Risk as an Indicator of Uncertainty in the Innovative Supply Chain of Enterprises

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***Abstract*– The formation of professional competence in modeling of innovative supply chain of enterprises has a number of problems associated with the instability and variability of the external environment of decision-making systems that generate uncertainty and increase the risk in decision-making. The indicator of uncertainty in such situations is the concept of "risk". This problem is especially acute in the energy sector, which not only ensures the level of people's comfort, but is also an important component of the economy. In this regard, the importance of bachelor's training is increasing. This research considers one of the ways to increase the professional training of bachelors in the oil and gas industry. To achieve this goal, a set of complementary research methods was used. The methods of analysis, generalization of theoretical and research data, and methods of mathematical modeling were most widely used. As a result, it is proposed to reorganize the course on studying risks in the innovative sphere of business. The necessary directions that will provide the maximum result for students are also indicated.**

***Keywords*–** *Risk management, Indicator, Uncertainty, Innovative Supply Chain, Enterprises.*

1. Introduction

The relevance of the research is due to the problems associated with the insufficient level of professional competence of bachelors in "Oil and gas engineering" in the field of modeling of innovative supply chain of companies in an unstable and volatile environment that generates uncertainty and increases the risk in decision-making. The company's investment activity depends on its long-term perspective to ensure a high rate of development and increase competitiveness.

The investment activity is related to [7, 8, 9]:

- Acquisition of integral property complexes;
- New construction;
- Reassignment;
- Reconstruction;
- Modernization;
- Updating of certain equipment;
- Innovative investment in intangible assets;
- Investment in the reserves growth of tangible current assets.

When conducting a financial analysis of induced investments, the problem of uncertainty of costs, profit and measurement of risks, as well as their impact on the results of investments, is relevant.

The risk management is a complex mechanism – the managing system affects the managed one, where the management object is the risk, risky capital investment, economic relations between business units in the implementation of the risk process. Therefore, when analyzing risk management systems, it is advisable to use the system approach as the main methodological tool. The risk management system is represented by methods and measures that allow for forecasting of risk events, exclude or reduce their negative consequences. The risk management system is influenced by both internal and external factors [10, 11, 12].

The system approach allows us to search for sources of problems arising in the work, first of all, in the external environment. When conducting a quantitative analysis, it is proposed to numerically determine: 1) individual risks and overall risk; 2) the probabilities of a risk event and their consequences; 3) quantification of risk; 4) the acceptable level of risk. The result of the risk analysis is the possible risk events, their likelihood and consequences.

After the received and maximum permissible levels of risks are compared, the development of a risk management strategy is carried out and the measures are taken to prevent and reduce risks, which consist of the following stages [13]:

- Assessment of the acceptability of the received risk level;
- Evaluation of a possible risk reduction or increase;
- Selection of methods for reducing (increasing) risks;
- Assessment of feasibility and selection of options for reducing (increasing) risks.

A preliminary analysis of the problem of improving educational activity of bachelors in the field of "Oil and Gas Engineering" made it possible to identify the following shortcomings: the students don't have the sufficient level of professional competencies in modeling of innovation supply chain of enterprises,

including [15]:
- Construction and use of mathematical models;
- Study of the correlation between project parameters;
- Assessment of the result determinism in models using the following factors (costs associated with the production expansion, time for the project implementation , marketing research costs, management costs, risks from losses, payback periods, product quality, product prices, etc.) aimed at expanding the market share of the enterprise while implementing innovative projects;
- An assessment of the influence of factors on the result.

Objective requirements for improving students' educational activity, on the one hand, and the insufficiently developed theoretical, methodological, organizational and methodological foundations for its development, on the other, determined the choice and relevance of the topic of our research: "Risk as an indicator of uncertainty in the innovative supply chain of enterprises". The contribution of our research to the world pedagogical science in "Theory and methodology of vocational education" is that a didactic system designed to improve professional training of bachelors in the oil and gas sector has been developed, which makes it possible to transform scientific knowledge into educational and to adapt professional training of bachelors to modern requirements in modeling of innovative supply chain using probabilistic-statistical tools and fuzzy set theory.

In the economic analysis of the enterprise supply chain, various decision theory methods are widely used under the conditions of uncertainty and risk. In the foreign and domestic literature, a lot of different methods for assessing innovation supply chain are given; the features of risk accounting in the context of uncertainty in various industries are described; the attempts to modernize or transform existing approaches to the evaluation of investment projects are also highlighted.

The situation is different in education. If it is a question of making a decision in the choice of investment projects of an educational institution, the previously described general methods (without taking into account the specifics of the area of application) are quite suitable for solving this issue. And in case of development of a methodological system for modeling the company's innovation supply chain (for example, "Strategic planning of enterprise supply chain", "Innovative economy", "Economic feasibility of investment projects", etc.), many questions arise about the contents of the proposed course and the specifics of teaching certain issues related to risk assessment of the enterprise innovation supply chain.

A number of articles are devoted to the evaluation of investment projects in the Russian literature, reflecting the following questions:
- Methodological basis for risk assessment of investment projects [14];
- Assessment of innovative projects in the educational institution [16, 17];
- Use of the mathematical tool for calculating the main indicators of investment projects and making decisions on their effectiveness [1, 2];
- Use of software to assess the risks of investment projects [3];
- Development of the theory and methodology of risk management of investment projects [5];
- Qualitative transformation of methods for assessment of efficiency [4];
- Monitoring of investment projects implementation [6].
- Modern foreign experience in risk assessment of investment projects is mainly focused on making decisions in industry or production, taking into account the risks in the implementation of investment projects.

The article [20] looks at the evaluation of investment projects in the aspect of multi-criteria decisions on environmental issues, which are the main problem in the "supplier-client" system.

The author of the articles [18, 21] examines the main factors that contribute to a high level of risk for foreign investors in the mining and oil and gas industry.

The article [22] provides an assessment of transport projects in terms of feasibility study and forecasting of the reference scenario (RSF).

The authors of the article [23] are studying legal risk reduction strategies for energy infrastructure projects.

Noting the unquestionable value of the conducted research in management of innovative development of enterprises, it should be recognized that the current stage of the development of vocational education requires a thorough analysis of the accumulated experience and theoretical approaches in the search for ways to improve professional training of bachelors in "Oil and gas engineering".

It should be noted that in decision-making theory in the management of innovative development of enterprises, along with the probability-statistical methods, the fuzzy-multiple approach is widely used. The main advantage of the fuzzy approach in the modeling of innovative supply chain is the possibility of increasing the reliability and quality of management decisions, taking into account the formalization of the available heterogeneous information (determined, interval, statistical, linguistic, etc.) in a single form.

The purpose of the research is to improve the quality of professional training of bachelors of oil and gas profile in modeling of innovative supply chain of enterprises in conditions of risk and uncertainty.

The tasks of the research:
- To reveal the specifics of professional training for students of the oil and gas industry and to identify the pedagogical conditions that can ensure the implementation of professional tasks in modeling of the innovative supply chain of enterprises in terms of risk and uncertainty;
- Analyze the methods and models existing in domestic and foreign practice in modeling of innovative supply chain of enterprises in conditions of risk and uncertainty;

- Identify the features of the multi-criteria analysis necessary for innovation supply chain modeling and taking risks into account while analyzing the sensitivity of projects;
- Develop technological provision of conditions for the implementation of assessment methods: the acceptability of the received risk levels, the possibilities of reducing or increasing risks, choosing methods to reduce (increase) the risks, and the appropriateness and choice of the option to reduce (increase) the risks.

2. Methods

To achieve the goal of the research and to solve the tasks, a set of research methods was used: expert evaluation; pedagogical experiment; modeling and design of didactic theories, including analysis and synthesis of data, abstraction, generalization of theoretical and research data; the analysis of universities experience on formation of professional competences of students; mathematical methods and computer programs for the processing of the research results.

The reliability and scientific integrity of the research results are due to the methodological validity of theoretical positions, the development of diagnostic techniques adequate to the tasks, the subject and object of the research, and the representativeness of the sample, quantitative and qualitative analysis of the experimental data; use of research results in pedagogical practice. In the development of experimental testing technique of the pedagogical experiment results, the readiness of students for modeling the innovative supply chain of enterprises under the conditions of uncertainty and risk was selected as an integrative indicator of the effectiveness of the technological approaches developed in the research [24].

3. Results

Improvement of professional training of bachelors in modeling of innovative supply chain of enterprises in terms of risk and uncertainty was carried out in our research on the basis of the principles and selection criteria developed in pedagogical science, taking into account the methodological grounds for meeting the requirements of federal state educational standards for higher education to the preparation of bachelors in management of innovation development of enterprises.

When analyzing the risk management system considered in our research, the system approach is used as the main methodological tool that allows us to consider the methods, techniques and supply chain on the basis of which risk events are predicted and measures are taken to exclude or reduce the negative consequences of such events. Multi-criteria risk analysis relies on probability theory and fuzzy ses theory methods. The content component of the developed didactic system is presented by the basic theory on the interpretation of the economic and technological processes of the oil and gas industry in innovative supply chain modeling based on the probabilistic-statistical tools and the fuzzy-multiple approach.

The fuzzy-multiple approach allows:

- To make decisions not on the basis of two assessments, but to take into account the whole set of assessments in the formation of all possible states of risk management systems;
- Evaluate the integral measure when obtaining negative results, that is, the degree of risk, on the basis of a set of interval values;
- Obtain the result with a low quality of the initial information, which is characterized by low sensitivity (high stability) with respect to changes in the membership functions of the original fuzzy numbers;
- Evaluate indicators in situations where there is insufficient information base based on small statistical samples;
- Apply methods in investment analysis, which is due to the lack of competitive approaches to the creation of a reliable (in terms of warranty) and transportable (on the inclusion) tool for solving numerical problems.

The main transformations of the content component of the projected special course "Modeling of innovative supply chain of enterprises based on the fuzzy-multiple approach" contain directions related to:

- Uncertainty and risk in the investment activity of the oil and gas industry;
- Classification of risks in the investment activity of oil and gas enterprises;
- Directions of risk reflection in calculations of economic efficiency of investments;
- Consideration of risks in the process of justifying the reliability of technical and organizational-economic systems;
- Taking into account risks when justifying a risk premium;
- Consideration of risks when analyzing the project sensitivity;
- Application of the fuzzy set theory in modeling of decision support systems;
- Using fuzzy set when evaluating the risk of bankruptcy of enterprises;
- A fuzzy model of the investment project;
- Choosing alternatives when using the fuzzy inference rule;
- The company's choice to expand the market share based on the additive convolution method;
- Selection of competitive goods by the method of fuzzy preferences;
- Using the method of linguistic assessments when choosing an enterprise for lending;
- Problems of description and analysis of complex systems in conditions of information deficit;
- An unclear approach in assessing quality and multi-criteria choice;
- Fuzzy sets and relations;
- Description and comparison of models of multi-criteria choice;
- The stability of the solution of the multi criteria choice;

- unclear methods for calculating oil and gas reserves;
- Description of measurements from the perspective of the information theory.

The construction and use of mathematical models on the basis of probabilistic-statistical tools, the study of the relationship between the investigated parameters of the project are an integral part of the financial analysis for the investor's decision.

The main transformations of the content component of the projected special course "Modeling of innovation supply chain of enterprises based on probabilistic and statistical tools" included the following areas:

- Assessment of the determinacy of the result (cash flow) in additive and multiplicative models by factors aimed at expanding the market share of an enterprise during implementing innovative projects assesses the influence of factors on the result;
- Choosing a less risky investment project and justifying a risk premium using a statistical method of risk assessment;
- Risk assessment in the analysis of project sensitivity (break-even point calculation and safety range).

We consider in more detail the following tasks:

1. Selection of a less risky investment project, justification of the risk premium based on the statistical method of risk assessment.
2. Risk assessment in the analysis of the project sensitivity of the project (calculation of the break-even point and the safety range).

Problem 1.

The sensitivity analysis of the projects allows us to identify the dependencies of the change in project efficiency for given changes in the initial project parameters. The stronger this dependence is, the higher the risk of project implementation. When carrying out the sensitivity analysis, the relative influences of the initial variables are compared to the resulting project indicators. During the analysis, the most important for the project initial variables (factors) are determined, the change of which must be controlled first. The measure of sensitivity is elasticity (Table 1, 2).

Table 1. Calculation of the expected internal return rate and risk indicators

IRR_1 project 1 internal return rate %	Project 1			
	$P_i \cdot B_i$	$P_i - P_{av.}$	$(P_i - P_{av.})^2$	$(P_i - P_{av.})^{2\cdot} B_i$
36,1	1,805	7,74	59,91	3,0
24,72	4,45	-3,64	13,25	2,39
12,24	3,92	-16,12	259,9	83,17
40,39	18,18	12,03	144,7	65.12
expected IRR_1 $Pav.=_i \Sigma P_i \cdot B_i$	**28,36**			Total: **148,29**
IRR_2 project 2 internal return rate %	Project 2			
	$P_i \cdot B_i$	$P_i - P_{av.}$	$(P_i - P_{av.})^2$	$(P_i - P_{av.})^{2\cdot} B_i$
22,8	1,14	1,22	1,49	0.075
29,4	5,3	7,82	61,2	11,02
1,69	0,54	-19,89	395,6	126,6
32,4	14,6	10,82	117,1	52,7
Expected IRR_2 $Pav.=_i \Sigma P_i \cdot B_i$	**21,58**			Total: **190,4**

Table 2. Risk assessment of investment

Risk indicators	Project 1	Project 2
Expected IRR	28, 36	21,58
Variation	148,29	190,4
Standard deviation	12,2	13,8
Coefficient of variation	0,43	0,64

Project 2 has the highest variation coefficient. Therefore, if we take into account the relative risk, then it is riskier. In assessing absolute risk, project 2 is also riskier (since standard deviation is higher). The higher the variation is, the greater the deviation, on the average. It results in higher uncertainty and risk.

Table 3. Variable change according to the project effectiveness criteria

Variables	Variable change, %	NPV_1 12%	NPV_1 15%	Δ_{y1}	Change NPV_1 $\Delta_{y1\%}$	E (NPV_1)
Rate	3	0,5131	0,428	0,0851	16,59	5,53
Non-variable costs	8	0,5131	0,328	0,1851	36,1	4,51
Residual value	5	0,5131	0,404	0,1091	21,3	4,26
Variable costs	4	0,5131	0,38	0,1331	25,9	6,48
Range of services provided	6	0,5131	0,486	0,0271	5,28	0,88
Service costs	7	0,5131	0,462	0,0511	10,0	1,43

In changing of the variables that affect the project, new values of the criteria for its effectiveness were obtained. Thus, the elasticity of the project to the interest rate change is 5.53; non-variable costs – 4.51; the residual value – 4,26; variable costs – 6.48; range of services provided – 0.88; service costs – 1,43.

Problem 2.

The sensitivity analysis assesses the risk of investing in the project under study and makes it possible to make timely decisions on the appropriateness of its implementation. An innovative project is acceptable if its performance indicators are least dependent on the environment state. In the research, the degree of project stability to changes of external conditions plays a big role, as well as the level of limit values when investing is considered to be ineffective. One of these limit values is the critical volume of production (breakeven point), the calculation of which involves determining the minimum allowable (critical) volume of services, in which the project remains breakeven. The lower the level is, the more likely the project will be viable in complete uncertainty of future events. We calculate break-even points, determine the critical volume of services provided, taking into account changes in the range of services in each production area. To characterize the project's sustainability to the impact of risk, we will determine the safety range.

Table 4. Risk assessment in project sensitivity analysis (calculation of the break-even point and the safety range)

Indicators, thous. roubles	**Type of services**							
	A_1	**B_1**	**C_1**	**Total**	**A_2**	**B_2**	**C_2**	**Total**
Range of services	160	140	160	**460**	120	220	120	**460**
Share of services, %	34,78	30,44	34,78	**100**	26,1	47,8	26,1	**100**
Variable expenses	100	100	110		60	80	60	
Gross profit	60	40	50	**150**	60	140	60	**260**
Gross profit in the range of services				**0,33**				**0,57**
Fixed expenses				**100**				**100**
Critical volume of services (CVS)	105,38	92,24	105,38	**303**	45,68	83,64	45,68	**175**
Safety range (SR)%				**34**				**62**

To determine the sustainability of projects to the impact of risk, a safety range (the breakeven point of the project) is defined as the ratio of the critical production volume (CPR) to the project. The greater the value of the safety range is, the more likely it is that the project will be viable under unpredictable risks. The project is considered to be resilient to the impact of risk if the safety range exceeds 25-30%. According to this, we determine the critical volume of services provided, taking into account changes in the share of the volume of services in each production area. We get the following:

1. The safety range is 34%; the reduction in the range of services to 66% of the total volume is considered to be safe;
2. The safety range is 62%; the reduction in the range of services to 38% of the total volume is considered to be safe.

The scientific novelty of the research is that for the first time:

1. The subject of special pedagogical research is the content of professional training of bachelors of oil and gas industry in modeling of innovative supply chain of enterprises in conditions of risk and uncertainty;
2. A didactic decision support system was developed in the context of uncertainty and risk. Its core is the

content of the basic theory on the interpretation of economic and technological processes of the oil and gas industry in the innovative supply chain modeling of enterprises based on the theory of probability, mathematical statistics and the fuzzy set theory.

Theoretical significance of the research lies in the fact that the basis for the content of professional training for bachelors in the oil and gas industry in innovative supply chain modeling under risk and uncertainty is made up of enterprise risk management systems. The system approach is used as the main methodological tool allowing us to consider a set of methods, techniques and measures on the basis of which the risk events are forecasted and the measures are taken to exclude or reduce the negative consequences of such events.

The practical significance of the research is that the developed innovative didactic system for improving professional training of bachelors in the oil and gas industry allows us to transform scientific knowledge into educational and adapt professional training of bachelors to modern requirements of innovative supply chain modeling of enterprises in conditions of uncertainty and risk. The educational and methodological complex for innovative supply chain modeling based on the fuzzy-multiple approach and probabilistic-statistical tools developed in the study contains a set of methods and models on the basis of which risk events are forecasted and measures are taken to exclude or reduce the negative consequences of such events [25].

The research hypothesis is that the professional training of bachelors in the oil and gas sector will be effective if:

- The design of educational supply chain of the students will be implemented taking into account the system approach to modeling the innovative supply chain of enterprises in terms of risk and uncertainty;
- At the level of the content and controlling components to form a system of inter-scientific knowledge and skills that will ensure a high level of bachelors' readiness for professional activity in modeling of innovative supply chain of enterprises in conditions of risk and uncertainty;
- When determining differential preparedness indicators of trained experimental groups for modeling the innovative supply chain of enterprises in conditions of uncertainty and risk, the dynamics of knowledge indicators and skills in risk management systems that can be characterized as a set of methods, techniques and supply chain that allow, to a certain extent predict risk events and take measures to eliminate or reduce the negative consequences, was investigated.

4. Discussion

In our research, an innovative didactic system has been developed. This makes it possible to adapt the professional training of oil and gas industry bachelors to modern requirements of innovative supply chain modeling in conditions of uncertainty and risk. The reliability and scientific validity of the results of the work are due to the methodological validity of theoretical positions, the development of diagnostic techniques adequate to the tasks, the subject and object of the study, and the representativeness of the sample, quantitative and qualitative analysis of the experimental data; use of research results in pedagogical practice.

The conducted research is not entitled to an exhaustive scientific description of all aspects of such a complex process as improving of the professional training of bachelors in the oil and gas industry in the field of innovative supply chain modeling under the conditions of uncertainty and risk.

The problems that need further development are the following:

- Improvement of technological approaches to the study of methods, techniques and supply chain that allow us to forecast risk events and take measures to eliminate or reduce the negative consequences of such events [3];
- Improvement of modern methods of information support that facilitates conducting multi criteria analysis, which is necessary for making decisions in risk management systems [19].

5. Conclusions

The pilot and experimental testing of the results of the research on improving the professional training of bachelors of the oil and gas industry confirms the correctness of the put forward hypothesis, the correctness of its conceptual provisions and allows us to draw the following conclusions:

1. The developed innovative didactic system for improving the professional training of bachelors in the oil and gas industry allows us to adapt the professional training of bachelors to modern requirements in the field of modeling of innovative supply chain of enterprises in conditions of uncertainty and risk.
2. The developed complex of interdisciplinary tasks on modeling the innovative supply chain of enterprises based on the fuzzy-multiple approach and the probability-statistical tools allows us to consider a set of methods, techniques and measures on the basis of which the risk events is forecasted and the measures are taken to exclude or reduce the negative consequences of such events [26].
3. The basis for the content of professional training of bachelors in crisis management is made up of risk management systems developed on the basis of multifactor analyses, which include the main issues related to the development of mathematical models, the study of the correlation between the parameters of the projects under study, the evaluation of proposed projects and the solution of problems aimed at reducing risks in the further development of the oil and gas industry.

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