Research article
DOI: https://doi.org/10.48554/SDEE.2021.2.5

DEVELOPMENT OF INNOVATIVE INDUSTRIAL CLUSTER STRATEGY USING COMPOUND REAL OPTIONS

Egor Koshelev[1]*, Thomas Dimopoulos[2], Enrico Sergio Mazzucchelli[3]

[1] Nizhny Novgorod State University named after N.I. Lobachevsky, Russian Federation, ekoshelev@yandex.ru
[2] Neapolis University Paphos, Cyprus, thomas.dimopoulos@gmail.com
[3] Politecnico di Milano, Italy, enrico.mazzucchelli@polimi.it
* Corresponding author: pfernandez@iese.edu

Abstract

The subject of the study is pilot clusters that are beneficial to a particular region, taking into account the traditions and production areas of the region. The work aims to develop an innovative strategy for state-supported pilot clusters that would allow for flexible management decision making. The proposed method involves the compound real options to be employed in the following order: 1) an option to reduce and abandon the cluster strategy; 2) an option to develop and replicate the experience accumulated in the cluster; 3) an option to switch from and temporarily stop the cluster strategy; and 4) an option to postpone the implementation of the new cluster strategy. As an example of the implementation of the method presented, the authors discuss the strategy for the development of a pilot electric power cluster in the Nizhny Novgorod region presented by the core company TNS energo NN PJSC. The use of the compound real option method enabled the cost increase of the strategy for this cluster – i.e., the effect of its implementation by the core company rose by 89.1%, from 2 710 022 to 5 124 706 thousand Rubles. Thus, using the compound real options precisely in the presented order avoids unreasonable management decisions to exit the current cluster strategy, which would include many tactical opportunities already implemented for cluster development. First, a put option, i.e., an option to reduce and exit the cluster strategy, supplements the evaluation of the current strategy. If the current strategy continues, the other three options are used.

Keywords: industrial innovation cluster, compound real option, abandonment option, growth option, switch option, project deferral option.

Citation: Koshelev, E., Dimopoulos, T., Mazzucchelli, E.S., 2021. Development of innovative industrial cluster strategy using compound real options. Sustainable Development and Engineering Economics 2, 5. https://doi.org/10.48554/SDEE.2021.2.5

Научная статья
УДК 336.645.1
DOI: https://doi.org/10.48554/SDEE.2021.2.5

РАЗРАБОТКА ИННОВАЦИОННОЙ СТРАТЕГИИ ИНДУСТРИАЛЬНОГО КЛАСТЕРА МЕТОДОМ СОСТАВНЫХ РЕАЛЬНЫХ ОПЦИОНОВ

Егор Кошелев[1]*, Томас Димопулос[2], Энрико Серджио Маццучелли[3]

[1] Национальный исследовательский Нижегородский государственный университет имени Н.И. Лобачевского, Российская Федерация, ekoshelev@yandex.ru
[2] Неаполисский университет Пафоса, Кипр, thomas.dimopoulos@gmail.com
[3] Миланский технический университет, Италия, enrico.mazzucchelli@polimi.it
* Автор, ответственный за переписку: ekoshelev@yandex.ru

Аннотация

Предметом исследования является выделение пилотных кластеров, которые наиболее выгодны населению региона, исходя из традиций и исторических направлений производства. Работа направлена на применение такой технологии для разработки инновационной стратегии для определяемых государством пилотных кластеров, которая позволит принимать гибкие управленческие решения. Предложенный способ включает использование составного реального опциона, включающего следующие компоненты, которые должны применяться в следующем порядке: 1) опцион сокращения и выхода из кластерной стратегии, 2) опцион развития и тиражирования опыта работы в кластере, 3) опцион переключения и временной остановки кластерной стратегии, 4) опцион отсрочки начала реализации новой кластерной стратегии. В качестве примера реализации представленного метода авторы обсудили процесс разработки стратегии развития пилотного электроэнергетического кластера в Нижегородской области, который был представлен основной компанией ПАО «ТНС энерго НН». Использование метода составных реальных опционов позволило увеличить стоимость стратегии этого кластера, то есть эффект от ее реализации основной компанией, на 89.1% – с 2 710 022 до 5 124 706 тыс. рублей. Таким образом, формирование составного реального опциона именно в представленном порядке позволяет избежать необоснованных управленческих решений о выходе из нынешней кластерной стратегии, которая включала бы множество тактических возможностей, уже реализованных для кластерного развития. То есть сначала к оценке текущей стратегии добавляется пут-опцион. Это опцион сокращения и выхода из кластерной стратегии. И затем, если текущая стратегия продолжится, к ней добавляются следующие три колл-опциона.

Ключевые слова: инновационно-индустриальный кластер, составной реальный опцион, опцион отказа, опцион роста, опцион на переключение, опцион на отсрочку проекта

Цитирование: Кошелев, Е., Димопулос, Т., Маццучелли, Э.С., 2021. Разработка инновационной стратегии индустриального кластера методом составных реальных опционов. Sustainable Development and Engineering Economics 2, 5.
https://doi.org/10.48554/SDEE.2021.2.5

Introduction

In the context of import substitution policy within a country, the development of large innovation systems within that country becomes integral. The development of a strategy for the value-oriented evolution of a region's innovation systems should be based on analysis of the prospects and socio-economic values of the region's existing innovation and industrial clusters. To do this effectively, it is necessary to bring the indicated values of the clusters into alignment with the value system of the region. For this purpose, in the present study, the clusters in the Nizhny Novgorod Region of Russia that were seen to have the production, financial, labour, and other resources necessary for successful development were thoroughly analysed (Yashin et al., 2019).

Today, clustering is one of the most effective ways for countries to overcome systemic economic challenges and crises. To address this, Polyanin et al. (2020) have created a methodology for assessing the economic security of an individual cluster; this methodology is characterised by an integrated approach that considers all possible risks and threats to the functioning of the individual components of a particular cluster structure.

Kudryavtseva et al. (2020) have developed a methodology for assessing and monitoring cluster structures. Their method makes it possible to assess the following: the level of cluster structure development, achieved through analysis of cluster transformations, in the information and communication sectors of a regional economy; the prerequisites for the formation of a cluster in the region; and the current level of digital cluster development in the region. To assess the prerequisites for the development of a digital economy cluster, an integral indicator is calculated, and a multi-parameter approach is used to assess the effectiveness of the cluster. The proposed methodology allows researchers to compare clusters in different regions and monitor their development.

Moeis et al. (2020) studied the dynamics and stability of the Indonesia Jakarta Port Tanjung Priok port cluster. They used system dynamics to study the issue, and the stability of the port cluster was assessed by simulating the system dynamics over a 20-year time period. The authors also studied the impact of an alternative port cluster development program (namely, free trade policy) and a coastal energy system (CES) program policy on the sustainability of the port cluster. The model indicated that when free trade policies and SFM programs were combined to maximise economic benefit and reduce environmental damage, they provided additional benefits to increase economic activities while managing emission levels.

In the field, considerable attention has been paid to issues of the digitalisation of industrial enterprises and clusters during the development of Industry 4.0. Tashenova et al. (2020) developed a method for assessing the digital potential of the main innovative industrial clusters in a region. The method is based on existing approaches for assessing the innovative potential of industrial clusters and the digital potential of industrial enterprises. Furthermore, the method enables the calculation of the final integral assessment, which includes the calculation of the seven parameters' sub-potentials (Material and technical, Financial and economic, Scientific, Organizational and managerial, Staff, Information and telecommunication, Infrastructure) that experts have identified as important. The suggested method was successfully tested on the example cluster "Development of information technologies, radio electronics, instrumentation, communication and info-telecommunication devices of St. Petersburg".

Clearly, strategic decisions regarding industrial clusters should be based on the systematic analysis carried out by the appropriate managers in order to obtain sustainable competitive advantages. In keeping with this, Bogdanova and Karlik (2020) considered the following aspects: sectoral and regional conditions within the strategic activities and interests of organisations, the prevailing forms and types of strategic interactions, the level of innovation potential of the industry and the region, as well as specific influencing factors at the macro and micro levels. However, it is not only the socio-economic significance (efficiency and rationality) of the decision that is crucial, but also the rate and timeliness of its implementation, predetermined by the dynamics of industry factors.

Despite the existence of numerous standard models of strategic cluster management, including Leontiev's model (Tukkel et al., 2011), none of the following have been thoroughly studied: a matrix approach to cluster management (Bergman et al., 1999), gravity models (Bogomolov et al., 2011), a model of an export-oriented regional cluster (Gnevko et al., 2006), a cluster construction model based on fractal theory (Fedorenko et al., 2010), and the processes of cluster development. The relevant models should adequately describe organisational problems and market mechanisms for their implementation, using the appropriate mathematical tools.

The identification of pilot clusters that are most important to the population of a particular region, based on the traditions and production areas, is a challenging task for the executive authorities of that region. To do so, it is necessary to use technologies that allow for the making of flexible management decisions towards developing an innovative strategy for pilot clusters as determined by the state. Given the wide range of both opportunities for and threats to such economic formations, compound real options have become a relevant technology.

Literature review

The compound real option method is closely linked to the implementation of innovative solutions, both in enterprises and in larger economic structures, including innovative industrial clusters. First, it is necessary to study this technology regarding manufacturing companies since initially real options were used for manufacturing companies (Rodionov, 2021; Zaytsev, 2020). In manufacturing, the compound real option method includes early investment – for example, research and development (R&D), the lease of undeveloped option land or oil reserves, strategic acquisitions or strategically related projects (complex investment is a prerequisite in the option chain) – and opportunities for future growth — for example, generating new products or processes, oil reserves, access to new markets, strengthening of core potential, and investments in strategic positioning (Smit et al., 2004).

Many project initiatives (R&D, capacity expansion, launch of new services, etc.) are multistage investments, within which management can decide to expand or close the project, maintain the status quo of the project, or abandon the project after receiving new information in order to eliminate uncertainty as shown by Kodukula and Papudesu (2006).

In the analysis of compound options, the value of one option depends on the value of another. For example, a pharmaceutical company may undertake a Food and Drug Administration FDA drug-approval process, in which the drug must be tested in human trials. The FDA approval is highly dependent on the success of the human trials, which are concurrently conducted as shown by Mun (2002).

In this case, the aggregate value of the interacting options may differ from the sum of the individual parts due to their interaction (Rogers, 2002).

Loncar et al. (2017) studied a multi-phase compound (nested) path-dependent real option, consisting of mutually exclusive options – a sequential investment option, as well expansion, retracement, reduction, and abandonment options – as a complex interaction of separate parts.

Baranov and Muzyko (2015) concluded that the cost of a compound real option increases the total cost of an innovative project due to the step-by-step investment factor and the possibility ofterminating financing.

The compound real option method can solve a variety of economic problems. For example, Yang and Lee (2011) presented a real option pricing model using an eight-fold compound option in the evaluation of defense R&D projects. They illustrated these ideas using a case study in the Republic of Korea.

Claire and Guiz (2019) evaluated different types of compound options and eventually applied their assessment to real options, evaluating a biotech firm's consistent investment in R&D. Scientists have found that a compound option with multiple exercise periods may necessitate the payment of transaction costs each time it is exercised. The total transaction costs cannot be negligible, and the appraised value of the option can be higher than the actual value of the option.

Hauschild and Reimsbach (2015) proposed a binomial approach to modelling sequential investment in R&D. More specifically, they presented a comprehensive approach to real options that simplified the existing valuation methodology. The authors demonstrated the applicability of their approach in a real-life example of evaluating new drug use.

Tavakkolnia (2016) developed a practical method for evaluating multi-stage strategic investment projects. In their case study, specific volatility is assigned to each stage of the project and is estimated using data from previous similar projects, as well as expert knowledge. These fuzzy volatilities are then incorporated into a multi-stage binomial tree estimation model. In the end, the presented model is implemented in the example of an R&D project. The advantage of this model is that it can be easily extended by building a variety of options into such multi-stage projects.

Wang, Hee, and Lee (2014) applied fuzzy set theory to model volatile inputs (interest rate and volatility). The authors outlined the fuzzy pricing of a compound option in terms of the fuzzy share and the volatility in the compound option pricing formula. Finally, they presented a numerical analysis to illustrate the pricing of a complex option in a fuzzy environment.

Liu, Yang, and Hsu (2018) obtained compound options in a double exponential jump diffusion model that was more generalised than earlier models.

Konstandatos (2015) assessed a multi-stage mining solution, in which mining operators had the option to postpone the start of a project, as well as the option to abandon mining or expand production to a new rock bed if conditions change.

Cassimon et al. (2011) derived an expanded model from their case study of the real option valuation of a multi-stage software application by a major mobile operator. They also showed the ways that project managers can estimate volatility by phase.

Although the components of a compound real option can vary, we outline the most common components below as shown by Smit and Trigeorgis (2004), Chance et al. (2002) and Brach (2003).

Abandonment option (option to exit the project). During the life of a project, the company can choose to terminate the project and stop financing it. This decision is referred to as the default option. Some default options include the opportunity to retain liquidating value from the project, which is commonly referred to as the abandonment option as shown by Chance et al. (2002).

Growth option (option to develop and replicate the project). The growth option, sometimes called an extension option, is one of the most common option types. When a company has this option, it has the opportunity to invest additional funds during the life of the project and expand the scale of the project (Chance et al., 2002).

Switch option. If prices or demands change, the management of the firm can plan to employ the switch option (for example, in the commodity composition of an object – 'product flexibility'). Alternatively, materials and goods can be produced using different manufacturing processes ('process flexibility') (Smit and Trigeorgis, 2004). Furthermore, the switch option often refers to technology.

 Sustain. Dev. Eng. Econ. **2021**, 2, 5. https://doi.org/10.48554/SDEE.2021.2.5

For example, one technology may be more cost effective or in high-demand regions, and another could be more cost effective in low-demand regions as shown by Brach (2003).

Option to temporarily end the production process (option to temporarily cease the progress of a project). If operations are less profitable than expected, production be temporarily halted and may then start again as shown by Smit and Trigeorgis (2004).

Option to defer the project. Many projects do not require urgent initiation by a company. While many projects may imply that a company will grow rapidly, significant value can also be gained while waiting for uncertainty to be resolved. Although this strategy can offer competitors an edge, it can reveal sensitive information about the nature of the market (Chance et al., 2002).

Dimopoulos and Proptopapas (2019) indicated that that the 'locational' characteristics' were the most significant variables affecting the price of industrial land, followed by 'physical and legal' characteristics and last by the wider 'economic conditions'.

With regard to the development of an innovative industrial cluster, we employ a compound option with components similar to those listed above as shown later in the article. The use of such components allows us to obtain sufficient flexibility in managing the cluster development strategy.

Materials and methods

The proposed method assumes the use of compound real options, which necessitates that the following components are applied in order:

1. Option to reduce and/or abandon the cluster strategy.
2. Option to develop and replicate the experience in the cluster.
3. Option to switch and/or temporarily stop the cluster strategy.
4. Option to defer the start of the implementation of the new cluster strategy.

Combining compound real options in this order allows one to avoid unreasonable managerial decisions to exit the current cluster strategy, which would include multiple tactical opportunities for cluster development that has already been implemented. This would increase the cost of the cluster strategy, that is, the effect of its implementation by the main company. First, a put option is added to the evaluation of the current strategy. This is an option to reduce and exit the cluster strategy. If the current strategy continues, the following three call options are added to it.

Our assessment of the development strategy of an innovative industrial cluster via the compound real option method was carried out according to the following algorithm:

1. Calculation of the expected value of future cash flows from the current cluster strategy at the time of assessment:

$$\mathrm{E}[S_0] = \frac{S_{1,\mathrm{opt}} \cdot p_{\mathrm{opt}} + S_{1,\mathrm{pes}} \cdot p_{\mathrm{pes}}}{1 + \mathrm{WACC}}, \tag{1}$$

where $S_{1,\mathrm{opt}}$ and $S_{1,\mathrm{pes}}$ are optimistic and pessimistic values of future cash receipts, reduced to their start value (rubles); p_{opt} and p_{pes} are the probabilities of optimistic and pessimistic scenarios; and WACC is the weighted average cost of the capital of the core company (%) as shown by Limitovsky (2019).

2. Calculation of the net present value $\mathrm{NPV}_{\mathrm{old}}$ of the basic variant of the cluster strategy – i.e., without options or with existing options:

$$\mathrm{NPV}_{\mathrm{old}} = \mathrm{E}[S_0] - K, \tag{2}$$

where K is the investment in the implementation of the strategy – i.e., the total discounted value of the shares of the company or the core of the cluster (rubles).

3. Calculation of the expected value of future cash flows from the cluster strategy for a new option on a strategy without options or a strategy with existing options.

4. Calculation of NPV_{new} – a new version of the cluster strategy.

5. Calculation of the premium for a call option (ΔC_0) or put option (ΔP_0):

$$\Delta C_0 = \mathrm{NPV}_{new} - \mathrm{NPV}_{old} \text{ или } \Delta P_0 = \mathrm{NPV}_{new} - \mathrm{NPV}_{old} . \quad (3)$$

This algorithm is repeated several times until all the possibilities of the cluster development strategy with the corresponding real options have been considered. Evaluating the components of a compound real option in terms of a cluster strategy requires a special approach. This also applies to the option to reduce and exit a strategy and to the option to defer the start of a strategy as shown by Yashin et al. (2017). Next, we consider these ideas in more detail.

Option to reduce and abandon the cluster strategy. In the pessimistic scenario of the cluster development, the value $S_{1,pes}$ under the condition of constant probability p_{pes} is calculated by the formula that was obtained in (Yashin et al., 2017) based on the formula of Limitovsky (2019):

$$\mathrm{APV} = \mathrm{PV} + P = \sum_{t=0}^{n-1} \mathrm{CF}_t \left(\frac{1 - p_{\mathrm{pes}}}{1 + \mathrm{WACC}} \right)^t + \frac{\mathrm{CF}_n}{(1 + \mathrm{WACC})^t} + \sum_{t=0}^{n-1} L_t p_{\mathrm{pes}} \left(\frac{1 - p_{\mathrm{pes}}}{1 + r_f} \right)^t , \quad (4)$$

where APV is the adjusted present value of the future cash flows of the cluster strategy in the pessimistic scenario, taking into account the possibility of exiting the strategy (rubles); PV is the present value of future cash flows of the cluster strategy in the pessimistic scenario (rubles); P is the cost of the put option to exit the cluster strategy (rubles); CF_t is cash flow of the strategy in the pessimistic scenario in years t (rubles); n is the planning horizon (number of years); L_t is the liquidation value in years t – i.e., the forecasted total discounted value of the shares of the core company (rubles); r_f – is the rate of risk-free profitability (%).

Option to postpone the start of the implementation of a new cluster strategy. This is when the core company can switch to a new technology. The cost of the ‘live,’ or not realised, call option in years t can be calculated using the following formula (Kruschwitz, 1999; Schafer et al., 1998):

$$C_t^N = \frac{1}{1 + r_f} \left(pC_{t+1,u} + (1 - p)C_{t+1,d} \right), \quad (5)$$

where pseudo-probability p is calculated as

$$p = \frac{r_f - r_d}{r_u - r_d}; \quad (6)$$

r_u is the annual growth rate of the cash flow of the new technology in the optimistic scenario (%); r_d is the annual growth rate of the cash flow of the old technology in the pessimistic scenario (%); $C_{t+1,u}$ is the cost of the option in case of its growth in the next year $t + 1$ (rubles); $C_{t+1,d}$ is the cost of the option in case of its decrease in the next year $t + 1$ (rubles).

The cost of the ‘dead,’ or realised, call option in years t can be calculated as

$$C_t^A = \max \{ S_t - K_t, 0 \}, \quad (7)$$

where S_t is the cash flow of the new or old technology in years t (rubles); K_t is the cost of exercising the option – i.e., management services of the core company in years t (rubles). Since the value K_t is projected for years t, based on the IFRS data in the year preceding year 0, this call option is Asian (average) – that is, an option with a variable strike price.

Results

The development of a pilot electric power cluster in the Nizhny Novgorod region is considered here as an example of the implementation of the considered method. Through our study (Yashin et al., 2019), we was found that it was profitable for the Nizhny Novgorod innovation–industrial cluster to develop the Electric power branch. The Nizhny Novgorod region has the necessary innovation potential – production, financial, labour, and other resources – for the successful evolution of the cluster.

This pilot cluster is represented by the cluster's core company – TNS energo NN PJSC. Cash flow (CF) of this company is presented in Table 1. At the time of valuation in 2019, the weighted average cost of its capital was WACC = 12.56%, the total discounted value of shares were K = 2233864, thousand rubles, and the risk-free rate of return[1] was r_f = 4.21%.

Using the Internet service *Wolfram Alpha* (approximated the dependence of the company's cash flows on time as follows (Fig. 1):

logarithm: 172 714 ln$x$ + 197 637, R^2 = 0.00222704;

parabola: 43 558.1x^2 – 274 774x + 635 915, R^2 = 0.0082628;

polynomial of the third degree: 274 73.4x^3 – 286 123x^2 + 851 635x – 353 127, R^2 = 0.0125885.

The dependences represented by the parabola and the logarithm were the most economically adequate. Therefore, we accepted them as equally probable optimistic and pessimistic scenarios. It was then possible to predict cash flows for the next five years for the two selected dependencies (Table 2).

Table 1. Annual cash flow of TNS energy NN PJSC (thousand Rubles)

	2013	2014	2015	2016	2017	2018	2019
CF	498 625	– 441 563	567 721	2 931 398	– 4 313 838	3 282 929	330 600

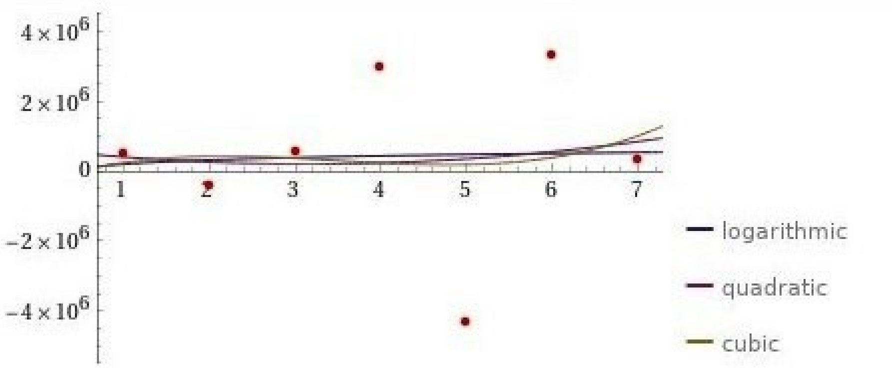

Figure 1. Forecast cash flow functions of TNS Energy NN PJSC

Table 2. Cash flow forecast for two equally probable scenarios of TNS energy NN PJSC (thousand Rubles)

Scenario	2020	2021	2022	2023	2024
Optimistic (parabola)	1 225 461	1 691 155	2 243 985	2 883 931	3 610 993
Pessimistic (logarithm)	556 786	577 128	595 326	611 787	626 815

[1] https://old.conomy.ru

Table 3. Liquidation value of TNS energy NN PJSC in the pessimistic scenario (thousand rubles)

	2020	2021	2022	2023	2024
L_t	2 514 437	2 830 251	3 185 730	3 585 858	–

Next, we estimated the profitability of the basic variant of the strategy of the pilot cluster – i.e., without options. Discounted forecasted cash flows for 2020 at the rate WACC = 12.56% amounted to:

- $S_{1,opt}$ = 8 770 806 thousand rubles, in the optimistic scenario;
- $S_{1,pes}$ = 2 358 870 thousand rubles, in the pessimistic scenario.

Then, using formulas (1) and (2), we concluded that

$$\mathrm{E}[S_0] = \frac{8\,770\ 806 \cdot 0.5 + 2\,358\ 870 \cdot 0.5}{1.1256} = 4\ 943\ 886 \text{ (thousand rubles)},$$

$$\text{NPV} = 4\ 943\ 886 - 2\ 233\ 864 = 2\ 710\ 022 \text{ (thousand rubles)},$$

which meant that the strategy was profitable. However, it did not account for the possibilities of the further development of the cluster. To do that, the analysis must be supplemented with the corresponding components of the compound real option as shown in paragraph 3.

1. *Option to reduce and abandon the cluster strategy.* In the case of the pessimistic scenario, the liquidation value in years t – that is, the predicted total discounted value of the shares of the cluster's core company (L_t) – can be calculated by increasing each year the total discounted value of shares K = 2 233 864, thousand rubles, at the rate WACC = 12.56% . At the same time, the last year of 2024 was not taken into account, since the core company has no plan to abandon the current cluster strategy as shown by Yashin et al. (2017). The calculation results for L_t are presented in Table 3.

Then, the method of a pilot cluster with a put option for a possible exit from the strategy was evaluated using formulas (4), (1) and (2) as shown in paragraph 3:

$$\text{APV} = 556\ 786 + 577\ 128 \cdot \frac{1-0.5}{1.1256} + 595\ 326 \cdot \left(\frac{1-0.5}{1.1256}\right)^2 + 611\ 787 \cdot \left(\frac{1-0.5}{1.1256}\right)^3 + \frac{626\ 815}{1{,}1256^4} +$$

$$+2\ 514\ 437 + 2\,830\ 251 \cdot \frac{1-0{,}5}{1.0421} + 3\,185\ 730 \cdot \left(\frac{1-0{,}5}{1.0421}\right)^2 + 3\,585\ 858 \cdot \left(\frac{1-0.5}{1.0421}\right)^3 =$$

$$= 1\ 374\ 728 + 5\ 001\ 847 = 6\ 376\ 575 \text{ (thousand rubles)},$$

$$\mathrm{E}[S_0] = \frac{8\,770\ 806 \cdot 0.5 + 6\,376\ 575 \cdot 0.5}{1.1256} = 6\ 728\ 581 \text{ (thousand rubles)},$$

$$\text{NPV} = 6\ 728\ 582 - 2\ 233\ 864 = 4\ 494\ 717 \text{ (thousand rubles)}.$$

Hence, due to the put option to exit the strategy, it became even more profitable. The premium for this option, according to formula (3), would amount to

$$\Delta P_0 = 4\ 494\ 717 - 2\ 710\ 022 = 1\ 784\ 695 \text{ (thousand rubles)}.$$

2. *Option to develop and replicate experience in the cluster.* Short-term investments in 2020 were shown to amount to 551,486 thousand rubles, and in the optimistic scenario they would increase

the CF by 13.5% by reducing losses through chain companies.[2] Then, the option to develop experience in the cluster allowed us to obtain even more value for the cluster strategy:

$$S_{1,opt} = 1\ 225\ 461 + (8\ 770\ 806 - 1\ 225\ 461)1{,}135 - 551\ 486 = 9\ 237\ 942 \text{ (thousand rubles)},$$

$$E[S_0] = \frac{9\ 237\ 942 \cdot 0.5 + 6\ 376\ 575 \cdot 0.5}{1.1256} = 6\ 936\ 086 \text{ (thousand rubles)},$$

$$NPV = 6\ 936\ 086 - 2\ 233\ 864 = 4\ 702\ 222 \text{ (thousand rubles)},$$

where the premium for a given call option according to formula (3) will amount to

$$\Delta C^0 = 4\ 702\ 222 - 4\ 494\ 717 = 207\ 505 \text{ (thousand rubles)}.$$

3. *Option to switch and temporarily stop the cluster strategy.* In the case of the pessimistic scenario for TNS energo NN PJSC, it was assumed that TNS energo NN PJSC would switch to the new technology of TNS energo Rostov-on-Don PJSC. CF per year for TNS energo Rostov-on-Don PJSC is presented in Table 4.[2]

At the time of valuation in 2019, the weighted average capital cost of TNS energo Rostov-on-Don PJSC was WACC = 12.62%. The increase in the total present value of shares at the time of the possible decision to switch to a new technology in 2020, according to data[2], amounted to

$\Delta K = K_{Rostov} - K_{NN} = 6\ 708\ 617 - 2\ 540\ 079 = 4\ 168\ 538$ (thousand rubles).

Using the Internet service *Wolfram Alpha*, we approximated the dependence of the cash flows of TNS energo Rostov-on-Don PJSC on time (Fig. 2):

logarithm: $720\ 254 \ln x - 486\ 173$, $R^2 = 0.318403$;

parabola: $-39\ 214{,}6x^2 + 525\ 189x - 925\ 454$, $R^2 = 0.301307$;

polynomial of the third degree: $12\ 033.9x^3 - 183\ 621x^2 + 1\ 018\ 580x - 1\ 358\ 670$, $R^2 = 0{,}330813$.

Table 4. Annual cash flow of TNS Energo Rostov-on-Don PJSC (thousand rubles)

	2013	2014	2015	2016	2017	2018	2019
CF	– 803 122	1 029 575	– 808 148	1 193 714	254 101	1 104 088	766 859

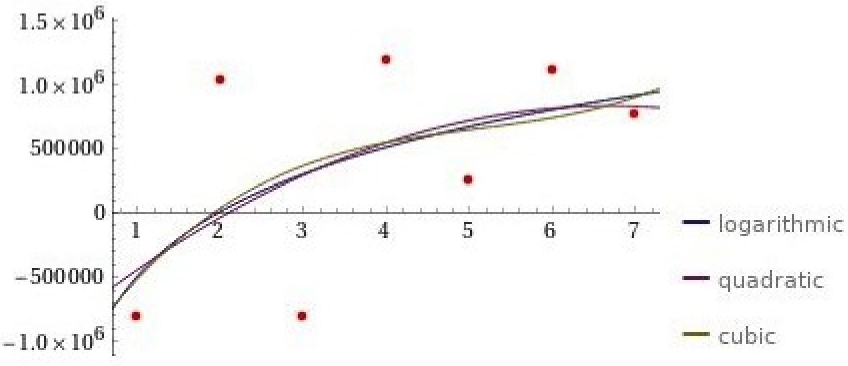

Figure 2. Forecast cash flow functions of TNS Energo Rostov-on-Don PJSC

Table 5. Cash flow forecast for optimistic scenario of TNS energo Rostov-on-Don PJSC (thousand rubles)

Scenario	2020	2021	2022	2023	2024
Optimistic (polynomial of the third degree)	1 199 583	1 707 962	2 498 930	3 644 690	5 217 445

[2] https://old.conomy.ru

The most optimistic scenario is the dependence of the company's cash flow on time, expressed by a polynomial of the third degree. This can be used to predict optimistic cash flows for the next five years (Table 5).

In the optimistic scenario, the predicted CF of TNS energo Rostov-on-Don PJSC, discounted for 2020 at the rate of WACC = 12.62%, amounted to $S_{1,opt}$ = 10 481 385 (thousand rubles). Then for TNS energo NN PJSC,

$$C_{1,pes} = 556\ 786 + 10\ 481\ 385 - 4\ 168\ 538 = 6\ 869\ 633 \text{ (thousand rubles).}$$

As a result, using formulas (1) and (2) for TNS energo NN PJSC, we obtained the following:

$$\mathrm{E}[S_0] = \frac{9\ 237\ 942 \cdot 0.5 + 6\ 869\ 633 \cdot 0.5}{1.1256} = 7\ 155\ 106 \text{ (thousand rubles),}$$

$$\mathrm{NPV} = 7\ 155\ 106 - 2\ 233\ 864 = 4\ 921\ 242 \text{ (thousand rubles).}$$

Thus, due to the call option to switch to a new technology, the cluster strategy became even more profitable. The premium for this option according to formula (3) would be as follows:

$$\Delta C_0 = 4\ 921\ 242 - 4\ 702\ 222 = 219\ 020 \text{ (thousand rubles).}$$

4. *Option to postpone the start of the implementation of the new cluster strategy.* It was shown that it would be possible for PJSC TNS energo NN to switch to the new technology of PJSC TNS energo Rostov-on-Don throughout the entire planning horizon, until 2024. In this regard, it was necessary to determine the optimal moment for the transition to a new technology. To do this, the prices of 'live' and 'dead' options should be compared in each node of the binomial tree for a deferral option.

In Figure 3, forecasted CF of old and new technologies are brought together, taking into account that we choose the pessimistic scenario for TNS energo NN PJSC (upper branch in the figure), and the optimistic one for TNS energo Rostov-on-Don PJSC (lower branch). At the starting point $t = 0$, the average value for the two technologies was taken. The obtained values were averaged in the internal nodes of the binomial tree.

Then, based on the data in Tables 2 and 5, the annual rates r_u and r_d were calculated for the new and old technologies, which were then substituted in formula (6) for each forecast year to calculate the pseudo-probabilities p and $1 - p$ (Table 6).

The considered option is Asian (average), so calculating the strike price for each of the five forecast years is necessary. For TNS energo NN PJSC, management services in accordance with IFRS amounted to 373.265 thousand rubles in 2019. This served as the strike price of the option

Table 6. Calculation of pseudo-probabilities of two technologies

	2021	2022	2023	2024
r_u	0.423796	0.463106	0.4585	0.43152
r_d	0.036535	0.031532	0.02765	0.024564
p	0.01437	0.024487	0.033538	0.043091
$1 - p$	0.98563	0.975513	0.966462	0.956909

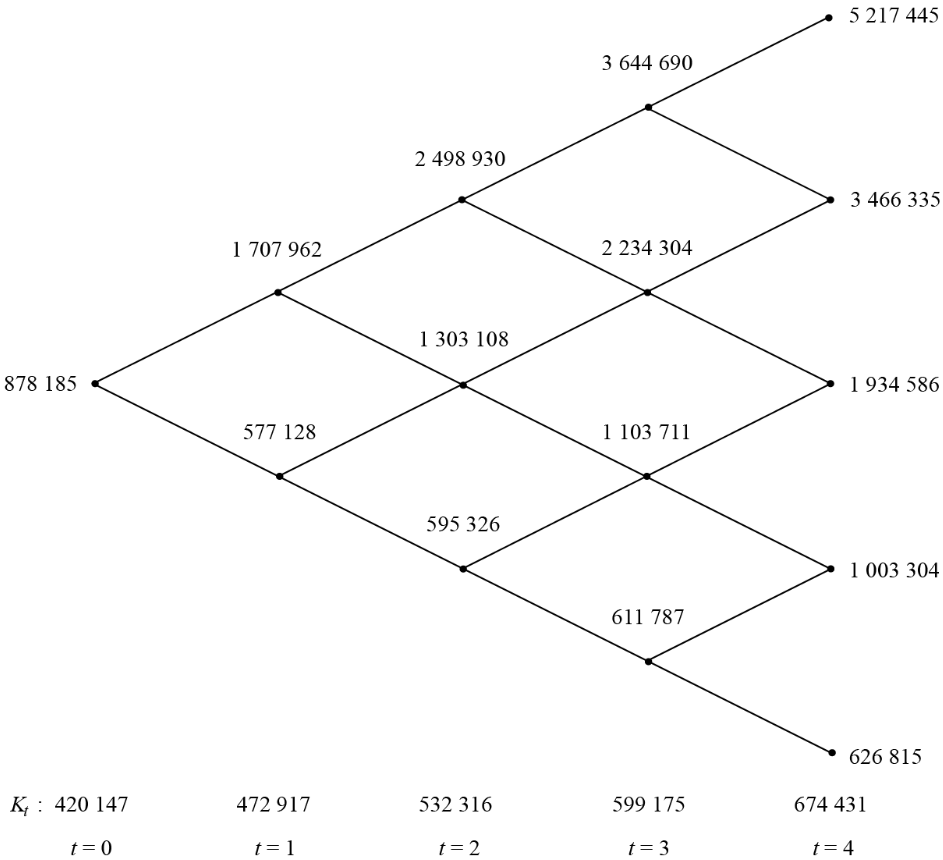

Figure 3. Change in cash flows of two technologies (thousand Rubles)

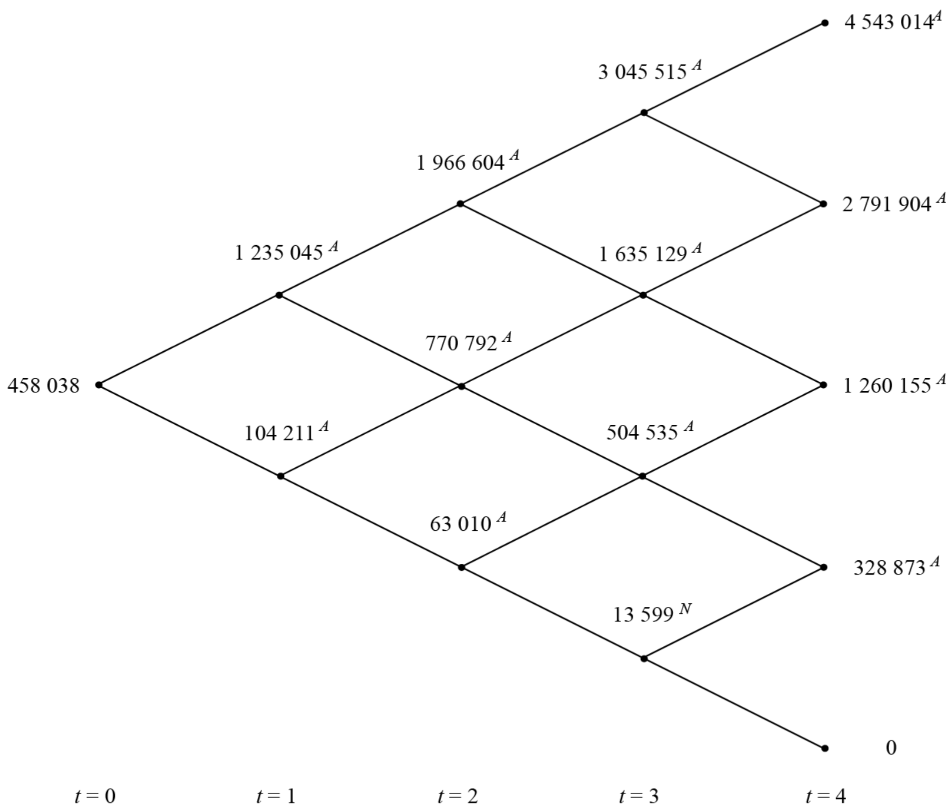

Figure 4. Change in the price of the real option for four years (thousand Rubles)

for the deferral in 2019. The increment rate of the strike price K_t was WAACC = 12.56% for TNS energo NN PJSC. Using this rate, we could calculate the strike prices of this option (Fig. 3).

After that, starting from the last year and gradually passing to the first forecast year, the prices of 'live' and 'dead' options were calculated in each node of the binomial option tree (Fig. 3) using formulas (5) and (7); the more expensive option was chosen as shown by Schafer et al. (1998). The results are shown in Figure 4.

As a result, Figure 4 shows that the 'dead' option was more expensive – e.g., for TNS energo NN PJSC, C_1 = 458 038 thousand rubles. Therefore, it was more profitable to execute the option immediately (i.e., in 2020).

Taking into account the deferral option, we found that the value of the pilot cluster strategy would become even higher:

$$C_{1,pes} = 6\ 869\ 633 + 458\ 038 = 7\ 32\ 7671 \text{ (thousand rubles)},$$

$$\mathrm{E}[S_0] = \frac{9\ 237\ 942 \cdot 0.5 + 7\ 327\ 671 \cdot 0.5}{1.1256} = 7\ 358\ 570 \text{ (thousand rubles)},$$

$$\text{NPV} = 7\ 358\ 570 - 2\ 233\ 864 = 5\ 124\ 706 \text{ (thousand rubles)}.$$

The premium for the analysed call option would amount to

$$\Delta C_0 = 5\ 124\ 706 - 4\ 921\ 242 = 203\ 464 \text{ (thousand rubles)}.$$

Discussion

The final conclusion regarding the strategy of the pilot cluster of the electric power industry was as follows: the use of the method of compound real options made it possible to increase the value of the strategy – that is, the effect of its implementation by the core company rose from NPV = 2710022 thousand rubles to 5 124 706 thousand rubles. This growth was achieved using the technology of compound real options to develop an innovative strategy for an industrial cluster, making this approach more effective compared to previous methods (Polyanin et al., 2020; Moeis et al., 2020; Tashenova et al., 2020; Bogdanova et al., 2020). Another advantage was the ability to make pre-calculated flexible management decisions in the process of implementing the planned innovative strategy of the industrial cluster.

Polyanin et al. (2020) developed the methodology for assessing the economic security of a cluster, which is characterised by an integrated approach that takes into account all possible risks and threats in the functioning of individual components of the cluster structure.

To assess the prerequisites for the development of a digital economy cluster, Kudryavtseva et al. (2020) calculated an integral indicator and used a multi-parametric approach to assess the effectiveness of the cluster. The proposed methodology allowed the researchers to compare clusters from different regions and monitor their development.

Moeis et al. (2020) studied the dynamics and stability of the Tanjung Priok port cluster. System dynamics were used to study the problem, and the stability of the port cluster was assessed by simulating the system dynamics over a 20-year time period.

Tashenova et al. (2020) developed a method for assessing the digital potential of backbone innovative industrial clusters. The method was based on existing approaches for assessing the innovative potential of industrial clusters and the digital potential of industrial enterprises. This method also allowed us to calculate the final integral assessment, which included the calculation of the parameters for each of the seven sub-potentials.

Bogdanova and Karlik (2020) considered sectoral and regional conditions within the framework of the strategic activities and interests of organisations, forms, and types of strategic interactions, considering the level of innovation potential of the industry and the region, as well as specific influencing factors at the macro and micro levels. However, not only the socio-economic significance (efficiency and rationality) of the decision itself is important, but also the rate and timeliness of its implementation, predetermined by the dynamics of industry factors (Kulagina, 2019).

The results obtained can be used for the development of innovative industrial clusters and the effective development of the regions with these clusters.

Conclusion

In conclusion, we formulated the following theoretical and practical statements.

1. To develop an innovation strategy for state-supported pilot clusters, it is necessary to apply the technologies that allow for flexible management decision making. Given the wide range of opportunities for and threats to such economic formations, compound real options could become a relevant technology as shown by Smit and Trigeorgis (2004), Chance (2002) and Brach (2003).

2. The method proposed in this paper involves compound real options, with components to be applied in order as follows: 1) the option to reduce and abandon the cluster strategy, 2) the option to develop and replicate the experience accumulated in the cluster, 3) the option to switch from the cluster strategy, and 4) the option to postpone the implementation of a new cluster strategy.

3. As an example of the implementation of the method presented, the authors considered the strategy for the development of a pilot electric power cluster in the Nizhny Novgorod region, presented by the core company TNS energo NN PJSC. The application of the method of compound real options made it possible to increase the value of the cluster strategy, which means that the effect of its implementation by the core company rose by 89.1% – from 2 710 022 to 5 124 706 thousand rubles.

Acknowledgements

The study was carried out with the financial support of the Russian Foundation for Basic Research within the framework of the Scientific Project No. 19-010-00932, ‘The development of the evolution model of the industrial regions’ innovative system in the modern conditions of socio-economic development.’

References

Baranov, A., Muzyko, E., 2015. Valuation of compound real options for investments in innovative projects in pharmaceutical industry. Procedia Economics and Finance 27, 116–125. https://doi.org/10.1016/S2212-5671(15)00980-6

Bergman, E.M., Feser, E.J., 1999. Industrial and regional clusters: Concepts and comparative applications. Regional Research Institute, West Virginia University, Morganton, WV, USA.

Bogdanova, T., Karlik, M., 2020. Problems of competitive strategy choice according to industry and regional factors. International Journal of Technology 11(8), 1478–1488. https://doi.org/10.14716/ijtech.v11i8.4531

Bogomolov, V.A., Surina, A.V., 2011. Ispol’zovaniye Modeli Dlya Otsenki Urovnya Rasprostraneniya Znaniy [Using the model to estimate the level of dissemination of knowledge]. Scientific and Technical Sheets, Informatics, Telecommunications, Management 2, 195–199.

Brach, M.A., 2003. Real options in practice. John Wiley & Sons, Hoboken, NJ, USA.
Cassimon, D., Engelen, P.-J., Yordanov, V., 2011. Compound real option valuation with phase-specific volatility: A multi-phase mobile payments case study. Technovation 31, 240–255.
Chance, D.M., Peterson, P.P., 2002. Real options and investment valuation. The Research Foundation of AIMR, Virginia, USA.
Claire, J., Guise, F., 2019 (July). Compound options: Numerical valuation methods and a real option application. B.Sc. Thesis in Applied Mathematics, Delft University of Technology, Delft, Netherlands.
Fedorenko, O.S., 2010. Aktivizatsiya Investitsionnoy Deyatel'nosti na Osnove Klasternogo Podkhoda [Activization of investment activity on the basis of cluster approach]. Management of Economic Systems 24(4). Available at: http://uecs.ru/innovacii-investicii/item/237-2011-03-24-12-20-16
Gnevko, V.A., Rokhchin, V.E., 2006. Voprosy Teorii I Praktiki Regional'nogo Strategicheskogo Upravleniya [Questions of the theory and practice of regional strategic government]. Spatial Economics 4, 101–114. https://doi.org/10.14530/se.2006.4.101-114
Hauschild, B., Reimsbach, D., 2015. Modeling sequential R&D investments: A binomial compound option approach. Business Research 8, 39–59. https://doi.org/10.1007/s40685-014-0017-5
Jang, W.-J., Lee, J.-D., 2011. The application of real options theory in defense R&D projects: An eight-fold sequential compound option model. International Journal of Innovation and Technology Management 08(01), 95–112. https://doi.org/10.1142/S0219877011002179
Kodukula, P., Papudesu, C., 2006. Project valuation using real options: A practitioner's guide. J. Ross Publishing, Inc., Fort Lauderdale, FL, USA.
Konstandatos, O., 2015. Third order compound option valuation of flexible commodity based mining enterprises. Archives of Business Research 3(1), 19–35. https://doi.org/10.14738/abr.31.801
Kruschwitz, L., 1999. Finanzierung und Investition. R. OldenbourgVerlag, Munchen, Wien.
Kudryavtseva, T., Kulagina, N., Lysenko, A., Berawi, M.A., Skhvediani, A., 2020. Developing methods to assess and monitor cluster structures: The case of digital clusters. International Journal of Technology 11(4), 667–676. https://doi.org/10.14716/ijtech.v11i4.4191
Limitovsky, M.A., 2019. Investment projects and real options in developing markets [Investitsionniye pro`ekty i Real`niye Optsiony na Razvivayushikhsya Rynkakh], 5th ed. Urait Publishing House, Moscow, Russian Federation.
Liu, Y., Jiang, I., Hsu, W., 2018. Compound option pricing under a double exponential jump-diffusion model. The North American Journal of Economics and Finance 43, 30–53. http://doi.org/10.1016/j.najef.2017.10.002
Loncar, D., Milovanovic, I., Rakic, B., Radjenovic, T., 2017. Compound real options valuation of renewable energy projects: The case of a wind farm in Serbia. Renewable and Sustainable Energy Reviews 75, 354–367. https://doi.org/10.1016/j.rser.2016.11.001
Moeis, A.O., Desriani, F., Destyanto, A.R., Zagloel, T.Y., Hidayatno, A., Sutrisno, A., 2020. Sustainability assessment of the Tanjung Priok port cluster. International Journal of Technology 11(2), 353–363. https://doi.org/10.14716/ijtech.v11i2.3894
Mun, J., 2002. Real options Analysis: Tools and techniques for valuing strategic investments and decisions. John Wiley & Sons, Hoboken, NJ, USA.
Polyanin, A., Pronyaeva, L., Pavlova, A., Fedotenkova, O., Rodionov, D., 2020. Integrated approach for assessing the economic security of a cluster. International Journal of Technology 11(6), 1148–1160. https://doi.org/10.14716/ijtech.v11i6.4420
Protopapas, P., & Dimopoulos, T., 2019. Factors affecting the price of industrial land in the district of Nicosia, Cyprus. In Seventh International Conference on Remote Sensing and Geoinformation of the Environment 11174, 1117419.
Rodionov, D., Zaytsev, A., Konnikov, E., Dmitriev, N., & Dubolazova, Y., 2021. Modeling changes in the enterprise information capital in the digital economy. Journal of Open Innovation: Technology, Market, and Complexity *7*(3), 166.
Rogers, J., 2002. Strategy, value and risk: The real options approach. Palgrave Macmillan, New York, NY, USA.
Schafer, D., Kruschwitz, L., Schwake, M., 1998. Studienbuch Finanzierung und Investition, R. OldenbourgVerlag, Munchen, Wien.
Smit, H.T.J., Trigeorgis, L., 2004. Strategic investment: Real options and games. Princeton University Press, Princeton, NJ, USA.
Tashenova, L., Babkin, A., Mamrayeva, D., Babkin, I., 2020. Method for evaluating the digital potential of a backbone innovative active industrial cluster. International Journal of Technology 11(8), 1499–1508. https://doi.org/10.14716/ijtech.v11i8.4537
Tavakkolnia, A., 2016. A binomial tree valuation approach for compound real options with fuzzy phase-specific volatility. In 12th International Conference on Industrial Engineering (ICIE). Tehran, Iran, 73–78. https://doi.org/10.1109/INDUSENG.2016.7519351

Tukkel', I.L., Surina, A.V., Kul'tin, N.B., 2011. Upravleniye InnovatsionnymI Proyectami [Management of innovative projects]. BHV–Petersburg, St. Petersburg, Russian Federation.

Wang, X., He, J., Li, S., 2014. Compound option pricing under fuzzy environment. Journal of Applied Mathematics. http://dx.doi.org/10.1155/2014/875319

Yashin, S.N., Koshelev, E.V., Kostrigin, R.V., 2019. Sostavleniye Lineynogo Funktsionala Tsennosti Innovatsionno-Industrial'nogo Klastera Dlya Regiona [Compilation of linear functional of the value of the innovation and industrial cluster for the region]. Management of Economic Systems: Scientific Electronic Journal 130(12). Available at: http://uecs.ru/innovacii-investicii/item/5774-2019-12-21-11-28-53

Yashin, S.N., Trifonov, Y.V., Koshelev, E.V., 2017. Metod Ispol'zovaniya Real'nogo Put-Optsiona v Upravlenii Riskami Innovatsionnoy Strategii Klastera [Method of using a real put-option in risk management of innovative strategy of a cluster]. Finance & Credit 23(26), 1518–1532. https://doi.org/10.24891/fc.23.26.1518

Zaytsev, A., Rodionov, D., Dmitriev, N., Ilchenko, S., 2020. Assessing intellectual capital from the perspective of its rental income performance. International Journal of Technology, 8, 1489–1498. https://doi.org/10.14716/ijtech.v11i8.4545

Список источников

Baranov, A., Muzyko, E., 2015. Valuation of compound real options for investments in innovative projects in pharmaceutical industry. Procedia Economics and Finance 27, 116–125. https://doi.org/10.1016/S2212-5671(15)00980-6

Bergman, E.M., Feser, E.J., 1999. Industrial and regional clusters: Concepts and comparative applications. Regional Research Institute, West Virginia University, Morganton, WV, USA.

Bogdanova, T., Karlik, M., 2020. Problems of competitive strategy choice according to industry and regional factors. International Journal of Technology 11(8), 1478–1488. https://doi.org/10.14716/ijtech.v11i8.4531

Brach, M.A., 2003. Real options in practice. John Wiley & Sons, Hoboken, NJ, USA.

Cassimon, D., Engelen, P.-J., Yordanov, V., 2011. Compound real option valuation with phase-specific volatility: A multiphase mobile payments case study. Technovation 31, 240–255.

Chance, D.M., Peterson, P.P., 2002. Real options and investment valuation. The Research Foundation of AIMR, Virginia, USA.

Claire, J., Guise, F., 2019 (July). Compound options: Numerical valuation methods and a real option application. B.Sc. Thesis in Applied Mathematics, Delft University of Technology, Delft, Netherlands.

Hauschild, B., Reimsbach, D., 2015. Modeling sequential R&D investments: A binomial compound option approach. Business Research 8, 39–59. https://doi.org/10.1007/s40685-014-0017-5

Jang, W.-J., Lee, J.-D., 2011. The application of real options theory in defense R&D projects: An eight-fold sequential compound option model. International Journal of Innovation and Technology Management 08(01), 95–112. https://doi.org/10.1142/S0219877011002179

Kodukula, P., Papudesu, C., 2006. Project valuation using real options: A practitioner's guide. J. Ross Publishing, Inc., Fort Lauderdale, FL, USA.

Konstandatos, O., 2015. Third order compound option valuation of flexible commodity based mining enterprises. Archives of Business Research 3(1), 19–35. https://doi.org/10.14738/abr.31.801

Kruschwitz, L., 1999. Finanzierung und Investition. R. OldenbourgVerlag, Munchen, Wien.

Kudryavtseva, T., Kulagina, N., Lysenko, A., Berawi, M.A., Skhvediani, A., 2020. Developing methods to assess and monitor cluster structures: The case of digital clusters. International Journal of Technology 11(4), 667–676. https://doi.org/10.14716/ijtech.v11i4.4191

Liu, Y., Jiang, I., Hsu, W., 2018. Compound option pricing under a double exponential jump-diffusion model. The North American Journal of Economics and Finance 43, 30–53. http://doi.org/10.1016/j.najef.2017.10.002

Loncar, D., Milovanovic, I., Rakic, B., Radjenovic, T., 2017. Compound real options valuation of renewable energy projects: The case of a wind farm in Serbia. Renewable and Sustainable Energy Reviews 75, 354–367. https://doi.org/10.1016/j.rser.2016.11.001

Moeis, A.O., Desriani, F., Destyanto, A.R., Zagloel, T.Y., Hidayatno, A., Sutrisno, A., 2020. Sustainability assessment of the Tanjung Priok port cluster. International Journal of Technology 11(2), 353–363. https://doi.org/10.14716/ijtech.v11i2.3894

Mun, J., 2002. Real options Analysis: Tools and techniques for valuing strategic investments and decisions. John Wiley & Sons, Hoboken, NJ, USA.

Polyanin, A., Pronyaeva, L., Pavlova, A., Fedotenkova, O., Rodionov, D., 2020. Integrated approach for assessing the economic security of a cluster. International Journal of Technology 11(6), 1148–1160. https://doi.org/10.14716/ijtech.v11i6.4420

Protopapas, P., & Dimopoulos, T., 2019. Factors affecting the price of industrial land in the district of Nicosia, Cyprus. In Seventh International Conference on Remote Sensing and Geoinformation of the Environment 11174, 1117419.

Rodionov, D., Zaytsev, A., Konnikov, E., Dmitriev, N., & Dubolazova, Y., 2021. Modeling changes in the enterprise information capital in the digital economy. Journal of Open Innovation: Technology, Market, and Complexity 7(3), 166.

Rogers, J., 2002. Strategy, value and risk: The real options approach. Palgrave Macmillan, New York, NY, USA.

Schafer, D., Kruschwitz, L., Schwake, M., 1998. Studienbuch Finanzierung und Investition, R. OldenbourgVerlag, Munchen, Wien.

Smit, H.T.J., Trigeorgis, L., 2004. Strategic investment: Real options and games. Princeton University Press, Princeton, NJ, USA.

Tashenova, L., Babkin, A., Mamrayeva, D., Babkin, I., 2020. Method for evaluating the digital potential of a backbone innovative active industrial cluster. International Journal of Technology 11(8), 1499–1508. https://doi.org/10.14716/ijtech.v11i8.4537

Tavakkolnia, A., 2016. A binomial tree valuation approach for compound real options with fuzzy phase-specific volatility. In *12th* International Conference on Industrial Engineering (ICIE). Tehran, Iran, 73–78. https://doi.org/10.1109/INDUSENG.2016.7519351

Wang, X., He, J., Li, S., 2014. Compound option pricing under fuzzy environment. Journal of Applied Mathematics. http://dx.doi.org/10.1155/2014/875319

Zaytsev, A., Rodionov, D., Dmitriev, N., Ilchenko, S., 2020. Assessing intellectual capital from the perspective of its rental income performance. International Journal of Technology, 8, 1489–1498. https://doi.org/10.14716/ijtech.v11i8.4545

Богомолов В. А., Сурина А. В., 2011. Использование модели для оценки уровня распространения знаний. Научно-технические ведомости Санкт-Петербургского государственного политехнического университета. Информатика, телекоммуникации и управление 2, 195–199.

Гневко, В. А., Рохчин, В. Е., 2006. Вопросы теории и практики регионального стратегического управления. Пространственная экономика 4, 101–114. https://doi.org/10.14530/se.2006.4.101-114

Лимитовский, М. А., 2018. Инвестиционные проекты и реальные опционы на развивающихся рынках. 5-е изд., пер. и доп. Издательство Юрайт, 486.

Туккель, И. Л., Сурина, А. В., Культин, Н. Б., 2011. Управление инновационными проектами. БХВ-Петербург, Санкт-Петербург, Россия.

Федоренко, О. С., 2010. Активизация инвестиционной деятельности на основе кластерного подхода. Управление экономическими системами: электронный научный журнал, 24 (4). Режим доступа: http://uecs.ru/innovacii-investicii/item/237-2011-03-24-12-20-16

Яшин, С. Н., Кошелев, Е. В., Костригин, Р. В., 2019. Составление линейного функционала ценности инновационно-индустриального кластера для региона. Управление экономическими системами: электронный научный журнал, 12, 90–90. Режим доступа: http://uecs.ru/innovacii-investicii/item/5774-2019-12-21-11-28-53

Яшин, С. Н., Трифонов, Ю. В., Кошелев, Е. В., 2017. Метод использования реального пут-опциона в управлении рисками инновационной стратегии кластера. Финансы и кредит, 23(26), 1518–1532. https://doi.org/10.24891/fc.23.26.1518

The article was submitted 16.05.2021, approved after reviewing 3.07.2021, accepted for publication 18.07.2021.

Статья поступила в редакцию 16.05.2021, одобрена после рецензирования 3.07.2021, принята к публикации 18.07.2021.

About the authors:
1. Egor Koshelev, Ph.D. in Economics, Associate Professor of the Department of Management and Public Administration, Nizhny Novgorod State University named after N.I. Lobachevsky, Nizhny Novgorod, Russian Federation, https://orcid.org/0000-0001-5290-7913, ekoshelev@yandex.ru
2. Thomas Dimopoulos, Ph.D. in Real Estate (AVMs and Mass Appraisals), Lecturer in Real Estate & Director of Real Estate Programs, Neapolis University Paphos, Cyprus, https://orcid.org/0000-0001-9553-4774, thomas.dimopoulos@gmail.com
3. Enrico Sergio Mazzucchelli, Associate Professor, Department of Architecture, Built environment and Construction engineering. Politecnico di Milano, Milano, Italy, https://orcid.org/0000-0001-7722-6700, enrico.mazzucchelli@polimi.it

Информация об авторах:
1. Егор Викторович Кошелев, кандидат экономических наук, Доцент кафедры менеджмента и государственного управления, Национальный исследовательский Нижегородский государственный университет имени Н. И. Лобачевского, Российская Федерация, https://orcid.org/0000-0001-5290-7913, ekoshelev@yandex.ru
2. Томас Димопулос, Преподаватель по недвижимости и Директор Программ по недвижимости, Неаполисский университет Пафоса, Кипр, https://orcid.org/0000-0001-9553-4774, thomas.dimopoulos@gmail.com
3. Энрико Серджио Маццучелли, доцент кафедры архитектуры, архитектурной среды и строительной инженерии, Миланский технический университет, Милан, Италия, https://orcid.org/0000-0001-7722-6700, enrico.mazzucchelli@polimi.it