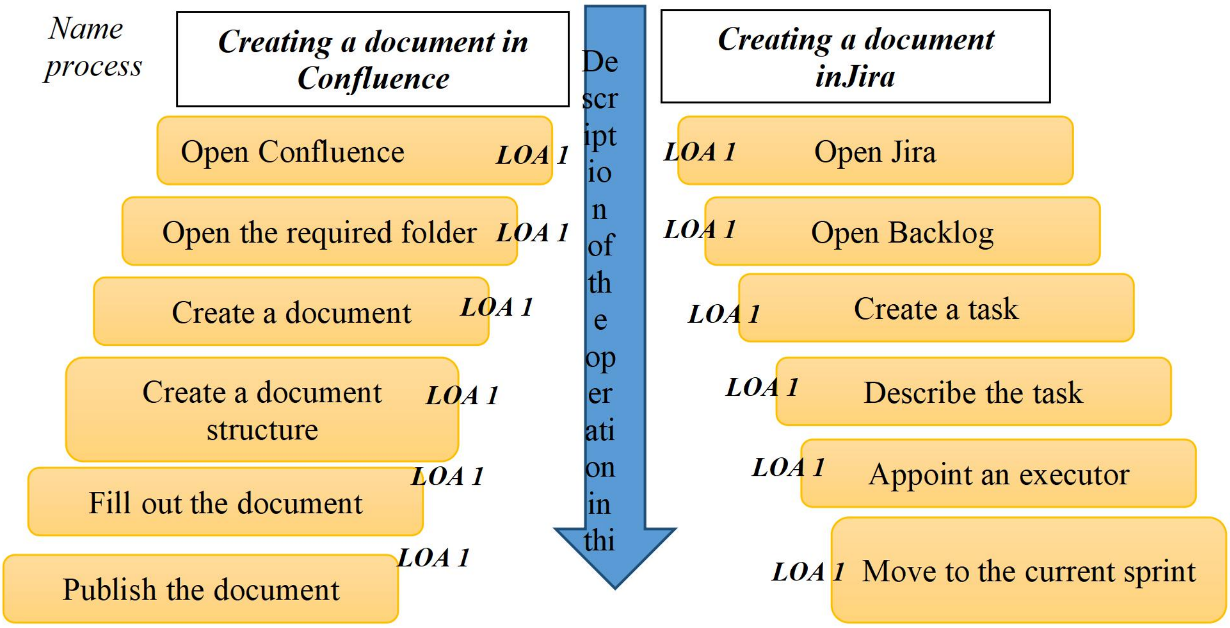



Table 4.28. The degree of automation of the processes of creating tasks and creating As Is documents.

Table 4.3. The degree of automation for the As Is process is on one complete branch of the decision tree

| | *The process of creating a task* | | *The process of creating a document* | |
|---|---|---|---|---|
| Type of operation | Manual operations | Automatic operations | Manual operations | Automatic operations |
| The number of operations in the problem | 6 | - | 6 | - |
| Number of tasks on one branch | 8 | -- | 6 | - |
| The total number of operations at the R&D stage for one branch | 48 | | 36 | - |
| The percentage of operations at the pre-project stage | 100% | - | 100% | - |

As can be seen from Table 4.3, the task creation and document creation processes are 100% manual. Let's build tables similar to Fig. 4.28. and Table 4.4., for the To Be model.

Table 4.4. The degree of automation of the processes of creating tasks and creating To Be documents

| | The name of the process | | | | | |
|---|---|---|---|---|---|---|
| | Creating a document | | | Create a task | | |
| Description of operations in this process | **Open Confluence** | **Open the desired folder** | **Create a document** | **Open Jira** | **Open Backlog** | **Create a task** |
| | **1** | **10** | **10** | **10** | **10** | **10** |
| | **Create a document structure** | **Fill out the document** | **Publish the document** | **Describe the task** | **Appoint an executor** | **Move to the current sprint** |
| | 10 | 1 | 1 | 10 | 1 | 10 |

Table 4.5. The degree of automation of the To Be process on one complete branch of the decision tree

| | ***The process of creating a task*** | | ***The process of creating a document*** | |
|---|---|---|---|---|
| Type of operation | Manual operations | Automatic operations | Manual operations | Automatic operations |
| The number of operations in the problem | 2 | 12 | 6 | 6 |
| Number of tasks on one branch | 16 | 8 | 10 | 10 |
| The total number of operations at the R&D stage for one branch | 16 | 96 | 30 | 30 |
| The percentage of operations at the pre-project stage | 14,3% | 85,7 | 50% | 50% |

Analysis of Tables 4.4 and 4.5 shows that from one branch of research, the degree of automation of task creation processes increased by 85.7%, and the degree of automation of the document creation process by 50%. An increase in the level of automation of processes also leads to an increase in some quality management indicators, among which one can indicate an improvement in the visual representation of decision cycles, the potential preservation of a larger amount of data about the created software solutions, and many others. The practical relevance and expediency of the developed model of the automated project management system at the Institute of Local Development is confirmed by the feedback of experts - the technical director and the executive director of the Institute of Local Development (appendices D). SWOT analysis was used to evaluate the effectiveness of the developed IPMS model. It made it possible to identify the advantages and disadvantages of the system, which should be paid attention to in the further development of the software product. Potential areas of development and methods of software product monetization were also identified. The last task of the SWOT analysis was the identification of possible risks associated with the development of the modeled component.

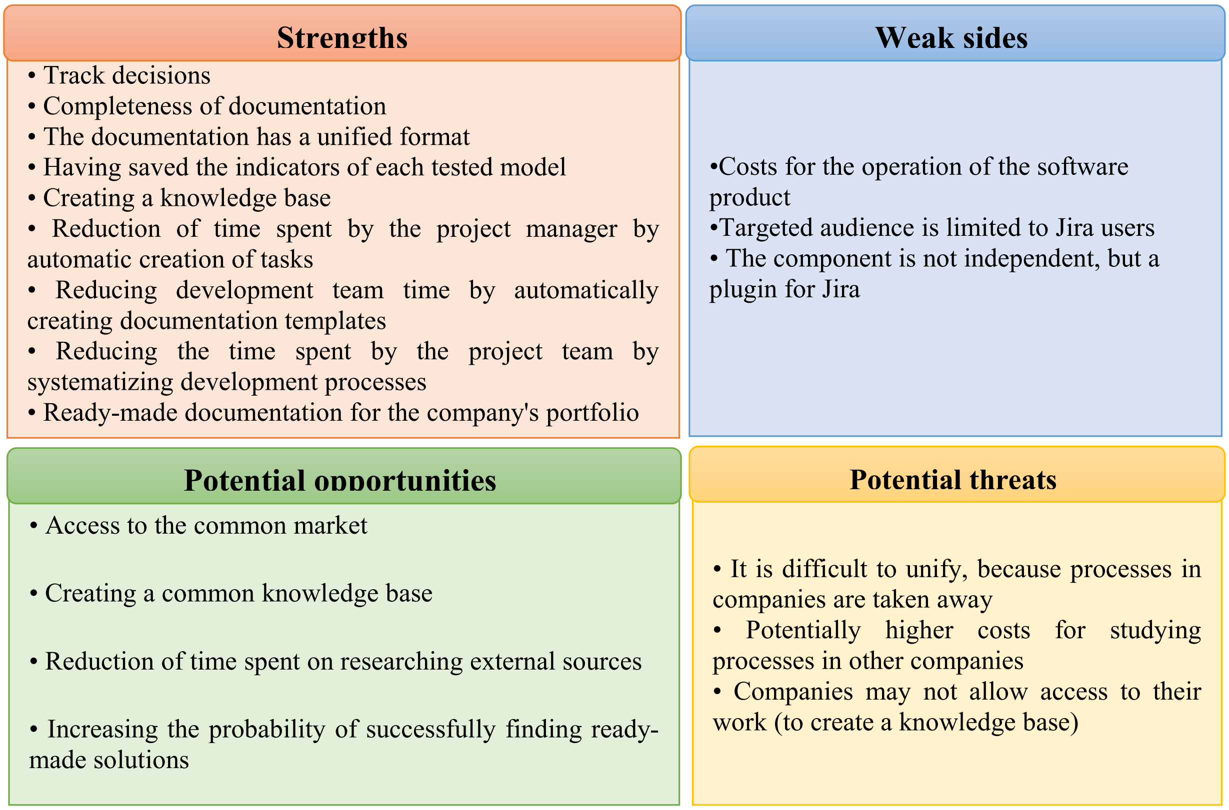



Fig. 4.29. SWOT analysis of SUM projects

The SWOT analysis showed that the proposed system has a significant number of strengths and advantages over the old management model. The To Be model offers such improvements as: streamlining document flow, increasing the degree of visual and functional comfort of the work of all project participants, improving communication between them, etc. Weaknesses are mainly related to the "binding" to the Jira system and their dependence in this way on the pricing policy of the Atlassian company and on how stable the functionality of the Atlassian products will be. Also, the narrowing of the target audience can be attributed to the weaknesses of the proposed plugin, since not all Data Science companies use Jira and Confluence.

### 4.5. Approbation of the software component "Choosing a project management approach"

This component implements an analysis model of existing projects, correlates parameters and their values, and plots project profiles on a chart. To do this, it is necessary to assemble another expert group, in which, in addition to already existing specialists, the following should be included:

• Project manager from the customer's side;

• Expected users of this feature of the information platform for choosing and structuring the approach to project management;

• Supporters of the product from the customer's side.

Based on the existing knowledge of the tasks of the employees from the customer's side, as well as the experience of the development team specialists, a project profile is created within the available parameters and plotted on the project parameters diagram. As an example for the analysis of the choice of development methodology, two actual projects were chosen:

- Project "Impulse" - implementation of a gas cleaning system of the paint shop, with horizontal or vertical arrangement of filter elements and constant impulse regeneration. The system cleans the filter elements automatically, without stopping, with the help of a pneumatic cleaning system (with the setting of a timer or when the specified resistance is reached). Fine air purification from dust particles less than 1 μm in size is provided, complying with Ukrainian and European standards of environmental safety (Order of the Ministry of Nature of Ukraine No. 309 "On approval of standards for maximum permissible emissions of pollutants from stationary sources", Directive of the European Parliament and Council 2010//EC "On industrial pollution (integrated prevention and control of pollution)").

- "Incom-Ukraine" project - development of an automated gas cleaning system for a cement plant. This system consists of a dust collector of the cyclone type, which allows you to capture low- and medium-adherent dust. The peculiarity of the system is the modernized design of the guiding devices with profiled vanes for shock-free entry. The range of application of the system is cleaning of flue gases and aspiration air with a temperature of up to 400°C from cement, dolomite, ash, limestone dust, for various technological processes.

These projects were chosen for several reasons:

1. at the time of approbation of the model, both projects were at the initial stage and it was necessary to determine the approach to their implementation;

2. both projects are significantly different from each other;

3. personal participation of the author in both projects is implied, which allows to be involved in the process of testing the model's capabilities.

The "Impulse" project is aimed at increasing the efficiency of business operations in accordance with the tasks of the Planning and Economic Management and the Marketing Department, as well as at automating the generation of reports used by various areas of the company

Table 4.6. Business tasks of the "Impulse" project.

| *Business task* | *The effect of the implementation of a business task* |
|---|---|
| Reduction of labor costs when reporting; | Reduction of labor costs when reporting |
| Increasing the efficiency of management decision-making; | Increasing the efficiency of management decision-making<br>Increasing the efficiency of management decision-making<br>The possibility of using statistical methods and data forecasting tools built into the BI platform at the next stage of development. |
| Improving the quality and reliability of data. | Increasing the reliability and convergence of various reporting indicators |

The project was received on a tender basis, this is the first cooperation with the customer, so both parties do not know what to expect from each other.

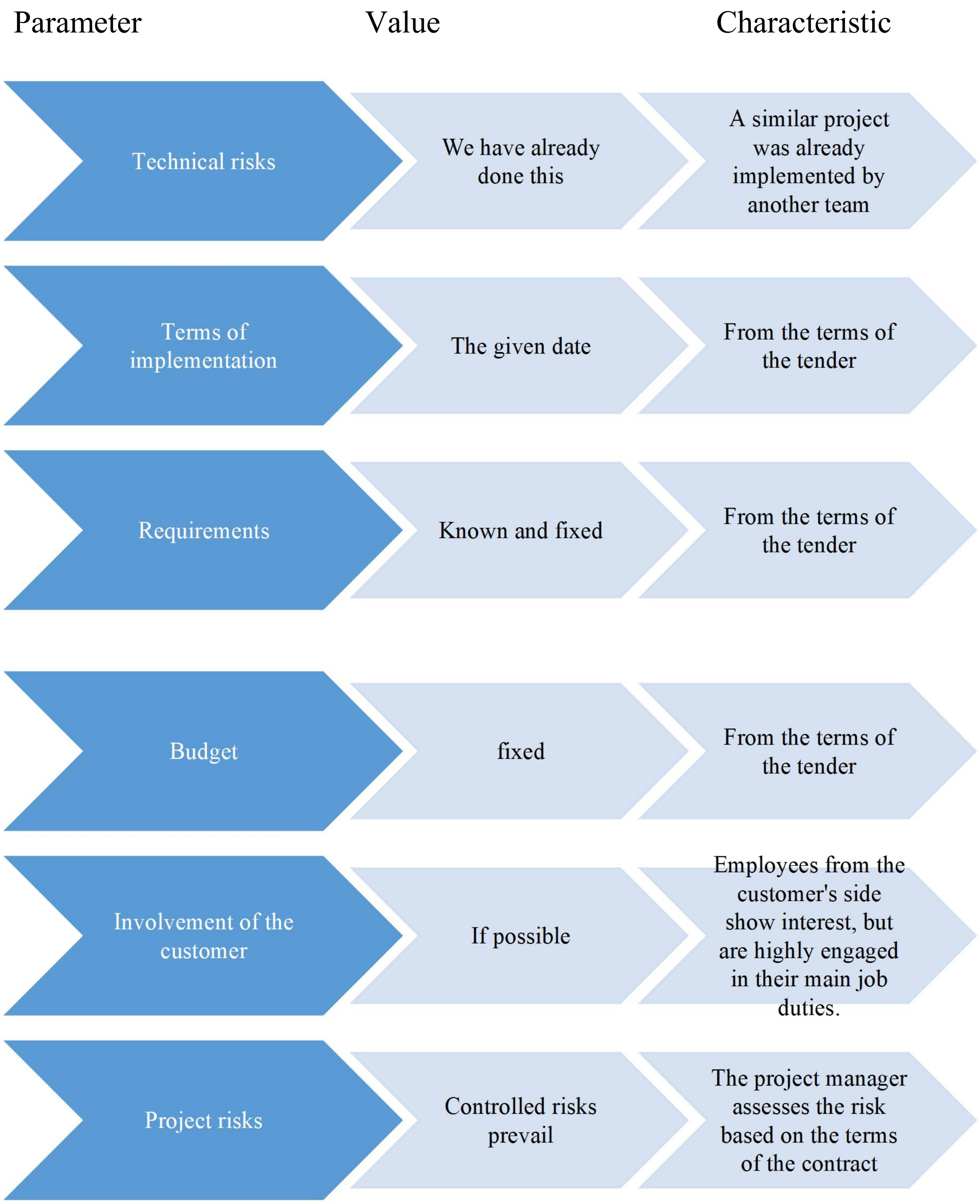



Fig. 4.30. Project parameters "Impulse"

"Incom-Ukraine" project, the goal of the project is the development and implementation of a gas cleaning system to ensure high-quality and operational air cleaning and obtain information on emission indicators for timely management decisions.

Table 4.7. Business tasks of the "Incom-Ukraine" project

| *Business task* | *The effect of the implementation of a business task* |
|---|---|
| Clarification of a set of key indicators necessary for timely management decisions. | Increasing the efficiency of management decision-making |
| Development of the graphic design of the System of visualization of indicators on mobile devices. | Reduction of labor costs when reporting |
| Development of a unified data model for storing information about indicators, development of a data warehouse, information cubes and reports. | Increasing the reliability and convergence of various reporting indicators |

Parameter Value Characteristic

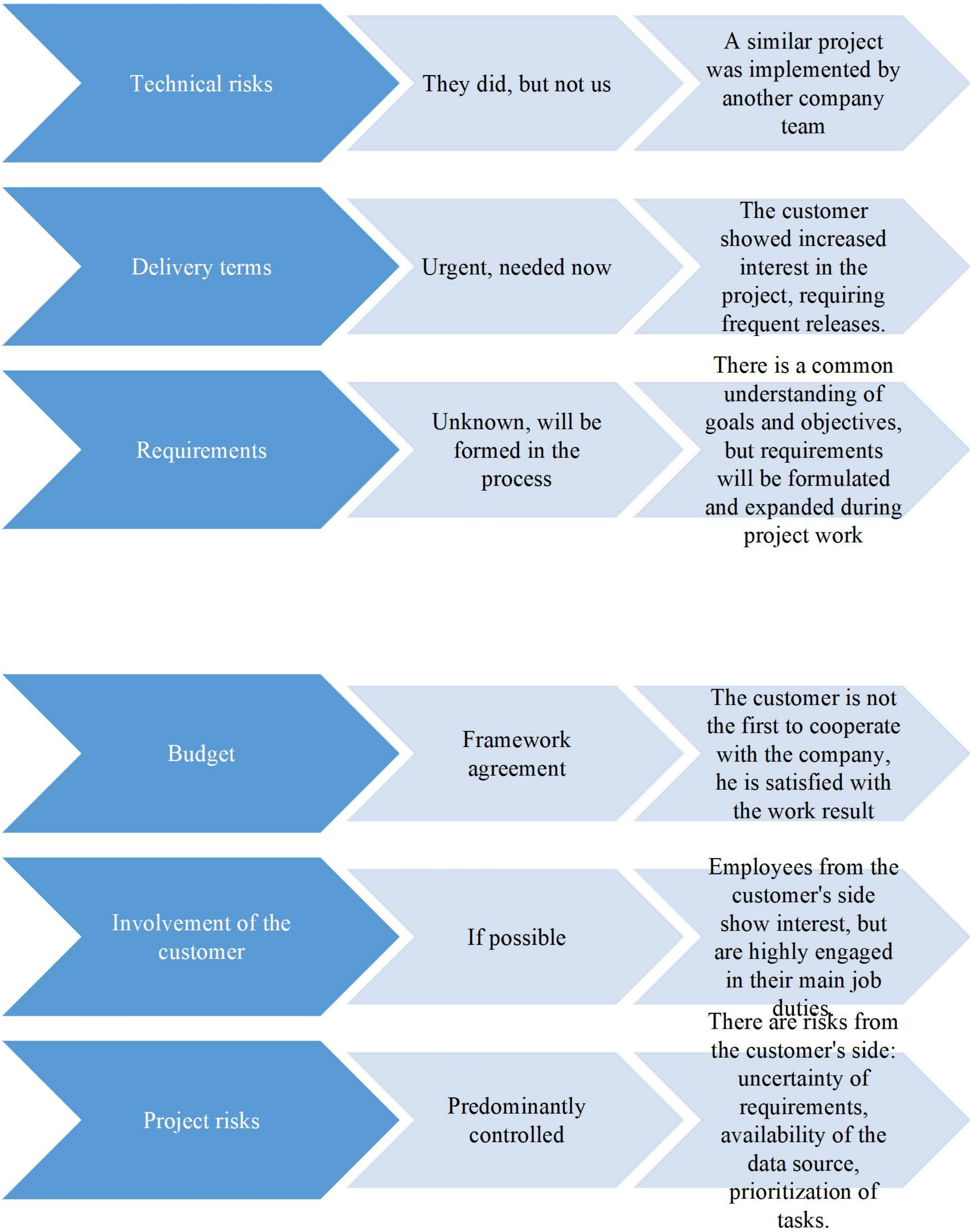



Fig. 4.31. Parameters of the "Incom-Ukraine" project

We transfer the data to the diagram of project parameters (Fig. 3-7)

| | |
|---|---|
| *Profile diagram of the "Impulse" project* | *Diagram of the profile of the "Incom-Ukraine" project* |

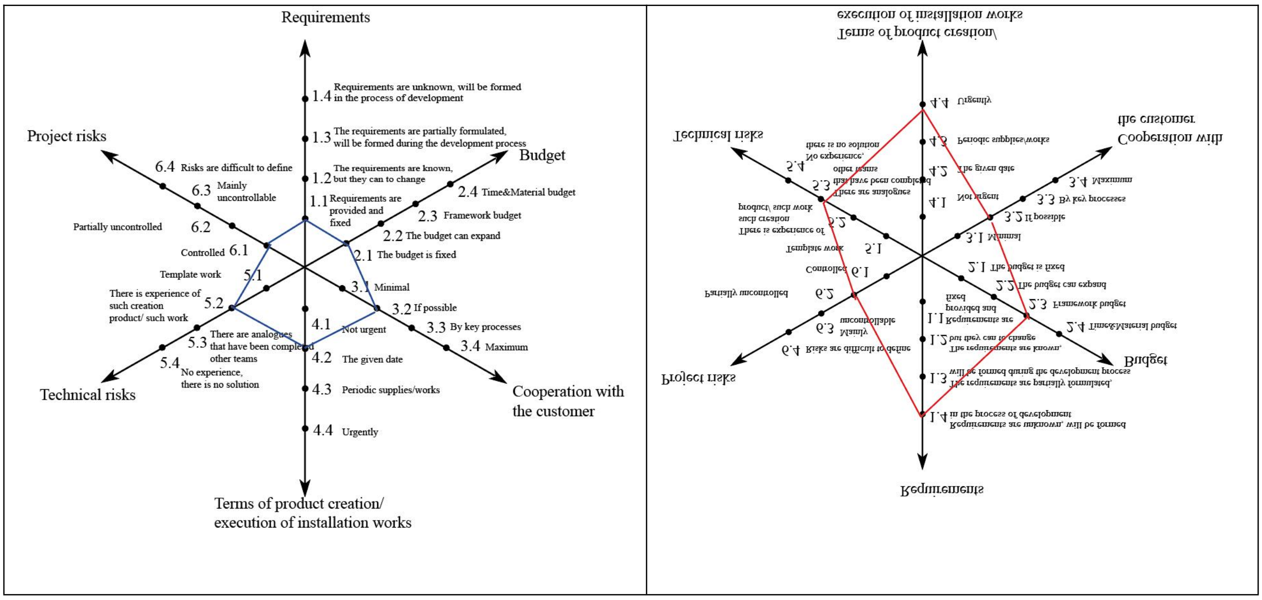



Fig. 4.32. Diagram of the profile of the project "Impuls" and "Incom-Ukraine"

When creating a model for choosing a software development methodology, two models were obtained:

• Model of methodology profiles on the diagram of project parameters;

• Model of project profiles on the project parameters diagram.

The next step was the unification of models and the analysis of whether the project profile falls into the profile of one or another methodology. If there are not many profiles of methodologies, it becomes possible to use a consolidated model of methodologies. In fig. 4.33. the final model of the selection of the development methodology for the "Impulse" project is presented.

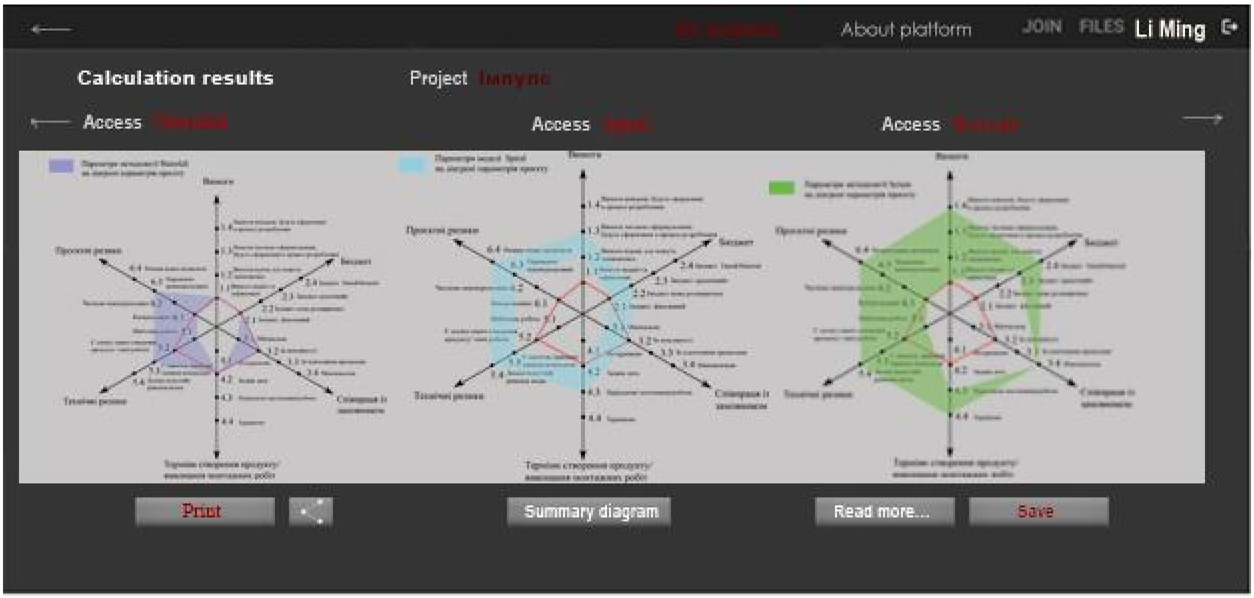



Fig. 4.33. "Choosing a development methodology for the Impulse project"

The model allows you to visually show the compliance of the parameters of the existing project with the parameters of one or another methodology. For example, the Waterfall model and methodology are well suited for Impulse. Based on the existing model, project managers can make decisions about the choice of these methodologies and defend the decision to senior management. On the example of this project, the cascade model was chosen because the customer had not previously worked with the company and was not familiar with the process of project work using the Kanban methodology. In addition, the tender fixed the requirements, terms and budget, controllable project risks prevailed - it made sense to use an easier-to-use cascade model.

In Fig. 4.34. the methodology selection model for the "Incom-Ukraine" project is presented.

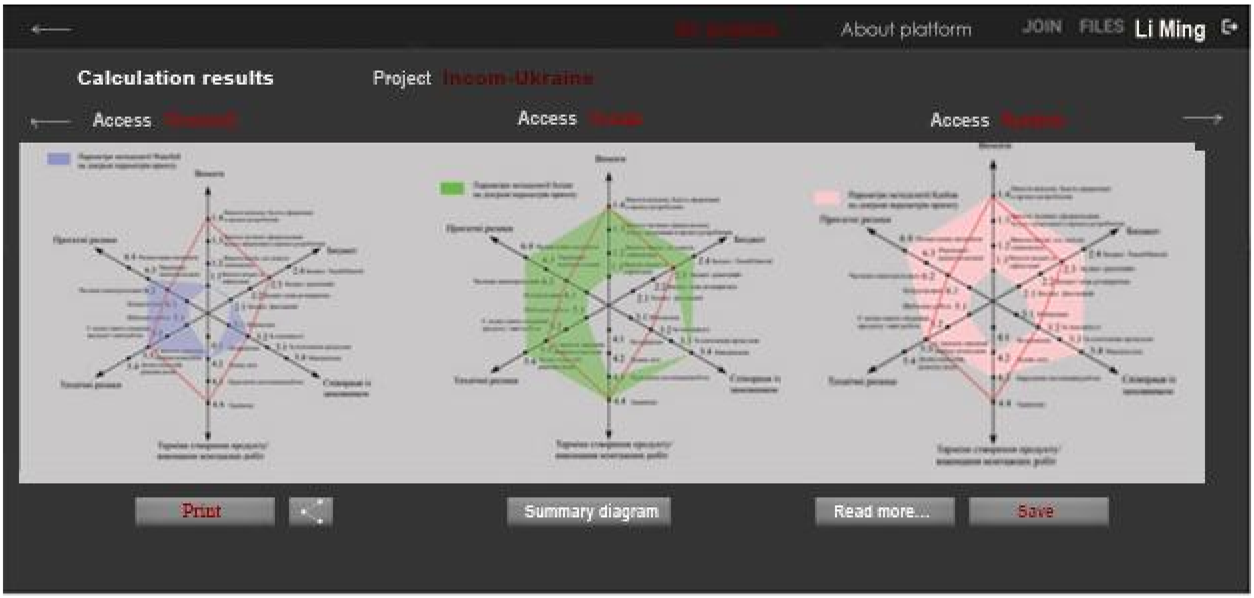



Fig. 4.34. A model for choosing a development methodology for the "Incom-Ukraine" project

According to the model, it can be seen that the "Incom-Ukraine" project has one high-risk parameter each when using the Scrum and Kanban methodologies. In the case of using Scrum, there is a risk of part-time employment of employees by the customer, which can significantly affect the project work process. When using Kanban, there is a risk of undersupplying updated versions to the customer, which does not meet his interests. After analyzing the model, the project manager together with the customer decided to use Kanban, because the risk of not providing the next prototype is less critical, compared to the risk of slowing down the development process or insufficient processing of requirements. If you wish, you can combine all the profiles of projects and methodologies on one diagram, but it is necessary to take into account their number and the convenience of such a representation. A summary model of software development methodology selection for the "Incom-Ukraine" and "Impulse" projects is presented in Fig. 4.35.

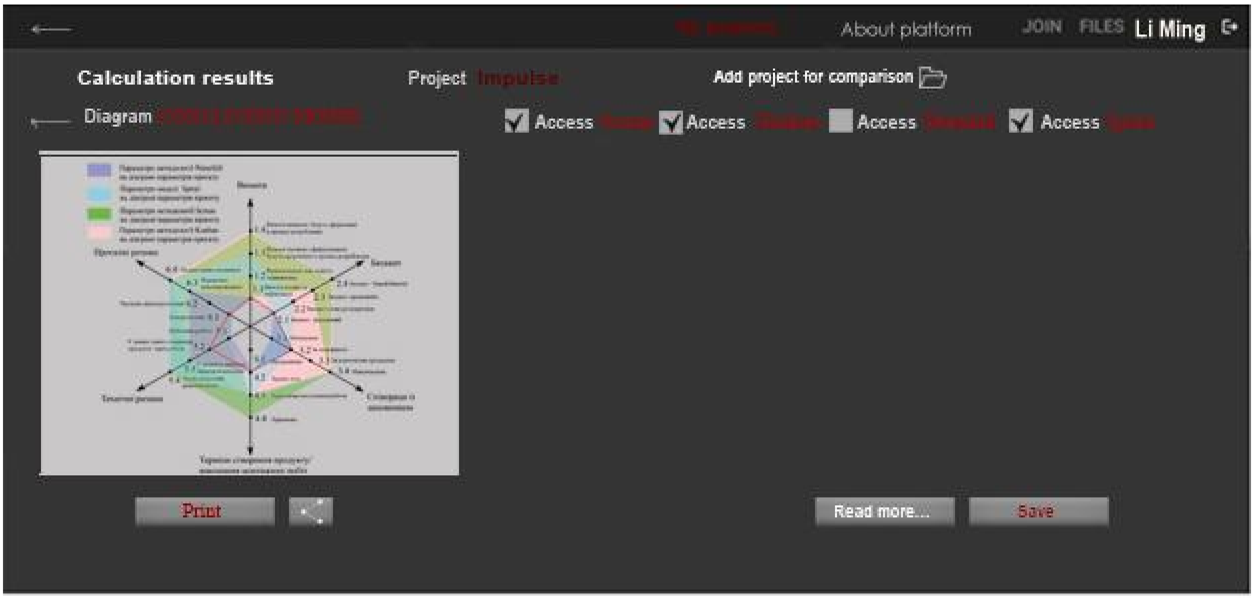



Fig. 4.35. Consolidated model of the "Impulse" project

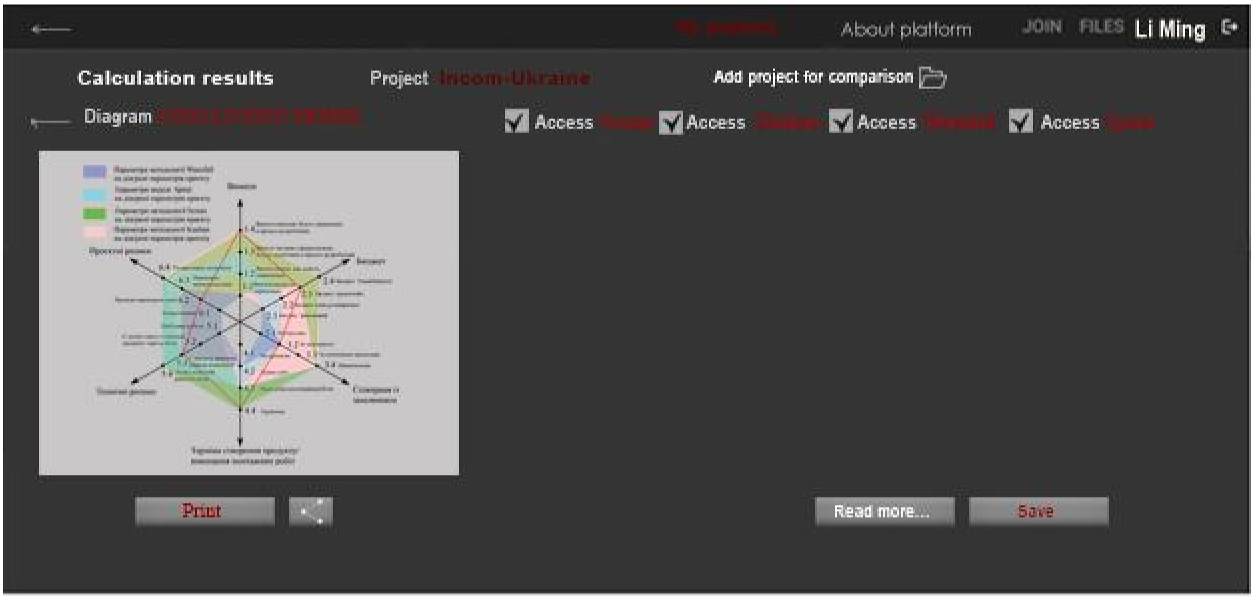



Fig. 4.36. Consolidated model of the "Incom-Ukraine" project

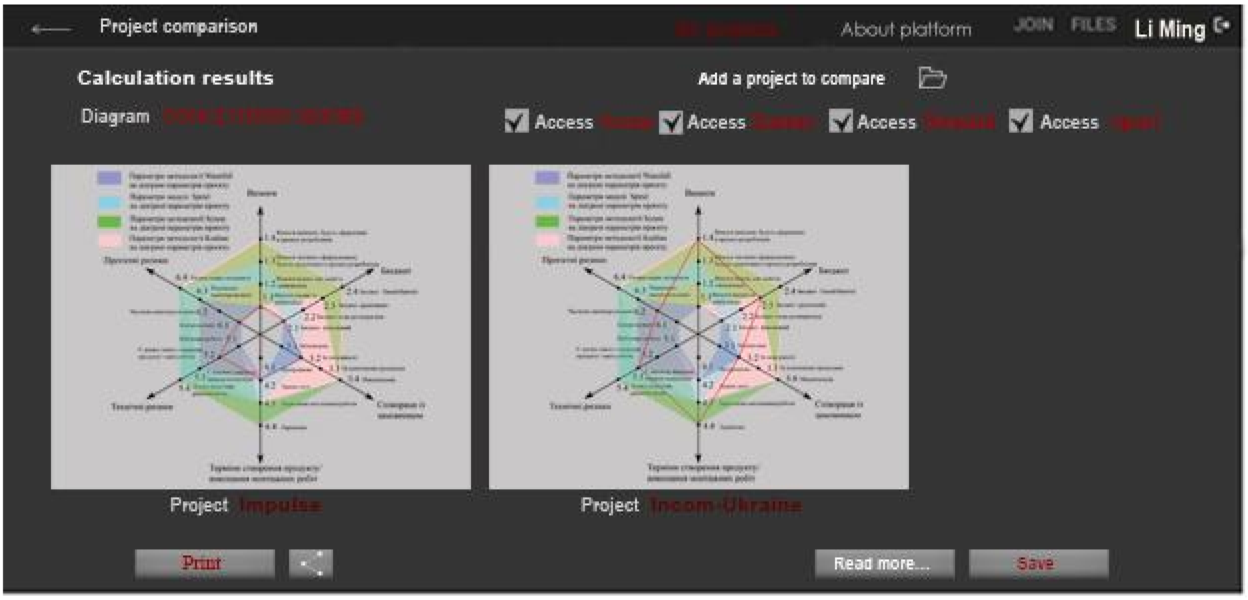



Fig. 4.37. Comparison of "Incom-Ukraine" and "Impulse" projects

In this way, the information platform for the selection and structuring of the project management approach was tested.

**Conclusions to the 4 section**

In this section, an information platform for choosing and structuring an approach to project management has been developed. The general characteristics and architecture of the information platform for choosing and structuring the approach to project management are proposed, the implementation of which allows to form an approach to the management of a certain project taking into account the specifics of this project and its environment. When solving this problem, great attention is paid to the principles and philosophy of Agile, which aggregates the components of the most common agile methodologies and project management approaches. The information platform for choosing and structuring the approach to project management was designed and implemented as a web application "in the language of the Russian People's Republic. The platform provides a client-server architecture. The proposed platform consists of four components, which are based on the methods and models described in the 3rd chapter. For the software implementation of the platform, in this section, diagrams of options for using the system are developed, which reflect the high-level requirements for the information system as a whole. The section presents a graphic description of business processes that are automated by an information platform for choosing and structuring an approach to project management. The functionality of the subsystems for the platform user is presented in the screenshots.

The characteristics of the "Choosing a project management approach" component of the platform for choosing and structuring a project management approach are described in detail. The components are based on a model in the form that is integrated into the proposed information platform for choosing and structuring an approach to project management, the synergy of which increases the effectiveness of project management, and therefore, project implementation in general. The proposed system is based on software products based on the Agile methodology and currently widely used: Jira and Confluence.

The proposed component is a separate functional unit that integrates into the Jira and Confluence system and interacts with them using their functionality.

Conducted in the second and third sections of the study of methods, tools and existing information systems of project management, a detailed analysis of the activities of the project team members at the pre-project stage allowed to develop the information components of the information platform for the selection and structuring of the approach to project management. The As Is model of the existing management processes of similar projects made it possible to develop the To Be model of the international project management system, which takes into account the management deficiencies present in the project, for example, unregulated document flow and the presence of routine actions. The To Be model offers to adapt the company's existing Jira and Confluence project management system by building a pre-project stage management plugin into it. At the same time (within the established limits), the structure, functions and organization of information flows of the existing system are slightly changed. The To Be model is fully described by four diagrams: Pre-Project Project Management Plug-in Ecosystem Diagram Pre-Project Project Management To Be Pre-Project Management Business Process Diagram Pre-Project Project Management To Be Pre-Project

Management Precedent Diagram ER Diagram "To Be" model of project management at the pre-project stage.

As a result of the practical application of the proposed platform for choosing a project management approach, the following results were obtained on the example of the "Impuls" and "Incom-Ukraine" projects:

1. Using the proposed model allows you to significantly reduce the risk of choosing a development methodology unsuitable for the project. In turn, the choice of an inappropriate development methodology entails, at a minimum, the risk of disruption of project deadlines, and at the maximum the risk of closing the project due to increased financial requirements or non-fulfillment of obligations to the customer. For example, due to the fact that the process of interaction with the customer was expected to be built in one way, but it turned out that the employees from the customer side were not sufficiently involved or loaded with the main work, were not found in the requirements for the software, the developers had to make significant changes to the already translated into experimental - industrial exploitation of the product. The price of correcting such an error is very high both financially and in terms of resource consumption, but this situation could have been avoided if a tool was used for the selection of the development methodology that allows for the analysis of such risks. In addition, the choice of an inappropriate methodology can significantly complicate and slow down the processes of work on the project. So, a non-initiative manager can decide to work on a project using a well-known and easy-to-use cascade model. With the direct contact of the team with the customer, it turns out that the customer is focused on the result, ready to interact with the development team to achieve the best result. In such a situation, opportunities for joint work and methods of team interaction are very limited, the work process is complicated by documentation. The chosen methodology does not satisfy either the customer or the development team, the development process could be organized more efficiently and profitably for both parties.

2. The use of the model allows taking into account the opinions of the customer and competent specialists when deciding on the choice of development methodology. secondly, responsibility for a wrong decision will be borne collectively by all participants, not just the performer.

Collective responsibility allows you to minimize the risk of making the wrong decision, but even if the risk is realized, all persons who participated in the creation of the model are responsible for it, not only the project manager or the executor. Thus, on the example of the use of the platform in the management of the "Impulse" and "Incom-Ukraine" projects, it was found that the use of the platform contributes to:

• Increasing the efficiency of the construction of the development process;

• Reduction of risks of non-fulfillment of development deadlines;

• Increasing the transparency of the development methodology selection process, which leads to increased customer loyalty; the case of the methodology, which can become a source of a complex of additional risks and problems;

• Reducing the risk of unplanned financial expenses;

• Reduction of the risk of premature closure of the project due to the customer's dissatisfaction with the contractor's work.

# GENERAL CONCLUSIONS

1. The expediency of using AGILE information technology for the needs of developing a multi-component information educational and scientific platform, which should ensure successful structuring, administrative support and implementation of international projects in conditions of insufficient certainty, is substantiated.

2. An analysis of existing theoretical and practical research on the modeling of organizational and information technology methods and models in project management was carried out. The analysis proved significant scientific and analytical advantages of using flexible management of international educational and scientific projects as a progressive and iterative methodological platform. This platform is suitable for use in such conditions of the project microenvironment, when at the initiation of the project there is no proper certainty about what the life cycle of the project and its final product should be.

3. As part of the study of the main approaches and models of the application of flexible modeling of the management of international projects with clear goals and transparency, it was found that the AGILE methodological platform allows in the circumstances of insufficient certainty and improperly prepared communicative space (at the beginning of the project cycle) to cover the content of large-scale and complex projects, further structure them step by step, make adjustments and work to ensure an increase in the level of satisfaction with the project product among stakeholders and project team members.

4. For the needs of information and communication support, office and analytical preparation and implementation of international projects on the basis of AGILE, a unique scientific and methodological foundation has been built, the components of which are:

- classification and analytical approach and grouping, models and methods of evaluation of project selection;

- method of expert evaluations and a comprehensive approach - to determine comprehensive indicators of the choice of information and communication technologies;

- theory of management decision-making, theory of simulation experiment, and methods of mathematical statistics;

- methods of multi-criteria assessment of managerial decisions in conditions of fuzzy logic;

- application of the basic principles of construction of computer numerical methods;

- simple iteration methods for solving systems of nonlinear equations.

Such a structure of the methodological basis of the research made it possible to build a successful criterion-parametric basis for the implementation of a flexible, AGILE-adapted approach in the administration of international projects. As part of the specified basis, the knowledge management system integrates two types of information: material - this is data and knowledge that are reflected in documents, letters, audio and video recordings, etc. For example, the rules of participation in the AM program, information from university websites, signed educational agreements; hidden knowledge is personal knowledge inextricably linked to individual experience. For example, the experience of participants who returned after AM, the experience of AM organizers from other universities.

5. An important advantage of the methodical approach introduced in the work of involving the Agile methodology in the management of international educational and scientific projects is the use of a work cycle visualization tool to display the status of project tasks. For office and analytical service of joint projects between NU named after T. Shevchenko, Astana IT University, numerous Ukrainian research institutions and the Yanchen Polytechnic Institute have used the Odoo software and analytical complex. The Odoo complex is a set of open source software that covers all the needs of a company: CRM, e-commerce, accounting, warehouse, point of sale, project management and much more. What makes Odoo unique is its ease of use and full integration.

6. Based on the approaches of hybrid project management, AGILE methodology and the scientific and methodological basis introduced in the work, an informational and communicative software model (...) of international project administration with a unique information architecture was developed and adapted. The uniqueness of this architecture is determined by its clear commitment to the application of the "spiral" model in project management. In contrast to the linear approach, where the beginning of a new stage of the project is based on the completion of the previous stage, the spiral model reflects an iterative approach, in which each station (phase) of the project is performed (adjusted) several times. This allows you to guarantee that the intermediate and final products of the project will adequately satisfy the main stakeholders and customers of the project. The model is built on the concept of a risk assessment tool (Risk Assessment Framework) for an approach to enterprise-level service planning (Enterprise Services Planning). The model uses a special digital coordinate system, the axes of which are project parameters. All axes are built from a single origin point. Project characteristics are applied to the axis, the number of axes depends on the project parameters, which are advisable to use. The characteristics are located on the axes in such a way that the closer to the point of origin of coordinates - the lower the risks associated with such a parameter, the further from the point of origin of coordinates - the higher the risks. For each parameter, it is necessary to select the characteristics that it can have and that affect the project activity process to the greatest extent. International experts and the customer determine and agree on the number and characteristics of the parameters, which are subsequently plotted on the diagram. Next, a block is formed (from existing knowledge and accumulated experience of applying this methodology) by the method of decomposing each methodology according to available parameters and selecting characteristics that reflect the application of the methodology in a more effective way.

7. As the defining scientific and applied results of the work, the architecture, analytical hardware and software tools for the functioning of the information platform for the selection and structuring of the approach to the

management of international educational-scientific techno-projects were developed. An important aspect in the development of the method is that solving the task is complicated by the vagueness of existing recommendations regarding the applicability of different management approaches in different cases and conditions, in particular for the development of projects that do not relate to software development and have an international direction. It is proposed to solve this task by using questionnaires. Questionnaires reflect information about the project, communications, team and all possible risks in a structured way. An important condition is that the questionnaires should be filled out not only by the project manager, but also by the involved experts, specifically in our case, experts on the development of gas cleaning devices for ventilation systems. Among the potential alternatives for implementing project approaches for a specific project, the following 4 approaches are distinguished: cascade Waterfall Methodology (according to RMVOK) (M_1), Spiral model (M_2), Scrum methodology (M_3), and Kanban (M_4). The feasibility of using each of the alternatives for the environmental conditions of a certain project is considered formally, using the mathematical apparatus of fuzzy sets. Using a linear metric, the total weighted Euclidean distances between project estimates and each approach are calculated. In particular, for the conditions of the researched international techno-project "Development of gas cleaning devices for ventilation systems", the Scrum methodology is best suited for project management with the given initial conditions. Next, as part of the adjustment of the content and leading characteristics of the project, the target functions are normalized for the purpose of their further comparison.

8. The problem of single-criterion optimization of each objective function is solved, in particular, the defuzzification procedure is carried out to get rid of vagueness. A component platform that manages projects within the framework of the Scrum technological system is used. Therefore, it is important not only to systematically and logically determine the architectural and technological aspects of the quality of project implementation, but also to create

specific recommendations for measures to improve quality in the current conditions of the technological processes of the project. The method of creating recommendations for ensuring product quality is aimed at ensuring the specified efficiency, by creating a software component in the project management platform, which in its essence is the correct localization of the method of structuring quality functions (SFC-method or, in the English abbreviation Quality Function Deployment: QFD- method) for the purpose of implementing a project on the development of gas cleaning equipment within the framework of the Scrum technological system.

Scientific-methodical and information-analytical research results are integrated into a complex of applied programs. The specified complex of programs "IPPM - international platform for project management" allowed to test the proposed models and methods of the international educational-scientific and information-technical project management system as components of the information platform and its application. The complex of programs integrates the following software subsystems and modules: software tools: - local web server Windows OpenServer-5.2.8; - Visual Studio Code source code integrator; - MySQ database management system. Built into the complex, the Information platform provides for a client-server architecture. A system use case diagram that reflects the high-level requirements for the information system as a whole. The "structuring of project management methodology components" component of the project management approach selection and structuring platform allows you to create and evaluate alternative specialized approaches to project management, choose the best one from the point of view of cost and management effort, as well as the risks accompanying the application of the approach. This component implements the calculations provided by the method of selecting and structuring the approach to project management. Implementation of the theoretical and applied results of the dissertation work in the practice of administration of international and educational-scientific projects based on the AGILE methodology proved that the scientific-applied approach and set of programs introduced for the researched projects allows for successful adaptation to the complex-structured, digitally-adapted environment of the projects, promotes significant increase in transparency and effectiveness of communications between interested parties (contractors, customers, consumers). The results of the research in aggregate use significantly reduce project risks, allowing them to be minimized at the initial stages of the project cycle. The joint participation of all stakeholders at each stage of the project cycle ensures that the project product meets the expectations of the end user..

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# APPENDIX A. ACTS OF IMPLEMENTATION

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# ACT OF IMPLEMENTATION

The act of implementing the results of the dissertation work of PhD student **Li Ming**

MODELS, METHODS AND INFORMATION TECHNOLOGY FOR CHOOSING THE MANAGEMENT METHODOLOGY OF INTERNATIONAL EDUCATIONAL PROJECTS

**THE ACT WAS DRAWN UP BY A DIRECTOR OF ZHEJIANG ACME INFORMATION TECHNOLOGY CO. LTD JIYONG YAN**

ZHEJIANG ACME INFORMATION TECHNOLOGY CO. LTD considered in detail the results of **Li Ming** dissertation research, «**Models, methods and information technology for choosing the management methodology of international educational projects**» and established:
Li Ming actively cooperated with our company to implement his methods and models on the dissertation research topic.

1. The commission believes that Li Ming's dissertation on Models, methods, and information technology for choosing the management methodology of international educational projects has a strong practical interest in the management of international educational projects based on vague ideas about the applicability of existing standards, guidelines, and project management methodologies.

2. The work developed a model and methods that allow choosing the best approach to international project management from such popular approaches as the RMVOK guide, IS021500 standard, PRINCE2 methodology, SWEBOK guide, Scrum, XP, and Kanban methodologies. Several parameters of the project and its environment, which affect the choice of the approach, are determined. For information and communication support, office and analytical preparation, and implementation of international projects based on AGILE, the author has built a unique scientific and methodological basis, namely the classification and analytical approach and grouping, models, and methods of evaluating project selection.

3. As the defining scientific and applied results of the work, the author developed the architecture, analytical hardware, and software tools for the functioning of the information platform for the selection and structuring of the approach to the management of international educational and scientific techno-projects. An essential aspect in the development of the method is that solving the task is complicated by the vagueness of existing recommendations regarding the applicability of different management approaches in different cases and conditions, particularly for developing projects that do not relate to software development and have an international direction.

4. The introduction of theoretical and applied results into the practice of administration of international and educational-scientific projects proved that the scientific-applied approach and set of programs introduced for the researched projects allow for successful adaptation to the complex-structured, digitally-adapted project environment contributes to a significant increase in transparency and effectiveness communications between interested parties (contractors, customers, consumers).

**The decision of the commission:**

The positive results of the implementation of results of Li Ming's scientific activity on the topic "Models, methods, and information technology for choosing the management methodology of international educational projects" testify to the practical value of his scientific work, his professional maturity, which, according to the company's management, corresponds to the level scientific degree of Doctor of Philosophy in specialty 122 Computer Sciences.

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11.05.2023

## 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. **Ming, Li.** (2020). Integrated Platforms for Managing a Pre-Owned Project. Management of development of complex systems, 41, 127 – 132, dx.doi.org\10.32347/2412-9933.2020.41.127-132 http://urss.knuba.edu.ua/files/zbirnyk-41/19.pdf

2. **Li Ming.** (2019). Management of competitiveness of foreign university in chinese field of education. Management of development of complex systems, 37, 116 – 120, dx.doi.org\10.6084/m9.figshare.9783122. dx.doi.org\10.6084/m9.figshare.9783122. http://urss.knuba.edu.ua/files/zbirnyk-37/20.pdf

3. **Lee, Min.** (2022). A model for the selection of the international project management methodology based on fuzzymultiple analysis. Management of Development of Complex Systems, 51, 20–30, dx.doi.org\10.32347/2412-9933.2022.51.20-30. http://urss.knuba.edu.ua/files/zbirnyk-51/20-30.pdf

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5. **Li Ming.** (2019). Application of the flexible (Agile) methodology for the implementation of international joint scientific projects. Management of development of complex systems, 38, 103 – 110. https://doi.org/10.6084/m9.figshare.9788555.v1


### Articles in professional publications of Ukraine

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

1. **Li Ming. (**2020). Application of agile methodology for the implementation of international joint research projects. Science Journal Innovation Technologies Transfer. 15-23. 10.36381/iamsti.4.2020.15-23.

**Approbation works**

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2. **Li Ming.** (2019). Competitiveness of foreign university in Chinese education process. "Management of projects in the development of society", 36-37.
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4. **Li Ming.** (2020). Інтегрована платформи для управління науковим проектом. Seventh international scientific-practical conference «Management of the development of technologies» Topic: "Information technology development of educational content» Kyiv, 25 – 26 March 2020, 137-138.