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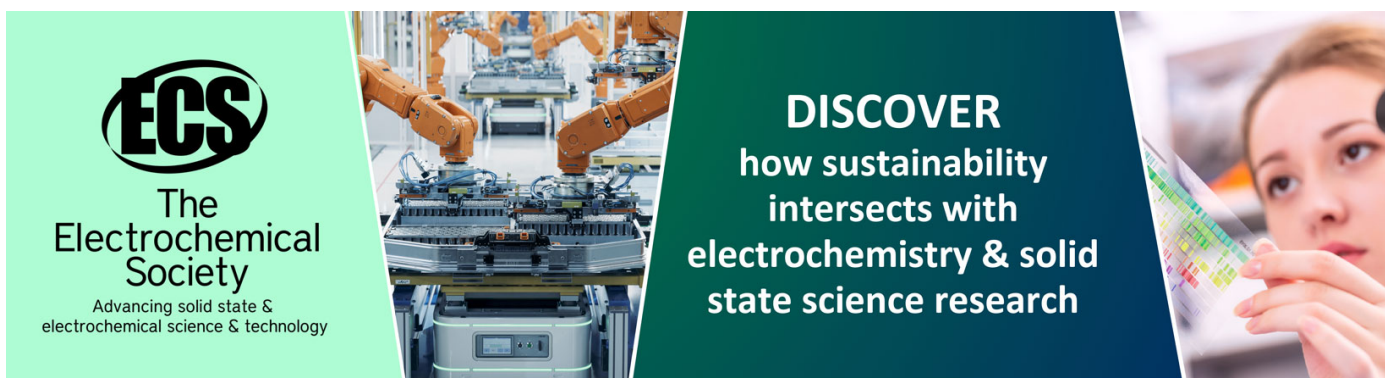
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Managing the efficiency of an innovative project in the chemical sector

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Abstract. The paper is dedicated to analyzing the process of innovative product development in the chemical industry, elaborating a methodology for evaluating the efficiency of innovative projects common for this sector of the economy, and testing this methodology using the example of a project. First, the authors consider the specifics of the development process in which a new product is created in the chemical sector. The emphasis is laid on the product-process approach, and a brief characteristic of this approach is provided. Then the authors discuss the general methodology of product development in the chemical sector using investment analysis methods and a decision tree. Then the authors tested the methodology using the example of a Russian chemical enterprise realizing an innovative project on production of urea-formaldehyde concentrate, urea-formaldehyde resins, and phenol-formaldehyde resins. The results of the investment attractiveness of the project demonstrate that the net present value from the implemented project, given the risk factors, is higher than if the project was implemented with the basic initial conditions. The elaborated methodology allows us to evaluate investment projects in the context of uncertainty, and the result of its application is that more informed management decisions about investment projects in the chemical industry become possible.

1. Introduction

Today the issues of innovative development are the objects of close attention both at the level of state regulation [1,2], and at the level of individual enterprises [3]. One of the ways to increase innovative activity is to finance innovations [4]. Investing in innovative projects determines the degree of advancement, and, consequently, how successful the structures of different levels are. So, the need for informed management decisions, which help us to manage innovative projects effectively, is growing [5]. Over the recent time, Russian scientific literature has been paying more and more attention to the issues related to studying the efficiency of innovative projects [6,7]. The growing interest of the Russian scientific community is supported by the government initiatives designed to set up and run innovative programs aimed at developing Russian industrial sectors [8,9].



Thus, the chemical industry is a capital-intensive sector, which needs regular investments and modernization of the production process. It has a number of distinctive features concerning innovation project management due to the specifics of the research and development methods used in chemistry [10–12]. Differently from investment projects, innovative ones are characterized by risks and uncertainties caused by the technical and market novelty of innovations [5,13]. So, new approaches are needed to measure the efficiency of an innovative project in different spheres.

The study is aimed at developing and testing the methodological guidelines on innovative project efficiency management in the chemical industry.

In order to achieve the established goal, the following objectives were fulfilled:

- The product development process in the chemical industry was analyzed;
- The methodology for effectiveness assessment of innovational project in chemical industry was proposed.
- The methodology was tested on the example of a chemical enterprise's project using the methods of investment analysis and a decision tree analysis.

2. Methods

The process of managing a project of innovative chemical product development includes acquiring knowledge from various fields. The problem of developing an innovative chemical product is defined by the physical and chemical properties. I.e. the composition, form and physical properties of the product determine the treatment operations necessary for its production. Both the product and the technology are evaluated in terms of economy, environmental impact, and safety [14,15].

Designing the chemical process includes determining practical means for a subsequent conversion of raw materials into products with the required properties and functionality. Designing a chemical product and designing the production are closely interrelated. Let us call it a product-process nexus. For achieving the best results, both the product and the process must be optimal. The tasks of designing an innovative chemical product and technological process, as well as their integration and application include designing the consumer characteristics (product properties), production technologies and equipment parameters [16]. It is important that the product obtained from the designed process should comply with its specification, i.e. it should be produced with a certain structure, composition and properties. Despite the fact that there is a wider range of possibilities of solving complex innovative problems, heuristic methods in combination with the use of databases are mainly employed in designing structured products [17]. Traditional treatment methods, such as crystallization and extraction, have been studied for a long time. Using these methods, models have been developed to set objectives of designing a product-process [18]. Designing a product-process is still limited by the lack of data and theory with which the required models of properties and processes can be developed and used [18]. Before a project aimed at developing a process is started, an innovation map and technology platforms must be elaborated and patents must be searched for. Technological platforms are important, since the technological operations have to be enhanced so that "non-traditional" chemical products can be created [19]. Therefore, process synthesis strategies, including heuristic methods and mathematical programming, should consider new treatment technologies associated with each technological platform [20].

Chemical process engineers, in addition to their unique role in designing processes, can, along with chemical physicists, materials scientists and food process engineers, make a significant contribution to product development. However, there are many problems related to studying the process design. The questions concerning how all possible technological methods can be included in process routes have not been answered yet. Although heuristics can be useful for generating possible processes, it does not produce comprehensive results, and sometimes there are problems of conflicts between processes [21]. Therefore, to make heuristics more useful for synthesizing a process, it has to be given a structure. The most well-known complex heuristic structure for the synthesis of chemical processes is the hierarchical decomposition method developed by [22–24]. Another common approach to designing processes is mathematical programming. To apply mathematical programming methods,

there is need for models that represent all alternatives, which adds the uncertainty-accessibility complexity to the model parameters [25–27]. Mathematical programming methods can be expanded to cover the production processes of more complex products, such as structured products, and even, possibly, make the designing of the product and process simultaneous [28,29]. However, there is a serious obstacle to using mathematical programming to solve these problems. There is still no full scientific understanding of the basic chemical and physical phenomena that underlie many products and their processes, while the relevant data that could be used to advance scientific understanding are carefully protected industrial secrets. This limited understanding prevents rigorous models from being created. In addition, very similar technological methods are used for many products, and in many cases these are non-traditional treatment technologies [30]. Frequently, there are no models for these unconventional processes, and so they must be developed and used for designing the product and its process at the same time. Another problem with designing processes lies in the integration of the issues of balance and life cycle assessment. Including the indicators of balance (such as economic, environmental and safety balance) is important in terms of integrating the product with the process. In the Grand Product Design Model proposed by Fung et al., these issues are integrated [31]. Moreover, when the process is being developed, such issues have to be considered as supply chain and the availability of resources for converting raw materials into the required products. Otherwise, many products are designed, but if they cannot be produced (manufactured) stably, they will not become real marketable products.

It can be concluded from the above that creating chemical products calls for new or changed technologies, which causes a close relation between the development of technology and consumer properties of an innovative product, as shown in Figure 1.

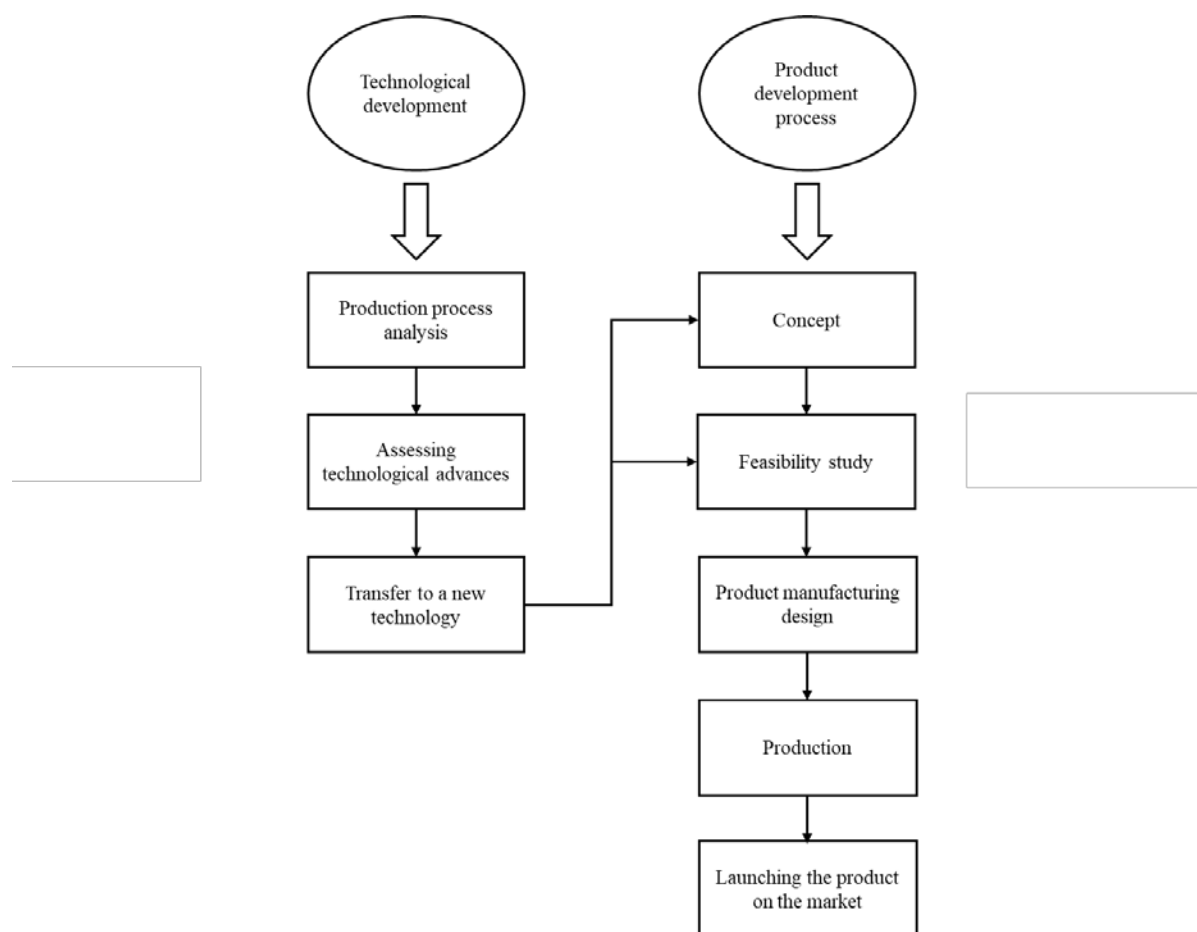


Fig. 1 - General methodology for product development in the chemical sector

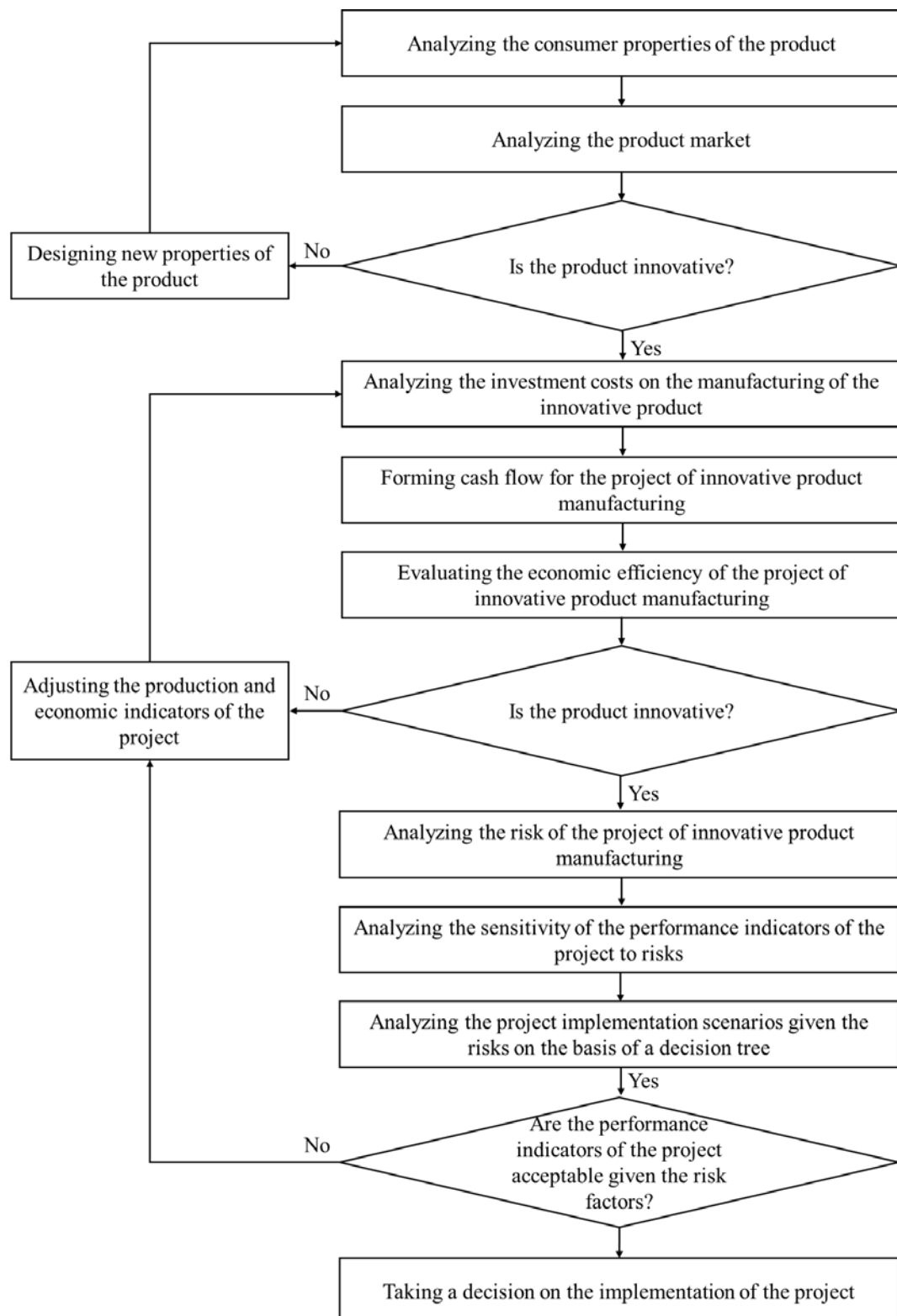


Fig. 2. Methodology for evaluating the efficiency of an innovative product in chemical industry

Launching a new product on the market allows the enterprise to consolidate in a particular segment, maintain competitiveness, and expand sales [32–34]. Since in the chemical sector development of a new product entails a change or update of the technology, detailed estimations are needed to realistically assess the investment in this product. Choosing the right method for measuring the return on investment in innovation is the basis for choosing a project for further implementation. Let us consider the approach proposed by Gutierrez. If an enterprise is aimed at evolving, the investment appraisal usually begins with evaluating the size of the target sales markets and the time to be spent on the development of a new product, overall costs and risks. An enterprise that plans to enter the related markets should start the investment appraisal with assessing the risks and consumers' willingness to purchase the product. An enterprise making investments to carry on its current business on the existing sales markets should set itself the objective of assessing the reduction in sales, revenues or the market share of one product of the company as a result of supplementing the range with another product [13,35]

Thus, the close nexus existing between technology and product development in the chemical industry plays an important role in the investment made by an enterprise in innovative products. Thus, a real assessment of investments related to launching a new product on the new market will allow the company to expand sales markets, and an assessment of investments in the existing product on the market will help it to increase sales.

Studying the theory and methodology for designing innovative products in the chemical industry and evaluating the return on investment in innovations, the authors propose a methodology for assessing the efficiency of an innovative project in the chemical industry, presented as an algorithm in Fig. 2.

In accordance with the methodology presented in Figure 2, at the first stage, the consumer properties of the product are assessed and the product market is analyzed. The degree of product innovativeness can be estimated by assessing the parameters of the product development methodology in the chemical industry, shown in Fig. 1. According to the study, a decision is made on the degree of product innovativeness and its compliance with the needs of the new and existing markets. In case the product is not innovative enough, the product process is redesigned and its consumer properties are evaluated again.

At the second stage, according to Figure 2, the investment costs related to the implementation of the project are estimated, the cash flows of the project are projected and project performance indicators are calculated. If the project is not efficient, its production and economic indicators are adjusted given the cascading approach to project management.

At the third stage, in accordance with Figure 2, the risks of the innovative production project are assessed. Risk assessment is based on the sensitivity of project performance indicators to the identified risk factors. The decision to implement the project is made after scenarios for project implementation are built and evaluated using a decision tree method. If the project is not effective given the risk factors, its production and economic indicators are adjusted.

3. Results and Discussion

The developed methodology has been tested on the example of a Russian chemical industry enterprise involved in an innovative project aimed at manufacturing an urea-formaldehyde concentrate and urea-formaldehyde resins, as well as phenol-formaldehyde resins.

In accordance with the methodology presented in Fig. 1, at the first stage, the consumer properties of the products were assessed and the product market was analyzed. As a result, a matrix of project opportunities and threats was built (see Table 1).

Table 1 – Threats and opportunities of the project

Threats	Opportunities
Price intervention – reduction in competitors' selling prices	- cutting costs on purchasing the basic raw materials (methanol) by making exclusive long-term contracts - optimization of the consumer's production process due to a customized technical solution
Lack of development in consuming sectors – falling outputs in construction and furniture industries	Realization of formaldehyde on other consuming segments
Partial transfer of consumers to applying other types of raw materials	Development a range of new types of resins with involvement of new partners

At the second stage, in accordance with the methodology developed, the investment costs for the implementation of the project were estimated, cash flows of the project were projected and the project performance indicators were calculated. Table 2 shows the data on the project. The enterprise is investing 311.77 million rubles in non-current and current assets, with 25.49% of the source of financing being the enterprise's own funds, and the rest being long-term borrowed funds, whose cost is 12% per annum.

Table 2 – The source data for estimating project efficiency, k rub.

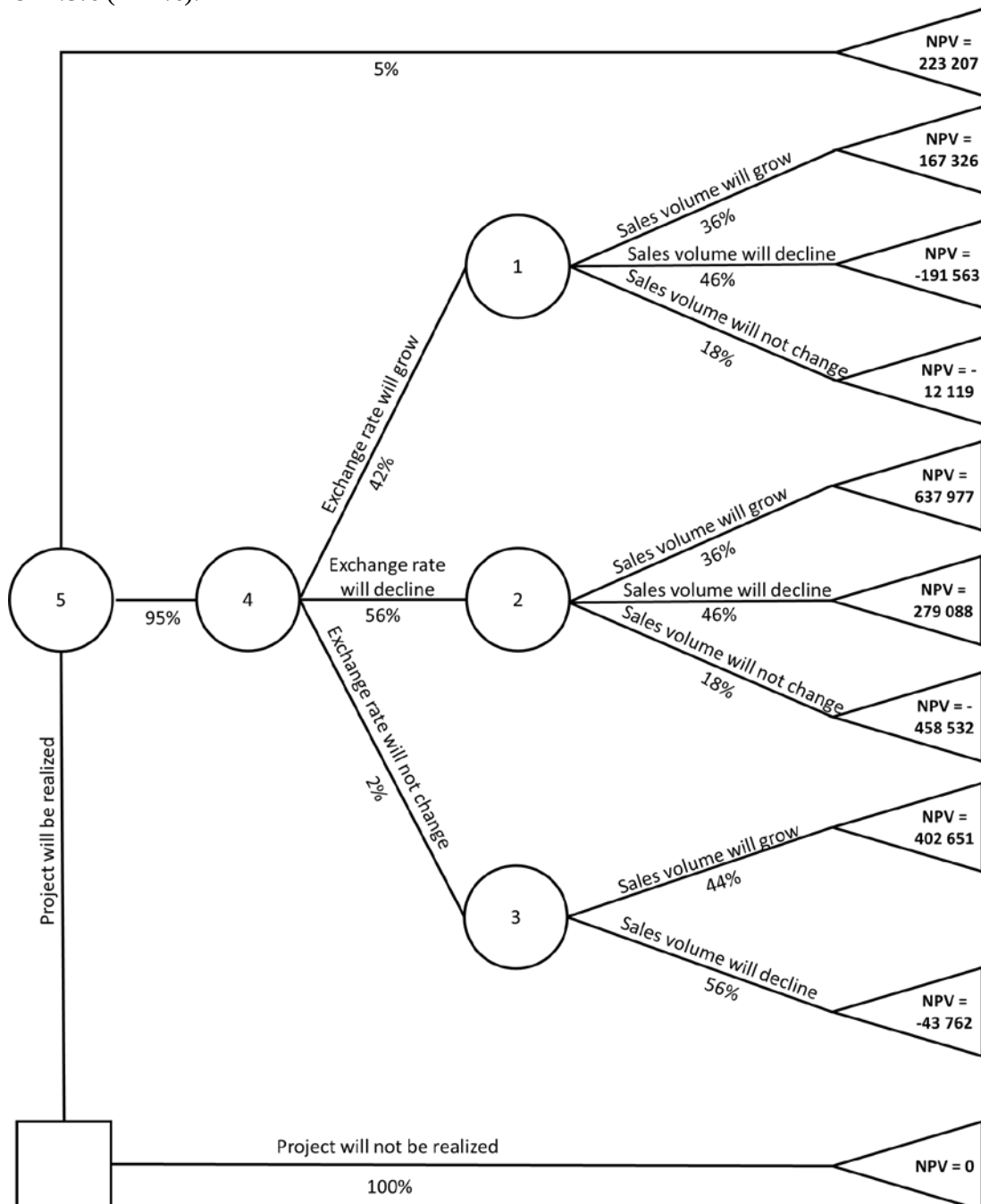
Indicator\year	0	1	2	3	4	5	6
1. Cash flow from operating activities	0	39108	117392	128803	127454	126789	126354
2. Cash flow from investment activities	-60869	-171431	0	0	0	0	0
3. Total cash flow	-60869	-132323	117 392	128 803	127 454	126 789	126 354
4. Discounted cash flow (DCF)	-60869	-118146	93584	91679	80999	71943	64015
5. Balance of accumulated DCF at the beginning of the period	0	-60869	-179015	-85430	6249	87248	159192
6. Balance of accumulated DCF at the end of the period	-60869	-179015	-85430	6249	87248	159192	223207

Table 3 – Performance indicators of the project

Indicators	Value
Net present value (NPV), k rub.	223 207
Internal rate of return (IRR), %	47.82%
Profitability index (PI), units	1.88
Discounted payback period (DPP), years	3 years 55 days

Table 3 includes calculation of the standard project performance indicators. Thus, with the values of the indicators presented in Table 3 being analyzed, it can be concluded that the conditions for the efficiency of the investment project have been met. The net present value of the project is

positive ($NPV > 0$), return on investment (PI) is $1.88 > 1$. This suggests that the project is profitable for investing. The payback period of the project will be 3 years 55 days. The internal rate of return (IRR) is 47.8% ($> 12\%$).



Characterizing the events of the decision tree:

1, 2, 3 are the nodes of sales changing events.

4 is the node of the changing costs of the equipment.

5 is the node of a success event of the innovative project implementation.

Fig. 3 – The decision tree of the project, k rub.

At the third stage of testing the methodology for evaluating the efficiency of the innovative project in the chemical industry, the risks of the project of innovative product manufacturing were assessed. In order to assess the risks, the study uses the methods of sensitivity analysis of project indicators and a decision tree. The main risks of the project are falling product sales and a fluctuating euro rate, since the equipment is imported. As a result of the risk analysis, a decision tree was built to make a decision on the implementation of the project (Fig. 3).

In order to build the decision tree, the probabilities of the euro exchange rate had to be assessed. They were calculated taking into account the exchange rate corridor acceptable for the enterprise. Thus, according to the statistics of the euro exchange rate for the months from April 1, 2013 to May 1, 2018, having determined the number of observations 1 euro = 64 rubles, and the values over 64 rubles per euro and less than that, the following probabilities were obtained: 42% is the probability of the rate to grow; 56% is the probability of the rate to fall; 2% is the probability that the rate will level off at 64 rubles per euro.

In addition, the probabilities of change in the sales was calculated for the project using the statistics of the chain sales indices for the past 11 years in the regions to which the company supplies products under the project. To calculate the probability of change in the sales, the change in indices was calculated for the project. Then the number of observations of the change in indices was calculated within the limits of 5%, over 5% and less than 5%. Thus, using the classical definition of probability, the following probabilities were obtained: 45% is the probability that the sales will fall; 36% is the probability that the sales will remain stable; 18% is the probability that the sales will go up.

To calculate the NPV in the decision tree, the results of the sensitivity analysis were used. So, an assumption was made that the sales for the project will increase by 5% and fall by 5%, since to calculate the probability, the change in the sales index in the regions was used within the limits of 5%, over 5% and less than 5%. As for the change in the euro exchange rate, the NPV ultimate values were taken from the sensitivity analysis when the project becomes unprofitable to carry out: an increase in the rate by 110% and, respectively, its decrease by 110%, since when the probabilities of change were calculated for the exchange rate, a currency corridor permissible for the enterprise was allowed for: 1 euro = 64 rubles, and also values over 64 rubles per euro or less than that.

As a result of applying the three methods for assessing the efficiency of the innovation project, it was found out that the net present value from the implementation of the project, given the risk factors, is higher than that from the realization of a project with the basic initial conditions. The obtained estimations indicate that this project is worth carrying out.

The main distinction of the methodology in comparison with the methods used by other authors in assessing the efficiency of innovative projects is that the specifics of designing innovative products in the chemical industry are considered, and the risks of the projects are assessed using a decision tree.

4. Conclusions

The problem of developing a chemical product lies in its physical and chemical properties. The composition, form and physical properties of the product determine the treatment operations necessary for its production. New or modified technologies are needed to create chemical products. Consequently, it is necessary to use methodologically appropriate and up-to-date approaches to assessing the efficiency of innovations in the chemical sector of the economy.

This research study considered an innovative project aimed at producing synthetic formaldehyde resins and low methanol highly concentrated formalin. Applying the model for evaluating investment in innovation proposed by Gutierrez [13,35] and using the developed methodology for estimating the efficiency of an innovative project in the chemical industry, the paper followed the method for calculating the net present value, carrying out a sensitivity analysis and building a decision tree, as the goal of this project is to change the existing product and expand its sales markets.

The main indicators of the efficiency of the innovation project were estimated on the basis of the cash flows for the project. Then, using the results of the sensitivity analysis and the main performance indicators for the project, the decision tree method was applied. As a result, it has been found out that this project is efficient for investing and will allow the company to improve the results of its innovative activity.

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