UZHHOROD NATIONAL UNIVERSITY

EVALUATION OF START-UP PROJECTS IN CONDITIONS OF RISK AND UNCERTAINTY

Scientific monograph

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Definition of a scientific monograph:

The scientific monograph is devoted to the development of a methodology for evaluating start-up projects in conditions of risk and uncertainty, based on a combination of expert experience and various factors for evaluating start-up projects using fuzzy logic, fuzzy sets, and neural fuzzy networks. The scientific monograph develops and tested fuzzy and expert mathematical models that allow: quantify start-up projects and teams of their developers, assess the risks of start-up projects, assess the security risks of start-up projects, evaluate and select start-up projects for investor purposes, evaluate commercial projects of various origin and evaluate the rating of the crowdfunding platform.
For master students, graduate students, expert analysts in evaluating start-up projects, venture funds, business angels and crowdfunding platforms.

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INTRODUCTION

Start-ups are key drivers of the structural changes required for the economy and economic growth and for maintaining their innovative performance and competitiveness. They ensure the development of innovative products and services that will create new markets, or redefine and expand existing ones, creating a strong growth potential. Start-ups as the determinants of structural changes can change the way in which companies, sectors, and the public sector operate. The attention of the Government of Ukraine is on developing the Ukrainian start-up system while linking the education and research system with the business environment remains an important issue.

At the same time, new investment opportunities and support for such projects are emerging. As a consequence, new technological ideas that grow into real projects are possible, as a rule, under external financing. There are various options for financing start-up projects, but they all have one issue: finding and financing a successful project with minimal risks. To comprehensively assess start-ups and minimize their funding risks decision support systems must be in place.

To date, there is no comprehensive methodological approach to evaluating start-up projects to support decision-making on its funding. In this regard, there is an urgent need to adequately assess start-up projects in conditions of risk and uncertainty to improve the security of their financing.

The scientific and applied problem solved in the monograph is to develop a methodology for evaluating start-up projects in conditions of risk and uncertainty, based on a combination of expert experience and various factors for evaluating start-up projects using fuzzy logic, fuzzy sets and neural fuzzy networks.

The scientific monograph develops and tested fuzzy and expert mathematical models that allow: quantify start-up projects and teams of their developers, assess the risks of start-up projects, assess the security risks of start-up projects, evaluate and select start-up projects for investor purposes, evaluate commercial projects of various origin and evaluate the rating of the crowdfunding platform. The developed methods and models can be adjusted to different areas of implementation of start-up projects and different tools for their financing.

The scientific monograph consists of an introduction, three chapters, conclusions, and a list of sources used.

The first chapter considers the introduction to the evaluation of start-up projects, analysis of literature sources, and relevance of the issue, namely: quantitative evaluation of start-up projects, risk assessment of start-up projects, security risk assessment of start-up projects, evaluation, and selection of start-up projects according to investor goals.

The second chapter is devoted to the development of evaluation models for start-up projects. The following methods and models are proposed.

- Fuzzy model for quantitative assessment of start-up projects: the model of fuzzy evaluation of start-up projects is developed, the information neuro-fuzzy model of the derivation of a rating of teams of developers of start-up projects is developed, the model of reception of the quantitative aggregate initial estimation is offered and levels of safety of financing of start-up projects are formulated.
- A fuzzy model of risk assessment for start-up projects: developed a model of fuzzy risk assessment based on expert knowledge using linguistic variables, while revealing the vagueness of input data and deriving risk assessment with linguistic interpretation.
- The expert model for safety risks assessment of start-up projects implementation within the investment phase: the developed model, on the one hand, uses the quantitative estimates of the project on various indicators and on the basis of different models, and on the other hand, uses the experience, knowledge and expertise of project and security experts in the subject area. The model is based on the neuro-fuzzy network, enhances the accuracy and objectivity of the project evaluation within the investment phase of the project life cycle.

- Model of evaluation and selection of start-up projects by investor goals: developed a fuzzy mathematical model that allows to solve the problem of evaluating alternatives in relation to the goals and evaluation models. It will be a useful tool to justify and increase the security of investors' choice of alternative financing for a start-up project, using their own target needs.
- Fuzzy model of information technology evaluation of projects of different origins: a fuzzy evaluation model of commercial projects of different origins has been developed, which allows to determine the most promising ones when investing. This model increases the objectivity of the assessment, reveals the uncertainty in the input data, allows to adequately approach the consideration of projects, increasing the degree of validity of investment decisions.
- The model of crowdfunding platform rating estimation: a model for improving the safety of crowdfunding platforms have been developed, based on the elimination of well-known shortcomings of this type of investment. A model of a rating system of a crowdfunding platform has been created to reduce the risk of platform fraud. As a result, the developed model will increase the security of platforms, which will stimulate the promotion of modern business and the implementation of new technologies.

The third chapter presents the results of the evaluation of start-up projects on real data, namely: example of the security of the financing of the environmental start-up projects in air transport; an example of the risk assessment of environmental start-up projects in air transport; an example of the expert model for safety risks assessment of start-up projects implementation within the investment phase; an example of the model of evaluation and selection of start-up projects by investor goals.

The developed models will become a useful tool for venture funds, business angels, or crowdfunding platforms for the development of innovative businesses.

1. INTRODUCTION TO EVALUATION ISSUES START-UP PROJECTS

1.1. QUANTITATIVE ASSESSMENT OF START-UP PROJECTS

The concept of a start-up is closely related to the modern innovation economy and is one of the forms of entrepreneurial activity.

A “start-up” is a new company (perhaps not yet officially registered but in the process of being registered) whose business based on innovative technologies that have not entered the market or have just started to enter it and need to attract external resources.

The term “start-up” is especially often used in relation to companies working in the field of information technology, however, today this concept is more general and extends to other areas of activity.

The innovations on which start-ups build their business can be both global (i.e. be innovated worldwide) and local (i.e. be innovated in a particular country, market or industry, but not be innovative in others).

The main difference of the start-up is that due to the peculiarities of the market, the company expects rapid growth. Because of this, not every newly created company can be interpreted as a start-up.

It doesn't matter the field of activity, technology, method, or source of investment, the end product – growth is the basis and the main distinguishing feature, and everything related to the concept of "start-up" is somehow related to growth in the first place.

For rapid growth, a start-up must produce a product that is sure to be in demand in the global market.

Rapid growth is mainly due to two factors:

a) the production of what a large quantity wants,

b) the ability to serve all customers, regardless of distance, time, and other physical limitations.

The first condition means that the idea underlying the start-up must include mass sales. Of course, the degree of mass may vary, however, the format of a start-up is generally unsuitable for creating and promoting a highly specialized idea or product. Moreover, as will be shown later, the choice of both the source of financing and its form significantly depends on the mass market, on which the start-up relies.

The second condition stipulates that the product must be universal and include comprehensive physical logistics, the possibility of licensing on the spot or distribution to virtual markets and shops (via the Internet). Both conditions must be met simultaneously.

The secret of a start-up's success is simple to formulate, but extremely difficult to implement: when starting a start-up, think of something that did not exist before, because entering the global market, the key to success is the realization of an idea that no one thought before.

The difference between successful start-up founders is that they are able to answer very different questions: they demonstrate a specific combination of technological literacy and skills with the ability to apply this literacy in a timely and appropriate manner to solve a wide range of tasks. Yesterday's "bad" idea may turn out to be brilliant today simply because the industry or business is changing too fast, and with them change and needs and new problems arise.

Today, the importance of the tasks in which compromise decisions have to be made in the process of researching complex social objects has increased to a great extent, in the case of fuzzy or incomplete information [1]. The sustainable economic growth and competitiveness of the economy are impossible without innovative development. The innovative development is linked to the activities of start-ups, which represent business initiatives with high growth and innovation potential. Their role, in addition to long-term support for smart and inclusive economic growth, should also attract foreign investments. From a procedural point of view, start-ups contribute to the development of sectors with high added value, to the creation of regional and global competitiveness, as well as to the creation of employment of qualified labour force in any country [2]. Each country tries to establish the most favorable legislative and regulatory environment by creating an appropriate ecosystem, as well as adequate financial schemes for supporting, in particular, the critical phases of start-ups [3]. It is also important to provide access to non-financial tools. The issue of start-up financing is a strategic subject to permanent discussions in both professional and scientific circles. The contribution in the monograph reflects on these facts and solves the problem of looking for methods to create optimal decision-making mechanisms in the financing process of start-ups with the aim of ensuring their financing security. There are some funding support models at present, the pressures for innovative development and the exploitation of the country's innovation potential that create new forms, but a deeper analysis of funding processes with complementary risk or safety assessments are absent so far [4–6]. The main problem is their considerable methodological difficulty and dependence on expert evaluations. For this reason, mostly standard evaluation processes use the economic indicators that do not capture many non-financial, so-called soft, qualitative aspects of the riskiness of financing processes, and their contribution to decision-making mechanisms are thus very limited. The presented models in the monograph declare the application possibilities of solving these economic problems and offer space for subsequent research focused on its usability in several areas of start-up development, in sectors and processes differentiated. New financial schemes will also require the availability of evaluation processes where the financial process efficiency and risk assessment at all stages will be compared which, in turn, may encourage the emergence and development of new hybrid forms of funding and new support programs.

Every day around the world, there are new start-up ideas that need to be improved: life, environment, safety, health, transport, education, etc., not only in the air transport industry. A large number of environmental start-ups are emerging: to eliminate the negative impact of aviation; to improve the work of airlines, airports; for “green services” working around the air transport industry; to improve the air traffic control; to create the new means of air transport.

For example, today, the number of companies in the aviation industry that are launching their own venture funds or crowdfunding platforms is constantly increasing. With the rapid development of technology, more and more large companies in the aviation industry believe that not all innovations begin inside. This confirms the creation of large aviation companies of subsidiary investment institutions to finance start-up projects in the air transport industry. In addition, there is a complex and urgent task to assess environmental start-up projects in air transport, the solution of which is of interest both to investment institutes and start-ups.

Start-ups have different stages of commercial development. The first stage is an output product on the market. After the successful completion of the first stage, the second stage comes–conquering the market as a competitive player in the industry. There is a large number of developed models [7-8] to estimate the amount of funding in the second stage since this stage is intended to finance an investment project that is on the market, and therefore quantitative estimates are used for the evaluation. Little attention is paid to the assessment of environmental start-ups at the stage of production of products for the market, especially in air transport. This raises the problem of the evaluation concept, since data on the unrealized project can only be expert-based, and therefore fuzzy.

The analysis of the sources on this subject has resulted in the conclusion where the authors have introduced a number of evaluating start-up simulation and expert models using economic quantitative indicators. For example, a method of the index value of start-up setting out [9], a method of assessment of a start-up value [10], a model of assessment of start-ups by qualitative features [11], and others. Therefore, the environmental start-ups in air transport, discussed in the works can apply the general ideas and benefits of using fuzzy logic in decision support systems. [12-13].

A fuzzy set is used in the issue of start-up project evaluation, raised in the work [14], but it does not focus on the analysis of environmental start-ups in the air transport sector. In the work [15], there is a cognitive model for evaluating start-ups, but used only as an auxiliary tool for decision-making by venture funds. Thus, the problems of evaluating environmental start-up projects in air transport, at the first stage of implementation with the use of the apparatus of fuzzy sets, did not rise.

In addition to evaluating the very start-up ideas for air transport systems, there is another feature. Investors are very cautious to finance such start-up projects because there is a problem of future customer confidence in the security of the implementation of such ideas in new air transport, either using technological innovations in existing transport or different systems and airport services or airlines. In such start-up projects, people can implement it to increase confidence because each project has a development team. The professionalism of developers of a start-up project depends on the success of its financing, as well as on increasing the credibility of consumers of the final product or technology. Therefore, people should develop, implement, and promote environmental start-up projects in air transport with professional experience and authority in the market of this industry.

In conclusion, after analyzing the sources for this topic, there are no special models for evaluating the developers of environmental start-up projects in air transport. The authors have already raised the issue of the development of an information model of evaluation and output rating of start-up project development teams [16], but it is a formalized, general model. Therefore, at work [17] the task of informational modeling of the selection of a group of experts for various research objects has been solved, but possible indicators for the evaluation of environmental start-up developers in air transport have not been indicated. To do this, an applied informational neuro-fuzzy model for the elimination of the ranking of teams of environmental start-up project developers in air transport systems should improve.

The selected theoretical framework has also been introduced in the study of authors as in [18] on the technology improving the safety of crowdfunding platforms, or as in [19] on the security management education and training of critical infrastructure of sectors' experts etc.

The problem of evaluating of start-ups can be formalized as a problem of decision making, which is commonly solved using different formalized methodologies like multi-criteria decision making, expert systems, fuzzy inference systems, or their combinations [20-21]. All these methodologies rely on the transfer of expert knowledge into a complex rule-base, however, the transfer of the expert knowledge is a heuristic process [22]. On the other hand, the mechanism of training neural networks does not rely on human expertise, but through a homogeneous structure of neural networks [23] it is difficult to extract the structured knowledge. Therefore, for this task, it can be very beneficial to develop a unique form of neuro-fuzzy system that is combining the advantages of a well-structured knowledge base with the ability to objectively create this base using quantitative parameters (data).

Many researchers around the world are working on the best choice of specialists for vacant positions. In [24] Gungor et al. considered quantitative and qualitative factors using a vague analytical hierarchical process to solve the problem of personnel selection. Some researchers have used the object-oriented programming model and the machine learning method to solve the problem of personnel selection for the project team [25-26]. Zhang and Liu [27] combined intuitionistic fuzzy numbers with the grey relational method to select suitable engineers for a software company. In [28], Afshari used a fuzzy integral to recruit staff when the recruitment criteria were interdependent. In [29], a fuzzy number is used to assess the weight of each criterion and the performance of the evaluated specialists. Heidary Dahooie et al. [30] developed a system of competencies with five criteria to select the best IT expert. Researchers [31] used vague linguistic terms to express the opinions of experts to solve the problem of recruitment. Ozdemir and Nalbant [32] used five main criteria for evaluating the applicants in Turkey. They combined consistent fuzzy preference relation with fuzzy analytic hierarchy process to rank the performances of those applicants. In [33], a method of multicriteria decision-making for the selection of suitable people for vacant positions, while taking into account quantitative and qualitative factors. In [34], a hybrid gray model of multi-ple-criteria decision-making methods for personnel selection is proposed, which allows eliminating the vagueness of the input information.

Hybrid models of multiple-criteria decision-making (MCDM) are rapidly emerging as alternative methods of information modeling [35-36]. Fuzzy or hybrid decision-making methods are extremely widely used in many areas that require effective information management when evaluating alternative decisions and making optimal decisions [37]. Fuzzy Output Systems can use human expertise [38] and perform fuzzy inference to obtain baseline estimates [39]. For example, in the works [40-41] the general ideas and benefits underlying current views on the use of fuzzy mathematics in decision support systems are considered. In the works [23, 42] the use of fuzzy mathematics in different fields of application is presented, which allows determining the optimal parameters in the uncertainty of the input variables. The work [17] presented the model of increasing the security of assessment of expert knowledge, based on fuzzy sets, but did not say how to evaluate the qualitative characteristics of a person.

The neuro-fuzzy networks have advantages over the multicriteria/expert methods. After receiving real data, the neuro-fuzzy networks can be trained, and their knowledge base could be supplemented. For the task, the rating of the developers' team of an environmental start-up project in air transport, the neuro-fuzzy network develops and works with fuzzy expert input signals and, based on the knowledge base, displays adequate results.

The construction of mathematical models, based on information about start-up projects and their developers, is subjective and inaccurate. It uses expertly generated information that reflects the substantive features of the researched object and is formulated in a natural language. In this case, the description of the object is a vague, qualitative reflection of decision-making knowledge. Therefore, it is advisable to use the fuzzy set theory to reflect knowledge of the object of study. The fuzzy model is a mathematical model based on the theory of fuzzy logic and fuzzy sets.

Application of this approach and the development of a fuzzy model of information technology for obtaining quantitative estimates of environmental start-up projects in air transport, in order to increase the safety of their financing, is the urgent task in the development of the innovative business.

1.2. RISK ASSESSMENT OF START-UP PROJECTS

Today's consolidated methodologies for assessing the risks of companies or projects are coherent on the basis of common economic parameters and quantitative indicators, which do not capture the so-called soft factors. This greatly limits their dissemination dimension and their applicability to practice and to different types of policies. Strategic frameworks, development concepts or various programs, and support for business development and support for start-up must be based mainly on feedback from the real environment of start-ups functioning [43].

The implementation of quality analyses revealing the critical points of start-up development will also test the adaptability of several methods to explore specific conditions for the development of start-ups either in sectors or developmentally (depending on the stages of the company, start-up development), differentiating and further supporting methodological developments, as well as national and international benchmarks. This is extremely important for the creation of a global start-up system, which is also of interest to several international documents.

Innovation, as compared to other activities, is more risk-related, since there is virtually no full guarantee of a positive result. As a result, start-up projects are more dependent on the uncertainty factors that cause the risks. Risks are generated by ignorance regarding the future of start-up projects and limited views on an existing problem. Decisions made in the face of limited knowledge may lead to mistakes in the future. Moreover, current risk assessment methods do not take into account subjectivism, leading to incorrect estimates. False risk assessments lead to funding losses.

Thus, risk is a social category because it arises in the process of conscious decision-making that is inherent only to the individual. Risk is directly dependent on uncertainty, so minimizing uncertainty is necessary to reduce risk. To do this, we use fuzzy set theory and fuzzy logic in our study. Repeatedly scientifically proven [ ], that this theory can adequately reveal the uncertainty of data and knowledge, and is best suited to support decision making under risk. Risk is subjective, since assessing the risk of a situation depends on the psycho-portrait, emotional state and other subjective features DM. To do this, we use different types of convolutions, which adequately provide an alternative version of the situation, taking into account the psychosomatic mood of DM. When making management decisions, where each step requires a choice of several alternatives, the problem of disclosing the uncertainty of the data on which decisions are based and adequate assessment to minimize risks is particularly relevant [43].

Start-ups have different stages of commercial development. The first stage is the output of the product on the market. This raises the problem of the concept of evaluation itself, as the data for a non-implemented project are expert and fuzzy [14,44]. After the successful completion of the first stage, the second will come– conquering the market as a competitive factor in the industry. To assess the financing of the second stage, there are large number of developed models, but they are identified by the evaluation of investment projects and mainly used quantitative approaches [45-46]. In addition, if you consider the nature of the start-up projects, then the stage of new financing (expansion) may come in a few months after the successful launch. As a result, the quantitative indicators of the firm's activities are not sufficient to apply classical methods of evaluating investment projects. In addition, in order to assess the feasibility of financing start-up projects, it is necessary to employ expert knowledge on the risks of such financing.

The issue of quantifying risk during an investment was presented in many papers [10, 47-48], but a holistic concept of determining the level of risk in the subjective aspects of evaluation is yet to be developed. There are a number of works that offered project risks assessment using the net present value (NPV) formula [49]. In papers such as [8, 50], fuzzy sets, fuzzy logic, and a systematic approach to project risk assessment were used. In addition, in papers such as [18, 51-52], the authors proposed a formal model for project risk assessment, but did not address the question of risk assessment of environmental start-up projects for the air transport sector at the stage of business expansion.

The main advantage of using a fuzzy set is that it requires a person who decides how to compare non-point probabilistic estimates, but at an interval, and this shows the corridor of the values of the predicted parameters. The convenience of these methods is manifested in increasing the degree of validity of decisions, as all possible scenarios of development depicting the continuous spectrum of the set of scenarios are taken into account [53-55]. Other experts and authors as in References [56-57] discussed the general ideas and advantages that underpin contemporary views on the use of fuzzy logic in decision support systems in various fields of application. To competently assess the risk of a start-up project, one must learn to scientifically model information uncertainty by drawing the formal boundaries between credible knowledge, knowledge with a certain level of certainty, and what we do not know. We also find inspiration in the work of authors on the "combination of data-driven active disturbance rejection and Takagi-Sugeno fuzzy control with experimental validation on tower crane systems" [57], or in the work on "density peaks clustering based on k-nearest neighbors and principal component analysis" [54], among others.

Risk is closely linked to the notion of economic security of the project, both as the security of the entity representing the project and the safety of the investor [18]. The security of the matter is that a risky and unsuccessful project will result in enterprise damage. Investor safety depends directly on an adequate assessment of the project and the subject of the project. Enhancing the security of start-up projects provides stability of the economy of the region/state/EU [52]. In general, the problem of evaluating start-ups can be formalized as a decision-making problem, which is commonly solved using various formalized methodologies such as multi-criteria decision-making, expert systems, fuzzy inference systems, or their combinations [20-21]. All these methodologies, mentioned in the last paper, rely on the transfer of expert knowledge to a complex set of rules. However, transferring expert knowledge is a heuristic process [22]. On the other hand, the mechanism of neural network training is not based on human expertise; however, through a homogeneous structure of neural networks [23], structured knowledge is difficult to extract. The selected theoretical framework was also part of References [58-59] on the applied knowledge of interdisciplinary investigation of special security issues.

Thus, developing a fuzzy model for risk assessment start-up projects is an urgent task in developing decision support systems for business analysts in assessing business financing opportunities.

1.3. Safety Risks Assessment of Start-up Projects Implementation within the Investment Phase

Today the urgent task of modeling safety risks for the implementation of start-up projects. An adequate solution to such a task is possible only with the involvement of competent experts with knowledge of the subject area and practical experience. In a decision support system, the final decision is made by a responsible person (persons). Such systems must assist, advise and increase the level of validity of decision-making of the responsible person (persons). This decision support is therefore brought to a new level with the formalization of experts' experience, together with a quantitative assessment of the various aspects of the subject of evaluation [8].

One of the purpose and contribution of this monograph is to develop a complex expert model for assessing the safety risks of implementing the start-up projects within the investment phase of the project, which combines the classical methods, the fuzzy methods of project evaluation, and the knowledge and experience of the security experts. Therefore, for this task, it can be very beneficial to develop a unique form of a neuro-fuzzy system that combines the advantages of a well-structured knowledge base with the ability to create this base objectively using the quantitative parameters (data).

The aim of the presented paper is to design and create a hybrid decision making support system, which will be able to integrate the advantageous properties of neural networks, which can provide tuning of the knowledge base of the system using the obtained real-world data, thus improving and automating the decision making process [60]. The application of fuzzy logic is aimed to improve the accuracy of the assessment of the investigated alternatives (projects), because the fuzzy logic provides an infinite set of logic values, which makes it especially suitable for decision support systems, compared to traditional Boolean logic or decision making tables or expert systems based on Boolean logic [61-62]. The development of a task-specific framework for evaluation of projects in the area using a hybrid neuro-fuzzy decision support system improving and automating the decision-making process can therefore be taken as an absolutely novel approach from a methodological and also a scientific point of view. The system is based on the developed methodology described in the paper [16]. The aim of the system is to be robust and can also contain expert inputs to improve their efficiency.

Risk assessment and quantification of their impacts at different stages of the life cycle have recently been the subject of research interest in several scientific disciplines. Increasing investor demands, searching for more accurate information, for decision-making mechanisms, and feeding them to economic evaluation systems has also changed the structure and dynamics of analytical processes in recent years [63-64]. This has prompted the development of new methods and approaches in the complementary use of traditional ones. ISO / IEC 31010: 2009 standards as well as literature from the last decade present the standardized, proven methods and techniques for each stage of the risk management process, such as Multi-criteria decision analysis, Cost-benefit analysis, Consequence/probability matrix, Monte Carlo simulation, Human reliability analysis, Cause, and consequence analysis, Event tree analysis, Failure mode effect analysis, Fault tree analysis, Hazard and Operability Studies, Primary Hazard Analysis, Check-lists Analysis, and others [65].

Recently, the professional and research spheres have begun to address methodological deficits noticeable in solving complex multisectoral problems caused by practice as well as problems aimed at eliminating losses from decision-making processes [66-67]. This has also supported economic developments - the economic quantification of the impact of decisions and forecasts [68-69]. The field of risk assessment in the different phases of the project cycle is very sector-specific and gives adequate scope to develop new methodological processes and to refine existing risk assessment approaches at each phase of the project cycle [70]. Research studies provide little relevant evidence for new methodologies applied at each stage of the project cycle, as project specificities, as well as the strong structuring and heterogeneity of components in the industry project system under review, do not allow for unified processes and standardization of their application processes. This consistent fact also fully corresponds to the motives and processes of our analytical part of the study, determined according to our research objective.

Let's look at the position of the task being solved within the project life-cycle. The life-cycle of project according to the United Nations Industrial Development Organization (UNIDO) is characterized by the following phases of the investment cycle [71]:

1. pre-investment phase (the project concept for the

project definition (feasibility study), with an emphasis on the preliminary planning and preparation of the project plan etc.);

2. investment phase (the development of project focused on the detailed planning, and the implementation of the project);

3. using and evaluation phase (it is also called the

operational phase or the project completion).

This investment phase, which is also the subject of our research, is the most challenging in many respects because it involves the synthesis of a wealth of information and a combination of many approaches that optimize decision-making processes. In practice, this also means making many compromises to satisfy stakeholders, as well as political and other requirements.

The UNIDO’s project cycle comprises five stages: Identification, Formulation, Review, and Approval, Implementation, Evaluation.

In accordance with the UNIDO for our mission in the aviation sector, we assess the security and uncertainty risks for the second, investment phase of the project – focused on the detailed project planning and implementation.

STN ISO 10006:2019-05 (01 0325) (Quality management. Guidelines for quality management in projects) specifies the following steps in a project [72]:

1. project concept;

2. project development (detailed project planning);

3. implementation of the project;

4. completion of the project.

STN ISO 100006 is not a guide to the project management itself. This document provides guidance on the quality of project management processes. Guidelines for project management and related processes are containedin ISO 21500 etc. This document focuses on both quality management concepts, namely “the project quality management” and “the project quality management systems” [73]. In accordance with the STN ISO 10006:2019-05 standard for our paper, we will evaluate the safety risks and uncertainties for the 2nd and the 3th stage of project development: detailed project planning and project implementation. Therefore, an environmental project in the aviation sector needs to be assessed in terms of the implementation risks.

The financing and security of the implementation of start-up projects requires a comprehensive and systematic approach to its solution. At present, there are not enough formalized solutions or unified methodologies that would be sufficient, considering the individualization of project intentions developed for a specific environment, reflecting the changes in the external macroeconomic and political environment. For this reason, there are pressures to develop new methods and procedures that also reveal specific causal links and identify potential risks, resp potential risk areas. The role of the human factor, knowledge and experience in expert teams remain in the spotlight. Expert meetings have their significance not only in the pre-investment but also in the investment phase of the project cycle, and their importance has been increasing significantly in recent years.

In the investment phase of a project focusing on detailed planning and implementation processes (Phase 2, UNIDO), it is especially important to analyze interest groups, which can have a diametrically different structure at different stages of the project cycle (pre-investment vs. investment). Different interest groups may also have differentiated concerns, opportunities, as well as interests in project implementation and outcomes, with financial implications and an assessment of the economic effectiveness of individual aspects of the project. The main objective of an interest group analysis is to maximize the economic, social, institutional positive impacts of projects on target groups and minimize their potential negative risks, including interest group conflicts.

The scientific sphere does not provide sufficient scientific evidence to quantify the economic and non-economic impacts of these complementary analyzes, which should be included in expert evaluations [6, 70, 74]. As part of these analyzes, it is important to examine the prospective roles of interest groups, their differentiated interests, and the capacity to participate in the project, to identify the degree of cooperation or conflicts resulting from the interrelations between entities. The results of these analyzes should be included in the project planning processes (Phase 2, UNIDO) to assess the potential of resources, the compliance of project management, and coordination with stakeholder participation, taking into account potential stakeholder conflicts.

1.4. EVALUATION AND SELECTION OF START-UP PROJECTS BY INVESTOR GOALS

Financing start-up projects is a complex, risky, fuzzy, and unpredictable activity. Such a task is borne out by the fact that the financing of projects depends largely on the opportunities, wishes, considerations, and opinions of investors. Such systems should help, advise and raise the level of validity of decision-making [75].

Recent scientific studies indicate the need to develop new models for evaluating innovative or start-up projects, for investors to choose for their own goals. The relevance and need of these models are indicated by an increase in the number of start-ups at university / regional / state level competitions; the emergence of specialized crowdfunding platforms (support for projects in a particular area) and venture funds [76]; a large number of grant and innovation funding programs [69]; the trend of development and implementation of own innovations in the enterprises with the involvement of employees.

Summarize of the above, there is an urgent task of multicriteria assessment of start-up (innovative) projects for investors to choose for the linguistic goals of the idea prospect, analysis of project implementation risks, and competencies of project developers. To do this, the problem of evaluating alternatives when there are multiple goals, each with its own set of criteria should be solved.

The most relevant methods of multicriteria selection: methods based on quantitative variables, multicriteria utility theory [77]; methods based on qualitative characteristics, the results of which are translated into quantitative form (analytical hierarchy methods) [77]; methods based on fuzzy set theory [38]; methods based on qualitative variables without moving to quantitative ones [79], and others.

Let's analyze the sources, related to the use of fuzzy mathematics apparatus to create support systems for managerial decision-making for various sectors of the economy. In works [23, 80] are reviewing general ideas and advantages that underpin modern views on the use of fuzzy logic in decision support systems. In [81] presents computational algorithms and procedures for solving practical problems of system analysis in various fields of human activity. The application of paired comparison methods and the consistency of expert assessments are presented in [42]. Thus, the general ideas and benefits of using fuzzy logic in decision support systems are discussed in [82-84]. There are a number of works [63-64, 85] that demonstrate models of enhancing the security of choice of alternatives by groups of goals, but the model is tested in the choice of banking institutions by the entity.

Concerning sources on the topic of evaluation of start-up projects, we conclude: there are currently a number of methods based on simulation and expert models using economic quantitative indicators [10, 45]. The problem of evaluating start-up projects is raised in [1, 86], where the apparatus of fuzzy sets is used. In works [43, 52, 87] uses the apparatus of fuzzy sets, fuzzy logic, and a systematic approach to assessing the risk of financing start-up projects. In [16, 88], the problem of constructing an information model for evaluating and rating the start-up teams is raised.

Thus, the issues of evaluating start-up projects, assessing risks, and evaluating development teams with the use of fuzzy sets have already been raised. The issue of multicriteria selection of alternatives by the target group was also raised. But there is no integrated, multi-criteria systematic approach for evaluating and selecting start-up projects, given the targeted needs of investors' wishes, which is so relevant in today's context.

Therefore, one of the purposes of this paper is to develop a fuzzy mathematical model for evaluating and selecting start-up projects for investors.

2. MODELS FOR EVALUATING START-UP PROJECTS

2.1. FUZZY MODEL FOR QUANTITATIVE ASSESSMENT OF START-UP PROJECTS

Let the investment institutions (venture funds, business angels, and capital investment organizations) evaluate some start-ups projects $P = \{P_1, P_2, \ldots, P_n\}$.

The start-up (ideas) and its team of developers will evaluate each project: $P_k = (S_k;\ X_k), k = \overline{1,n}$, where $S = \{S_1, S_2, \ldots, S_n\}$ – is the plural start-up projects, $X = \{X_1, X_2, \ldots, X_n\}$ – or the set of their developer teams. The incoming expert assessments of the proposed set of criteria will help evaluate start-up projects and teams. Without diminishing the universality, a single start-up project P will continue, in the case of a plurality of start-ups, on the initial estimates received. The mathematical model of the formulated problem is as follows [1]:

$$M\ (O_S,\ O_F) = O_P, \tag{2.1.1}$$

where $(O_S,\ O_F) = P(S,\ X)$; O_S – fuzzy evaluation of the start-up project S which is obtained by fuzzy multicriteria evaluation of alternatives; O_F – a rating team of developers; X an start-up project for air transport which is obtained by the method of neuro-fuzzy networks; O_P – a quantitative aggregated initial estimate from the interval [0; 1]; M – an operator that matches the output variable O_P.

The researchers have used the system approach for an objective and integrated solution of the problem, based on multicriteria assessment alternatives for start-up projects [8, 51] and neuro-fuzzy networks to evaluate their developers [89-90].

Thus, the purpose is developing a fuzzy model of information technology for obtaining quantitative estimates of environmental start-up projects in air transport in order to increase safety of their financing.

Mathematical Model of the Fuzzy Estimation of Start-Ups Projects

The goal is to propose the following set of evaluation criteria $SK = (SK_1, SK_2, \ldots, SK_m)$. To get an assessment for each criterion, the form of a question the authors used for a description of the corresponding assessment grading scale. It has been necessary to choose the variant for evaluation that is close to the truth [1, 14].

SK_1 – Proposes innovation is a technology or service:

1. Occurred at a given time (5 points);
2. Currently under development, with marketing and business plans (10 points);
3. At the stage of the working prototype, is tested by potential clients (15 points);
4. Currently receives income (20 points).

SK_2 – The value of the start-up:

1. Insignificance of novelty (5 points);
2. Making life a little easier and more enjoyable for many people, but does not solve any fundamental problems (10 points);
3. Helps people or businesses at work (15 points);
4. Will help save a lot of lives and / or money (i.e., the product is urgently needed in the market) (20 points).

SK_3 – Strategic partners in industry:

1. Exchanged letters with potential partners (5 points);
2. An existing letter of intention prepared by a potential distributor for our product (10 points);
3. Several signed partnership agreements with enterprises (15 points);
4. Partnership, licensing, delivery or sale agreements signed with many enterprises (20 points).

SK_4 – An intellectual property:

1. Patents have not yet been considered (0 points);

2. A preliminary application for a prepared and filed patent (5 points);
3. Team awaiting patents that have already been filed (10 points);
4. Availability of several patents that cover the entire chain of creation and commercialization of the invention, including trademarks (15 points).

SK_5 – Presence of a specialist in intellectual property:

1. The team will handle all intellectual property issues on its own (5 points);
2. A small company that does not have experience in working with the topic of the project (10 points);
3. A small or medium-sized company that works with a large number of start-ups (15 points);
4. An international law firm of intellectual property (20 points).

SK_6 – Availability of a business plan for project implementation:

1. Does not exist (0 points);
2. Lots of errors occur (5 points);
3. Ideal in the opinion of developers (10 points);
4. Quite qualitative according to consultants, lawyers and accountants (15 points).

SK_7 – Availability of sales and marketing plans:

1. No marketing plans (0 points);
2. Presence of the site with the product and popularization of it on the network (5 points);
3. The team has quality marketing and sale plans that include a combination of proven, cost-effective sales and marketing tactics (10 points).

SK_8 – The start-up project will compete with similar projects whose annual revenues make up:

1. Less than $100,000 (5 points);

2. \$100,000–\$500,000 (15 points);
3. More than \$500,000 (20 points).

SK_9 – Presence of a corporate lawyer:

1. A lawyer or a small firm that does not have experience in the investment field (5 points);
2. Medium-size company operating in the investment field (10 points);
3. A national law firm with a lot of connections in the venture community (15 points).

The set of criteria presented is open and investors can always add their own indicators when considering highly specialized projects. The given scale for the answers to the questions describes the level of the start-up. The higher the number of points, the more promising is the project.

The answers on the questions on the start-up project result in a set of numerical variables $SP = \{sp_1,\ sp_2, \ldots,\ sp_m\}$ according to criteria $SK = \{SK_1,\ SK_2, \ldots,\ SK_m\}$, taking values at a certain numerical interval. Each of these numerical variables, plural-carrier of the linguistic variable A, consists of the following terms: A_{l1} – "criterion evaluation $SK_l$is much lower relative to the "investor's wishes"; A_{l2} – "criterion evaluation SK_l is lower relative "investor's wishes"; A_{l3} – "criterion evaluation SK_l is close to the "investor's wishes"; A_{l4} – "criterion evaluation SK_l is slightly better relative to the "investor's wishes"; A_{l5} – "criterion evaluation SK_l is much better relative to the "investor's wishes".

"Investor's wishes" – is a conditional convolution of points that satisfies the person who makes decisions when considering, evaluating and choosing start-ups. The model of fuzzy evaluation of the start-up projects follows in the next steps:

Step 1. Fuzzification of the input data

The resulting numerical variables $\{sp_1,\ sp_2, \ldots,\ sp_m\}$ take different numerical values, then, for their comparison, it is necessary to have the normalized values. With this purpose, let us create the s–shaped membership function in the following form [16]:

$$\mu_l(sp_l, a_l, b_l) = \begin{cases} 0, & sp_l \le a_l; \\ 2\left(\frac{sp_l - a_l}{b_l - a_l}\right)^2, & a_l < sp_l \le \frac{a_l + b_l}{2}; \\ 1 - 2\left(\frac{b_l - sp_l}{b_l - a_l}\right)^2, & \frac{a_l + b_l}{2} < sp_l < b_l; \\ 1, & sp_l \ge b_l. \end{cases}, \quad (2.1.2)$$

where a_l – minimal / b_l – the maximum number of points of the grading scale of evaluation by the criterion SK_l, sp_l – received the number of points on the grading scale for the considered start-up ($l = \overline{1, m}$).

Step 2. Take into account the wishes of a decision maker

The decision maker (DM) is a person who makes the project evaluation decisions according to the criteria proposed by a group of start-up eco-system experts in the in the field of air transport.

Each DM criterion has its own reasoning, which should include the meaning of "investor's wishes". The vector $T = (t_1,\ t_2, \ldots,\ t_m)$, according to the criteria SK_l, ($l = \overline{1, m}$) will be denoted, and for each value, the membership function by the formula (2.1.2) will be calculated. The vector of the membership function "investor's wishes" is denoted by $\alpha = (\alpha_1,\ \alpha_2, \ldots,\ \alpha_m)$, where $\alpha_l = \mu_l\ (t_l)$,

Step 3. Estimation of the usefulness of the start-up

Regarding the "investor's wishes" and the results obtained for each criterion SK_l, project the value of the membership function on the plural of the linguistic variable carrier A. Each term A builds the membership function as follows (2.1.3)–(2.1.7) [14]:

$$\mu_{A1}\left(\mu; \alpha - \frac{\alpha}{2}; \alpha - \frac{\alpha}{4}\right) = \begin{cases} 1, & \mu \le \alpha - \frac{\alpha}{2}; \\ \frac{3\alpha - 4\mu}{\alpha}, & \alpha - \frac{\alpha}{2} < \mu \le \alpha - \frac{\alpha}{4}. \end{cases}, \quad (2.1.3)$$

$$\mu_{A2}\left(\mu; \alpha - \frac{\alpha}{2}; \alpha - \frac{\alpha}{4}; \alpha\right) = \begin{cases} \frac{4\mu - 2\alpha}{\alpha}, & \alpha - \frac{\alpha}{2} < \mu \le \alpha - \frac{\alpha}{4}; \\ \frac{4\alpha - 4\mu}{\alpha}, & \alpha - \frac{\alpha}{4} < \mu \le \alpha. \end{cases}, \quad (2.1.4)$$

$$\mu_{A3}\left(\mu;\alpha-\frac{\alpha}{4};\alpha;\alpha+\frac{\alpha}{4}\right)=\begin{cases}\frac{4\mu-3\alpha}{\alpha}, & \alpha-\frac{\alpha}{4}<\mu\le\alpha;\\ \frac{5\alpha-4\mu}{\alpha}, & \alpha<\mu\le\alpha+\frac{\alpha}{4}.\end{cases},\qquad(2.1.5)$$

$$\mu_{A4}\left(\mu;\alpha;\alpha+\frac{\alpha}{4};\alpha+\frac{\alpha}{2}\right)=\begin{cases}\frac{4\mu-4\alpha}{\alpha}, & \alpha<\mu\le\alpha+\frac{\alpha}{4};\\ \frac{6\alpha-4\mu}{\alpha}, & \alpha+\frac{\alpha}{4}<\mu\le\alpha+\frac{\alpha}{2}.\end{cases},\qquad(2.1.6)$$

$$\mu_{A5}\left(\mu;\alpha+\frac{\alpha}{4};\alpha+\frac{\alpha}{2}\right)=\begin{cases}\frac{4\mu-5\alpha}{\alpha}, & \alpha+\frac{\alpha}{4}<\mu\le\alpha+\frac{\alpha}{2};\\ 1, & \mu\ge\alpha+\frac{\alpha}{2}.\end{cases},\qquad(2.1.7)$$

Depending on the interval μ it belongs in, for each criterion one or another membership function μ_{Alg} $(g=\overline{1{,}5})$, relative to “investor's wishes” α, is chosen. Then for each criterion SK_l, a linguistic meaning, and an assessment of the validity of the term is the result. The assessment of the criterion belongs to one or the other term. This gives the opportunity to reveal the subjectivity of the recruited expert points and to understand the presented start-up project [14].

Step 4. Quantitative evaluation of the project regarding DM wishes

Let the DM have own considerations regarding the choice of terms for the criteria SK_l. These terms, called desirable and designated, are A^*_{lg} $(l=\overline{1,m};\ g=\overline{1{,}5})$. Then the estimates for the obtained and desired terms use the next membership function in the calculation (2.1.8) [1]:

$$\mu(O_l)=max\ \{\mu\ (A_l);\ \mu\ (B_l)\},\qquad(2.1.8)$$

where $\mu(A_l)=\begin{cases}\mu_{Alg} & A_{lg}=A^*_{lg}\\ 0, & A_{lg}\neq A^*_{lg}\end{cases}$, and $\mu(B_l)=\begin{cases}\frac{\mu_{Alg}}{2} & A_{l(g\pm1)}=A^*_{lg}\\ 0, & A_{l(g\pm1)}\neq A^*_{lg}\end{cases}$.

The resulting membership function shows how much the start-up project meets the wishes DM for each criterion. The constructed functions of the membership (2.1.3)–(2.1.7) have intersections, then obtain either one or two terms for the criteria with the same amount of reliability accordingly. Therefore, the built-up function of membership (2.1.8) for the next stage chooses the largest of them [15].

Step 5. Introduction of weight coefficients

DM sets weight coefficients for each criterion $(p_1, p_2, \ldots, p_m)$, from the interval [1; 10]. Then one can define normalized weight coefficients for each group of criteria [89]:

$$w_l = \frac{p_l}{\sum_{l=1}^{m} p_l}, l = \overline{1, m}; w_l \in [0, 1], \quad (2.1.9)$$

Step 6. Construction of the quantitative assessment of the start-up project and linguistic interpretation

Let us consider one of the convolutions for building aggregated assessment [90]. For example, take the average of weighted convolution:

$$O_S = \sum_{l=1}^{m} w_l \cdot \mu(O_l). \quad (2.1.10)$$

Let us introduce the linguistic variable $ES(O_S)$ = "*Evaluation of the Start-up Project*". The multiplier for variable O_S is an interval [0; 1], and a set of values is a term-set $ES = \{es_1,\ es_2, \ldots,\ es_5\}$. The resulting value of the formula (2.1.10) is comparable to one of the term sets:

- $O_S \in (0.67; 1]$ – es_1 = "Assessment of the start-up project is high";
- $O_S \in (0.47; 0.67]$ – es_2 = "Assessment of the start-up project is above average";
- $O_S \in (0.36; 0.47]$ – es_3 = "Assessment of the start-up project is average";
- $O_S \in (0.21; 0.36]$ – es_4 = "Assessment of the start-up project is low";
- $O_S \in [0; 0.21]$ – es_5= "Assessment of the start-up project is very low".

These limits, if necessary, investors can change. The developed model reduces the subjectivity of expert evaluations, shows the place of the start-up among others, and takes into account the DM wishes.

Informational Neuro-Fuzzy Model for Output Rating of Teams of the Start-Up Project

Let the entrance of the neuro-fuzzy network provide expert data of the start-up team which has developed a project X according to the criteria of evaluation $DK = (DK_{11}, DK_{12}, \ldots, DK_{34})$. For this purpose, for example, the following set of evaluation criteria for a team of developers of start-up projects create three groups, Figure 2.1.1. The evaluation criteria have the form of a questionnaire, where each team chooses the answer that comes close to them [1, 16].

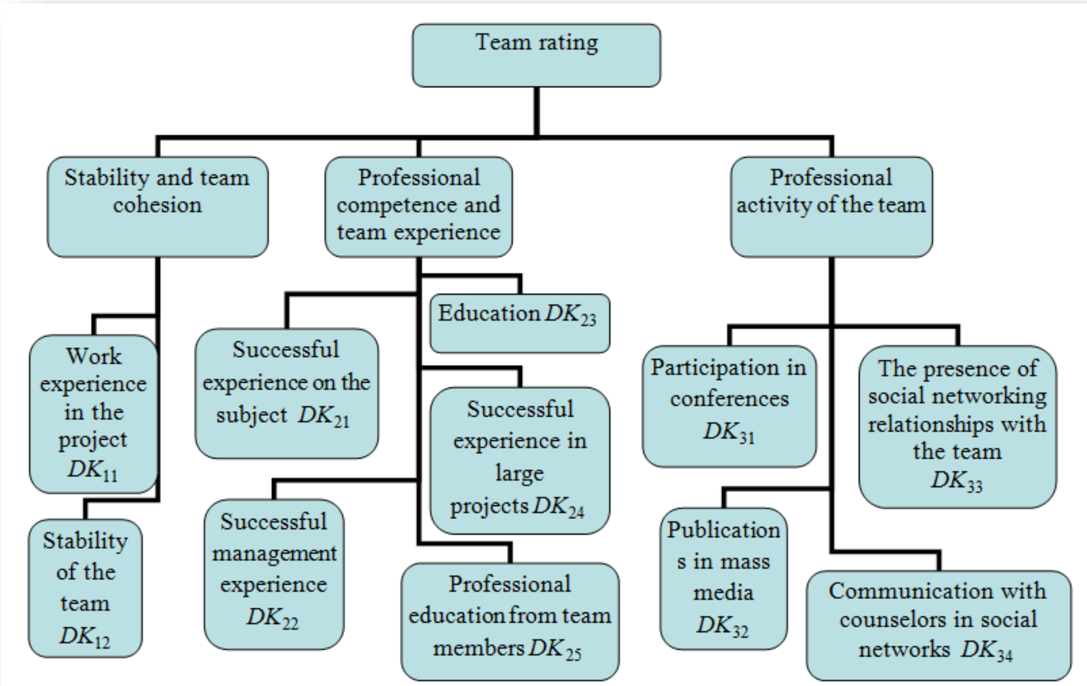

Fig. 2.1.1. Scheme of evaluation criteria for teams of developers of environmental start-up projects

The first group of criteria is stability and team cohesion [16].

DK_{11} – The length of work on the project is measured in months of work:

1. From 0 to 6 months;
2. From 6 to 12 months
3. From 12 to 24 months;
4. Months 24 and more.

DK_{12} – Changing of leaders and team members determines the stability of the team:

1. Totally new team members and part of the leaders;
2. Insignificant changes in the number of team members;
3. The composition of the team is unchanged since all members and leaders meet the requirements of professionalism;
4. The team's initial membership is unchanged, but there was an expansion of team members and leaders to reach the highest competence in the project.

Professional competence and team experience create the second group of criteria.

DK_{21} – Successful experience of leaders in projects (the topic of consideration):

1. Experience is absent as the project is the first one;
2. Availability of the first experience and obtaining a small income;
3. A successful innovative project has been implemented;
4. Leaders have implemented not only one successful project.

DK_{22} – Successful experience in managing projects:

1. Management experience is absent as this project is the first one;
2. Management experience available, but insignificant;
3. Management experience available – mid-level managers;
4. Management experience available – managers of high level.

DK_{23} – Education leaders:

1. No technical or managerial education;
2. Graduated college, or university student;
3. Completed higher education;
4. At least one of the leaders has a scientific degree in the specialization of the project.

DK_{24} – Successful experience of team members in projects:

1. The team members´ experience is absent as this project is the first one;

2. The experience of team members is available, but not in the topic of consideration projects;

3. Experience of team members in the topic of consideration projects;

4. All team members have experience in large/successful projects.

DK_{25} – Professional education of team members [1]:

1. Team members do not have special education to implement the project;

2. Some team members have special education to implement the project;

3. Most team members have special education to implement the project;

4. All team members have special education to implement the project.

The third group of criteria is the professional activity of the team.

DK_{31} – Participation of the team in conferences, investment sessions, or specialized events in the topic of consideration project:

1. Not involved in professional events for the project;

2. There is a single activity;

3. Existing activity;

4. Existing and systematic activity of advanced training.

DK_{32} – Publications in mass media or professional online sources for project topic:

1. There are no publications;

2. Information about the project and the team available, but mainly in social networks;

3. No single information about the project and the team;

4. Present and systematic activity of publications and popularization of the project.

DK_{33} – The presence of team ties in social networks and messengers:

1. No links;

2. Few, isolated links;

3. Wide circles of friends in different social networks;

4. Large activities with a significant number of subscribers.

DK_{34} – The presence of ties with advisors in the sphere of project topic in social networks:

1. No links;
2. Few, isolated links;
3. Wide circles of friends in different social networks;
4. Large activities with a significant number of subscribers.

Each criterion, evaluated by the team of developers of the start-up projects, is evaluated professionally using one of the terms, the following term-set of linguistic variables L = {L; BA; A; H}, where: L – "A low-level indicator"; BA – "An indicator below average"; A – "An average level of the indicator"; H – " A high level of the indicator". Therefore, "A low-level indicator" is the first answer to the question, and the last answer, is "a high level of the indicator" [16].

For every assessment, the expert also puts the "confidence factor" d in assigning an assessment [18] from the interval (0; 1). For example, if the answer is not the one that corresponds to the developer team, then the metric d corrects the accuracy of the answer.

Therefore, the input signals present the form of linguistic terms and coefficients of expert confidence in their assignment.

Then, have a look at the object of the species $EF = f(X)$ for which the connection "input X – output EF" can be filed in the form of a set of production rules of fuzzy knowledge base:

If (DK_{11} = ($L_{11};\ d_{11}$) (with weight α_{11}) **and** DK_{12} = ($L_{12};\ d_{12}$) (with weight α_{12})) (with weight α_1) **also** (DK_{21} = ($L_{21};\ d_{21}$) (with weight α_{21}) **and** … **and** DK_{25} = ($L_{25};\ d_{25}$) (with weight α_{25})) (with weight α_2) **also** (DK_{31} = ($L_{31};\ d_{31}$) (with weight α_{31}) **and** … **and** DK_{34} = ($L_{34};\ d_{34}$) (with weight α_{34})) (with weight α_3) **then** $EF = ef_g, g = \overline{1,5}$.

Where $DK_{ij}, i = \overline{1,3}; j = \overline{1,5}$ – a criterion of evaluation of the *i*-th group, *j*- th serial number of the rule in the group; L_{ij} – a variable with the term-set L for the *j*-

th group an indicator i; d_{ij} – "a confidence factor" expert on assigning a variable L_{ij}; $(L_{ij}; d_{ij})$ – grouped input data received from κ-th start-up team by DK_{ij} criterion; α_{11}, α_{12}, $\alpha_{21}, \ldots,$ α_{25}, $\alpha_{31}, \ldots,$ α_{34} – synaptic weight criteria from the interval [1; b]; α_1, α_2, α_3 – synaptic weight groups of criteria according to the interval [1; b]; $EF = \{ef_1,\ ef_2, \ldots,\ ef_5\}$ – a linguistic interpretation of the rankings of the teams of developers of the start-up [9].

The scale of the output variable $EF = \{ef_1,\ ef_2, \ldots,\ ef_5\}$ offers the following:

- ef_1 = "the rating of the team start-up project is high". The highest level of start-up team rating. Very low expectations regarding the risks of non-fulfilment of project development obligations. Very high ability to respond and solve current or strategic problems of project realization in a timely manner;
- ef_2 = "the rating of the team start-up project is higher than the average". High ranking team start-up. Low expectations of non-fulfilment of project development obligations. Ability to react in a timely manner and solve current or strategic problems of project implementation. However, negative changes in circumstances and economic conditions are likely to reduce this ability;
- ef_3 = "the rating of the team start-up project is average". Speculative level of start-up team rating. There is a possibility of development of project risks or the risk of conflicts in the middle of the team, especially as a result of negative economic changes that may occur over time;
- ef_4 = "the rating of the team start-up project is low". The rating says that realizing the project in time is not a real opportunity. The ability to fulfil the project obligations of the team entirely depends on the favorable business and economic conditions;
- ef_5 = "the rating of the team start-up project is very low". Very high risks of non-fulfilment of project development obligations. Formed start-up team is not able to work on a project.

The aggregated rating of developer team ratings can be presented in the form of a four-layer neuro-fuzzy network of type integrated neuro-fuzzy systems (similar to Mamdani neuro-fuzzy approximation) [23], Figure 2.1.2.

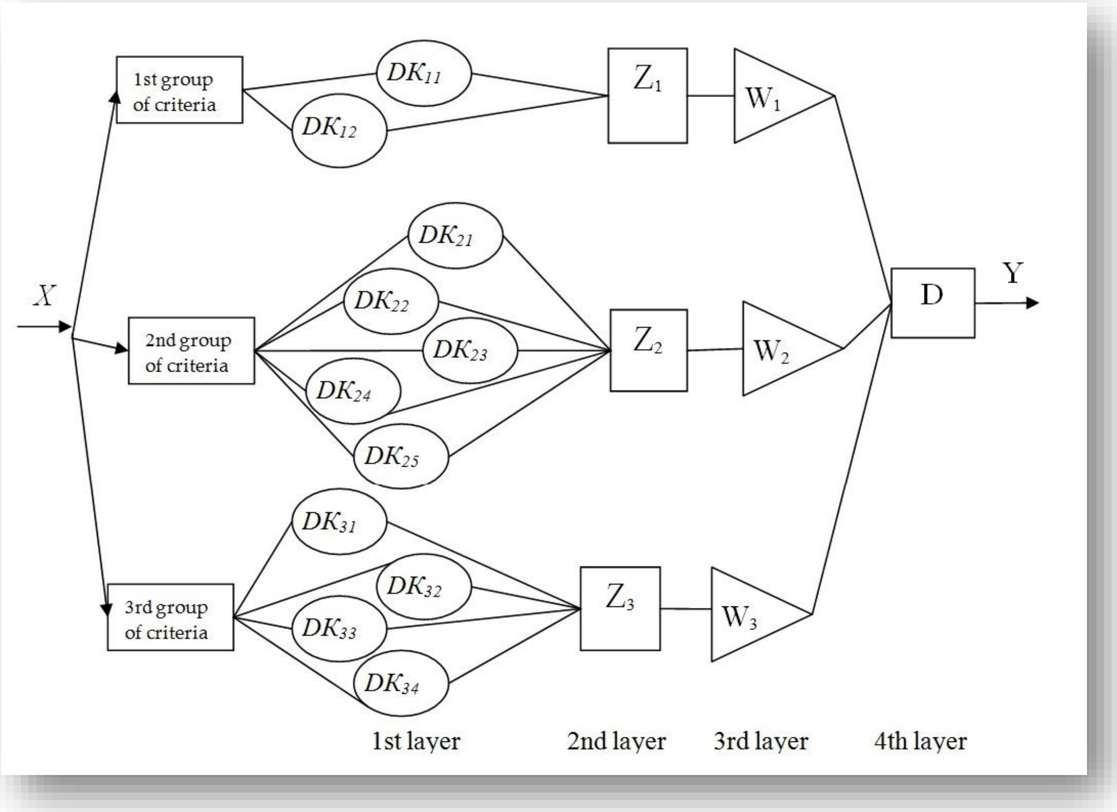

Fig. 2.1.2. The structure of the neuro-fuzzy network of the team start-up project

Next, let us consider in more details what happens on each layer of the neuro-fuzzy network.

1st layer

The fuzzification operation is performed in the first layer neurons, which means that for each input value $(L;\ d)$ the value of the membership function acquires conformity $\mu\ (O)$. Therefore, it is necessary to establish membership rules at the first level in order to obtain a standardized estimate of the input data. Let the term-set of linguistic variables L = {L; BA; A; H} represent on a certain numerical interval $[a_1;\ a_5]$ where $L \in [a_1;\ a_2]$, $BA \in [a_2;\ a_3]$, $A \in [a_3;\ a_4]$, $H \in [a_4;\ a_5]$. The value of breakdowns may be determined in the learning process of a neuro-fuzzy network using real data from teams of developers of start-up projects. Let´s calculate criterion estimates O using linguistic variables L, “a confidence factor” expert on their assignment d and value decomposition interval $[a_1;\ a_5]$, with the help of a characteristic function [16]:

$$O_{ij}=\begin{cases} a_2\cdot d_{ij}, & if \quad L_{ij}\in L;\\ a_3\cdot d_{ij}, & if \quad L_{ij}\in BA;\\ a_4\cdot d_{ij}, & if \quad L_{ij}\in A;\\ a_5\cdot d_{ij}, & if \quad L_{ij}\in H.\end{cases} \qquad (2.1.11)$$

This will make it possible to adjust the assessment regarding the expert's confidence in the assignment, or reckon how close is the answer to the question of the developer team to the truth. Next, the membership rule to help *S*-similar membership function as follows [16, 89]:

$$\mu(O_{ij})=\begin{cases} 0, & O_{ij}\le a_1;\\ 2\left(\dfrac{O_{ij}-a_1}{a_5-a_1}\right)^2, & a_1<O_{ij}\le\dfrac{a_1+a_5}{2};\\ 1-2\left(\dfrac{a_5-O_{ij}}{a_5-a_1}\right)^2, & \dfrac{a_1+a_5}{2}<O_{ij}<a_5;\\ 1, & O_{ij}\ge a_5.\end{cases} \qquad (2.1.12)$$

Constructed in this way, it is clear from the membership function, the resulting value will go to 1, in case if there is the high estimation of the criterion and the sufficiently high confidence of the expert on the assignment [10]. Thus, the experts' evaluations of teams of developers of start-up projects and expert confidence in their assignment turn to normalized comparable data [8, 90].

Consequently, the subjectivity of expert opinions discloses and switches from fuzzy expert linguistic evaluations to normalized and comparable in neurons of the first layer.

2nd layer

On the second layer, we have grouped the calculation of functions of postsynaptic potential according to the criteria of evaluation. The second layer contains the number of neurons that corresponds to the number of groups of criteria. Let the DM set the synaptic weights $\alpha_{11}, \alpha_{12}, \alpha_{21}, \ldots, \alpha_{25}, \alpha_{31}, \ldots, \alpha_{34}$, from the interval $[1; b]$ for each criterion. Input signals with synaptic weights form the value of the excitatory level of the neurons Z_1, Z_2, Z_3. The calculation of the postsynaptic potential functions is as follows:

$$Z_1 = \frac{1}{\alpha_{11}+\alpha_{12}} \cdot (\mu(O_{11}) \cdot \alpha_{11} + \mu(O_{12}) \cdot \alpha_{12}), \quad (2.1.13)$$

$$Z_2 = \frac{1}{\alpha_{21} + \alpha_{22} + \ldots + \alpha_{25}} \cdot (\mu(O_{21}) \cdot \alpha_{21} + \mu(O_{22}) \cdot \alpha_{22} + \ldots + \mu(O_{25}) \cdot \alpha_{25}), \quad (2.1.14)$$

$$Z_3 = \frac{1}{\alpha_{31}+\alpha_{32}+\ldots+\alpha_{34}} \cdot (\mu(O_{31}) \cdot \alpha_{31} + \mu(O_{32}) \cdot \alpha_{32} + \ldots + \mu(O_{34}) \cdot \alpha_{34}). \quad (2.1.15)$$

Output neurons of the second layer Z_1, Z_2, Z_3, normalized because the calculations use the relative importance of the synaptic scales of the criteria [16].

3rd layer

On the third layer, there is the second layer correction of neurons, in relation to the importance of one or the other group of evaluation criteria, provided. In this case, for each group of criteria, the person who is making the decision has his own considerations regarding the synaptic weights α_1, α_2, α_3 respectively, from an interval $[1; b]$. The functions of the postsynaptic potential of the third layer of neurons will be calculated in the following way [16]:

$$W_i = \frac{\alpha_i}{\sum_{i=1}^{3} \alpha_i} \cdot Z_i, i = \overline{1,3}, \quad (2.1.16)$$

Similarly, the output neurons of the third layer W_1, W_2, W_3 will be normalized since the calculations use the relative importance of the synaptic weights of the groups of criteria.

4th layer

On the fourth layer, the data will be defuzzificated. To do this, the following activation function in the output neuron should be is used [1]:

$$O_F = \sum_{i=1}^{3} W_i, \qquad (2.1.17)$$

The method of creating the knowledge base and generating new rules of production is a proposal for training the neuro-fuzzy network.

Training a neuro-fuzzy network

We offer the method of forming the knowledge base by generating new production rules that do not contradict the rules from the knowledge base of the system, based on the analysis of experimental data about the teams of developers [16, 91].

Let's have a sample S value pairs $\langle x^s, Z^s \rangle,\ s = \overline{1, S}$. Method of the formation knowledge base of the start-up team developer is next.

Stage 1. With $m, (m < S)$ arbitrary values $\langle x^s, Z^s \rangle$, the initial knowledge base of the model, which is represented by a matrix with strings, is composed $\langle x^s, Z^s \rangle = \langle K_{11}^s, K_{12}^s, \dots, K_{34}^s, Z^s \rangle$. This representation is equivalent to the formulated set of production rules, the fuzzy knowledge base described above.

Stage 2. Next, for each new experimental point $\langle x^*, Z^* \rangle$ we calculate the predicted value by the centroid method [92]:

$$Z_{new}^* = \frac{\sum_{s=1}^{m} Z^s \mu(\|x^s - x^*\|)}{\sum_{s=1}^{m} \mu(\|x^s - x^*\|)}. \qquad (2.1.18)$$

Where μ – function of exponential form: $\mu(\|x^s - x^*\|) = exp(-\lambda \sum_{h=1}^{hs} |x_h^s - x_h^*|)$, λ – function parameter (considered predefined), hs– number of rules.

Stage 3. If $|Z^* - Z_{new}^*| > \varepsilon$, where ε – a constant is given that determines the error of the approximation, then the knowledge base is replenished by expanding the matrix U, in the opposite case, the matrix U remains unchanged.

Stage 4. The rule of stop is checked. In this variant, the construction of the model is considered complete if, in accordance with steps 2 and 3, all are selected S experimental points, otherwise we go to stage 2.

It was accomplished training of the neuro-fuzzy network on a training set of data from a university team of developers (a total of 28 teams) taken from Incubator of Uzhhorod National University. Verified correctness of work the neuro-fuzzy network based on test data of successful start-up projects and their developers. Based on the training of the neuro-fuzzy network, the rankings of teams of developers of start-up projects are set [16].

Rating levels for start-up teams of developers are the result of the training on neuro-fuzzy networks. Let us match the aggregated score O_F with output variable $EF = \{ef_1,\ ef_2, \dots,\ ef_5\}$ as follows: $O_F \in$ (0,87; 1] – ef_1; $O_F \in$ (0,67; 0,87] – ef_2; $O_F \in$ (0,37; 0,67] – ef_3; $O_F \in$ (0,21; 0,37] – ef_4; $O_F \in$ [0; 0,21] – ef_5.

The described teaching method corresponds to the simplified method of fuzzy logic output but differs that the knowledge base is not fixed but is complemented by the arrival of experimental data. The contradiction of the new production rule is guaranteed by the procedure for updating the knowledge base [93].

Determination of the Quantification for the Withdrawal of the Security Rating of Project Financing

The assessment of the start-up project O_S, and evaluation of the team implementation O_F, is a result of the evaluation, for a submitted start-up P. In addition to the quantitative evaluation, a linguistic interpretation ES and EF is obtained. In the case of a plurality of projects, the following data are acquired, Table 2.1.1.

Tab. 2.1.1. Data for the case of a plurality of projects

Projects	**Start-up Projects**		**Team Developers**	
	Estimation	**Linguistic Interpretation**	**Estimation**	**Linguistic Interpretation**
P_1	O_{S_1}	ES_1	O_{F_1}	EF_1

P_2	O_{S_2}	ES_2	O_{F_2}	EF_2
…	…	…	…	…
P_n	O_{S_n}	ES_n	O_{F_n}	EF_n

Based on estimation O_S, O_F, a model for obtaining a quantitative aggregate initial estimation O_P from the interval [0; 1] is a proposal for the considered start-up of the project. To do this, a convolution is used in the form of the Gaussian two-dimensional functions [94], on the interval [0; 1] by coordinates x, y, z, according to the following formula:

$$O_P = F(O_S; O_F) = e^{-((O_S-1)^2+(O_S-1)(O_F-1)+(O_F-1)^2)}, \qquad (2.1.19)$$

Figure 2.1.3 presents the graphical interpretation of aggregated estimation.

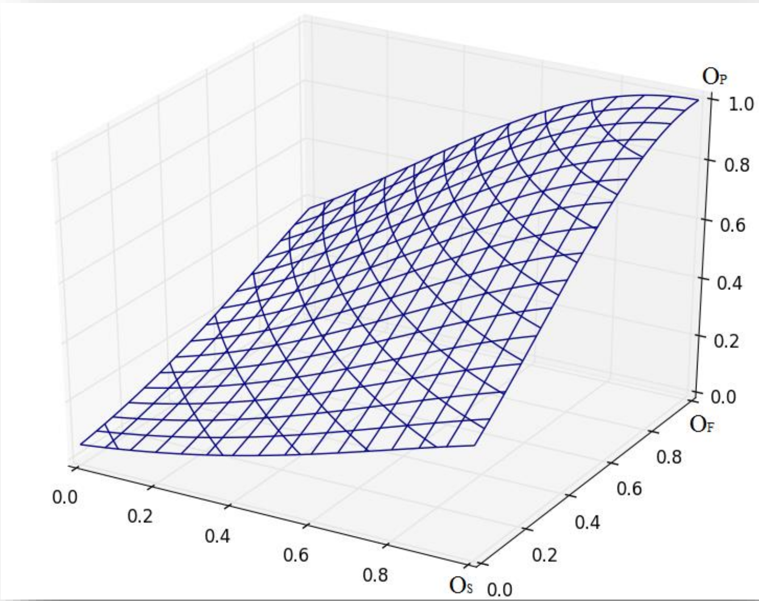

Fig. 2.1.3. Graphic interpretation of aggregated estimation

Thus, we obtain an initial estimate O_P from the interval [0; 1].

In order to determine the level of security of financing, received value start-up projects according to the formula (2.1.19) compared to one of the term settings $PS = \{ps_1,\ ps_2, \ldots,\ ps_5\}$ with the following content:

- $O_P \in (0.7;\ 1]$ – ps_1 = "a high level of security of start-up project financing". It's the highest level of security financing and provides very low expectations regarding the risks of non-compliance with project development obligations. The team's ability to react promptly and solve current or strategic problems in project implementation is very high;
- $O_P \in (0.5;\ 0{,}7]$ – ps_2 = "level of security of start-up project financing an above average". It is a high level of security financing and provides low expectations of non-compliance with project development obligations. The ability of the team to react in a timely manner and to solve current or strategic problems of the project implementation is low, but this ability can reduce negative operational or economic changes;
- $O_P \in (0.4;\ 0.5]$ – ps_3 = "an average level of security of start-up project financing". It is a speculative level of security financing. There is the possibility of developing project risks and / or conflict risks in the middle of the team due to the deterioration of economic changes;
- $O_P \in (0.2;\ 0.4]$ – ps_4 = "a low level of security of start-up project financing". The rating says that realizing the project in time is not a real opportunity. The ability of a team to work depends on the favorable business and economic conditions;
- $O_P \in [0;\ 0.2]$ – ps_5 = "a very low level of security of start-up project financing". Very high risks of non-fulfillment of project development obligations and the formed start-up team are not able to work on the project.

The applied fuzzy model of information technology for quantitative estimation of the start-up projects will increase the degree of validity of decision-making regarding the safety of such project financing by investors. For this purpose, a mathematical model of fuzzy evaluation of the start-up projects and an informative neuro-fuzzy model for output rating of teams of the start-up project. Based on the initial estimates for the project start-up, there is a model for obtaining a quantitative aggregate estimate. The assessment has reached a decision on the security of project financing. The developed model of the fuzzy estimation of the start-up projects has a number of advantages. First, it gives an opportunity to understand the nature and place of the proposed project start-up in the estimation area. It then reveals the uncertainty of upcoming expert assessments using a set of linguistic variables in relation to the " the investor´s wish", and determines the level of start-up assessment and its linguistic value taking into account the wishes of DM in considering, evaluating and selecting start-ups. The disadvantages of this approach include the use of different models of membership functions, which can lead to ambiguity of the results [14]. There are some advantages of the informational neuro-fuzzy model for output rating of teams of the start-up project. The objectivity of expert assessments in evaluating teams of developers has increased. A neuro-fuzzy network has the ability to change the synaptic weighting of criteria and groups of criteria for evaluating the teams of developers. The arrival of experimental data help conducts the neuro-fuzzy network training by completing the knowledge base and adjusting the rating levels of the developer teams of start-up projects.

The disadvantages of this approach contribute to the fact that the received membership function in the neuro-fuzzy network corresponds to the stage of rough debugging. Therefore, the process of debugging a neuro-fuzzy network, depending on the breakdown of the gap $[a_1; a_5]$ is possible in a sample of reliable experimental data [16].

The result of the paper is an applied model of information technology for obtaining a quantitative assessment of start-up projects, working with fuzzy data, and increasing the validity of the decision-making process regarding the security of their financing. Its output is a quantitative assessment and a linguistic interpretation of the level of security of the project start-up financing. The rationality of this assessment proves the benefits of the developed model. The correct use of the apparatus of fuzzy logic, fuzzy sets, and neuro-fuzzy networks, confirmed by the research results, ensures the reliability of the obtained results.

2.2. A FUZZY MODEL OF RISK ASSESSMENT FOR START-UP PROJECTS

Modeling uses expertly generated information that reflects the substantive features of the object under study, and it is formulated in a natural language. In this case, the description of the object is unclear. Therefore, it is advisable to use fuzzy set theory to reflect object knowledge. Thus, the transition of knowledge in the classical sense proceeds to the fuzzy knowledge. To do this, fuzzy multiple descriptions are used to model uncertainty [53–55].

The configuration of the evaluation problem involved multiple steps. Firstly, the start-up projects $S_1, S_2, \ldots, S_n$ are considered, for which it is necessary to assess the risk of financing them at the expansion stage. Start-up projects are evaluated on the basis expert input estimates proposed by a set of criteria, $K = (K_{g1}, K_{g2}, \ldots, K_{gm})$, which is classified in groups g. Experts evaluate each risk criterion [4] under one of the conditions of the following definition of linguistic variables $T = \{L; \quad BA; \quad A; \quad AA; \quad H\}$, where L is "low risk", BA is "risk below average", A is "average risk", AA is "risk above average", and H is "high risk" [43].

For each risk assessment, the expert quantifies the "certainty" $\mu(T)$ [18, 52] of his/her consideration in the interval [0, 1]. The input data for assessing the risk of start-up projects are presented in Table 2.2.1.

Tab. 2.2.1. Input data

The name of the criteria	S_1		S_2		**…**	S_n	
K_{g1}	T_{g11}	$\mu(T_{g11})$	T_{g12}	$\mu(T_{g12})$	…	T_{g1n}	$\mu(T_{g1n})$
K_{g2}	T_{g21}	$\mu(T_{g21})$	T_{g22}	$\mu(T_{g22})$	…	T_{g2n}	$\mu(T_{g2n})$
…	…	…	…	…	…	…	…
K_{gm}	T_{gm1}	$\mu(T_{gm1})$	T_{gm2}	$\mu(T_{gm2})$	…	T_{gmn}	$\mu(T_{gmn})$

In Table 2.2.1, T_{gij} is a variable with the T term defined for the i-th group indicator g and the j-th start-up project, and $\mu(T_{gij})$ is the accuracy of the expert estimates related to the suitability of the variable T_{gij}, where $i = \overline{1,m}$, $j = \overline{1,n}$.

Consequently, on the basis of the inputs data submitted for start-up projects, it is necessary to assess their financing risk.

Knowledge Models for Risk Assessment of Start-Up Projects

We offer a set of criteria for forecasting the potential risks of start-up projects [18]. A set of criteria were set up to predict the potential risks of projects resulting from the consensus of several experts from the start-up ecosystems. An expert meeting was held with selected entities of emerging start-up ecosystems (investors, co-working sites, state organizations, start-up support organizations, corporations, and start-ups). There were also a set of criteria based on the expert evaluation of our researchers and colleagues from the University Science Park TECHNICOM ecosystem in Kosice and the start-up incubator at the Uzhhorod National University.

In our view, the proposed classification can be applied to all start-up projects. On the other hand, the peculiarities of the start-up projects are taken into account, as firms aim to create a product that solves current problems, by identifying markets, and scaling up business rapidly. The classification offers the following groups: KC – "risks from the current start-up project of the company"; KM – "risks of motivating a start-up team"; KI – "risks of initial investment and business models"; KF – "risks of a financial activity"; KS – "risks for developing a start-up projects".

A set of indicators represent each group of criteria [8, 52]. The criteria proposed for the evaluation process by their description (groups) are defined and summarized in Table 2.2.2.

Tab. 2.2.2. Definition of the criteria and their groups

Criteria groups	Label of criteria	Definition of criteria
$\boldsymbol{KC}$	KC_1	The risk of losing a large client (the absence of signed contracts with enterprises or companies operating in the industry of the project);
	KC_2	Risk of losing the supplier of raw materials (replacing the supplier is always accompanied by new risks arising from the new relationship);
	KC_3	The risk of losing market share (the market is likely to acquire new start-ups, which is likely to take away customers);
	KC_4	The risk of unsecured resources (this risk is linked to inappropriate formation of resource stocks, particularly the expansion of production).
$\boldsymbol{KM}$	KM_1	The risk of lowering the level of management (when the leaders of the start-up team act in their own interest, forgetting the initial arrangements among investors);
	KM_2	The risk of lowering the quality of the processes in the start-up team (mainly due to the loss of motivation of the team members, which directly affects the quality of the work);
	KM_3	The risk of reducing the productivity of the start-up team (occurs when there is a crisis in the system of motivation);
	KM_4	Personnel risks (aspects related to lack of skilled workers, violations of labor, and executive discipline).
$\boldsymbol{KI}$	KI_1	The risk of the inefficiency of investment (when the investment cost is higher than the return on investment);

Tab. 2.2.2. *Cont.*

Criteria groups	Label of criteria	Definition of criteria
	KI_2	Risk of failing to achieve a return on investment capital (failure to reach a projected return on start-up project);
	KI_3	The risk of disrupting the timing of the creation of production assets (delay in commissioning production assets – a typical violation of project investment plans);
	KI_4	The risk of exceeding the amount of investment costs (a characteristic defect of the financial plan and of the part responsible for calculating the investment costs, usually due to lack of detail in business planning);
	KI_5	The risk of a lack of investment capital (closely linked to the previous risk and accompanied by a threat to the cost of financing the project).
$\boldsymbol{KF}$	KF_1	Risk of loss (arises in relation to price changes when sudden expenses cover revenue);
	KF_2	The risk of loss of solvency (perhaps a large-scale payment, which was not considered and, therefore, was not prepared for, or when there is a force majeure need for large-scale payments);
	KF_3	The risk of a suboptimal capital price (when it results in higher financial cost than operating profit).
$\boldsymbol{KS}$	KS_1	The risk of ineffective new innovative investments (when the investment cost is higher than the return on innovation performance);
	KS_2	The risk of ineffective new innovative ideas (innovative upgrading of start-up projects must focus on increasing sales trend);

Tab. 2.2.2. *Cont.*

Criteria groups	Label of criteria	Definition of criteria
	KS_3	Risks of violating the conditions of development of start-up projects (the period of implementation of innovations is measured in months and weeks, where a delay means losing market);
	KS_4	Risks of technological start-up projects (the risk relates to the technology of organizational change when insufficient attention paid to the transition to the stages of change resulted in the failure of implementation);
	KS_5	The risk of resource scarcity when designing start-up projects (sometimes the difficulty of accessing scarce resources by these specialists may be considered specialized, as well as technologies and components whose access is limited) is overlooked.

The set of risk criteria cannot reveal all aspects of a company's activity in any launch projects in different sectors of activities. Therefore, the set is open. Decision-makers (DMs) and the group of other experts who know how they can contribute to the development of a set of relevant criteria that change over time (depending on changes in the external and internal environments) can always add additional risk criteria. The model is built in a way that does not depend on the number of criteria in the group. This allows the expert more flexibly, based on his/her experience, to add criteria based on knowledge of the real project.

The Fuzzy Mathematical Model for Quantitative and Linguistic Risk Assessments for Start-Up Projects

A mathematical model for risk assessment for start-up projects is described, based on linguistic input variables. In the first stage, it is necessary to establish the membership rules and the knowledge base in order to reach the resulting term-evaluation T_g for each group of risk criteria, and to determine the aggregated estimation of certainty $\mu(T_g)$. In the second stage, based on the estimates obtained T_g and $\mu(T_g)$, we define a project risk assessment for each group of criteria g [26].

Consider the first stage – the construction of the membership rules that result from the term-evaluation of risk criteria groups.

Analyze an object from m inputs and the following output:

$$T_{gj} = L(T_{g1j}, T_{g2j}, \dots, T_{gmj}), \qquad (2.2.1)$$

where T_{gj} is the resulting term-evaluation with a term-set T for a group of criteria$g$, and $T_{g1j}, T_{g2j}, \dots, T_{gmj}$ are the input linguistic evaluation criteria for the group g. L is the operator that matches the resulting term-evaluation T_{gj} for a group of criteria, for input variables $T_{g1j}, T_{g2j}, \dots, T_{gmj}$ (rule of logical output), where $j = \overline{1, n}$ [39-40].

Next, an expert (or a group of experts) builds the rules of membership of the resulting terms for everyone. These rules can be constructed as a percentage of the membership of one or another term of the input variable. Formally, the rules of a membership represent a system of logical utterances, “if, then, else” [43], which associate the values of the input variables $T_{g1j}, T_{g2j}, \dots, T_{gmj}$ with one of the possible values T_{gj}, $g = \{O; M; I; F; S\}$, $j = \overline{1, n}$, as shown below.

If ($K_{g1j} = L$ **and** $K_{g2j} = L$ **and**… **and** $K_{gmj} = L$) **Or** ($K_{g1j} = L$ **and** $K_{g2j} = L$ **and**… **and** $K_{gmj} = BA$) **Or** … **Or** ($K_{g1j} = BA$ **and** $K_{g2j} = L$ **and**… **and** $K_{gmj} = L$) **Then** $T_{gj} = L$, **Else** …

Similarly, all functional dependencies are formed, which embodies the rules of decision-making reduced to the knowledge base in mathematical form.

The following rules of membership were formulated as a result of practical experience in the risk assessment of start-up projects, as done in References [18, 51, 52]:

Level L – "low risk": the start-up project receives the resulting term-evaluation L, if the minimum number of criteria with the term "low risk" is not less than 60%, and the remaining 40% of the criteria at the level are not lower than that of "risk below average".

Level BA – "risk below average": the start-up project receives the resulting term-evaluation BA, if the minimum number of criteria under "risk below average" is at least 60%, with the remaining 40% at a level not lower than the "average risk".

Level A – "average risk": the start-up project receives the resulting term-evaluation A, if the minimum number of criteria with the term "average risk" is at least 60%, and the remaining 40% level is not lower than "risk above average".

Level AA – "risk above average": the start-up project receives the resulting term-evaluation AA, if the minimum number of criteria with the term "risk above average" is at least 60%, and the remaining 40% of the criteria can be deemed "high risk".

Level H – "high risk": the start-up project receives the resulting term-evaluation H, if the minimum number of criteria with the term "high risk" is 60% or more.

Then, based on the rules for membership in the resulting term, the evaluation of risk criteria groups, as well as a fragment of the knowledge base, for example, with the group criteria K_I and the resulting term-evaluation L, can be given as shown in Table 2.2.3.

Because the expert puts each variable of T_{gij} authenticity and their reasoning $\mu(T_{gij})$ in the interval [0, 1], then the linguistic variables can be represented in the form of triangular membership functions as done in Reference [89]. This means that each linguistic variable T can be replaced by the neighbor T^* with certainty $\mu(T^*) = 1 - \mu(T)$. This gives the opportunity to polarize the risks within a group of criteria in order to obtain the resulting term-evaluation according to the knowledge base.

Tab. 2.2.3. Fragment of knowledge base

№ rules	K_{I1}	K_{I2}	K_{I3}	K_{I4}	K_{I5}	Resulting term evaluation
1	L[1]	L	L	L	BA[2]	L
2	L	L	L	BA	BA	
3	L	L	L	BA	L	
4	L	L	BA	BA	L	
5	L	L	BA	L	L	
6	L	BA	BA	L	L	
…	…	…	…	…	…	

[1] "low risk", [2] "risk below average".

The aggregated score certainty $\mu(T_{gj})$ is calculated according to the following formula [51]:

$$\mu(T_{gj}) = \frac{1}{k}\sum_{i=1}^{m}\mu(T_{gij}), g = \{C; M; I; F; S\}, j = \overline{1, n}, \quad (2.2.2)$$

where $\mu(T_{gij})$ is the estimation of the certainty of those linguistic variables, which coincides with the resulting term-evaluation for the *i*-th criterion by g group of risk criteria, k is their number, and j is the start-up project.

Thus, in the first stage, we obtain the resulting term-evaluation, based on the membership rules, for each group of risk criteria, the considered start-up project, and an aggregate assessment of its reliability.

In the second stage of problem solution, the approach described below is used to determine the generalized risk assessment start-up project for each group of criteria g, to achieve an aggregated risk assessment, as well as its linguistic interpretation.

Next, consider the following mathematical model [51]:

$$R = V\big(x(T_{gj}); \mu(T_{gj}); O_{gj}; O_R(S_j)\big), \quad (2.2.3)$$

where $x(T_{gj})$ is the value of a function equal to the numerical interpretation of the resulting term-estimates, $T = \{L; \;\; BA; \;\; A; \;\; AA; \;\; H\}$, $\mu(T_{gj})$ is the aggregated assessment of the certainty of the expert's thoughts, O_{gj} is a project risk assessment for each group of criteria g, $O_R(S_j)$ is the aggregated risk assessment for start-up projects across all groups of criteria g, and R is its output linguistic interpretation. V is the operator that matches the output variable R for input variables $x(T_{gj}); \mu(T_{gj}); O_{gj}; O_R(S_j), j = \overline{1, n}$.

Because the resulting term-assessment T_{gj} has a level of risk content, then its terms can be adequately determined on a percentage scale (0–100%), each of which sets values from interval $[a; b]$, for example L [0, 15], BA [15, 30], A [30, 50], AA [50, 80], and H [80, 100]. That is, a value of 85% risk is treated as "high risk".

We then consider the dependence of the resulting term evaluation T_{gj} and its certainty $\mu(T_{gj})$ in the form of the S-shaped membership function as in References [18, 51], which, in our view, appropriately expresses this dependency.

$$\mu(T_{gj}) = \begin{cases} 0, & x_{gj} \le a; \\ 2\left(\frac{x_{gj}-a}{b-a}\right)^2, & a < x_{gj} \le \frac{a+b}{2}; \\ 1 - 2\left(\frac{b-x_{gj}}{b-a}\right)^2, & \frac{a+b}{2} < x_{gj} < b; \\ 1, & x_{gj} \ge b. \end{cases} \tag{2.2.4}$$

$$g = \{C; M; I; F; S\}, j = \overline{1, n}.$$

Since the membership function values (aggregated estimation of certainty) and the intervals of numeric values for T are known, then, for each group of criteria g, x_{gj} is expressed from Equation (2.2.4) [18].

$$x_{gj} = \begin{cases} \sqrt{\frac{\mu(T_{gj})}{2}}(b-a) + a, & 0 \le \mu(T_{gj}) \le 0.5; \\ b - \sqrt{\frac{1-\mu(T_{gj})}{2}}(b-a), & 0.5 < \mu(T_{gj}) \le 1. \end{cases} \tag{2.2.5}$$

Equation (2.2.5) denotes that a higher value x_{gj} signifies a greater risk of a project start-up in the appropriate group of criteria.

For generalized risk assessments of start-up projects by groups of criteria g, the normalized values x_{gj} are obtained, changing the orientation of objectives.

$$O_{gj} = (b - x_{gj})/b, j = \overline{1,n}. \quad (2.2.6)$$

The estimates $O_{gj}, j = \overline{1,n}$ are normalized and represent a criterion for each group g aggregated risk assessment of the considered start-ups projects in relation to the resulting thermal ratings and their reliability.

For DMs for each group of criteria, the weight coefficients are denoted as $\{p_C, p_M, p_I, p_F, p_S\}$ from some interval. Then, the corresponding weighted coefficients are set accordingly.

$$\alpha_g = \frac{p_g}{\sum_g p_g}, \; g = \{C; M; I; F; S\}, \sum_g p_g = 1. \quad (2.2.7)$$

Since all the estimates obtained are normalized by the interval [0, 1], then, in order to obtain a final assessment of the risk of financing the start-up of projects, the approach below can be used. Depending on the size of the investment, DMs can choose one of the following convolutions:

$$O_{R1}(S_j) = \frac{1}{\sum_g \frac{\alpha_g}{O_{gj}}} \text{ – Pessimistic;} \quad (2.2.8)$$

$$O_{R2}(S_j) = \prod_g (O_{gj})^{\alpha_g} \text{ – Cautious;} \quad (2.2.9)$$

$$O_{R3}(S_j) = \sum_g \alpha_g O_{gj} \text{ – Average;} \quad (2.2.10)$$

$$O_{R4}(S_j) = \sqrt{\sum_g \alpha_g (O_{gj})^2} \text{ – Optimistic.} \quad (2.2.11)$$

The resulting estimates $O_R(S_j)$ are normalized and then matched to the output variable R to provide the following scale:

- r_1 = “Insignificant risk of financing the start-up project”;
- r_2 = “Low risk of financing the start-up project”;
- r_3 = “Average risk of financing the start-up project”;

- r_4 = “High risk of financing the start-up project”;
- r_5= “Critical risk of financing the start-up project”.

The linguistic interpretation of the aggregated risk assessment for financing the start-up projects $R = \{r_1, r_2, r_3, r_4, r_5\}$ is as follows: O_R ∈ (0.85, 1] – r_1; O_R ∈ (0.67, 0.85] – r_2; O_R ∈ (0.36, 0.67] – r_3; O_R ∈ (0.21, 0.36] – r_4; O_R ∈ [0, 0.21] – r_5.

The suggested decision levels are experimentally obtained, and the decision-maker can change them. To improve the accuracy of boundary estimation, one can change the experience of experts in evaluating the start-up projects. Also, depending on the investment opportunities of investors, if necessary, the level of decision-making can also change [16].

Generalized Algorithm for Obtaining an Aggregated Risk Assessment for Start-Up Projects

Based on the above fuzzy risk assessment model, the start-up projects can be written as a generalized aggregated estimation algorithm.

Step 1. Determine the resulting term-evaluation

Based on the data entered, the projects introduced from the start-up, and the built knowledge base, the resulting term-evaluation by Equation (2.2.1) for the groups of criteria is determined: KC; KM; KI; KF; KS.

Step 2. Determine the aggregated estimation of the reliability of the expert's thoughts

The aggregated evaluation certainty $\mu(T_{gj})$, $g = \{C; M; I; F; S\}$, $j = \overline{1, n}$ is calculated according to Equation (2.2.2).

Step 3. Obtain a generalized risk assessment for projects by groups of criteria g.

For each group of criteria$g$, calculate the level of risk x_{gj}, relative to the percentage scale $[a; b]$ and the resulting term-evaluation T_{gj}, using Equation (2.2.5). The generalized evaluation O_{gj} risk start-up projects for each group of criteria g is given by Equation (2.2.6).

Step 4. Weight coefficients introduced by groups of risk criteria

For each group of criteria, DMs set weight coefficients $\{p_C, p_M, p_I, p_F, p_S\}$ after which, according to Equation (2.2.7), the normalized weight coefficients are calculated.

Step 5. Aggregated risk assessment calculated for all groups of criteria

We determine the aggregated risk assessment using one of the convolutions in Equations (2.2.8)-(2.2.11).

The equate assessment $O_R(S_j)$ with the output variable R is to obtain a linguistic interpretation of the level of risk financing start-up projects.

In this way, a fuzzy mathematical model was constructed to obtain an aggregated risk assessment for start-up projects. The model used expert's knowledge and reasoning to evaluate the various risk criteria and, based on this, there was an aggregation of views according to the groups of criteria in the final evaluation.

The fuzzy model of risk assessment for start-up projects, as part of this research, will increase the degree of validity of decision-making regarding the financing of these investors by the investing public at the stage of market expansion. The model is based on expert knowledge, uses the linguistic variables, reveals the fuzzy input estimates, raises the objectivity of expert judgments, and combines experts' opinions in the benchmark groups of criteria for the final assessment of the risk of start-ups.

The developed fuzzy risk assessment model for financing the start-up projects has several advantages, such as the following:

- increasing the objectivity of expert assessments in project risk assessment using inbound linguistic variables and the credibility of expert estimates, where their mission and developed knowledge base do not depend on the number of criteria in the groups;
- they can be increased if needed, which also changes the level of decision-making;
- the model combines the criteria group's views in the final risk assessment of the start-up project and derives linguistic interpretation.

The disadvantages of this model include the use of different types of membership functions (triangular for the linguistic variable and its authenticity of an assignment, as well as for the dependence on the resulting evaluation term), which can lead to ambiguity of results.

Rationalizing the risk assessment taken to finance start-up projects brings the benefits of the developed model. The reliability of the results is achieved by the proper use of the apparatus of fuzzy sets, which is confirmed by the results of the research.

Each model operates with some limitations; the platform of fuzzy models and their associated methodologies also provide room for complementary application of several types of structural analysis, which, in their initial phase, could determine the impact and dependence of variables on various processes and financial aspects of start-ups. These should be explored depending on the specific type of start-ups. This is a challenging research area due to the strong individuality of the start-up projects and their high degree of innovation.

The results of our study will also support the development of economic indicators for assessing the potential success rate of start-up projects and, consequently, for national and international benchmarking. Our follow-up research area will also examine the forecasted development of the potential success of start-up projects linked to the country's macroeconomic indicators, as well as their economic and innovation performance. As some studies indicated [95], many important indicators are missing in the available EU macroeconomic databases, and those that are often monitored are incomplete (data on patents and inventions in countries, etc.) The results of our study will provide valuable information to experts dealing with regional strategic concepts, regional innovation, and economic development plans, as well as the financial sector, and will support the development of new forms of financing for this future segment.

2.3. The Expert Model for Safety Risks Assessment of Start-up Projects Implementation within the Investment Phase

Therefore, the project P has to be assessed in the terms of the risks of implementation. Depending on the task of assessing the security of implementation, we have a plurality of quantitative estimates $O = (O_1, O_2, \dots, O_m)$ from the interval [0; 1], respectively, according to the criteria $K = (K_1, K_2, \dots, K_m)$. Moreover, the criteria K can represent a whole system of criteria and models, on the basis of which one standardized estimate is aggregated O. Based on the experience and knowledge of the project, a group of experts (or expert) will analyze it, make the conclusions and make one linguistic assessment for each indicator K, from the set: $L = \{l;\quad ba;\quad a;\quad aa;\quad h\}$. Where:

- l – « the low evaluation of an indicator by the project»;
- ba – «the evaluation of an indicator by the project below average»;
- a – «the average evaluation of an indicator by the project»;
- aa – «the evaluation of an indicator by the project is above the average»;
- h – «the high evaluation of an indicator by the project» [65].

In addition, the linguistic assessment can be aggregated, obtained on the basis of an expert(s)' opinion(s).

Thus, in order to evaluate the project on the implementation of safety risks, the inputs data we have: $A_1(L_1; O_1), A_2(L_2; O_2)$, …, $A_m(L_m; O_m)$, where L_i – variable with term-set L for *i*-th criteria; O_i – the normalized score for the *i*-th criteria $i = \overline{1, m}$. On the basis of submitted input data, according to the project P, it is necessary to withdraw the initial aggregated evaluation $Y \in [0; 1]$. Analyzing the evaluation Y, a decision is taken on the level of safety risks of projects' implementation.

The purpose of this monograph is to propose a complex decision-making support model for assessing the safety risks of project implementation using a neuro-fuzzy network [23, 89, 92]. To do this, we will take the network as a basis TSK (Takagi-Sugeno-Kang) fuzzy inference system [23], to output the initial estimate $Y \in [0; 1]$, as shown in Figure 2.3.1.

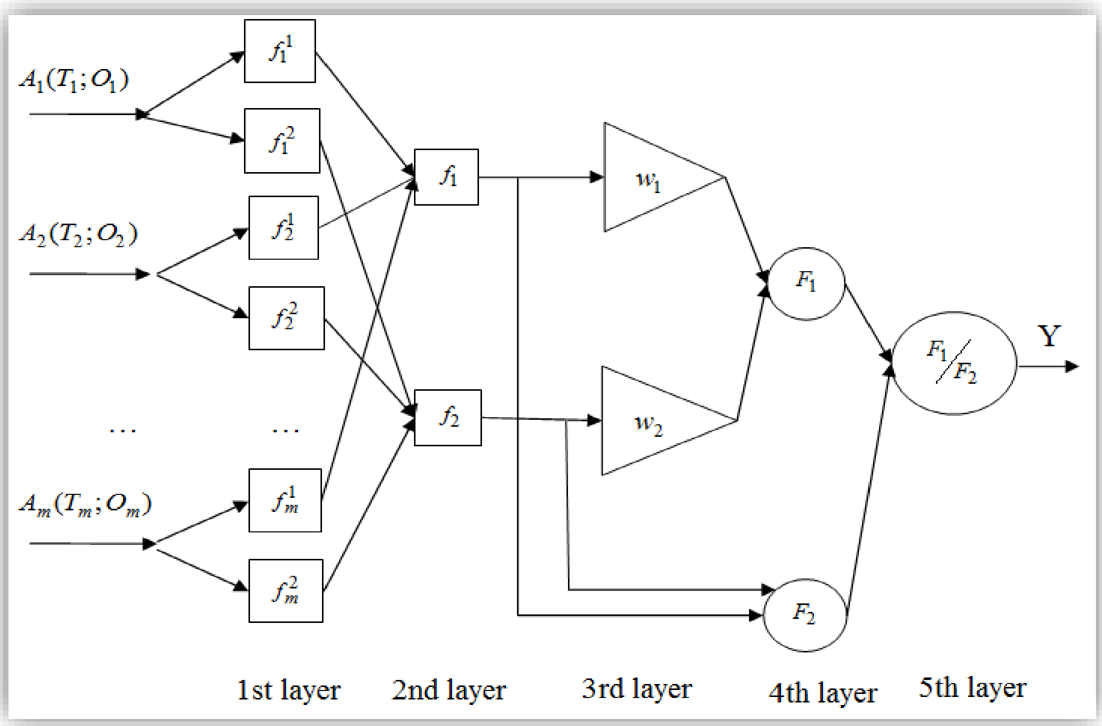

Fig. 2.3.1. The structure of the neuro-fuzzy network of the safety risks assessment of project implementation

The output is fuzzified using m variables $A_1(L_1; O_1)$, $A_2(L_2; O_2)$, …,$A_m(L_m; O_m)$, according to the following layers of the neuro-fuzzy network [65].

1st layer

In the neurons of the first layer, the fuzzification operation is performed, that is, for each input value $A_i(L_i; O_i), i = \overline{1, m}$ the value of the membership function is brought into the conformity. Let the term-set of linguistic variables T represent as triangular membership functions [65], on the numerical interval [0; 1], Figure 2.3.2, with the break: $l \in [0; a_2]$, $ba \in [a_1; a_3]$, $a \in [a_2; a_4]$, $aa \in [a_3; a_5]$, $h \in [a_4; 1]$.

The values of breakdowns of the intervals can be determined in the learning process of a neuro-fuzzy network using the real data of the task.

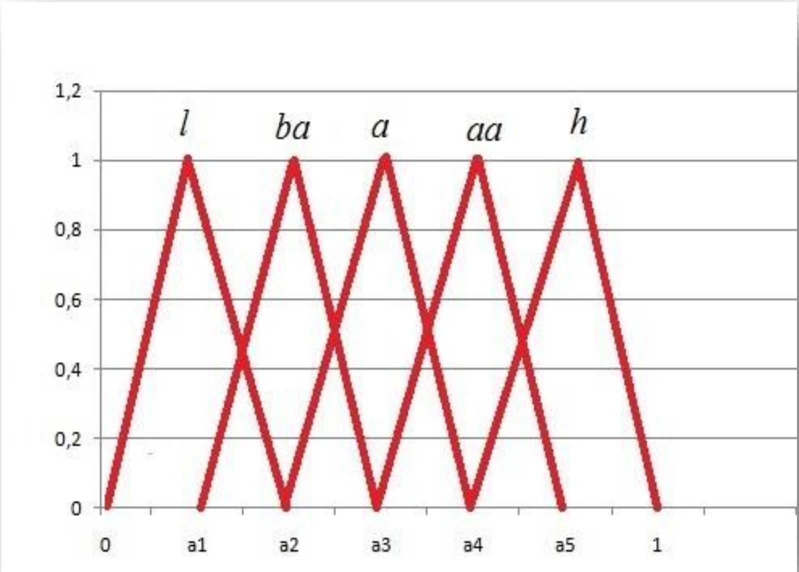

Fig. 2.3.2. The fuzzification operation term-sets of linguistic variables using the triangular membership functions

Each variable x_i has to be defined in order to make it possible to combine the values of quantitative assessments and the expert(s) opinions with regard to the project indicators:

$$x_i = A_i(L_i; O_i) = \begin{cases} a_1 \cdot O_i & if \quad L_i \in l; \\ a_2 \cdot O_i & if \quad L_i \in ba; \\ a_3 \cdot O_i & if \quad L_i \in a; \\ a_4 \cdot O_i & if \quad L_i \in aa; \\ a_5 \cdot O_i & if \quad L_i \in h. \end{cases} , i = \overline{1, m}. \qquad (2.3.1)$$

In this case, the analytic form of the recording of the triangular membership functions will be as follows [65]:

$$\mu_i^l = \begin{cases} 0, & if \quad x_i \le 0, \\ \dfrac{x_i}{a_1}, & if \quad 0 < x_i \le a_1, \\ \dfrac{a_2 - x_i}{a_2 - a_1}, & if \quad a_1 < x_i < a_2, \\ 0, & if \quad x_i \ge a_2. \end{cases} ; \qquad (2.3.2)$$

$$\mu_i^{ba} = \begin{cases} 0, & if \quad x_i \le a_1, \\ \dfrac{x_i - a_1}{a_2 - a_1}, & if \quad a_1 < x_i \le a_2, \\ \dfrac{a_3 - x_i}{a_3 - a_2}, & if \quad a_2 < x_i < a_3, \\ 0, & if \quad x_i \ge a_3. \end{cases}; \tag{2.3.3}$$

$$\mu_i^{a} = \begin{cases} 0, & if \quad x_i \le a_2, \\ \dfrac{x_i - a_2}{a_3 - a_2}, & if \quad a_2 < x_i \le a_3, \\ \dfrac{a_4 - x_i}{a_4 - a_3}, & if \quad a_3 < x_i < a_4, \\ 0, & if \quad x_i \ge a_4. \end{cases}; \tag{2.3.4}$$

$$\mu_i^{aa} = \begin{cases} 0, & if \quad x_i \le a_3, \\ \dfrac{x_i - a_3}{a_4 - a_3}, & if \quad a_3 < x_i \le a_4, \\ \dfrac{a_5 - x_i}{a_5 - a_4}, & if \quad a_4 < x_i < a_5, \\ 0, & if \quad x_i \ge a_5. \end{cases}; \tag{2.3.5}$$

$$\mu_i^{h} = \begin{cases} 0, & if \quad x_i \le a_4, \\ \frac{x_i - a_4}{a_5 - a_4}, & if \quad a_4 < x_i \le a_5, \\ \frac{1 - x_i}{1 - a_5}, & if \quad a_5 < x_i < 1, \\ 0, & if \quad x_i \ge 1. \end{cases}. \tag{2.3.6}$$

Then, we get the first layer in the process of the fuzzification *2m* membership functions:

$$\begin{cases} f_i^1 = \begin{cases} \mu_i^l & if \quad L_i \in l; \\ \mu_i^{ba} & if \quad L_i \in ba; \\ \mu_i^a & if \quad L_i \in a; \\ \mu_i^{aa} & if \quad L_i \in aa; \\ \mu_i^h & if \quad L_i \in h. \end{cases} \\ f_i^2 = O_i. \end{cases} \tag{2.3.7}$$

Provided that $f_i^1 \neq 0$; $f_i^2 \neq 0$, $i = \overline{1,m}$. Otherwise, further calculations are not possible from the mathematical point of view and have no meaning in the solution to be solved.

Thus, in the neurons of the first layer, we combine the quantitative and expert(s)' estimates of the projects according to the indicators and proceed to the normalized and comparable estimates.

The 2nd layer is an aggregation of membership levels. It consists of *m* multiplicative nodes and forms radially basic activation functions [23]:

$$\begin{cases} f_1 = \prod_{i=1}^{m} f_i^1, \\ f_2 = \prod_{i=1}^{m} f_i^2. \end{cases} \tag{2.3.8}$$

The 3rd layer is one of the synaptic weights w_1, w_2, which are corrected in the learning process. This is a parametric layer in which adaptations are subject to linear scales. In general, we can present the synaptic weights as the polynomials for deep learning:

$$\begin{cases} w_1 = w_0^1 + \sum_{i=1}^{m} w_i^1 x_i\,, \\ w_2 = w_0^2 + \sum_{i=1}^{m} w_i^2 x_i\,. \end{cases} \tag{2.3.9}$$

If, for a task to be solved, there is not enough data to study, then you can limit it to the incident $w_1 = w_0^1$, $w_2 = w_0^2$.

In this approach, talking about the adequacy of training, and therefore the receipt of initial assessment, is possible only if, in accordance with the initial conditions, a group of experts (expert) is competent and gives the conclusions close to the truth. Otherwise, the system will display the result regarding the competence of the group of experts.

The 4th layer is formed by two modules of summation, it calculates the sum of the output signals of the second and third layers:

$$
\begin{cases}
F_1 = w_1 f_1 + w_2 f_2 = w_1 \prod_{i=1}^{m} f_i^1 + w_2 \prod_{i=1}^{m} f_i^2, \\
F_2 = f_1 + f_2 = \prod_{i=1}^{m} f_i^1 + \prod_{i=1}^{m} f_i^2.
\end{cases} \tag{2.3.10}
$$

This network contains two parametric layers (the first and the third), their parameters are specified in the learning process. The parameters of the first layer are the nonlinear parameters, and the third, respectively, are the linear ones. If the task defines the parameters of the first layer and known dependence $Y(A_1, A_2, \dots, A_m)$, then, by the method of system solutions of the linear equations, linear parameters (synaptic weights) w_1, w_2. This is how the neural network is trained [23].

We suggest another way of presenting the synaptic weights – this is an "interval representation". Let the interval values be changed in relation to the function F_2. With a sufficiently large selection of projects and experience, you can adjust the intervals appropriately. For example, if $F_2 \in [0; 0{,}1]$ then $w_1 = 0{,}1$; $w_2 = 0{,}2$; $F_2 \in [0{,}1; 0{,}3]$ – $w_1 = 0{,}2$; $w_2 = 0{,}3$;$F_2 \in [0{,}3; 0{,}5]$ – $w_1 = 0{,}3$; $w_2 = 0{,}4$; $F_2 \in [0{,}5; 0{,}7]$ – $w_1 = 0{,}4$; $w_2 = 0{,}5$; $F_2 \in [0{,}7; 0{,}9]$ – $w_1 = 0{,}5$; $w_2 = 0{,}6$; $F_2 \in [0{,}9; 1{,}1]$ – $w_1 = 0{,}6$; $w_2 = 0{,}7$; $F_2 \in [1{,}1; 1{,}3]$ – $w_1 = 0{,}7$; $w_2 = 0{,}8$; $F_2 \in [1{,}3; 1{,}5]$ – $w_1 = 0{,}8$; $w_2 = 0{,}9$; $F_2 \in [1{,}5; 2]$ – $w_1 = 0{,}9$; $w_2 = 1$.

5th layer (output data). There is a normalization, resulting in an output signal:

$$
Y = \frac{F_1}{F_2} = \frac{w_1 \prod_{i=1}^{m} f_i^1 + w_2 \prod_{i=1}^{m} f_i^2}{\prod_{i=1}^{m} f_i^1 + \prod_{i=1}^{m} f_i^2}. \tag{2.3.11}
$$

In this way we will decrypt the data and obtain an estimate of the security risk of the implementation of the project. The resulting value of formula (2.3.11) is comparable to one of the term sets $BR = \{br_1, br_2, \dots, br_5\}$ putting the following content [65]:

- if $Y \in (0{,}7; 1]$ then br_1 = « low risk of the safe implementation of the project»;
- if $Y \in (0{,}5; 0{,}7]$ then br_2 = «average risk of the safe implementation of the project»;

- if $Y \in (0,4;\ 0,5]$ then br_3 = «speculative risk of the safety for the implementation of the project»;
- if $Y \in (0,2;\ 0,4]$ then br_4 = «high risk of the safety for the implementation of the project»;
- if $Y \in [0;\ 0,2]$ then br_5 = «very high risk of the safety for the implementation of the project».

The developed model improves the accuracy and objectivity of the evaluation, since on the one hand it uses quantitative estimates of the project (based on statistical data) on different models, and on the other experts´ experience, knowledge and expertise in the subject area. The model is based on the neuro-fuzzy network, which has the ability to change the values of its synaptic weights using the applied learning algorithm and adjust the decision-making levels. In addition, according to the proposed interval representation of weights, the model can be used to solve new problems where no data for training of neuro-fuzzy network are available.

The disadvantage of this approach is the fact that the resulting membership functions depend on the partitioning interval $[a_1; a_5]$, and their value is set by the experts. This also depends on data, which were supplied to the neural network for its training phase.

The general concept of this approach can be applied to other complex tasks, for example in the aviation sphere: to investigate aviation disasters. In this case, the model will evaluate the decisions taken by the pilots in an emergency. As the indicators can be taken: the pilot, airplane, and the environment of flight. The model input is based on the quantitative estimates obtained from the known aviation models of quantitative evaluation, and the experts’ linguistic considerations for the selected indicators. The synaptic weights are adjusted by "the interval presentation" depending on the situation of the flight: a stressed situation, limit situation, crisis situation, and disaster situation [96]. The higher the initial score, weighed on the flight situation, the pilot's actions were more correct.

2.4. MODEL OF EVALUATION AND SELECTION OF START-UP PROJECTS BY INVESTOR GOALS

Set multiple start-up s or innovative projects (alternatives) P= $\{p_1, p_2, \dots, p_n\}$, which need to be evaluated according to goals $G = \{G_1, G_2, \dots, G_g\}$ and sort by some rule. Each of the goals of G has some model of evaluating alternatives. According to the condition of the problem, alternatives P= $\{p_1, p_2, \dots, p_n\}$, it is necessary to evaluate by models of estimation and to build a ranking series of choosing the best start-up project, depending on the following goals of the investor: needs for a prospect start-up project, risk assessment of the project implementation and assessment of the competence of the team of start-up project developers [75]. The block diagram of the solution of the problem can be presented as a follow, Fig. 2.4.1.

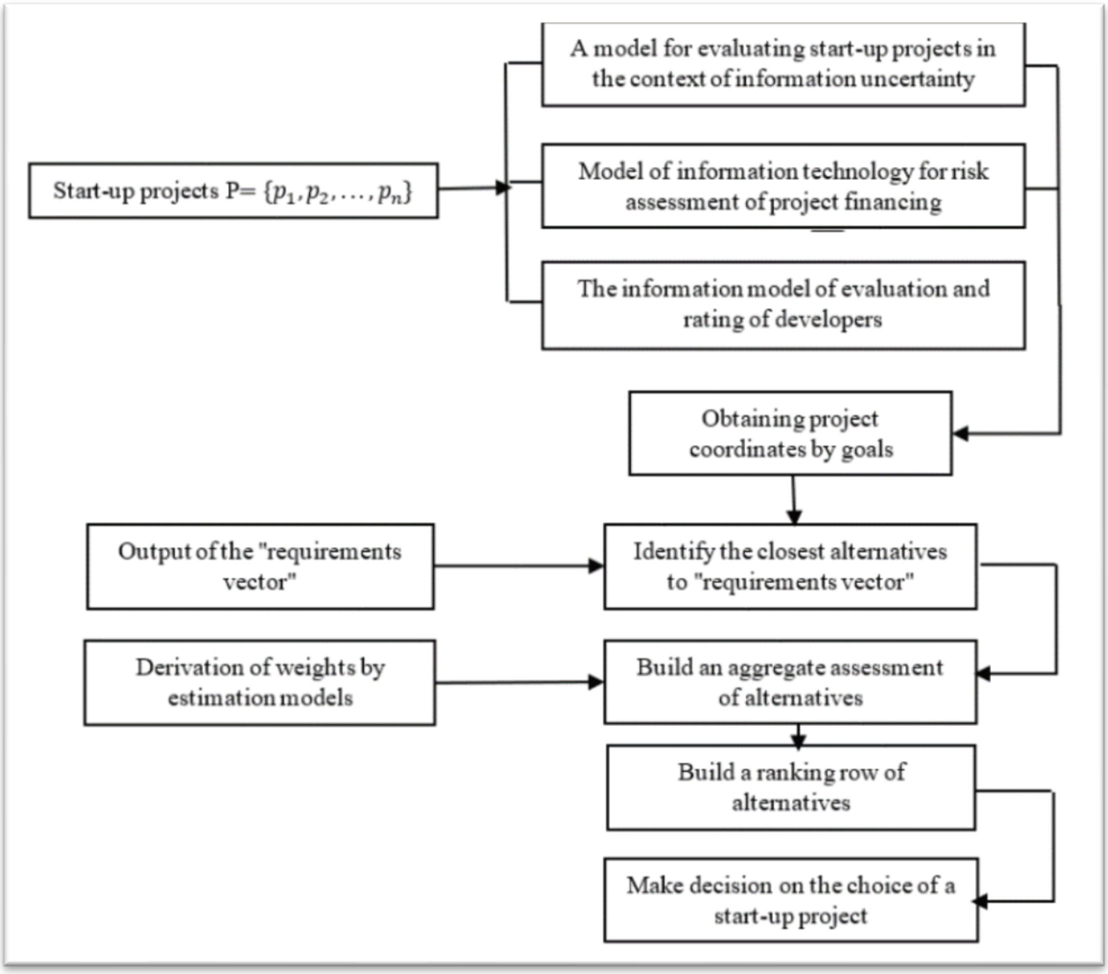

Fig. 2.4.1. Structural diagram of the solution of the problem

The model for obtaining an aggregate estimate is represented as:

$$M(G_1(s_1, \dots, s_n); G_2(r_1, \dots, r_n); G_3(t_1, \dots, t_n)) \rightarrow P^*. \qquad (2.4.1)$$

As a result, for each alternative P= $\{p_1, p_2, \dots, p_n\}$, there are finding of normalized estimates that determine the best alternative P^*; $s_1, s_2, \dots, s_n$ – assessing the relevant alternatives P= $\{p_1, p_2, \dots, p_n\}$ for a goal G_1; $r_1, r_2, \dots, r_n$ – estimates for the goal G_2 and $t_1, t_2, \dots, t_n$ for G_3.

If we have many start-up projects P= $\{p_1, p_2, \dots, p_n\}$, which need to be evaluated and selected by investors to fund them. Each project is evaluated using models that output estimates from the interval [0; 1]. The following goal evaluation models are proposed:

- model of estimation of start-up projects in the conditions of information uncertainty of vectors [1], as a result we get a set $S = \{s_1, s_2, \dots, s_n\}$;
- model of information technology for project risk assessment [43] – $R = \{r_1, r_2, \dots, r_n\}$;
- an information model of evaluating and rating teams of start-up development [16] – $T = \{t_1, t_2, \dots, t_n\}$.

Because we have the task of evaluating alternatives consisting of three goals, then vectors $S = \{s_1, s_2, \dots, s_n\}$, $R = \{r_1, r_2, \dots, r_n\}$ and $T = \{t_1, t_2, \dots, t_n\}$ we design on a three-dimensional coordinate system where the values set by S – is the value plotted on the *x*-axis, R – axis *y*, T – axis *z*. For each alternative, we will get the coordinates by goals G_1, G_2, G_3 which we present in the form: (s_1, r_1, t_1), (s_2, r_2, t_2), …, (s_n, r_n, t_n).

Next, we introduce the three-dimensional "satisfaction vector" $T^* = (A_1, A_2, A_3)$, which takes into account the wishes of a DM regarding the value of the alternatives for the goals G_1, G_2, G_3.

Definition. “Vector of satisfaction of requirements” is an imaginary alternative in which estimates of coordinates by purpose could satisfy a decision-maker [97].

We describe the model of the "requirements vector" as follows. Let the object with 3 inputs and one output be analyzed:

$$U = (A_1, A_2, A_3), \tag{2.4.2}$$

where $U -$ is the vector of the initial estimate (u_1, u_2, u_3), whose components take one of the values {0,2; 0,4; 0,6; 0,8; 1}, A_1, A_2, A_3 – are input linguistic variables.

To evaluate the linguistic variables A_1, A_2, A_3 we use qualitative terms from the following term sets:

$$\begin{gathered} A_1 = (a_{11}, a_{12}, \dots, a_{1t}),\ A_2 = (a_{21}, a_{22}, \dots, a_{2t}), \\ A_3 = (a_{31}, a_{32}, \dots, a_{3t}). \end{gathered} \tag{2.4.3}$$

The knowledge of the “requirements vector” $T = (t_1, t_2, t_3)$ defines a base of fuzzy knowledge in the form of a system of logical statements – “If - Then, Else”, which associates the values of input variables A_1, A_2, A_3 with one of the possible values U.

$$\begin{gathered} \text{If } A_1 = a_{1t} \text{ and } A_2 = a_{2t} \text{ and } A_3 = a_{3t} \\ \text{Then } U = (u_1, u_2, u_3) \text{ Else}\dots \end{gathered} \tag{2.4.4}$$

Thus, DM sets the linguistic desire for the “satisfaction vector”, which we transfer into the vector of initial quantitative and normalized estimation (u_1, u_2, u_3), denoted respectively $(u_1, u_2, u_3) = (t_1, t_2, t_3)$.

Therefore, the fuzzy knowledge base can be formulated as follows:

IF we have goals:

project start-up prospects (group of indicators G_1):

- a_{11} there is a need for a promising concept then $u_1 = 0{,}2$;
- a_{12} there is a priority need for a promising concept then $u_1 = 0{,}4$;

- a_{13} there is a need for a strong idea and a finished product then $u_1 = 0{,}6$;
- a_{14} the significant need for a promising, strong idea and finished product then $u_1 = 0{,}8$;
- a_{15} the priority need for a promising, strong idea and finished product then $u_1 = 1$.

AND project implementation risk (group of indicators G_2):

•a_{21} high then $u_2 = 0{,}2$;

•a_{22} average then $u_2 = 0{,}4$;

•a_{23} low then $u_2 = 0{,}6$;

•a_{24} very low then $u_2 = 0{,}8$;

•a_{25} minimum then $u_2 = 1$.

AND Competencies of the start-up project team (group of indicators G_3):

•a_{31} very low then $u_3 = 0{,}2$;

•a_{32} low then $u_3 = 0{,}4$;

•a_{33} average the $u_3 = 0{,}6$;

•a_{34} above average then $u_3 = 0{,}8$;

•a_{35} high then $u_3 = 1$.

THEN logical statement can be formulated as follows:

If we need the prospect of A_1 start-up and the risk of A_2 and the competence of the A_3 start-up team then $U = (u_1, u_2, u_3)$.

Next we find the values of the quantities $\mu(f_{1i})$, $\mu(f_{2i})$, $\mu(f_{3i}), i = \overline{1,n}$, which will allow us to determine the closest alternatives to the “requirements satisfaction vector” [98]:

$$\mu(f_{1i}) = \frac{|u_1 - s_i|}{max\left\{u_1 - \min_i s_i; \max_i s_i - u_1\right\}}, \quad (2.4.5)$$

$$\mu(f_{2i}) = \frac{|u_2 - r_i|}{max\left\{u_2 - \min_i r_i; \max_i r_i - u_2\right\}}, \quad (2.4.6)$$

$$\mu(f_{3i}) = \frac{|u_3 - t_i|}{max\left\{u_3 - \min_i t_i; \max_i t_i - u_3\right\}}, i = \overline{1,n}. \quad (2.4.7)$$

After that, we calculate the values $Z_i = (z_{1i}, z_{2i}, z_{3i}), i = \overline{1,n}$, which characterize the relative estimates of the proximity of alternatives to the "requirements satisfaction vector" for each individual objective G_1, G_2, G_3, which removes the question of different rating scales [97]:

$$Z_i = (1; 1; 1) - (\mu(f_{1i}); \mu(f_{2i}); \mu(f_{3i})), i = \overline{1,n}. \quad (2.4.8)$$

Let the decision maker set the weights for each estimation model $\{\alpha_1, \alpha_2, \alpha_3\}$, for example from the interval [1,10]. For further calculations we carry out their normalization [97]:

$$w_1 = \frac{\alpha_1}{\alpha_1 + \alpha_2 + \alpha_3}, w_2 = \frac{\alpha_2}{\alpha_1 + \alpha_2 + \alpha_3}, w_3 = \frac{\alpha_3}{\alpha_1 + \alpha_2 + \alpha_3}. \quad (2.4.9)$$

Next, to construct an aggregate estimate, we use one of the convolutions, for example, take a weighted average [97]:

$$Z_i^* = w_1 \cdot z_{1i} + w_2 \cdot z_{2i} + w_3 \cdot z_{3i}, i = \overline{1,n}. \quad (2.4.10)$$

Based on the estimates obtained, we select the best start-up project considering the goals of investors:

$$P^* = \max_i Z_i^*, \quad i = \overline{1,n}. \quad (2.4.11)$$

Therefore, the best alternative solution will be closest to the “requirements vector” for the goals G_1, G_2, G_3.

Built-in model for evaluating and selecting start-ups for investors' goals has several advantages, namely: it increases the objectivity of evaluating alternative options; allows to solve the problem of evaluating alternatives to goals and models of evaluation; builds a ranking number of start-up projects represented by evaluation vectors on different valuation models and improves security of choice of alternatives; investors' wishes are set in natural language, which allows for rapid adaptation to various financial institutions and design contests; the model allows to work with different rating scales that boil down to comparatives.

The disadvantages of this approach can be attributed to the use of different convolution models to obtain an aggregate estimate, which may lead to ambiguity in the final results.

2.5. Fuzzy Model of Information Technology Evaluation of Projects of Different Origins

We offer a model for solving the problem of evaluating projects of different origins to determine among them the most promising for investment. The complexity of this task is that each project is implemented by different actors, has different perspectives and opportunities, and has both a common and its own set of criteria for evaluation. In such a problem, there are inhomogeneous alternatives [8].

A characteristic feature of decision-making tasks that have to be solved in practice is multicriteria. The essence of multicriteria means that any practical solution to the problem leads to the emergence of alternative solutions, the consequences of which depend on several initial characteristics that affect the final result. The class of problems of multicriteria selection of a set of alternatives, in relation to criteria, includes a class of alternatives - partially comparable to a common set of criteria. Such alternatives are called inhomogeneous alternatives [8]. They have a common set of criteria, but evaluation by them does not provide comprehensive information. For each alternative, there are additional criteria, using which we will obtain an improved and adequate assessment. This set of alternatives arises in problems where they are combined into one area, but each has its own specific functional direction. This task includes the task of evaluating projects of different origins.

Depending on the origin, commercial projects are divided into three categories:

A_1 – classic investment projects for which a clearly formulated business plan, arise in a company operating in the market and require partial attraction of funds from outside;

A_2 – start-up projects, an "idea" that arises in companies whose business is based on innovative technologies, such companies have not entered the market or have just begun to enter it and need to attract external resources;

A_3 – innovative projects or start-up projects that represent long-standing companies in the market.

Depending on the problem, the set of inhomogeneous alternatives $X = \{x_1, x_2, \dots, x_n\}$ is divided into categories $A = \{A_1, A_2, \dots, A_\alpha\}$ on common grounds, $A_i = \{x_1^i, x_2^i, \dots\}$, $i = \overline{1, \alpha}$, where A_i – is the *i*-th category of alternatives.

All alternatives will be evaluated by a common set of performance criteria $\{K_1, K_2, \dots, K_{p-1}\}$, and each category of alternatives in turn will be evaluated by its own set of criteria $K_p = \{K_1, K_2, \dots, K_{m_i}\}$.

The block diagram of the fuzzy evaluation model of commercial projects of different origins can be depicted as follows, Fig. 2.5.1.

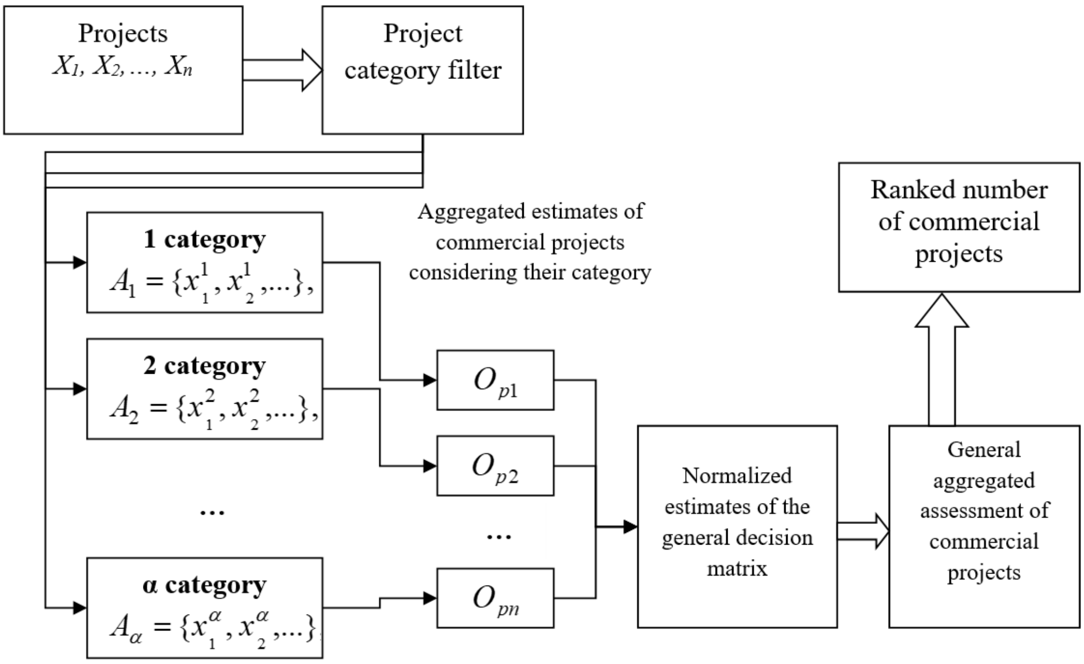

Fig. 2.5.1. Block diagram of a fuzzy model for evaluating commercial projects of different origins

At the entrance we have commercial projects of different origins, then the projects are divided into categories, after which the aggregate evaluation of commercial projects is calculated taking into account their category, there is a rationing of the general matrix of decisions taking into account common criteria.

There is an urgent task of developing a fuzzy model of information technology for evaluating commercial projects of various origins to determine among them the most promising for investment.

Input data models

To evaluate commercial projects, we offer the following set of indicators.

The first category of alternatives A_1 – classic investment projects can be evaluated by the following set of criteria [89]: K_1^P– net present value of the project (NPV - Net Present Value); K_2^P – simple payback period of the project (years); K_3^P – coefficient of own funds; K_4^P – level of competition in the regional market segment; K_5^P – experience of managers (owners) in the implementation of similar projects (except for the current project); K_6^P– marketing risks (related to sales of products or provision of services).

To evaluate the second category of alternatives A_2 – start-up projects, we use the criteria discussed in detail above. The criteria are presented in the form of a questionnaire and for evaluation it is necessary to choose the answer that is close to the truth [1]. For example: K_1^S – the proposed idea is a product or service ?; K_2^S – to which field the developed idea belongs; K_3^S – the social significance of the idea; K_4^S – the power of the idea (if venture companies have decided to supply their resources to competitors in this area, then tomorrow the product based on the idea will be?); K_5^S – level of entrepreneurial experience; K_6^S – the number of hours invested in their own time in the development of the start-up; K_7^S – the main competitors (meeting the same consumer needs) and others.

The third category of alternatives A_3 – i innovative projects (start-up projects that represent long-standing companies in the market). For example, the following criteria for evaluating start-ups may apply: K_1^{SC} – the proposed idea is a product or service; K_2^{SC} – to which field the developed idea belongs; K_3^{SC} the social significance of the idea. Also included are the indicators of the business entity [14]: total liquidity ratio – K_4^{SC}; coefficient of financial independence – K_5^{SC}; criterion term of existence of the enterprise – K_6^{SC} (are specified in years of functioning); the ratio of the share of enterprise funds in the cost of the loan project – K_7^{SC}.

Next, you need to define a set of common criteria for all projects. This set includes criteria that assess the level of risk and are evaluated expertly using one of the terms of the term set of linguistic variables $R = \{\text{Н}_R;\ \ \text{НС}_R;\ \ \text{С}_R;\ \ \text{ВС}_R;\ \ \text{В}_R\}$, where: H_R – «low level risk»; НС_R – «below average risk level»; С_R – «average level of risk»; ВС_R – «above average risk level»; В_R – «high level of risk». For example: K_1 – risk of losing the customer base; K_2 – risk of loss of supplier; K_3 – risk of loss of market share; K_4 – risk of investment inefficiency; K_5 – risk of exceeding the amount of initial investment; K_6 – risk of lack of investment capital; K_7 – investor risk of loss; K_8 – risk of inefficient innovative investments; K_9 – risks of failure of terms of development of innovations.

Also, to each assessment the expert puts the number of "reliability" $\mu(O_{gj})$, $g = \overline{1,p}$; $j = \overline{1,n}$ of their reasoning from the interval [1%; 100%].

The above set of criteria cannot reveal all aspects, so it is open and DM can add to it certain criteria for more adequate evaluation of projects.

Fuzzy mathematical model of information technology

The choice problem can be formulated as follows: to construct a ranking series and choose the best alternative from the set *X*, when the estimates of the criteria are known on this set. The model of the problem can be presented in the form of Table 2.5.1.

Tab. 2.5.1. Table of evaluations by criteria

	x_1	x_2	$\dots$	x_n
K_1	O_{11}	O_{12}	$\dots$	O_{1n}
K_2	O_{21}	O_{22}	$\dots$	O_{2n}
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
K_{p-1}	O_{p-11}	O_{p-12}	$\dots$	O_{p-1n}
K_p	O_{p1}	O_{p2}	$\dots$	O_{pn}

Or decision matrices:

$$O = (Ogj),\ g = 1, \dots, p;\ j = 1, \dots, n; \qquad (2.5.1)$$

where *Ogj* – is the evaluation of the *j*-th alternative by the *g*-th criterion. Each column of the matrix is a vector of estimates that characterizes the alternative, and each row of the matrix is a criterion. $O_{p1}, O_{p2}, \dots, O_{pn}$ – aggregate estimates of alternatives obtained by a set of criteria of the corresponding category.

The task of choice is divided into two stages [8]:

- at the first stage of solving the problem it is necessary to find aggregate estimates of $O_{p1}, O_{p2}, \dots, O_{pn}$ alternatives taking into account their category;
- at the second stage, having all estimations of alternatives on criteria to construct a ranking series of a matrix of decisions (2.5.1).

Suppose that in this problem we have several alternatives in one category $A_i = \{x_1^i, x_2^i, \dots, x_k^i\}$, $k < n$ which are evaluated by static evaluation criteria $\{K_1^i, K_2^i, \dots, K_{m_i}^i\}$, where i – is a category of alternatives, $i = \overline{1, \alpha}$. The model of the problem can be presented in the form of Table 2.5.2.

Tab. 2.5.2. Table of evaluations of alternatives by criteria

	x_1^i	x_2^i	$\dots$	x_k^i
K_1^i	O_{11}^i	O_{12}^i	$\dots$	O_{1k}^i
K_2^i	O_{21}^i	O_{22}^i	$\dots$	O_{2k}^i
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
$K_{m_i}^i$	$O_{m_i 1}^i$	$O_{m_i 2}^i$	$\dots$	$O_{m_i k}^i$

Or decision matrices:

$$Z^i = \left(O_{df}^i\right), d = \overline{1, m_i}; f = \overline{1, k}; i = \overline{1, \alpha}, \quad (2.5.2)$$

where O_{df}^i is the evaluation of the *f*-th alternative by the *d*-th criterion for the *i*-th category of alternatives.

The number of decision matrices will be determined by the number of categories of alternatives. Based on the decision matrices, it is necessary to obtain the vectors of estimates of alternatives $V_1, V_2, \dots, V_\alpha$, which will contain all the required estimates $O_{p1}, O_{p2}, \dots, O_{pn}$, for the criterion K_p. This problem is a problem of multicriteria choice, so the vectors of evaluation of alternatives $V_1, V_2, \dots, V_\alpha$ can be found as one of the approaches [8].

Without reducing the generality, consider the model of obtaining estimates $O_{p1}, O_{p2}, \dots, O_{pn}$ on the matrix of solutions of the first category of alternatives:

$$Z^1 = \left(O_{df}^1\right), d = \overline{1, m_i}; f = \overline{1, k}. \quad (2.5.3)$$

We present an algorithm for a mathematical model of information technology to obtain a ranking of a number of commercial projects.

Step 1. In the first step, it is necessary to normalize the evaluation of alternatives by criteria. Estimates O_{df}^1 in this problem can be quantitative or qualitative depending on the specific indicator. In the case of quantitative estimates, we use one of the convolutions of rationing [18]. For the case of rationing of qualitative assessments, we propose the following approach [8].

Each criterion is evaluated expertly using one of the terms of the term-set of linguistic variables $L = \{H;\ \ HC;\ \ C;\ \ BC;\ \ B\}$, where: H – "low level of indicator"; HC – "level below average"; C – "average level of the indicator"; BC – "above average"; B – "high level of indicator".

Also, for each linguistic assessment, the expert puts the percentage of "reliability" $\mu(O_{df}^1)$ of his reasoning from the interval [1%; 100%].

Then the input data of linguistic estimates can be presented in the form of Table 2.5.3.

Tab. 2.5.3. Input data of linguistic assessments

Criteria	Linguistic variable	Reliability of expert opinions
K_1^1	L_{1f}^1	$\mu(L_{1f}^1)$
K_2^1	L_{2f}^1	$\mu(L_{2f}^1)$
…	…	…
$K_{m_i}^1$	$L_{m_i f}^1$	$\mu(L_{m_i f}^1)$

Where $f = \overline{1,k}$, $K_{m_i}^1$ is the linguistic criterion m_i of the first category, $L_{m_i f}^1$ is a variable from the term set L for the m_i criterion of the first category, $\mu(L_{m_i f}^1)$ – the validity of the expert's reasoning on the assignment of $L_{m_i f}^1$ variable.

For each linguistic variable we set the value from the interval $[0; 1]$: H – $[a_1;a_2]$, HC – $[a_3;a_4]$, C – $[a_5;a_6]$, BC – $[a_7;a_8]$, B – $[a_9;a_{10}]$. Example: H – [0; 0,2], HC – [0,2; 0,4], C – [0,4; 0,6], BC – [0,6; 0,8], B – [0,8; 1].

Let's calculate one normalized estimate based on the linguistic variable and the reliability of its assignment, according to:

$$Z_{df}^1 = a_r + \frac{1}{100} \cdot \mu(L_{m_i f}^1) \cdot (a_{r+1} - a_r). \tag{2.5.4}$$

where a_r is the value of the interval for the linguistic variable, $r = \overline{1,10}$, Z_{df}^1 is the normalized numerical value of the linguistic criterion adjusted for the reliability of the expert's reasoning $d = \overline{1, m_i}; f = \overline{1,k}$.

Thus, from linguistic or quantitative non-normalized estimates we pass to the matrix of decisions of normalized estimates:

$$Z^i = \left(Z^i_{df}\right), d = \overline{1, m_i}; f = \overline{1, k}; i = \overline{1, \alpha}, \quad (2.5.5)$$

where Z^i_{df} is a normalized estimate of the *f*-th alternative by the *d*-th criterion for the *i*-th category of alternatives.

Step 2. For each criterion $\{K^i_1, K^i_2, \dots, K^i_{m_i}\}$ DM are known or can specify weights $\{p^i_1, p^i_2, \dots, p^i_{m_i}\}$ from the interval [1; a]. Then, it is possible to determine the normalized weights for each criterion for different categories of alternatives [10]:

$$\alpha^i_d = \frac{p^i_d}{\sum_{d=1}^{m_i} p^i_d}, d = \overline{1, m_i}; \alpha^i_d \in [0; 1]; \quad (2.5.6)$$

which meet the condition $\sum_{d=1}^{m_i} \alpha^i_d = 1$.

Step 3. We use one of the convolutions to obtain an aggregate assessment of alternatives, which are obtained by a set of criteria of the *i*-th category [1]. For example, take a weighted average convolution:

$$O_{pj} = \sum_{d=1}^{m_i} \alpha^i_d \cdot Z^i_{df}, \quad (2.5.7)$$

where $i = \overline{1, \alpha}; f = \overline{1, k}; j = \overline{1, n}; i = \overline{1, \alpha}$.

Thus, we obtained all estimates of alternatives for the solution matrix (2.5.1) and performed the first stage of the problem.

In the second stage, having all the evaluations of alternatives by criteria, we can build a ranking series of alternatives based on the matrix of solutions (2.5.1). Without reducing the generality, we assume that the elements of the matrix $O = \left(O_{gj}\right),\ g = \overline{1, p-1};\ j = \overline{1, n}$ are normalized. Otherwise, depending on the specific application problem, the rationing of estimates can be done in the same way as for the matrix (2.5.3).

Step 4. Let the DM know or can assign weights to each efficiency criterion *{p_1, p_2, ..., p_p}* from the interval [1; a]. Then, similarly determine the normalized weights for each criterion by the formula:

$$\alpha_g = \frac{p_g}{\sum_{g=1}^{p} p_g}, g = \overline{1,p}; \alpha_g \in [0;1]. \quad (2.5.8)$$

Step 5. Next, similarly, we take one of the convolutions to construct an aggregate estimate of the alternative from the solution matrix (2.5.1) [1]. For example, a weighted average convolution, in our case, will look like:

$$A(x_j) = \sum_{g=1}^{p} \alpha_g \cdot O_{gj}, j = \overline{1,n}. \quad (2.5.9)$$

Step 6. Based on the values of $A(x_j)$ we build a ranking series of commercial projects of different origins:

$$A = (A_1, A_2, \dots, A_n). \quad (2.5.10)$$

Thus, a vague mathematical model of information technology presented, with the help of which it is possible to evaluate and build a ranking series of commercial projects, based on static evaluation criteria, having both quantitative and qualitative expert data.

The constructed fuzzy mathematical model of information technology for evaluating commercial projects of different origins has a number of advantages, namely, increases the objectivity of expert evaluations in project evaluation using input linguistic variables and reliability of expert opinions to their assignment; combines opinions by categories of criteria into a final assessment, based on the constructed two-level fuzzy mathematical model of obtaining a general aggregate assessment of commercial projects.

The disadvantages of this approach include the use of different models of convolutions to obtain an aggregate estimate, which can lead to ambiguity of the final results.

The result of the study is a fuzzy mathematical model of information technology for evaluating projects of different origins based on fuzzy expert evaluations, the output of which is a general aggregate evaluation of commercial projects and their ranking. The rationality of the obtained assessment proved by the advantages of the developed model. The reliability of the obtained results ensured by the correct use of the apparatus of fuzzy logic and fuzzy sets, which is confirmed by the research results.

The development of information technology for the evaluation of commercial projects of various origins, based on the fuzzy mathematical model, will be a useful tool for investment institutions, venture funds or crowdfunding platforms in the evaluation and selection of projects [82].

2.6. THE MODEL OF CROWDFUNDING PLATFORM RATING ESTIMATION

Today's experience shows that millions of people, who had nothing in common with investing, can invest money in start-ups and their economy. “Observing the development of a large number of start-ups, it is clear that using modern technology one can find a good alternative to lending” [18].

Crowdfunding – is investing in a start-up that is performed by a lot of people, including micro investors and business angels.

Crowdfunding has great potential. In general, in every country, there is a huge amount of money which is not used. Usually, a particular average person has not enough spare cash to think about the traditional investment. People do not invest a small amount of money but waste it. The world economy can get much more if small amounts of spare cash come into the development of the economy through crowdfunding platforms. If there are more funded start-ups, there are more workplaces, products, and services they created.

Therefore, there is the urgent primary task of improving the safety of crowdfunding platforms. “It needs to be solved systematically by developing new models of information technology and the introduction of a reasonable law regulation and distribution of business” [18]. The secondary task is to strengthen the criminal protection of investors in start-up projects, which also do not avoid financial fraud. These aspects are not in line with the further safe and sustainable development of society and required the protection of interests. “Security and law-based research generally point to the "struggle" with the technical and the anti-social phenomena, which is complex, lengthy, demanding but socially necessary for the healthy, sustainable and sustainable development of a democratic society: state security and citizen security, protection of fundamental human rights and freedoms and other protected interests” [99].

The main disadvantages of crowdfunding are:

1. The risk of fraud: possibly, under the guise of start-up pyramid scheme gathers the capital or the platform itself is created for phishing scams.

2. The risk that the required amounts of investments will not be collected and the project will not be implemented.

3. The risk that the project will be unprofitable and closed, and the investment will be lost.

4. In many cases, crowdfunding schemes do not correspond to the legislation of the country, which does not allow to resolve the disputes in court in fairness.

5. Unprofitability – many platforms are closed soon after they were opened.

There is a direct correlation between platform safety level, the submitted projects, and the number of investments made. Therefore, it is necessary to develop scientific approaches to eliminate the disadvantages of crowdfunding that will improve the safety level of modern investment platforms. “The secondary theme is also the enforceability of law within the safeguarding of protected rights and interests.” [99].

The first disadvantage is the risk of fraud.

Either platform that attracts investment in non-existent projects or start-ups presented in the form of a pyramid scheme can turn out to be scammers. Therefore, it is necessary to reduce the risks of fraud. The main tools for platform security are:

1. Accreditation – the platform must meet the legal requirements, to be registered and obtain a state license, as an object of a financial institution.

2. Rating System – unified evaluation obtained on the basis of characteristics system. These indicators may include the assessment of platform

owners; the rating of start-ups; the estimation of investors; the indicators of successful performance; etc.

Rating of the platform should be assigned automatically while in operation and updated in real-time. The metrics of ranking must be dynamic. It is necessary to develop a mathematical model to calculate the rating and information technology.

The main means of safety improvements and reducing the risk of fraud for start-up projects are the following:

1. Evaluation of start-ups to select them for the platform to prevent access of fraudulent pyramid schemes to the platform. "Evaluation model of start-ups in case of information uncertainty" described in [14] can be used to assess start-ups.

2. Development of a mathematical model of information technology of risk assessment start-ups relating to the safety of their financing, using fuzzy math.

The development of technologies of this type will enable us to consider the projects adequately, to increase the validity of investment decisions, and to increase economic and management security. This will allow evaluation projects that are registered on the platform. Investors will be able to make informed investment decisions.

Increasing platform security is possible with the help of its accreditation and rating system that will be displayed on the website, and access if start-ups and their risk related to security funding level.

Disadvantages described in points 2-3 can be solved as follows. The platform should enable an investor to resell its investment in secondary trading. If there is a need to send back their investments before the launch of the project, or on the contrary to maximize profits at the peak of popularity of the project, it should be possible to sell the investment share in secondary trading. Therefore, the successful sale of investment shares allows making an additional profit. The platform should be able to refund. In case the investment project did not assemble the declared amount of money, the investments should be sent back into the investor's account without platform commissions.

Point 4 should be solved systematically by developing legislation for a new type of IT maintenance business that has great prospects. Laws should be simple, clear and start-ups and investors supporting. Investors should not be afraid to be unable to bring their investments into projects during the successful launch phase. And “the start-uppers” have to be sure that in case of a successful project launch the investors will not get their business. There should be a clear law that governs modern business and prevents fraud.

If disadvantages described in points 1-4 are solved systematically, the unprofitability of platforms is automatically reduced.

We offer a mathematical approach to evaluating crowdfunding platforms that can be used as an auxiliary tool to trust the platform or possibly certify it. Good where investors and start-uppers have complete analytical and rating information about the platform.

The model of the task is formulated as follows:

$$EK = PR(PR_1, PR_2, PR_3, PR_4), \quad (2.6.1)$$

where PR_1 – aggregate assessment of platform owners, PR_2 – in targeted risk estimation concerning the project’s funding safety level, PR_3 – aggregated estimation of investors who worked on the platform, PR_4 – success estimation of the realized projects. EK – output rating and linguistic estimation of the crowdfunding platform. PR – operator that makes the output EK variable corresponding to input estimations PR_1, PR_2, PR_3, PR_4.

A set of criteria in the form of expert questions is suggested to get platform owners aggregated evaluation. Also, an appropriate tonal estimate range is described. Platform owners answer the questions and choose the most appropriate option [18].

K_1^P – Platform holders comprehensive income in the last 12 months?:

1. $0 - $24 999 (5 points);
2. $25 000 - $99 999 (20 points);
3. $100 000 - $249 999 (25 points);

4. $250 000 or more (30 points).

K_2^P – Platform owners business experience level is achieved due to?:

1. lack of business keeping knowledge (5 points);
2. successful small business launch (15 points);
3. working as co-founders or co-workers in a successful high-tech company (20 points);
4. there is the founder of several successful companies among the owners (30 points).

K_3^P – The owners are experienced in IT or investment market occupying executive positions in the branch?:

1. none of the owners is (5 points);
2. less than 2 years (15 points);
3. 2-5 years (20 points);
4. has an experience for over 5 years (30 points).

K_4^P – The number of scientists working on a platform development full time for at least three months?:

1. none (5 points);
2. a group of 1-3 (15 points);
3. a group of 3-5 (20 points);
4. more than 5 (30 points).

K_5^P – The number of sales / marketing development / business experts working to promote the platform full-time for at least three months?:

1. none (5 points);
2. a group of 1-3 (15 points);
3. a group of 3-5 (20 points);
4. more than 5 (30 points).

K_6^P – The authorized capital of crowdfunding platform is?:

1. $0 - $24 999 (5 points);
2. $25 000 - $99 999 (20 points);

3. $100 000 - $249 999 (25 points);

4. $250 000 or more (30 points).

K_7^P – Corporate attorney of the platform is:

1. the lawyer with only a law degree (5 points);

2. a small local firm (10 points);

3. a medium-sized company, which operates in the investment area (20 points);

4. a nationally recognized corporate law firm with a lot of connections in the venture community (30 points).

The following scale for the scores of the answers is heuristic and characterizes the level of the platform owners. The more points there are, the more trust the platform and its owners have.

For each criterion, the platform and its owners correspond to one of the answers to which the corresponding scores assigned. Let us define the assessments convolution, such as the number of graduation range answers points divided into the number of maximum points:

$$PR_1 = \frac{\sum_{i=1}^{7} b_i}{\sum_{i=1}^{7} \underset{max}{b_i}}, \qquad (2.6.2)$$

Where b_i – scoring by the i-criterion, $\underset{max}{b_i}$ – maximum scoring by the i-criterion. PR_1 – normalized aggregate assessment of the platform owners.

To get an integrated risk assessment regarding the project funding security level let us use the following formula:

$$PR_2 = \frac{\sum O_R}{d}. \qquad (2.6.3)$$

Where O_R – start-up risk assessment (described in the previous point), d – a number of start-ups on a platform.

The next step is building an aggregated assessment of investors working with a platform – PR_3. Thus, let us sum up the assessment of the presence of the following subject on the platform: Venture fund which is a part of the top 20 global investors (0,4points); Worldwide-known business angels (0,3 points); Large national investment firms (0,2 points); National-known business angels (0,1 points).

PR_3 assessment obtained by summing the number of points will be normalized. Of course, such concepts as "top 20" or "known business angels" are fuzzy. A knowledge base, which is based on the world rankings, should be created to build up a computer information technology based on the proposed model. It has to be updated every time when new rankings are published.

To get PR_4 – the assessment of accomplished project success the following formula is suggested:

$$PR_4 = \begin{cases} R_4, & R_4 < 1, \\ 1, & R_4 \geq 1. \end{cases} \quad (2.6.4)$$

Where $R_4 = \frac{k^*}{n_0}$, k^*– the number of projects on the platform which raised the start-up budget and got the investments, n_0– the number of projects which didn't raise the start-up budget.

At this point, let us build about going rating and linguistic assessment of crowdfunding platform EK. If an expert defines the weight coefficient $\{w_1, w_2, w_3, w_4\}$ of an interval. Normalized weight coefficients should be defined as follows:

$$\alpha_i = \frac{w_i}{\sum_{i=1}^{4} w_i}, i = \overline{1,4}, \sum_i \alpha_i = 1. \quad (2.6.5)$$

Let us use the following formula to rate the scoring:

$$PR = \sum_{i=1}^{4} \alpha_i \cdot PR_i. \quad (2.5.6)$$

The obtained PR assessment is set from the interval [0;1], the following scale is suggested to compare it with its outgoing variable EK: ek_1= «very high platform rating»; ek_2=«high platform rating»; ek_3=«sufficient platform rating»;

ek_4=«speculative platform rating»; ek_5=«very low platform rating». The linguistic explanation of the aggregated risk assessment $EK = \{ek_1, ek_2, ek_3, ek_4, ek_5\}$ is defined as follows: $PR \in (0{,}87; 1] - ek_1$; $PR \in (0{,}67; 0{,}87] - ek_2$; $PR \in (0{,}36; 0{,}67] - ek_3$; $PR \in (0{,}21; 0{,}36] - ek_4$; $PR \in [0; 0{,}21] - ek_5$.

Based on the analysis and practical experience, a set of criteria for obtaining a unified rating assessment of crowdfunding platforms was given, and a set of criteria for start-up projects risk assessment was suggested. Sets of criteria are heuristic, and they can be supplemented when needed. Information technology models do not depend on the number of criteria. Therefore, the number of criteria does not affect the work of developed models, and an increase in their number during the technology implementation leads to more accurate estimates.

Thus, the building model of the crowdfunding rating assessment is given. The program realization of the models hold gets the information from the platform and should be its inseparable addition. It gives the opportunity to assign the platform rating based on the dynamic indicators in real-time.

Crowdfunding has a range of commonly known disadvantages and their reduction can improve and develop new types of business activity. The information technology model is a new ideological approach that does not have analog. The system solves the problem of safety of crowdfunding platform functioning based on developed models: rating assignment system of unified assessment crowdfunding platforms; start-up projects assessment; start-up projects risk assessment concerning their financing safety level and criminal law protection of investors against the financial fraud, ect. The models are based on the correct usage of fuzzy logic and fuzzy set device to reveal the uncertainty of experts’ consideration that ensures the authenticity of scientific results.

Rating system crowdfunding platform model can evaluate the platform and give the linguistic interpretation of such evaluation using a systematic approach of the platform owners, start-ups risks, investors and successful projects.

3. RESULTS OF EVALUATING START-UP PROJECTS

3.1. EXAMPLE OF THE SECURITY OF THE FINANCING OF THE ENVIRONMENTAL START-UP PROJECTS IN AIR TRANSPORT

We will test the results of the Fuzzy model for quantitative assessment of start-up projects on an example of the security of the financing of the environmental start-up projects in air transport [1]. Let us have five environmental start-ups projects in air transport $P = \{P_1, P_2, \ldots, P_5\}$ to evaluate the security of their financing by investors. Each project will be evaluated by the start-up (ideas) and the team of developers: $P_k = (S_k;\ X_k),\ k = \overline{1,5}$. All the projects, under consideration, from the university incubators (the Technical University of Kosice – TECHNICOM and the Uzhhorod National University). The projects have undergone an expert evaluation on the proposed sets of criteria. The input data for the project, weighting factors of the criteria, "investor's wishes" T and wish the meaning of the term DM is given in Table 3.1.1. Expert evaluation data, teams presented in Table 3.1.2.

Tab. 3.1.1. Input of environmental start-up projects on the criteria of evaluation

Name Criteria	p	T	A^{*}_{ig} [1]	S_1	S_2	S_3	S_4	S_5
SK_1	10	15	A^{*}_{13}	5	5	10	20	20
SK_2	10	18	A^{*}_{23}	5	20	5	20	15
SK_3	7	20	A^{*}_{34}	10	5	20	10	20
SK_4	7	10	A^{*}_{42}	0	5	0	15	15
SK_5	6	15	A^{*}_{53}	10	10	15	20	20
SK_6	8	15	A^{*}_{63}	0	10	5	15	15
SK_7	7	10	A^{*}_{73}	5	5	5	10	10
SK_8	9	18	A^{*}_{83}	5	5	5	15	15
SK_9	6	13	A^{*}_{92}	5	5	10	10	15

[1] These terms, called desirable.

Tab. 3.1.2. Inputs of developers of environmental start-up projects on the criteria of evaluation

Name Criteria	X_1		X_2		X_3		X_4		X_5	
	L	**d**	**L**	**d**	**L**	**d**	**L**	**d**	**L**	**d**
DK_{11}	L	0.6	L	0.9	A	0.8	H	0.9	H	0.7
DK_{12}	BA	0.7	BA	0.8	A	0.6	A	0.8	H	0.9
DK_{21}	L	0.8	BA	0.7	A	0.4	H	0.7	H	0.7
DK_{22}	BA	0.8	A	0.9	BA	0.8	H	0.7	A	0.8
DK_{23}	BA	0.6	A	0.8	BA	0.6	H	0.9	A	0.6
DK_{24}	BA	0.6	BA	0.9	A	0.8	A	0.8	A	0.5
DK_{25}	A	0.8	A	0.7	BA	0.8	A	0.7	A	0.7
DK_{31}	A	0.9	H	0.8	BA	0.8	BA	0.9	BA	0.8
DK_{32}	L	0.8	H	0.6	L	0.8	H	0.9	H	0.9
DK_{33}	L	0.7	H	0.6	H	0.6	H	0.6	H	0.9
DK_{34}	BA	0.6	A	0.8	BA	0.8	BA	0.8	A	0.8

First, we will evaluate start-up projects for the fuzzy evaluation model, according to the steps below:

Steps 1–2. The fuzzification of the input data and the consideration of the DM require calculating the value of membership functions according to Equation (2.1.2), Table 3.1.3.

Tab. 3.1.3. Normalized data on the criteria for evaluating environmental start-up projects

Name Criteria	S_1	S_2	S_3	S_4	S_5	α
SK_1	0.000	0.000	0.222	1.000	1.000	0.778
SK_2	0.000	1.000	0.000	1.000	0.778	0.964
SK_3	0.222	0.000	1.000	0.222	1.000	0.778
SK_4	0.000	0.222	0.000	1.000	1.000	0.778
SK_5	0.222	0.222	0.778	1.000	1.000	0.778
SK_6	0.000	0.778	0.222	1.000	1.000	1.000
SK_7	0.500	0.500	0.500	1.000	1.000	1.000
SK_8	0.000	0.000	0.000	0.778	0.778	0.964
SK_9	0.000	0.000	0.500	0.500	1.000	0.920

Step 3. Estimation of the usefulness of the start-up, for each criterion, we obtain the linguistic meaning and validity of the term for (2.1.3)–(2.1.7), Table 3.1.4.

Tab. 3.1.4. Evaluating the usefulness of the start-up

Name Criteria	S_1		S_2		S_3		S_4		S_5	
	A_{lg}	μ_{Alg}	A_{lg}	μ_{Alg}	A_{lg}	μ_{Alg}	A_{lg}	μ_{Alg}	A_{lg}	μ_{Alg}
SK_1	A_{11}	1	A_{11}	1	A_{11}	1	A_{14} A_{15}	0.857 0.143	A_{14} A_{15}	0.857 0.143
SK_2	A_{21}	1	A_{23} A_{24}	0.853 0.147	A_{21}	1	A_{23} A_{24}	0.853 0.147	A_{22} A_{23}	0.774 0.226
SK_3	A_{31}	1	A_{31}	1	A_{34} A_{35}	0.857 0.143	A_{31}	1	A_{34} A_{35}	0.857 0.143
SK_4	A_{41}	1	A_{41}	1	A_{41}	1	A_{44} A_{45}	0.853 0.147	A_{44} A_{45}	0.853 0.147
SK_5	A_{51}	1	A_{51}	1	A_{53}	1	A_{54} A_{55}	0.853 0.147	A_{54} A_{55}	0.853 0.147
SK_6	A_{61}	1	A_{62} A_{63}	0.889 0.111	A_{61}	1	A_{63}	1	A_{63}	1
SK_7	A_{71}	1	A_{71}	1	A_{71}	1	A_{73}	1	A_{73}	1
SK_8	A_{81}	1	A_{81}	1	A_{81}	1	A_{82} A_{83}	0.774 0.226	A_{82} A_{83}	0.774 0.226
SK_9	A_{91}	1	A_{91}	1	A_{91} A_{92}	0.826 0.174	A_{91} A_{92}	0.826 0.174	A_{93} A_{94}	0.652 0.348

Steps 4–5. The quantitative evaluation of the project in terms of DM´s wishes. The result of computing the estimates for the obtained and desirable terms using the membership function (2.1.8) and determining the normalized weight coefficients for (2.1.9), are presented in Table 3.1.5.

Tab. 3.1.5. Values of assessments by evaluation criteria

Name Criteria	$\boldsymbol{S_1}$	$\boldsymbol{S_2}$	$\boldsymbol{S_3}$	$\boldsymbol{S_4}$	$\boldsymbol{S_5}$	$\boldsymbol{w}$
SK_1	0	0	0	0.429	0.429	0.14
SK_2	0	0.853	0	0.853	0.387	0.14
SK_3	0	0	0.857	0	0.857	0.10
SK_4	0.5	0.5	0.5	0	0	0.10
SK_5	0	0	0.5	0.429	0.429	0.09
SK_6	0	0.445	0	1	1	0.11
SK_7	0	0	0	1	1	0.10
SK_8	0	0	0	0.387	0.387	0.13
SK_9	0.5	0.5	0.413	0.413	0.326	0.09

Step 6. We build a quantitative estimate of the environmental start-up of the projects by the formula (2.1.10): $O_S = (0.095; 0.263; 0.218; 0.516; 0.528)$. As you can see, the best start-up project S_5, with linguistic interpretation – es_2 = “an assessment of start-up project is above average”.

Then, the evaluation of development teams continued with the fuzzification of the input signals in the neurons of the first layer. To achieve this, the membership function in a numerical interval $[0;\ 10]$, where $L \in [0; 2]$, $BA \in [2; 5]$, $A \in [5; 8]$, $H \in [8; 10]$ must be defined.

We use equations (2.1.11)–(2.1.12) to obtain the value of the membership function, and we write the results in Table 3.1.5.

Tab. 3.1.5. Fuzzification of the input signals

Name Criteria	X_1	X_2	X_3	X_4	X_5
DK_{11}	0.029	0.065	0.741	0.980	0.820
DK_{12}	0.245	0.320	0.461	0.741	0.980
DK_{21}	0.051	0.245	0.205	0.820	0.820
DK_{22}	0.320	0.843	0.320	0.820	0.741
DK_{23}	0.180	0.741	0.180	0.980	0.461
DK_{24}	0.180	0.405	0.741	0.741	0.320
DK_{25}	0.741	0.613	0.320	0.613	0.613
DK_{31}	0.843	0.920	0.320	0.405	0.320
DK_{32}	0.051	0.680	0.051	0.980	0.980
DK_{33}	0.039	0.680	0.680	0.680	0.980
DK_{34}	0.180	0.741	0.320	0.320	0.741

On the second, up to third layer we calculate the functions of postsynaptic potential. Let the DM´s wishes be for the synaptic scales of the criteria (8; 9; 8; 10; 9; 10; 7; 8; 6; 7; 9)$\in [1;10]$ and the synaptic weights for a group of criteria (10; 9; 8)$\in [1;10]$. By the equations (2.1.13)–(2.1.15) for the second layer and (2.1.16) for third layer, the results follow in Table 3.1.6.

Tab. 3.1.6. Function of postsynaptic potential of neurons of the second and third layers

Name Criteria	X_1	X_2	X_3	X_4	X_5
Z_1	0.143	0.200	0.593	0.853	0.905
Z_2	0.278	0.577	0.366	0.802	0.582
Z_3	0.298	0.762	0.350	0.559	0.732
W_1	0.053	0.074	0.219	0.316	0.335
W_2	0.093	0.192	0.122	0.267	0.194
W_3	0.088	0.226	0.104	0.166	0.217

Next, in the fourth layer, there is the defuzzification of the data for (2.1.17): O_F = (0.234; 0.492; 0.445; 0.749; 0.746). As you can see, the best developer – X_4, with linguistic interpretation – ef_2 = "the rating of the team start-up project is higher than the average".

Based on ratings O_S, O_F the quantitative aggregate initial estimates O_P is received from the interval by the formula (2.1.19): O_{P_1} = (0.095; 0.234) = 0.123; O_{P_2} = 0.309; O_{P_3} = 0.258; O_{P_4} =0.658; O_{P_5} = 0.665. The projects can be ranked according to the quantified estimates: P_5; P_4; P_2; P_3; P_1.

Estimates suggest that the conclusion means the best combination of the environmental start-up and its development teams in air transport – P_5, and "the level of security of funding for the start-up project is above average".

The problem of the impact of aviation on our public health in the context of the United Nations Agenda for the Sustainable Development (2030), which supports the spirit of the Sustainable Development Goals focused on the Goal 13 Climate Action too, requires the effective solutions. The proposals of environmental projects in the aviation sector are an important source of innovation [1].

3.2. EXAMPLE OF THE RISK ASSESSMENT OF ENVIRONMENTAL START-UP PROJECTS IN AIR TRANSPORT

The results of the Fuzzy model of risk assessment for srart-up projects were tested for an example of the risk assessment of environmental start-up projects in air transport [43]. To simulate the situation, there were three environmental start-up projects S_1, S_2, S_3 (taken from the University Science Park TECHNICOM ecosystem in Kosice and the start-up incubator at the Uzhhorod National University), for which the risk of their financing during the expansion needed to be assessed. The input data for the expert evaluation of start-ups on the proposed set of criteria are listed in Table 3.2.1.

Tab. 3.2.1. Input expert evaluation risk of start-up projects

Criteria groups	The name of the criteria	S_1		S_2		S_3	
		T	$\mu(T)$	T	$\mu(T)$	T	$\mu(T)$
KC	KC_1	L[1]	0.6	L	0.9	BA[2]	0.8
	KC_2	BA	0.7	L	0.8	BA	0.6
	KC_3	BA	0.8	L	0.7	L	0.4
	KC_4	A[3]	0.6	BA	0.9	L	0.8
KM	KM_1	A	0.6	L	0.8	BA	0.6
	KM_2	A	0.9	A	0.4	BA	0.8
	KM_3	A	0.8	L	0.7	A	0.8
	KM_4	BA	0.7	BA	0.8	BA	0.8
KI	KI_1	AA[4]	0.9	L	0.8	BA	0.7
	KI_2	A	0.7	L	0.8	A	0.6
	KI_3	BA	0.6	BA	0.8	A	0.7
	KI_4	AA	0.9	L	0,7	L	0.9
	KI_5	L	0.6	BA	0.6	BA	0.6
KF	KF_1	A	0.8	L	0.7	BA	0.7
	KF_2	AA	0.7	BA	0.6	BA	0.6
	KF_3	AA	0.6	L	0.8	BA	0.8
KS	KS_1	BA	0.8	BA	0.6	A	0.5
	KS_2	A	0.9	BA	0.8	BA	0.6
	KS_3	A	0.8	BA	0.8	A	0.8
	KS_4	BA	0.7	BA	0.7	A	0.8
	KS_5	A	0.6	L	0.8	BA	0.8

[1] "low risk", [2] "risk below average", [3] "average risk", [4] "risk above average".

The risks of financing start-up projects were evaluated based on the proposed generalized algorithm.

Step 1. Determine the resulting term-evaluation.

Based on the projects introduced from the start-up and the built knowledge base, the resulting term-evaluation was determined.

Step 2. Determine the aggregated estimation of the reliability of the expert's thoughts using Equation (2.2.2).

The results of the calculation of steps 1and 2 are given in Table 3.2.2.

Step 3. Obtain a generalized risk assessment for projects by groups of criteria$g$.

Tab. 3.2.2. The results and aggregated estimates of expert confidence

Criteria groups	S_1		S_2		S_3	
	T	$\mu(T)$	T	$\mu(T)$	T	$\mu(T)$
KC	BA	0.63	L	0.8	L	0.53
KM	A	0.77	BA	0.43	BA	0.73
KI	A	0.33	L	0.77	BA	0.5
KF	AA	0.65	L	0.75	BA	0.77
KS	BA	0.63	BA	0.73	BA	0.63

For each group of criteria, x_{gj} was calculated using Equation (2.2.5) and the generalized assessment O_{gj} risk using Equation (2.2.6). For example, to illustrate this, for a group of criteria KC related to the start-up S_1: $x_{C1} = 30 - \sqrt{\frac{1-0.63}{2}}(30-15) = 23.55$; $O_{C1} = (100 - 23.55)/100 = 0.7645$. The results of all calculations are listed in Table 3.2.3.

Step 4. Weight coefficients are set for groups of risk criteria.

For each group of criteria, DMs set weight coefficients {9; 7; 8; 6; 9} and the normalized weighting coefficients were calculated using Equation (2.2.7): {0.23; 0.18; 0.2; 0.16; 0.23}.

Tab. 3.2.3. The generalized ratings

Groups of criteria	S_1		S_2		S_3	
	x	O	x	O	x	O
KC	23.55	0.7645	10.26	0.8974	7.73	0.9227
KM	43.22	0.5678	18.26	0.8174	24.5	0.755
KI	38.12	0.6188	9.91	0.9009	22.5	0.775
KF	67.45	0.3255	9.7	0.903	24.19	0.7581
KS	23.55	0.7645	24.5	0.755	23.64	0.7636

By matching the received assessments O_R with the output variable R, the following result was obtained: S_1 – “average risk of financing start-up project”; S_2 – “insignificant risk of financing start-up project”; S_3 – “low risk of financing start-up project”.

From these estimates, the following conclusion could be drawn: the least risky environmental start-up project in the air transport sector, for its financing at the expansion stage, was the project designated as S_2, with an assessment of 0.8518 and insignificant financing risk. The fuzzy model developed enhanced the accuracy and objectivity of the assessment, as it used linguistic risk assessments on the one hand and, on the other, the expertise and competencies of experts in the form of a value of “certainty” of their considerations for different risk criteria. On this basis, opinions were aggregated by groups of criteria into a final evaluation. Quantitative assessment increases the validity of decision-making, and, on this basis, the decision-maker can compare projects and select qualitative ones for financing.

3.3. EXAMPLE OF THE EXPERT MODEL FOR SAFETY RISKS ASSESSMENT OF START-UP PROJECTS IMPLEMENTATION WITHIN THE INVESTMENT PHASE

For the task of assessing the safety risk of financing a project for the aviation sector, we will propose the indicators $\{K_1; K_2; K_3\}$ and their evaluation models to obtain a quantitative aggregate estimate [65].

K_1 – «an idea of the project». The quantitative evaluation O_1 can be obtained, for example, by using the Model of start-ups assessments under conditions of information uncertainty [1, 100], or other well-known approaches. For example, the following criteria are used for the assessment criteria:

- SK_1 – What is the proposed innovation technology or service for improving the environment in air transport?
- SK_2 – What is the value of the environmental start-up for air transport?
- SK_3 – Will the project help preserve the environment and / or increase the environmental safety of the air transport (i.e., an idea-based product is urgently needed on the market)?
- SK_4 – What are the strategic partners in the aviation industry? And others.

Another important criteria for project evaluation is the team of project developers – K_2. The quantitative evaluation O_2 can be obtained, for example, by using the Information Model of Evaluation and Output Rating of Start-up Projects Development Teams [16, 100]. As the criteria of evaluation we propose the following:

- DK_1 – the length of work in the project, measured in months of work on the project;
- DK_2 – successful experience of leaders in the environmental air transport projects;
- DK_3 – successful experience in managing the environmental air

transport projects;

- DK_4 – team participation in the conferences, investment sessions or profile events in the field of air transport;
- DK_5 – the professional education of team members and others.

K_3 – criteria of the risk of environmental project implementation in the air transport. We can use one quantitative estimate to get one Fuzzy mathematical modelling financial risks [43]. The evaluation criteria will determine the following, for example:

- RK_1 – risk of unprofitable environmental aviation project;
- RK_2 – the risk of inefficient new innovative investments;
- RK_3 – the risks of technology innovation in the aviation project;
- RK_4 – the risk of lowering the level of management, and others.

Illustrate the developed model on the example of assessing the safety risks of implementation of an environmental aviation project P. The project is from the University Science Park at the Technical University of Kosice – TECHNICOM [65]. Let the project pass an expert(s)' evaluation on the criteria $\{K_1; K_2; K_3\}$ and gt the following aggregated results: A_1 (*aa;* 0,77); A_2 (*h*; 0,85); A_3 (*aa*; 0,94).

The risks will be evaluated according to the built-in the model of a neuro-fuzzy network.

1st layer. The fuzzification operation using the triangular membership functions is performed with the subsequent breakdown of the intervals – $l \in [0; 0{,}2]$, $ba \in [0{,}1; 0{,}4]$, $a \in [0{,}2; 0{,}6]$, $aa \in [0{,}4; 0{,}8]$, $h \in [0{,}6; 1]$. To the vertex of a triangle, the average value of the corresponding interval is set. By formula (2.3.1), is obtained: x_1 =0,462; x_2 =0,68; x_3 =0,546. Then, the value of the membership function is calculated (formulas (2.3.2)-(2.3.6)) and the value (formula (2.3.7)) is the following: f_1^1 =0,31; f_1^2 =0,77; f_2^1 =0,4; f_2^2 =0,85; f_3^1 =0,82; f_3^2 =0,94.

On the 2nd layer there is an aggregation of membership levels according to the formula (2.3.8): f_1 =0,10168; f_2 =0,61523.

On the 3rd layer, we introduce the synaptic weights.

The neuro-fuzzy training was conducted on the real data of 23 aviation projects that had both very low results and high results. The aviation environmental projects were evaluated by other fuzzy methods that had an initial aggregated estimate. The training was not deep. The scales installed: $w_1 = 0{,}469$; $w_2 = 0{,}631$. Without reducing the generality, the scales according to the proposed "interval representation" will be used $w_1 = 0{,}5$; $w_2 = 0{,}6$.

On the 4th layer, the sum of the output signals of the second and third layers, for (2.3.10): F_1 =0,42; F_2 =0,7169.

On the 5th layer, we will be defuzzification the data according to the formula (2.3.11) and the safety risks assessment of the implementation of an aviation environmental project is obtained: $Y = 0{,}5859$. Therefore, on the basis of the obtained assessment, we conclude that the project has average safety risks of implementation.

3.4. EXAMPLE OF THE MODEL OF EVALUATION AND SELECTION OF START-UP PROJECTS BY INVESTOR GOALS

Consider some start-up projects $P = \{p_1, p_2, \ldots, p_5\}$ (taken from the University Science Park TECHNICOM ecosystem in Kosice and the start-up incubator at the Uzhhorod National University), which should be evaluated on the proposed models and selected for financing according to the following investor goals: G_1 – perspective of the start-up project, G_2 – project implementation risk, G_3 – the competencies of the start-up project development team [75].

Consider the proposed assessment models and their criteria established by the group of experts.

To evaluate start-up projects, we use an evaluation model in the context of information uncertainty [75]. The model reduces the subjectivity of expert judgment, shows the place of the “idea” among others, allows to set the level of its risk and to take into account the wishes of the decision maker. The evaluation criteria are as follows:

- SK_1 – type of goods;
- SK_2 – field of application;
- SK_3 – social significance;
- SK_4 – the power of the idea;
- SK_5 – strategic partners;
- SK_6 – the value of the percentage growth of the market for this start-up.

As a result of the estimation, by the model given in [1], we obtain a set of normalized estimates $S = \{s_1, s_2, \dots, s_5\}$.

To assess the risks of start-up projects, we use the information technology model to evaluate the risk of project financing [43]. Model: Increases the objectivity of expert judgment in project risk assessment, using input linguistic variables and the credibility of expert judgment regarding their assignment; allows changing the levels of decision-making in the knowledge base, depending on the liquidity of the investment institution; integrates opinions by criteria groups into the final assessment and degree of risk of the project, based on a two-level fuzzy mathematical model [43].

The evaluation criteria in this model are as follows:

- RK_1 – risk of the client base loss;
- RK_2 – risk of supplier loss;
- RK_3 – the risk of reducing processes quality;
- RK_4 – the risk of reduced productivity;
- RK_5 – risk of resource insecurity;
- RK_6 – risk of inefficient investment;
- RK_7 – risk of disruption of terms of creation of production funds;
- RK_8 – risk of exceeding the amount of start-up investment;
- RK_9 – risk of investor loss.

As a result of the estimation, by the model given in [43], we obtain a set of normalized estimates $R = \{r_1, r_2, \dots, r_5\}$.

To evaluate start-up project developers, we use an information model to evaluate and derive the rating of start-up project development teams [16]. The proposed model: increases the objectivity of peer review in evaluating development teams, using input linguistic variables and the “confidence coefficient” of expert judgment on their assignment; is based on a neuro-fuzzy network that can change the synaptic weight setting; has the ability to train the neuro-fuzzy network by complementing the knowledge base and adjusting the rankings of start-up project development teams [16].

The evaluation criteria in this model are as follows:

- TK_1 – successful experience in related or close to the topic;
- TK_2 – successful management experience;
- TK_3 – education of leaders;
- TK_4 – successful experience in large or similar projects;
- TK_5 – professional education of team members;
- TK_6 – participation of the team in professional conferences, investment sessions or profile events;
- TK_7 – publications in the media or professional sources for the project;
- TK_8 – availability of social networking and messaging with the team;
- TK_9 – having links with social media advisors.

As a result of the estimation, according to the model given in [16], we obtain a set of normalized estimates $T = \{t_1, t_2, \dots, t_5\}$.

Projects were modeled and aggregated, Table 3.4.1.

Tab. 3.4.1. Inputs for start-up projects

Models of evaluation	p_1	p_2	p_3	p_4	p_5
S	0.87	0.82	0.6	0.77	0.69
R	0.66	0.83	0.71	0.98	0.91
T	0.78	0.4	0.54	0.85	0.82

Let the investor express wishes regarding the start-up project as follows: “The prospect of a start-up project A_1 ={ there is a priority need for a promising concept} and the risk of project implementation A_2 ={low} and the competencies of the start-up project development team A_3 ={ above average}”.

Then accordingly $(t_1, t_2, t_3) =$ (0,4; 0,6; 0,8). Find the values of quantities$\mu(f_{1i}),\ \mu(f_{2i}),\ \mu(f_{3i}), i = \overline{1,5}$, that will determine the closest alternatives to the “requirements vector” according to formulas (2.4.5)-(2.4.7), for example: $\mu(f_{11}) = \frac{|0.4-0.87|}{max\{0.4-0.6;0.87-0.4\}} = 1$; $\mu(f_{12}) = \frac{|0.4-0.82|}{max\{0.4-0.6;0.87-0.4\}} = 0.894$.

All results of calculations will be presented in the Table 3.4.2.

Tab. 3.4.2. Results of calculation values $\mu(f)$

Models of evaluation	p_1	p_2	p_3	p_4	p_5
S	1.000	0.894	0.426	0.787	0.617
R	0.158	0.605	0.289	1.000	0.816
T	0.050	1.000	0.650	0.125	0.050

Next, we calculate the values $Z_i = (z_{1i}, z_{2i}, z_{3i}), i = \overline{1,5}$, according to formula (2.3.8), Table 3.4.3.

Tab. 3.4.2. Results of calculation values Z

Models of evaluation	$\boldsymbol{p_1}$	$\boldsymbol{p_2}$	$\boldsymbol{p_3}$	$\boldsymbol{p_4}$	$\boldsymbol{p_5}$
S	0.000	0.106	0.574	0.213	0.383
R	0.842	0.395	0.711	0.000	0.184
T	0.950	0.000	0.350	0.875	0.950

Let the decision-maker determine the weighting coefficients for the estimation models – $\{10,8,9\}$. Normalize them by the formula (2.4.9): $w_1 = 0.37$; $w_2 = 0.3$; $w_3 = 0.33$.

Calculate the aggregate estimate by the formula (2.4.10): $Z_1^* = 0.37 \cdot 0 + 0.3 \cdot 0.842 + 0.33 \cdot 0.95 = 0.566$; $Z_2^* = 0.156$; $Z_3^* = 0.54$; $Z_4^* = 0.37$; $Z_5^* = 0.513$.

Based on our estimates, we build a ranking of alternatives – $\{p_1, p_3, p_5, p_4, p_2\}$. As a result, we conclude that the best start-up project considering the goals of investors is – p_1 with the highest score of 0.566.

CONCLUSION

Development of methodology for obtaining an assessment of start-up projects to improve the security of their funding, based on the developed applied fuzzy models, will be a necessary tool for investment institutions (venture funds, "business angels", crowdfunding platforms) to support innovative business and promoting funding for such projects. This will provide significant support for the creation and development of new financial schemes aimed at financing the critical phases of start-ups that are essential to exploit the maximum potential of start-ups while creating a favorable legislative and regulatory framework and accessing non-financial tools.

The obtained results will be considered in more detail in the context of the developed models.

Fuzzy model for quantitative assessment of start-up projects

The real research task of obtaining a quantitative estimation of start-up projects is to increase the safety of their funding. The model applied has helped develop the quantitative estimating start-up projects at the stage of product output to the market, in the conditions of uncertainty with the use of the apparatus of fuzzy mathematics and create a model for evaluating and eliminating the start-up team rating using a neuro-fuzzy network. The following results are as follows:

- Formulations of a set of nine criteria for estimating the start-up projects and a grading scale of assessments, in the form of a question-answer to obtain an assessment for each criterion. In order to evaluate teams of developers of the start-up projects, the authors have classified eleven proposed criteria in three groups and presented the input data in the form of four linguistic terms and the expert confidence coefficient for their assignment;
- An applied model of fuzzy evaluation of project start-ups, based on six steps, allows reducing the subjectivity of expert assessments by valuing the input data of the evaluation grading scale. The features of the model allow revealing the essence and place of the project start-up among others. The base includes the

"investor's wishes" and the results obtained for each criterion, projecting the value of the function of belonging to the plural of the carrier of the linguistic variable. Taking into account the wishes of the DM, the model determines the level of assessment of the start-up project;

- The informational neuro-fuzzy model for the elimination of the rating of start-up developer teams, based on a four-layer neural-fuzzy network was developed. The model reveals the subjectivity of expert opinions for outputting the rating of the development teams and does not require much computation, formulated production rules of the fuzzy knowledge base, and five levels of the rating of teams of developers;
- Based on the conducted research, the model of quantitative aggregate initial estimation was proposed using a two-dimensional Gaussian function for the aggregation of results;
- The developed applied fuzzy model is tested on an example of the financing security of environmental start-up projects in air transport.

A Fuzzy model of risk assessment for start-up projects

Investigation of the actual task involved the risk assessment for start-up projects, at the stage of gaining a successful start-up project. The result was an output quantitative assessment which increases the validity of decision-making, and, on its basis, the decision-maker can compare projects and select qualitative ones for financing. At the same time, the following results were obtained for the first time:

- The set of 21 criteria, for assessing the risk of developing start-up projects was divided into five groups that revealed different aspects of risk assessment at the project extension stage. The inputs were presented in the form of a linguistic risk assessment, a set of five linguistic variables, and a number of expert opinions;
- The rules for membership in the resulting term evaluation for risk criteria groups were set out to build the knowledge base, where the level of decision-

making can be changed, which does not depend on the number of criteria per group;

- The model of fuzzy risk assessment for start-up projects was developed, based on expert knowledge, using linguistic variables, and it reveals the uncertainty of input data, as well as integrates experts' opinions into groups of criteria in the final assessment of risk with linguistic interpretation;
- A generalized five-step algorithm for obtaining an aggregated risk assessment for start-up projects was constructed;
- The developed fuzzy model was tested in a risk assessment example to finance three environmental start-ups of air transport projects at the stage of business expansion.

The creation of software based on the risk assessment model developed to finance start-up projects will be a useful tool to support the decision support systems of investment institutions (venture funds, business angels, and crowdfunding investment platforms) in financing the start-up projects at the market conquest stage.

The expert model for safety risks assessment of start-up projects implementation within the investment phase

The real challenge was to develop a comprehensive expert model to obtain a quantitative assessment of safety risks in the implementation of start-up projects. The following tasks were solved for this purpose. For the first time, a five-layer neuro-fuzzy model was developed that derives a quantitative and linguistic assessment of the safety risk of implementing a project. For the first time, it was proposed for the neuro-fuzzy network to use the quantitative project estimates, across the different models, and the experts' linguistic considerations. An approach using the interval representation of synaptic weights can be considered as a methodological contribution to neuro-fuzzy network training. The indicators and their assessment models are presented in order to obtain the quantitative summary assessment of safety risks of project implementation. For the first time, 5 levels of safety risks for the implementation of a project have been formulated. The data was tested during the research and the results were verified on the selected environmental projects in the aviation sector.

The model developed increases the degree of validity of investors' decision-making regarding the implementation of projects. The rationality of the safety risks assessment of the project implementation is proved by the advantages of the developed expert model. The reliability of the results is ensured by the correct use of the apparatus of fuzzy sets and the neuro-fuzzy networks, which is confirmed by the research results.

The advantages of applying these new methodological approaches are seen in several aspects with an impact on the macroeconomic sphere. In particular, further development and improvement of procedures based on expert selection and evaluation of criteria that may be applicable to evaluation mechanisms also in other projects are encouraged. We can also see their contribution to the process of more accurate determination of investment and operational costs of the project individual phases, as well as the local ability to cover the costs. Another advantage is the support for institutional capacity building.

Model of evaluation and selection of start-up projects by investor goals

The result is a model of choice of start-up projects for the purposes of investors, the output of which is the overall aggregated assessment of start-up projects and their ranking. The rationality of the obtained estimation is proved the advantages of the developed model. Therefore, investigation results as follow:

- For the first time, a mathematical model is presented for solving the problem of evaluating start-up projects according to the investor's goals: the need for prospects for a start-up project, an assessment of the risk of project implementation, and an assessment of the competence of the start-up project team. For these purposes, start-up project evaluation models based on fuzzy set theory and neuro-fuzzy networks have been proposed to reduce the uncertainty of project appraisals and the subjectivity of evaluators;

- For the first time, a “requirements vector” is proposed for the model for solving the multicriteria choice of start-up projects using investor wishes in the form of linguistic considerations of this task;
- Tested model to evaluate and build a ranking of five start-up projects. For example, the investor's linguistic desire was considered for the following purposes: “Priority needs for a promising concept for a start-up project and low risk of project implementation and competence of the above-average start-up project team”.

The model developed will be a useful tool to substantiate and increase the security of investors' choice of alternative start-up project financing, using their own targeted needs.

Fuzzy model of information technology evaluation of projects of different origins

A study of the current problem of evaluating commercial projects of various origins. A fuzzy model of information technology for evaluating projects of different origins based on fuzzy expert evaluations has been developed. The following results were obtained:

- Set a set of criteria for evaluating projects in three categories by origin (criteria for classic investment projects, start-up projects and innovative projects) and formulated a set of common criteria that assess the level of risk for all projects;
- developed a two-level fuzzy mathematical model for obtaining a general aggregate assessment of commercial projects, based on: development of a model for rationing quantitative and qualitative input assessments, to obtain an aggregate assessment of commercial projects, taking into account their category; construction of standardized estimates of the general matrix of decisions, taking into account common criteria for projects; construction of a general aggregate assessment on the basis of which a ranking series of commercial projects is built.

Thus, a fuzzy mathematical model of information technology has been developed with the help of which it is possible to build a ranking series of commercial projects of different origins for their financing. This model increases the objectivity of the assessment and the reliability of expert assessments, reveals the uncertainty in the input data, combines the assessments of alternatives taking into account their category and displays the overall assessment of alternatives.

The model of crowdfunding platform rating estimation

The research of a crowdfunding platform functioning is conducted and the technology of improving the security of investing in start-ups on the platform is proposed. The following results were obtained:

- there is a developed mathematical model of information technology for fraud risks reducing in start-up using expert arguments on assessments by different risk criteria, reliability of its reasoning and based on the opinion aggregation of criteria groups in the final evaluation;
- there is a created model of the crowdfunding platform rating system to reduce the fraud risk. This model allows evaluating the platform and giving a linguistic interpretation of such evaluation, aggregating considerations on expert estimates: the platform owners; the project financing safety risk; the investors working with a platform; the project's successfulness.

Thus, the technology of crowdfunding safety improving based on the model of fraud risks reducing in the start-ups and platforms, as well as recommendations on elimination of existing disadvantages, will be a useful tool for promotion of the crowdfunding platforms activities and within the support tools against the financial fraud.

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EVALUATION OF START-UP PROJECTS IN CONDITIONS OF RISK AND UNCERTAINTY

Scientific monograph