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DEVELOPMENT OF A SYSTEM-SYNERGETIC APPROACH TO COST MANAGEMENT FOR A HIGH-TECH INDUSTRIAL ENTERPRISE

Ekaterina Burova[1]*, Sergei Grishunin[2], Svetlana Suloeva[1]

[1] Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia,
burova_ev@spbstu.ru, suloeva_sb@spbstu.ru
[2] National Research University Higher School of Economics Moscow, Russia,
sergei.v.grishunin@gmail.com
* Corresponding author: burova_ev@spbstu.ru

Abstract

This study develops a system-synergetic approach to cost management and a mechanism for its implementation in high-tech industrial enterprises. The relevance of the study is determined by the dominant role of the high-tech industrial sector in developing national economies and the increasing impact of costs on the performance of enterprises. The aim of the study is to eliminate methodological, functional, and systemic problems in cost management for high-tech industrial enterprises. In the study, the features of the function of high-tech industrial enterprises were determined, the approach to cost management for enterprises was proposed, and the cost management mechanism, including the description of the stages, was developed. The works of foreign and Russian researchers in cost management, risk management, and enterprise economics are the theoretical and methodological basis of the study. The authors propose a system-synergetic approach based on the systematisation of existing approaches to cost management. The following tools were used to develop a cost management mechanism: (1) a cost model of the company's profitability in terms of cash flow, (2) statistical data analysis, (3) a bow tie diagram to identify risk factors by key cost drivers, (4) simulation modelling using the Monte Carlo method, (5) a graph of accumulated profitability in terms of cash flow, and (6) a graph of strategic well-being by periods to trace the decline in profitability as innovative products lose their innovative nature. In comparison with existing approaches, the approach proposed in the study considers the specifics of a high-tech industrial enterprise and considers it as a complex open system operating under conditions of uncertainty and under the influence of external and internal risks on the cost management system. The cost management mechanism, based on the system-synergetic approach, calculates the profitability of an enterprise by cash flow, determines the target price of innovative products, analyses the impact of risks on key cost factors and their parameters, considers the correlations between risks, and calculates the expected level of profitability of innovative products under risk conditions. These advantages make the cost management process dynamic, responding to new threats and changes in the external and internal environment of the enterprise.

Keywords: system-synergetic approach, cost management, high-tech industrial enterprise, key cost drivers, risk factors.
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РАЗРАБОТКА СИСТЕМНО-СИНЕРГЕТИЧЕСКОГО ПОДХОДА К УПРАВЛЕНИЮ ЗАТРАТАМИ ДЛЯ ВЫСОКОТЕХНОЛОГИЧНОГО ПРОМЫШЛЕННОГО ПРЕДПРИЯТИЯ

Екатерина Бурова[1]*, Сергей Гришунин[2], Светлана Сулоева[1]
[1] Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия, burova_ev@spbstu.ru, suloeva_sb@spbstu.ru
[2] Национальный исследовательский университет «Высшая школа экономики», Москва, Россия, sergei.v.grishunin@gmail.com
*Автор, ответственный за переписку: burova_ev@spbstu.ru

Аннотация

Целью данного исследования является разработка системно-синергетического подхода к управлению затратами для высокотехнологичного промышленного предприятия и механизма его реализации. Актуальность исследования объясняется доминирующей ролью высокотехнологичного промышленного сектора в развитии национальных экономик и увеличивающимся влиянием затрат на результаты деятельности предприятий. Исследование направлено на устранение существующих в литературе методологических, функциональных и системных проблем по управлению затратами для высокотехнологичных промышленных предприятий. Результаты включают определение особенностей функционирования высокотехнологичных промышленных предприятий, обоснование подхода к управлению затратами предприятий данного типа, разработку механизма управления затратами на основе предложенного подхода, а также описание и спецификации, входящих в него блоков. Теоретической и методологической базой исследования послужили труды зарубежных и российских исследователей в области управления затратами, управления рисками и экономики предприятия. На основе систематизации существующих подходов к управлению затратами в работе предложен системно-синергетический подход. При разработке механизма управления затратами применен следующий инструментарий: (1) стоимостная модель рентабельности компании по денежному потоку; (2) методы статистического анализа данных; (3) диаграмма «галстук-бабочка» для идентификации факторов риска по ключевым факторам затрат; (4) имитационное моделирование с помощью метода Монте-Карло; (5) график накопленной рентабельности по денежному потоку и (6) график стратегического благополучия по периодам, позволяющий проследить спад рентабельности по мере «старения» инновационной продукции. По сравнению с существующими подходами предложенный в исследовании подход позволяет учитывать особенности функционирования высокотехнологичного промышленного предприятия и рассматривать его как сложную открытую систему, функционирующую в условиях неопределенности и учитывающий влияние внешних и внутренних рисков на систему управления затратами. Функционал механизма управления затратами на основе системно-синергетического подхода включает расчет рентабельности предприятия по денежному потоку, определение целевой цены инновационной продукции, анализ влияния рисков на ключевые факторы затрат и их параметры, учет корреляций между рисками и расчет ожидаемого уровня рентабельности инновационной продукции в условиях риска. Эти преимущества делают процесс управления затратами динамичным и итеративным, реагирующим на изменения внешних и внутренних условий функционирования и появление новых угроз.

Ключевые слова: системно-синергетический подход; управление затратами: высокотехнологичное промышленное предприятие; ключевые факторы затрат; факторы риска.

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1. Introduction

The high-tech industrial complex is the backbone of the industrial sector in the era of the "fourth industrial revolution" (FIR). The performance indicators of high-tech enterprises determine the role of the state in the international competitiveness rating. One factor affecting the efficiency of production and the output of industrial enterprises are costs. Despite the existing methods and tools, there is a need for the development and improvement of approaches to cost management, allowing us to consider the specifics of high-tech industrial enterprises as complex open systems in continuous interaction with the external environment (Su and Wu, 2019; Khesal et al., 2019).

A literature review showed that high-tech industrial enterprises most often use use some combination of design and systemic approaches to cost management. Traditional methods consider the enterprise as an integral system that interacts with the external environment (Johannknecht et al., 2017; Wegmann, 2019). The main disadvantages of traditional approaches are: (1) the focus on the internal processes and relationships at the enterprise and (2) the lack of consideration of external influences (risks) and their impact on the cost management system. Traditional approaches to cost management do not allow the system to respond effectively to changes in the external environment, while the influence of external factors on the enterprises is constantly growing. McKinsey Global Institute directors note that the collision of four destructive forces – urbanisation, constantly accelerating scientific and technological progress, demographic shifts (ageing and slower reproduction rates), and globalisation – are leading to fundamental changes in the way enterprises operate (Bogoviz, 2019). In comparison with the industrial revolution of the 18th–19th centuries, these changes occur ten times faster, and their impact is 3000 times stronger (Zaycev, 2014). Such a sharp increase in the changes of the external environment and their unpredictability and irreversibility confirm the irrelevance of traditional approaches to managing the costs of a high-tech industrial enterprise.

The aim of the study is to develop a system-synergetic approach to cost management of a high-tech industrial enterprise (HTIE) and a mechanism for its implementation. This approach considers an enterprise as: (1) an integral manageable system (systemic approach); (2) an open complex system (synergetic approach). Within the framework of the proposed approach to cost management, there is a self-organisation mechanism (Sheth & Sinfield, 2019; Snow et al., 2017), which makes it possible to continuously adjust the cost management process to changing external and internal conditions through interaction with the risk management system. This will ensure sustainable, effective cost management. To substantiate the chosen approach, this study highlights the features of the organisation, management, and functioning of a high-tech enterprise in modern conditions.

2. Literature review

Today, industrial enterprises traditionally use the following approaches to cost management: functional, process, project and systemic (Johannknechtetal, 2017; Wegmann, 2019). Each of the above approaches has its own characteristics and limitations. The functional approach to cost management focuses on the achievement of functional targets, rather than on the targets of the cost management system, which does not allow for its application at the strategic level of cost management[1].

The project approach allows to get maximum results with limited resources, but not every activity of the enterprise can be a project. The process approach to cost management allows one to op-

[1] OECD. Main Science and Technology Indicators https://doi.org/10.1787/0bd49050-en

timise costs by identifying ineffective processes, but it does not consider the external relationships of the enterprise. Management of enterprise costs using a systematic approach allows you to coordinate the goals of the cost management system (CMS) with the strategic goals of the enterprise. The systematic approach considers not only the internal relationships of the enterprise, but also its interaction with the external environment. However, cost management within the framework of this approach is reduced only to “ neutralizing” all random influences from the external and internal environment that do not correspond to the target settings of the system, which does not allow the system to develop under the influence of these factors. Thus, using traditional approaches cannot effectively manage the costs of a modern high-tech enterprise.

There is a wide variety of methods described by experts in cost management (Banker et al., 2018; Labunska et al., 2017). Target costing and kaizen-costing are now widely used among cost management methods in high-tech industrial enterprises (Manucharyan & Adamova, 2019; Olszewska, 2019). These methods allow enterprises to consider such features of HTIE as customer-oriented production and customised marketing (Dăneci-Patrău & Coca, 2017), and also give the enterprise a valuable competitive advantage: lower production costs compared to competitors. To understand the origin of costs and their analysis for HTIE, it is necessary to use the concept of cost-generating factors (Andriushchenko et al., 2019). This concept implies an in-depth analysis of costs and their cost-generating factors, which improves the quality and efficiency of cost management, but does not allow tracking changes in cost factors due to the interaction of the enterprise with the external environment. One solution to this problem is the complex use of these methods combined with the concept of risk controlling, described in Grishunin et al. (2018), which will make it possible to implement the self-organisation mechanism inherent in the system-synergetic approach to cost management.

The review of scientific literature (Paté-Cornell et al., 2018; Samimi, 2020; Grishunin et al., 2020) has shown that modern risk management tools consider the peculiarities of the HTIE’s functioning, but there is not enough research in integrating risk management and cost management. The scientific research on risk management at HTIE is highly specific, as it focuses on identifying and assessing risks in developing enterprise investment programmes.

3. Materials and methods

The theoretical and methodological basis of the study was the work of foreign and Russian researchers in cost management, risk management, and enterprise economics. Based on the systematisation of existing approaches to cost management, a system-synergetic approach based on the interaction of the CMS and the risk management system is proposed. Developing the cost management mechanism based on the proposed approach applies the main principles of target costing and kaizen-costing systems and the concept of cost-generating factors and risk controlling, providing an inextricable link between key cost factors, risk factors, and target profitability of innovative products. The integrated use of these methods will allow us to consider risk factors in cost management, which will increase the adaptability, flexibility, and sustainability of the CMS at HTIE.

The following tools were applied: (1) the cost model of the company’s return on investment in terms of cash flow; (2) statistical data analysis; (3) a bow tie diagram to identify risk factors by key cost drivers; (4) simulation modelling using the Monte Carlo method; (5) a graph of accumulated profitability in terms of cash flow; and (6) a graph of strategic well-being by periods, which allows us to trace the decline in profitability as innovative products “age”.

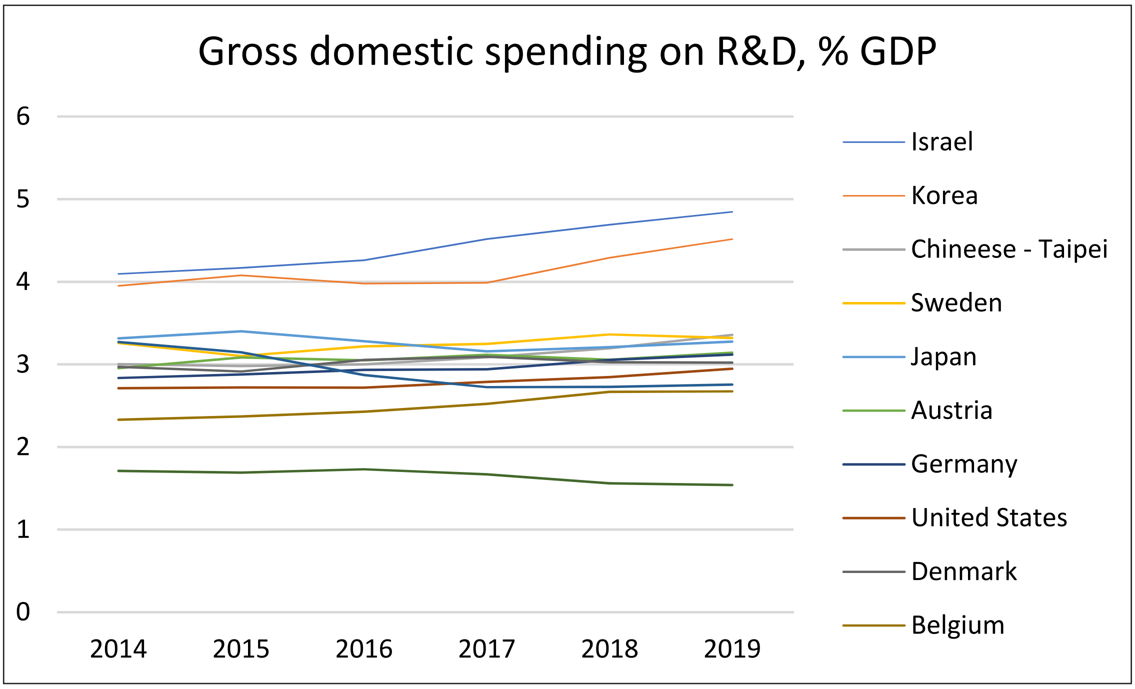

Figure 1. Gross domestic spending on R&D
(Compiled by the authors based on the data from the Organisation for Economic Community and Development[2])

4. Results

4.1 Determination of the features of high-tech industrial enterprises functioning and substantiation of an approach to cost management

According to the literature, the high-tech sector (HTS) determines the scientific, technical, and economic potential of the country and is an indicator of national economic status (Litvinenko & Ustuzhanina, 2016; Zherdev, 2017; Roberts & Wolf, 2018). Globally, there is a clear trend towards an increase in the share of R&D expenditures: in 2014, the total level of expenditures on R&D in the world amounted to 1.6% of global GDP; in 2019, it reached 2.1% of global GDP with a significant increase in the volume of gross output. The volume of gross domestic expenditure on R&D in advanced economies in the period from 2014 to 2019 is shown in Fig. 1.

The basis of HTS is HTIE, whose activities, under the modern concept of developing a high-tech industrial complex, are characterised by high uncertainty and risks. The review of the literature related to the HTIE's activities made it possible to highlight their main features (Fig. 2) (Su and Wu, 2019; Khesal et al., 2019; Korotkova, 2014). The main factor in developing modern HTIE is innovation (see Fig. 2), which explains its priority among the business projections of an industrial enterprise. Innovative activity is a source of structural changes for the entire industrial enterprise and affects all management processes (Vasilenko, 2019).

The highlighted features of the HTIE and the constantly increasing level of uncertainty in the external environment make it possible to study these enterprises from the standpoint of the theory of self-organisation of complex systems based on a synergetic approach:

[2] https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

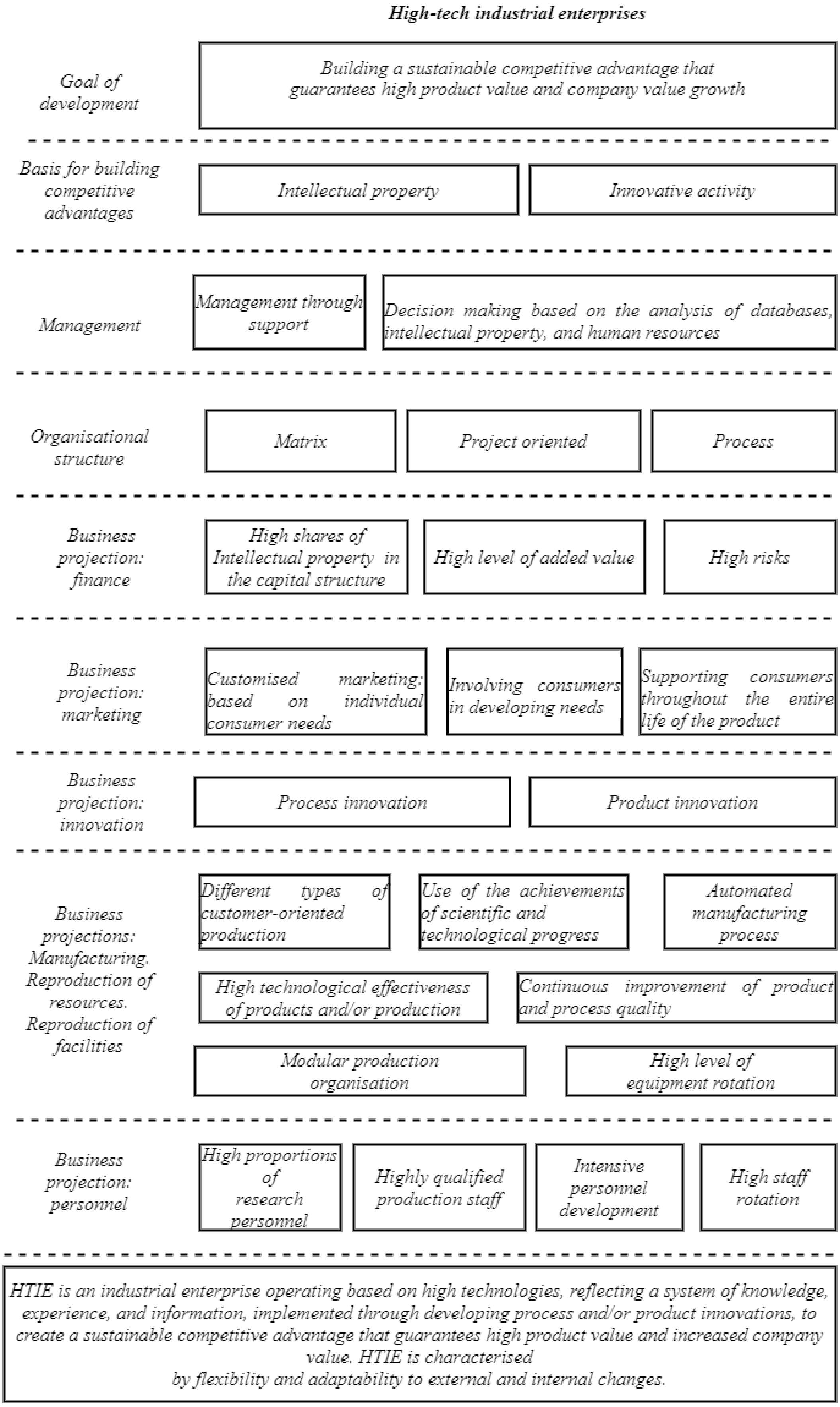

Figure 2. Features of HTIE

(1) HTIE is an open complex system characterised by intense and continuous interaction with the external environment, which leads to various uncertainties under the influence of external and internal environmental factors; (2) HTIE is a non-linear system in which quantitative changes in exposure lead to changes in qualitative characteristics; (3) HTIE is a self-organising system capable of adaptation to the external environment. Constant changes and high uncertainty in the functioning conditions of the HTIE can be one manifestation of chaos. In accordance with the synergetic approach, a new organised structure can emerge from chaos under the influence of internal mechanisms (self-organisation mechanism). Uncertainty in terms of the synergetic theory is a constructive mechanism for developing the system. Thus, it is advisable to use a synergistic approach when managing HTIE. A synergetic approach to control is based on the mechanism of resonant effects on a non-linear system, during which the system develops. The impact itself may be insignificant. The main task of management in a synergetic approach is to manage such impacts to ensure the development of the system in a favourable direction (Sheth & Sinfield, 2020; Snow et al., 2017).

In this work, we propose using a system-synergetic approach to cost management, which combines the principles of systemic and synergistic approaches. This approach, on the one hand, makes the process of cost management more effective since it considers the CMS as an integral controllable system. However, it considers the continuous interaction of the enterprise with the external environment in cost management and "focuses on the rejection of isolated cost management"[3]. We propose to implement a system-synergetic approach to cost management at the HTIE through the mechanism of interconnection of the CMS and risk management.

4.2 Development of the cost management mechanism based on a system-synergetic approach

Helped by the proposed mechanism, it is possible to analyse the influence of uncertainties and risks of the external and internal environment on the key cost factors and the assessment of this influence on the target profitability (TP) of the innovative product (IP). In the mechanism, using simulation modelling, the deviations of the expected TP level from the planned value are calculated for a specific period. If, at the established level of confidence, the calculated deviations exceed the established permissible values (risk appetite), measures are taken to reduce the cost using cost engineering methods and optimisation of business processes, or a decision is made that the product will not be put into production (Ibusuki & Kaminski, 2007). The diagram of the mechanism is shown in Fig. 3.

The first step in the mechanism is determining the TP indicator. Leaders can choose from a wide variety of possible metrics to measure ROI or ROI by Coverage[4]. However, their disadvantage is static; indicators can measure profitability only in one analysis period, and they do not consider the time factor and the volume and cost of capital required for IP production.

Therefore, we propose using monetary return on investment (CFROI) as an indicator of profitability, as designed by HOLT ValueAssociates[5]

[3] Yurjeva, L, Dolzhenkova, E, Kazakova, M, 2015. Management accounting of costs at industrial enterprises in an innovative economy. M. Knorus, p. 191

[4] Veber U., Shefer U., 2014. Introduction to Controlling. Per. s nem/Pod red i s predisl. prof, d.e.n. S.G. Fal'ko. M. «Ob»edineniekontrolllerov», p. 416

[5] Fabozzi, F., Grant, J., 2000. Value-Based Metrics: Foundations and Practice, Wiley, p. 294

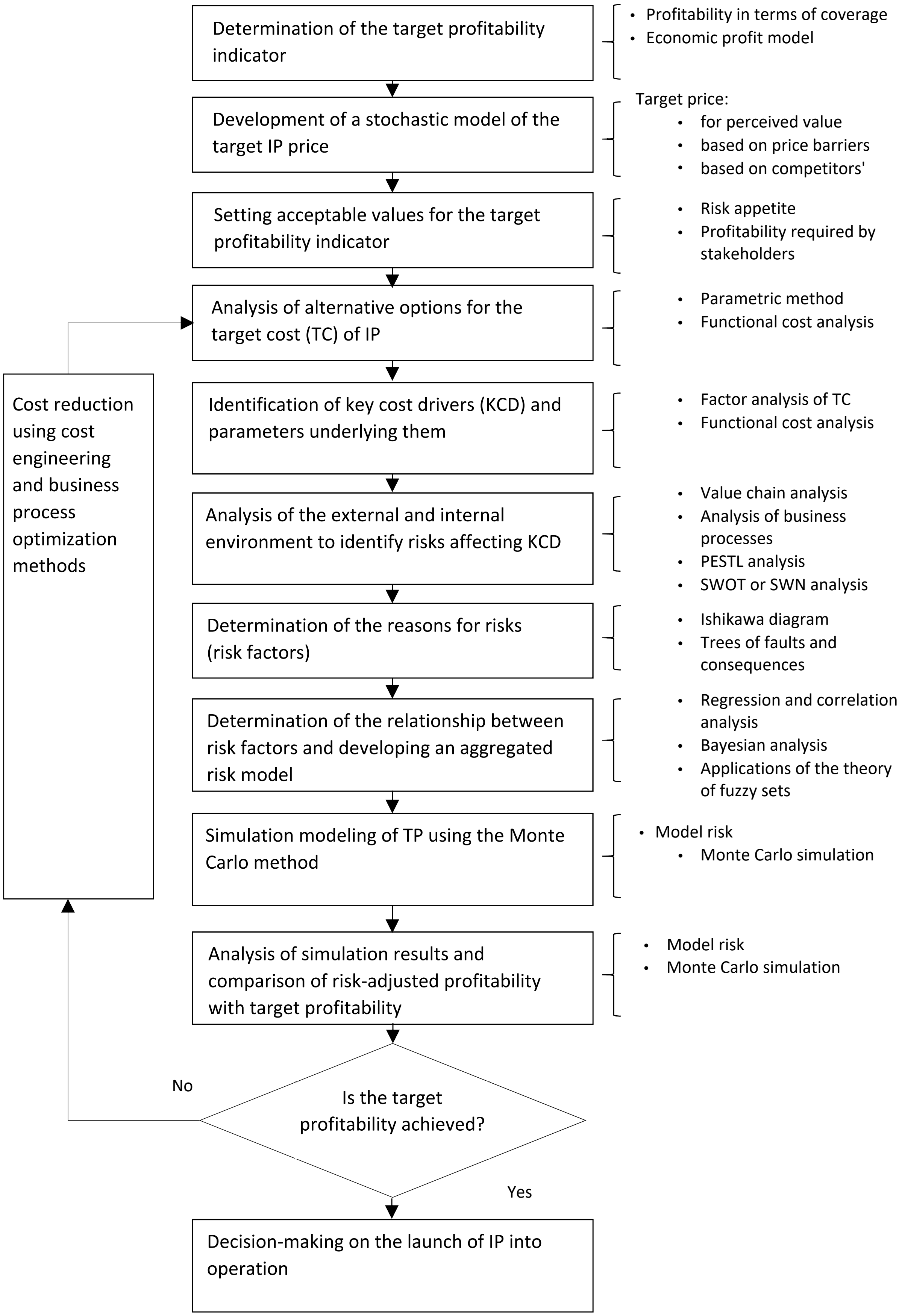

Figure 3. Block diagrams of the cost management mechanism based on the system-synergetic approach

$$CFROI = \frac{\sum_{t=0}^{T}\left(\frac{(CMC_t - ED_t)}{(1+WACC)^t}\right)}{\sum_{t=0}^{T}\frac{I_t}{(1+WACC)^t}} \tag{1}$$

$$ED_t = \frac{WACC}{(1+WACC)^t - 1} * (TA_t - NDA_t) \tag{2}$$

CMC_t is the coverage of cash costs (marginal profit) for period t; I_t is investments made in period t; ED_t is the economic depreciation for period t; TA_t is the average value of the company's assets used for period t; and NDA_t is the average asset value not subject to depreciation over period t.

The advantage of this indicator is the ability to consider changes in the marginal profit of the IP during its life cycle. Such changes can be due to the actions of competitors, improvements in the production process, the accumulation of experience in production and implementing continuous improvements of the IP, etc.

At the second stage of the mechanism's operation, the target price is determined depending on the period under consideration. To determine the target price, various methods of marketing analysis are used, such as studying the perceived value of the IP and its components, the prices of competitors and substitute products, possible price barriers, and others.[6]

Here, the marketing department must provide stochastic models (probability distributions) of the IP price for each period analysed. In the simplest case, the PERT distribution can be used, the main parameters of which are the minimum, maximum, and most probable price values during the period:

$$\begin{gathered} P(X / a,b.c) = \frac{(x-a)^{\alpha-1}(c-x)^{\beta-1}}{B(\alpha,\beta)(c-a)^{\alpha+\beta-1}} \\ \alpha = \frac{4b+c-5a}{c-a} \\ \beta = \frac{5c-a-4b}{c-a} \end{gathered} \tag{3}$$

B is beta probability distribution, a, b, c – minimum (a), most probable (b), and maximum expected price value in the period under consideration. P (X / a,b,c) is the probability that the price will take one value in the interval from a to c.

At the third stage of the mechanism operation, the TP value (for example, the target value of CFROI) and the maximum allowable deviation from the TP (risk appetite, rCFROI) are determined, as well as the minimum deviation from the TP, which does not imply active actions on lower costs (tCFROI tolerance level).

At the fourth stage of the mechanism operation, the controlling service calculates the TC based on the interaction with engineering and R&D services. We suggest considering several options for TC, depending on the alternative methods of IP manufacturing. The deviations are set by decision-makers based on the results of implementing past projects for developing IP. Initially, the IP can be determined using the feasibility study of the project based on the parametric method. However, if the CFROI for the project without considering the risk goes beyond the permissible deviation from

[6] Nagle, T., 2017. The Strategy and Tactics of Pricing: A guide to growing more profitably. Routledge, 2017, p. 252

the TP, then it is necessary to use other methods to determine the TC, such as functional cost analysis or cost calculation based on functions (Ievtushenko & Hodge, 2012; Suloeva & Gulceva, 2017).

Attention should be paid not only to the methods of calculating the TC, but also to the interaction between engineering services, procurement and logistics services and controlling to avoid hidden costs. If these methods fail to achieve the TP of CFROI, then the R&D project should be abandoned. While calculating the TC, the key cost factors (KCF) and the parameters underlying them are identified. The main tool for this is also a functional cost analysis, which allows determining the KCF both in terms of functions and in terms of resources (Soekardan, 2016). Here, the Pareto principle should be used: the key factors will be 20% of all KCFs, which form 80% of all costs in the TC.

In the fifth stage of the mechanism, the analysis of the external and internal environment is carried out to identify the risks affecting the KCF and to determine the reasons for implementing these risks (risk factors). Here, risks are understood as uncertainties that affect the achievement of the target values of KCF. The source of information for this analysis can also be a functional cost analysis, within which business processes and a value chain are analysed. This makes it possible to trace the process of formation of the KCF from product functions to the source of KCF (including those outside the boundaries of the enterprise) and identify weaknesses and bottlenecks. To identify risks in the external environment, the following analysis methods can be used: (1) benchmarking of KCF and the business processes with competitors that form them; (2) analysis of strengths, weaknesses, opportunities, and threats (SWOT) or its simplified version of SWN (analysis of strengths, neutrals, and weaknesses); (3) analysis of various aspects of the external environment (PEST (STEP) analysis and its varieties).

At the sixth stage of the mechanism's operation, the sources of risks (S_i) are determined, the prerequisites for events, causing deviations from the target values for each KCF. The reasons and causes of risks are also determined. To do this, we propose using a bow tie diagram, which is a combination of a fault tree (FTA) and an effect tree (ETA) (Ferdousetal, 2011). The analysis of the chain of influencing events is carried out until (1) an external source is found that the company either cannot control or has limited control over; or (2) the ultimate source of risk is found; or (3) a source of

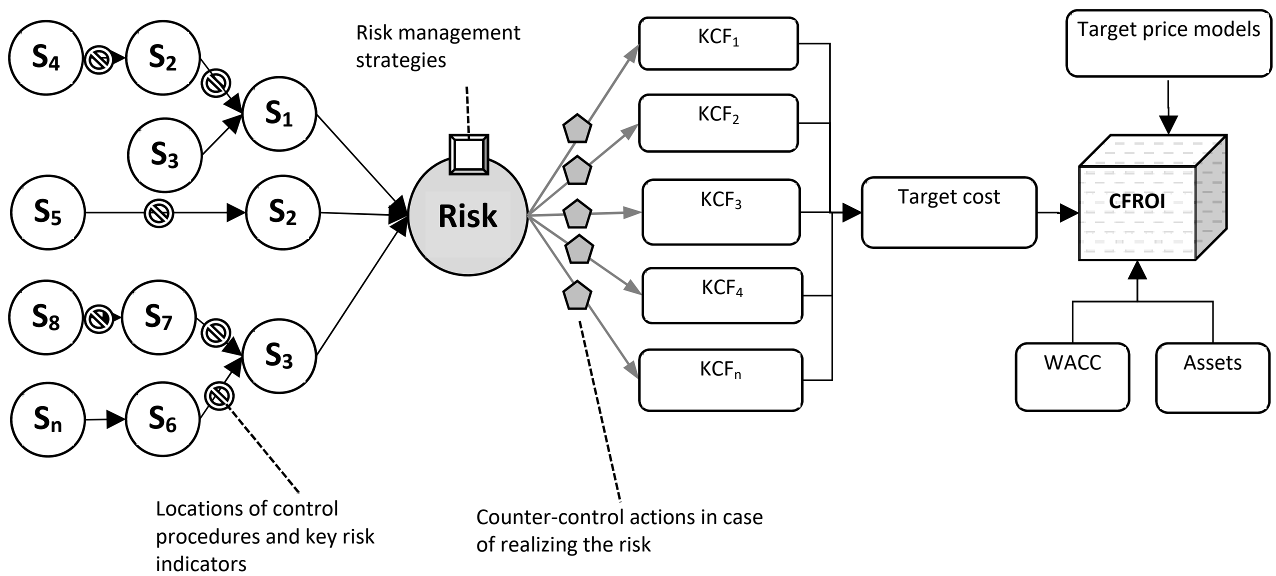

Figure 4. A bow tie diagram to analyse the causes and consequences of the risks

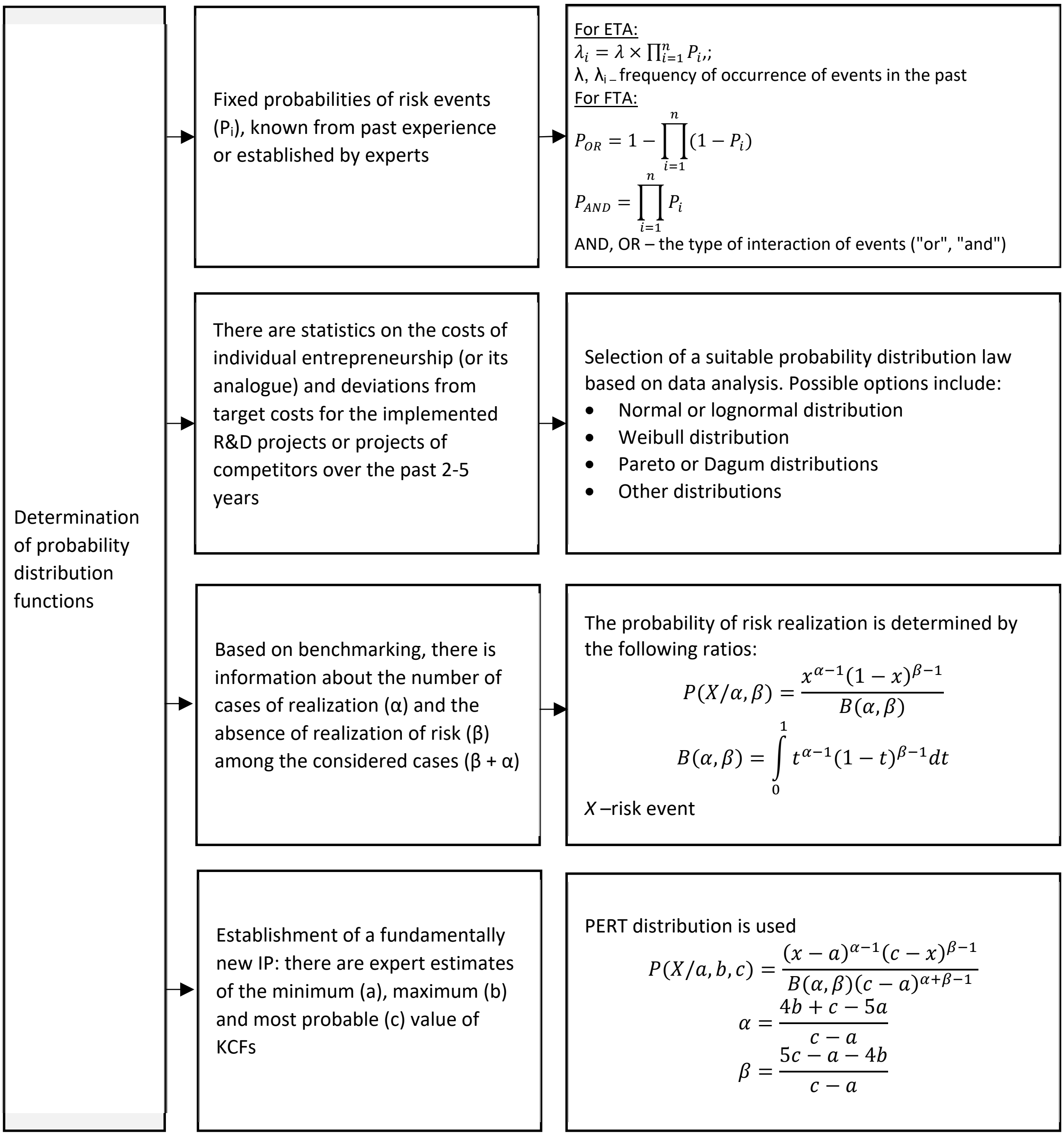

Figure 5. Approaches to assessing the probability distribution functions of risk events affecting KCF

risk is found that determines 80% or more causes of risk development; hence, further analysis is not advisable. An example diagram is shown in Fig. 4.

Analysis using a bow tie diagram allows us to determine the links between the risk and its sources and to build a model of their relationship. For the mechanism, we propose using a probabilistic approach (Ferdous et al., 2011), where for each node (S_i) (1) the probability distribution function of the event occurrence and the correlation coefficients between events are determined either according to the results of the past projects or by experts; (2) the probability of risk occurrence is determined either by building a Bayesian network connecting events, or by adding the probabilities considering correlations. However, for projects with high uncertainty, more sophisticated models can be used, such as (1) applications of fuzzy set theory; (2) applications of evidence-based theory; (3) artificial intelligence methods and neural networks; (4) probabilistic models of epidemic outbreaks and others (Ferdous et al., 2011). Once models for individual risks are built, they are (1) extended to key cost drivers and (2) associated with the TP formula considered at the first stage of the mechanism. The target price model must be included in the TP formula.

When using the probabilistic approach, we have developed the following options for approaches when choosing the probability distribution functions for risk events (Fig. 5).

In the seventh stage of the mechanism, the profitability indicator is modelled using the Monte Carlo method (Grishunin et al., 2018). The purpose of the modelling is to obtain the confidence interval of the TP, considering the exposure of the IP to risks. Its calculation methodology is comparable to the value-at-risk approach used in financial management (Grishunin et al., 2018). For modelling, it is recommended to use a specialised package of MS Excel applications (such as @Risk or Model Risk) or (for complex projects) to develop a program code (for example, in Phyton). Within this stage, these series of successive steps are carried out: (1) assessment of the correlation between risks and the calculation of correlation coefficients; (2) aggregation of stochastic models for all risks; (3) simulation modelling; (4) visual and quantitative analysis of results and comparison with risk appetite; and (5) deciding on the implementation of the IP project, developing risk management strategies, and the associated internal control system.

For a visual analysis of the TP considering risks, we recommend using tools such as the graphs of the accumulated CFROI (S-curve) and the graph of strategic well-being (U-curve) by period, which allows one to trace the decline in profitability as the IP ages (Fig. 6 and 7). The S-curve allows you to trace the accumulated monetary return on investment, considering the risks by period, to predict possible deviations from the TP even before the launch of the IP, and to determine the effectiveness of the planned risk management measures. The graph of strategic well-being allows enterprises to trace the change in monetary profitability over the life cycle of the product, locate critical points (simple payback, full payback, accumulation of productive capital, ageing and death) and

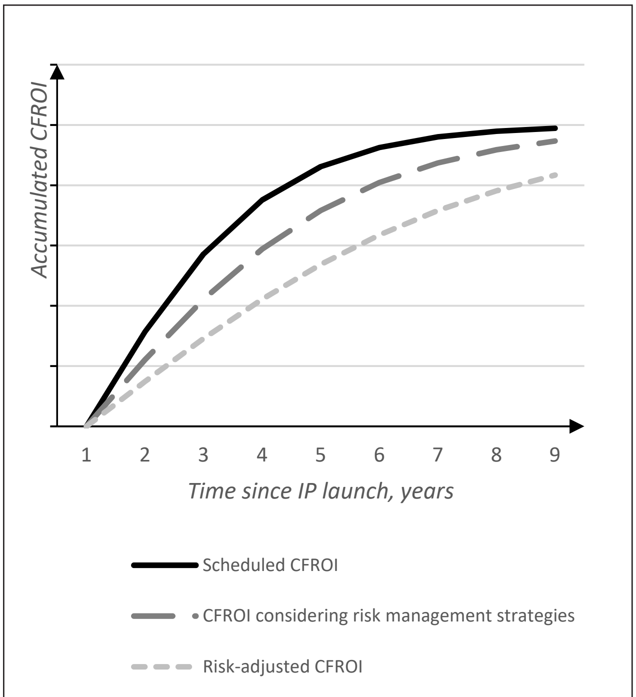

Figure 6. S-Curve of CFROI

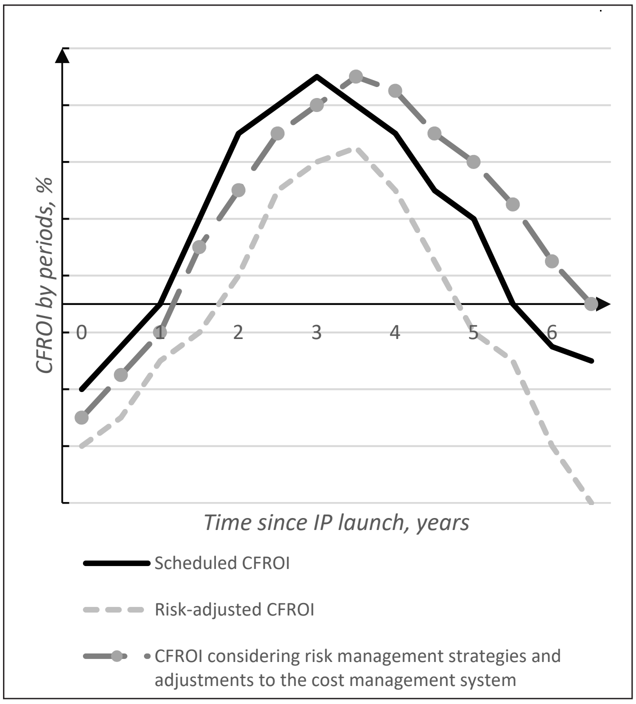

Figure 7. Graph of TP by periods of IP launch

their "movement" considering the risks, and predict a possible "early old age" of the IP due to exposure to risks. For the convenience of analysis, this graph can be plotted by the elements of formula (1). This graph also allows enterprises to determine which CMS (standard-costing, kaizen-costing, lean manufacturing methods) should be used at what point in the life cycle (including passing critical points) to counter the decline in CFROI as the IP ages.

An important visual analysis tool is a histogram of distributing predicted values of TP, considering risks at a point or for a period (Fig. 8). It allows one to assess (1) the expected deviations of the TP from the strategic plan with a level of confidence (γ); (2) the most likely value of the TP, considering the risks; (3) the probability of a decrease in TP below the values of the level of tolerance and risk appetite (rCFROI and tCFROI); or (4) the likelihood of reaching the target value.

If the lower limit of the γ-confidence interval of TP is higher than the level of risk tolerance, then additional efforts to reduce the identified risks when developing an IP should not be undertaken. If the TP risk tolerance is excluded, it may mean that too few risks were considered in developing the projects. It is necessary, then, to consider accepting more uncertainties to obtain a higher TP (for example, increasing the price, proposing more complex technological solutions, using new materials, or adding additional options for the consumer).

If the lower limit of the s-confidence interval of TP is lower than tCFROI, but higher than rCFROI, then the project must involve active strategic risk management actions. Here, for each risk, (1) risk management strategies should be developed, aimed at reducing (managing), accepting, transferring, or refusing to accept risks; (2) detailed action plans based on these developed strategies; and (3) a system of monitoring key risk indicators (KRIs), which allows monitoring the implementation of risks for decision making. For developing detailed plans, a bow tie diagram determines the location and type of control procedure. Their task is to prevent the implementation of the threat factor ("barrier control procedure"), or to timely identify the threat factor and take counter-control measures ("revealing control procedure"). Second, the diagram defines action plans for counter-control

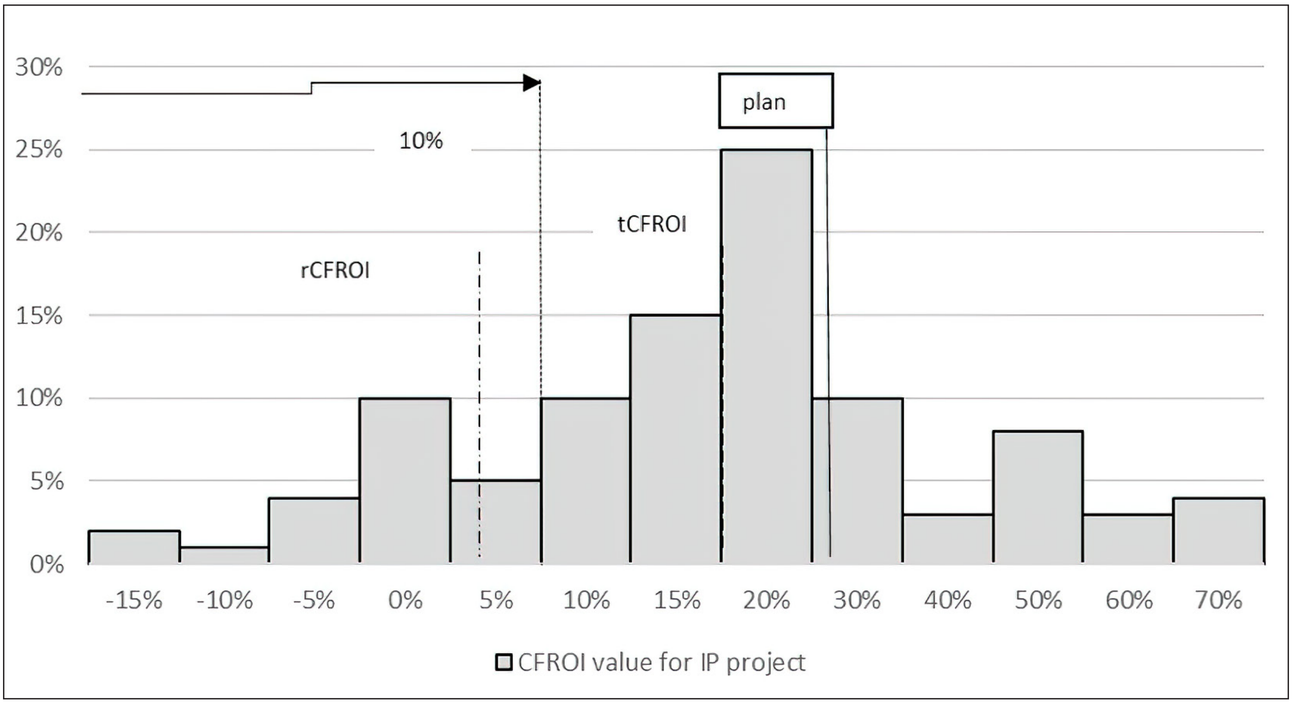

Figure 8. Histogram of the distribution of predicted TP values

if realising risks occur, allowing us to reduce the negative consequences. In addition, the diagram locates the KRI.

If the lower limit of the γ-confidence interval TP is lower than the value of risk appetite (rCFROI), then this means that the IP development project is ineffective in terms of risk exposure and should either be terminated or sent for revision. The first step will be to develop the risk management actions described earlier. The likelihood of ineffectiveness of the actions and control procedures that make up the risk management plan should be assessed. These probabilities can be described by the Bernoulli or PERT laws of distribution. Second, actions are taken to reduce costs through functional cost analysis, cost reengineering, or alternative options to develop an IP are proposed. Then, the simulation is repeated (seventh stage of the mechanism), and the analysis of the results obtained is carried out. If the lower limit of the confidence interval is still below the value of the risk appetite, then it is necessary to repeat the steps for revision with tougher assumptions or to cancel the project, thus ensuring the principle of self-regulation of the system.

It is necessary to note that to maintain an acceptable level of TP throughout the entire life cycle of an IP, the mechanism for assessing the TP should be periodically repeated at the most important control points. After completing each stage of IP development, all steps to assess cost risks and the description of measures taken to counter them are to be submitted to the internal audit service to assess the effectiveness of the actions taken. The goal of the internal audit will be to develop recommendations for improving the risk assessment process.

5. Discussion

The developed system-synergetic approach to cost management of HTIE has significant advantages over the traditional approaches analysed in the second section of the study. The system-synergetic approach proposed by the authors (1) considers the specific of the HTIE functioning, (2) considers this enterprise as a complex open system operating under conditions of uncertainty and risks, (3) considers the influence of external and internal risks on the CMS and, (4) corresponds with the principles of adaptability, flexibility, sustainability, and consistency, which are necessary for effective cost management of HTIE. The developed mechanism underlying the system-synergetic approach evaluates the continuous interaction of an enterprise with a turbulent external environment and considers this interaction in the CMS.

To date, the problem of risks in cost management has not been sufficiently studied. Existing approaches to integrating the risk management system with the CMS are too specific since they focus on identifying and assessing risks when developing investment programmes for enterprises. Yin and other researchers (Yin et al., 2013) propose using the scenario method to account for risks in cost management. This approach to managing the costs of an HTIE is not effective and lacks flexibility, since it is limited by the number of scenarios (realistic, pessimistic, and optimistic), which will not allow for timely monitoring and consideration of all the risks arising from the interaction of the enterprise with the external environment. Feili, Anđelić and other researchers (Feili et al, 2012; Anđelić et al, 2020), propose an approach to managing the costs of investment projects using the synthesis of cost engineering and risk management. This approach is aimed at improving the risk management system, not the CMS, since it allows you to analyse and consider the risks arising at all stages of the life cycle of investment projects and decide on risk management depending on their cost. The mechanism proposed in the study is based on modern concepts of target costing, kaizen-costing, the concept of cost-generating factors, and risk controlling, which provide an inextricable link between KCF, risk factors, and TP of innovative products. The integrated use of these methods will consider risk factors in cost management, which will increase the adaptability, flexibility, and sustainability of the CMS in a HTIE.

Using a system-synergetic approach is limited by the need to ensure the following conditions: (1) a high level of digitalisation of the enterprise, (2) a high level of qualifications of personnel involved in the cost management process, and (3) a high level of development of the risk management system at the enterprise.

The authors see the prospects for further research in the following areas: (1) the development of individual cost management mechanisms, such as a mechanism for determining the KCF and their parameters, a mechanism for choosing an optimal cost management model based on risk; and (2) the adaptation of a system-synergetic approach to cost management for certain business fields of the VCCI (finance, marketing, personnel, etc.).

6. Conclusion

The article develops a system-synergetic approach to managing the costs of HTIE, considering the distinctive features and the conditions for their operation. The authors present a cost management mechanism based on the proposed approach. The system-synergetic approach has the following advantages: (1) it considers the specifics of modern HTIEs as complex self-organising systems operating in conditions of uncertainty and the impact of risks on the CMS, and also makes it possible to continuously adjust the cost management process in accordance with changing external and internal conditions; (2) the developed mechanism offers a holistic approach to identifying and assessing risks at the level of KCF using high-precision tools and methods for quantifying risks, calculating the aggregate effect of the project realisation of risks, and assessing the impact of this effect on indicators of investment attractiveness and project efficiency. These advantages make the cost management process dynamic, able to respond to new threats and changes in the external and internal environment of the enterprise.

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About the authors:

1. Ekaterina Burova, assistance lecturer, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia,
https://orcid.org/0000-0003-3310-6074, burova_ev@spbstu.ru

2. Sergey Grishunin, PhD, senior lecturer, The National Research University Higher School of Economics, Moscow, Russia,
https://orcid.org/0000-0001-5563-5773, sgrishunin@hse.ru

3. Svetlana Suloeva, Doctor of Economics, Professor, Peter the Great Saint Petersburg Polytechnic University, Saint Petersburg, Russia,
https://orcid.org/0000-0001-6873-3006, suloeva_sb@spbstu.ru

Информация об авторах:

1. Екатерина Бурова, ассистент, Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия,
https://orcid.org/0000-0003-3310-6074, burova_ev@spbstu.ru

2. Сергей Гришунин, к.э.н., доцент, Национальный исследовательский университет «Высшая Школа Экономики», Москва, Россия,
https://orcid.org/0000-0001-5563-5773, sgrishunin@hse.ru

3. Светлана Сулоева, д.э.н., профессор, Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия,
https://orcid.org/0000-0001-6873-3006, suloeva_sb@spbstu.ru