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Innovation and sustainable development

One of the main aims of achieving the United Nations' Sustainable Development Goals is the transition of the world's economies to an innovative and socially oriented development model; therefore, innovation is becoming a key factor in economic and social development. Investments in the innovation sector are the driving force of long-term development and sustainable growth of the world's economies.

In the second issue of *Sustainable Development and Engineering Economics*, our authors examine how innovation and innovation activities affect the sustainable development of enterprises and regions.

The first section, *Economics of Engineering and Innovation Decisions as a Part of Sustainable Development*, presents the article 'Total return and total return for all shareholders: differences of sustainably developing companies in the S&P100', by P. Fernandez and E. de Apellaniz. In the course of their study, they investigate what indicators of sustainable development companies' shareholders should focus on for the most effective investment of dividends to increase their own profits.

The section *Enterprises and the Sustainable Development of Regions* features the article 'Innovation and resource potential on key performance indicators of water supply enterprises', by A. Furtatova, N. Viktorova and E. Konnikov. Using the example of SUE Vodokanal of St. Petersburg, the authors determine the value of innovation and resource potential, after which they build six regression models reflecting the impact of potential on the key performance indicators of a water supply company. The results of the study showed that the indicators of profit, revenue and costs depend directly on innovation and resource potential, and that losses and water consumption have an inverse relationship.

The authors O. Zaborovskaya, E. Zhogova and A. Alamshoev contribute to solving the problems of *Sustainable Development of Regional Infrastructure* with their article 'Ranking the regions of the Northwestern Federal District as a sustainable development policy tool'. They propose ranking regions according to an algorithm for calculating the indices of socio-economic development, to assess whether the territories are developing sustainably. The result of the study is a rating of the regions of one of the Russian districts according to its socio-economic development and the identification of the most favourable climate for achieving the sustainable development of territories. This information can be used to build a regional development strategy.

The second article in this section is 'Economic security and innovation component of the region: complex assessment', by A. Zaitsev, P. K. Sun, O. Elkina, T. Tarasov and N. Dmitriev. For a comprehensive assessment of regional economic security levels, taking into account their innovative components, the authors propose averaging the normalised values of all indicators using the simple average method. As a result of the study, the criteria boundaries of the integral indicator for the assessment of economic security levels were established, which made it possible to identify the level of a territory's development in the economic sphere. The authors propose using the developed methodology to solve a wide range of issues to ensure regional economic security.

In the final section, *Management of Knowledge and Innovation for Sustainable Development*, E. Koshelev, T. Dimopoulos, and E.S. Mazzucchelli's article 'Development of innovative industrial cluster strategy using compound real options' investigates the allocation of pilot clusters to determine which are the most beneficial to the population of a region, based on its traditions and historical direction of production. In view of the relevance of the holistic development of the country's large innovation systems, the allocation of pilot clusters within the regions will contribute to achieving their sustainable development.

Irina Rudskaia, Editor-in-Chief, Doctor of Economics, Professor

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SECTION 1

ECONOMICS OF ENGINEERING AND INNOVATION DECISIONS AS A PART OF SUSTAINABLE DEVELOPMENT

РАЗДЕЛ 1

ЭКОНОМИКА ИНЖЕНЕРНЫХ И ИННОВАЦИОННЫХ РЕШЕНИЙ КАК ЧАСТЬ УСТОЙЧИВОГО РАЗВИТИЯ

Research article

DOI: https://doi.org/10.48554/SDEE.2021.2.1

TOTAL RETURN AND TOTAL RETURN FOR ALL SHAREHOLDERS: DIFFERENCES OF SUSTAINABLY DEVELOPING COMPANIES IN THE S&P100

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Abstract

he purpose of the study is to discover which indicators should be directed to shareholders who can reinvest dividends to acquire additional shares, buy back shares and increase their capital. To solve this problem, a method of comparing indicators, such as Total Return (TR) and Total Return for All Shareholders (TRAS), is used. TR, also called 'return including dividends' and 'Total Index Return', provides the theoretical return of a share – assuming that dividends are reinvested to purchase additional shares. TRAS is the return that all the shareholders of a company have in a given period. It is also the return of a shareholder that always had a constant proportion (i.e. 0.1%) of the shares. It takes into account not only the dividends but also the share repurchases and the capital increases. We calculated both returns for the S&P100 companies during December 2004–April 2020. For 18 companies, annual TR exceeded annual TRAS in more than 1% (i.e. Blackrock 3.9%, Microsoft 2%). For 19 companies, annual TRAS exceeded annual TR in more than 1% (i.e. Citigroup 7.8%, Altria 5.4%). Most databases provide TR valid for a shareholder that reinvested 100% of the dividends, did not sell any share in repurchases and did not subscribe any new share when the company increased capital.

Keywords: total return, total return for all shareholders, dividend reinvestment, share repurchase, shareholder capital increase.

Citation: Fernandez, P., Apellaniz, E., 2021. Total return and total return for all shareholders: differences of sustainably developing companies in the S&P100. Sustainable Development and Engineering Economics 2, 1. https://doi.org/10.48554/SDEE.2021.2.1

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Научная статья

УДК 336.6

DOI: https://doi.org/10.48554/SDEE.2021.2.1

ОБЩАЯ ПРИБЫЛЬ И ОБЩАЯ ДОХОДНОСТЬ ДЛЯ ВСЕХ АКЦИОНЕРОВ: РАЗНИЦА ДЛЯ УСТОЙЧИВО РАЗВИВАЮЩИХСЯ КОМПАНИЙ В S&P100

Пабло Фернандез^{1*}, Эдуардо де Апелланиз¹

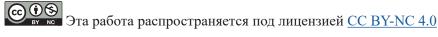
Аннотация

ель исследования заключается в попытке выяснить, на какие показатели следует ориентироваться акционерам, которые могут реинвестировать дивиденды для приобретения дополнительных акций, выкупать акции и увеличивать свой капитал. Для решения поставленной задачи применяется метод сравнения таких показателей, как общая прибыль (TR) и общая доходность для всех акционеров (TRAS). Общая прибыль (TR), также называемая «возврат с учетом дивидендов» и «полное возвращение индекса», обеспечивает теоретический возврат акций, предполагая, что дивиденды повторно инвестируются для приобретения дополнительных акций. Общая доходность для всех акционеров (TRAS) — это доходность, которую имели все акционеры компании за определенный период. Это также возвращение для акционера, который всегда имел постоянную долю (т. е. 0.1% акций). Он учитывает не только дивиденды, но и выкуп акций, и увеличение капитала. Мы рассчитываем обе доходности для компаний S&P100 в период с декабря 2004 года по апрель 2020 года. Для 18 компаний годовые TR превысили годовые TRAS более чем на 1% (т. е. Blackrock 3.9%, Microsoft 2%). Для 19 компаний годовая TRAS превысила годовую TR более чем на 1% (т. е. Citigroup 7.8%, Altria 5.4%). Большинство баз данных предоставляют общую прибыль (TR), действительную для акционера, который реинвестировал 100% дивидендов, не продавал какую-либо долю в выкупе и не подписывал какую-либо новую акцию, когда компания увеличивала капитал.

Ключевые слова: общая прибыль, общая доходность для всех акционеров, реинвестирование дивидендов, выкуп акций, увеличение капитала акционеров.

Цитирование: Фернандез, П., Апелланиз, Э., 2021. Общая прибыль и общая прибыль для всех акционеров: разница для устойчиво развивающихся компаний в S&P100. Sustainable Development and Engineering Economics 2, 1.

https://doi.org/10.48554/SDEE.2021.2.1



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1. Introduction

The share value is the present value of the expected equity cash flows, and the two main components of equity cash flows are dividends and share repurchases (Fernandez, 2013).

The all-shareholder return is the return that all the shareholders of a company had in a given period and is equal to the hypothetical return of a unique shareholder of the company. It is also the return of a shareholder that always had a constant proportion (i.e. 0.2%) of the shares. The all-period shareholder return is the return that a shareholder who maintained the shares for the whole period had. There are many all-period shareholder returns depending on the actions of the shareholder during the period, such as fraction of dividends reinvested, fraction of shares sold when the company repurchased them and number of shares subscribed when the company increased capital. Most databases provide a special all-period shareholder return valid for a shareholder that reinvested 100% of the dividends, did not sell any shares in repurchases and did not subscribe any new share when the company increased capital. In many situations, there are substantial differences among these returns (Fernandez, 2012).

Since 1997, the total amount of buybacks has exceeded the cash dividends paid by U.S. firms (Fernandez, 2013). The proportion of dividend-paying companies decreased to 43% in 2018 from 78% in 1980, while the proportion of companies with share buybacks increased to 53% from 28% during the same period. The increased use of share repurchases is mainly driven by some key advantages of this method, including tax benefits and financial flexibility.

The purpose of the study is to ascertain which indicators should be directed to shareholders who can reinvest dividends to acquire additional shares, buy back shares and increase their capital. To solve this problem, a method of comparing indicators, such as Total Return (TR) and Total Return for All Shareholders (TRAS), is used. This approach allows shareholders to assess their real returns on shares more accurately.

The classical total return index is adjusted according to the amount of dividends paid in by index constituent companies. Total shareholder return (TSR) is a measure of financial performance, indicating the total amount an investor reaps from an investment – specifically, equities or shares of stock. Whichever way it is calculated, TSR means the same thing: the sum total of what a stock has returned to those who have invested in it.

When we analyse companies, TRAS provides the most comprehensive average of individual returns. It could also be the return with a unique shareholder as well as the return of a shareholder that always holds a constant percentage of the outstanding shares.

If we think of 'TRAS' as providing an average return for all shareholders, then 'TR' calculates an Internal Rate of Return (IRR) for a subset of shareholders. We aim to determine if there is a way to calculate an IRR for other shareholders and assume that if TR > TRAS, then the returns for these 'other' shareholders are < TRAS return.

2. Literature review

Repurchasing firms experience a significant reduction in the systematic risk and cost of capital relative to non-repurchasing firms. Further, consistent with the free cash flow hypothesis, Grullon and Michaely (2004) found that the market reaction to share-repurchase announcements is more positive among firms that are likelier to overinvest.

Ikenberry, Lakonishok and Vermaelen (Ikenberry et al., 1995) examined long-run firm performance following open market share-repurchase announcements, 1980–1990. For repurchases announced by 'glamour' stocks, where undervaluation is less likely to be an important motive, no positive drift in abnormal returns is observed. Thus, at least with respect to value stocks, the market errs in its initial response and appears to ignore much of the information conveyed through repurchases announcements.

Forecasters often exaggerate the reliability of their forecasts and trace this exaggeration to the illusion of validity. Fisher and Statman (2020) discussed five cognitive biases that underlie the illusion of validity: overconfidence, confirmation, representativeness, anchoring and hindsight. Fisher and Statman used forecasts based on P/E ratios and dividend yields to illustrate biases and offer remedies.

A simplified stock valuation model based on the general principle that the price of a common stock equals the present value of its future dividends, the H-model is more practical than the general dividend discount model, yet more realistic than the constant growth rate model. The H-model assumes that a firm's growth rate decreases (or increases) in a linear fashion from an above-normal (or below-normal) rate to a normal, long-term rate. Given estimates of these two growth rates, the length of the period of above-normal growth, and the discount rate, an analyst may use the H-model to solve for current stock price (Fuller et al., 1984).

However, as stock repurchases and dividends serve the same basic economic function, the rapid growth of repurchases greatly contrasts this and is perplexing. Part of the explanation is that, because repurchases are taxed as capital gains and dividends as ordinary income, repurchases are a more tax-efficient way of distributing excess capital. Perhaps even more important than their tax treatment is the flexibility that (at least) open market repurchases provide corporate managers-flexibility to make small adjustments in capital structure to exploit (or correct) perceived undervaluation of the firm's shares and possibly even to increase the liquidity of the stock, which could be particularly valuable in bear markets (Grullon and Ikenberry, 2000).

Guay and Harford (2000) hypothesised that firms choose dividend increases to distribute relatively permanent cash-flow shocks and repurchases to distribute more transient shocks. As predicted, Guay and Harford found that post-shock cash flows of dividend-increasing firms exhibit less reversion to pre-shock levels compared with repurchasing firms.

Kahle (2002) examined how stock options affect the decision to repurchase shares. Once the decision to repurchase is made, the amount repurchased is positively related to total options exercisable by all employees but independent of managerial options. These results are consistent with managers repurchasing both to maximise their own wealth and to fund employee stock option exercises. The market appears to recognise this motive, however, and reacts less positively to repurchases announced by firms with high levels of nonmanagerial options.

Lease et al. (1999) acknowledged the irrelevance of dividend policy in a world with perfect capital markets; they stress how market imperfections such as taxes, imperfect information and agency issues can alter the dividend irrelevance conclusion.

The dividend discount model, the most widely used method of common stock valuation, equates a firm's stock price to the discounted value of its expected future dividends. The trinomial dividend valuation model (Yao, 1997) provides a new way to estimate the value of a firm in these circumstances. The results show that our model, in general, produces better price estimates than the Hurley and Johnson model (Hurley et al., 1994).

Hurley (2013) presented models of equity valuation in which future dividends are assumed to follow a generalised Bernoulli process consistent with the actual dividend payout behaviour of many firms. This uncertain dividend stream induces a probability distribution of the present value.

Bezawada and Tati (2017) set our objective to determine the impact of dividend policy on share-holders' wealth in the Indian electrical equipment manufacturing industry. The results indicate that there is a negative non-linear association between the market value of a share and dividend yields.

Research by Kien and Chen (2020) aimed to investigate the relationship between the ownership structure and dividend policy of Vietnamese listed companies. The empirical findings show that government-controlled companies, companies with high concentrated ownership and companies with recent right issue activities would have higher dividend payments.

The results of research by Hassan et al. (2013) showed that the tax shield has no significant relation to the dividend payout ratio, but mostly dividend policy is due to the size of the firm and its profitability.

To come to a conclusion on management's contribution to value creation and relative increase in shareholder wealth, it is necessary to use appropriate performance measures. Hence, the objective of research by Cupic and Todorovic (2011) was to analyse TSR as a measure of the value created due to managers' decisions. The remaining structure is organised as follows. The introduction is followed by an analysis of TSR, its drawbacks and the correlation between TSR and Total Business Return. After presenting alternatives to TSR, the conclusion closes the paper.

Burgman and Van Clieaf (2012) scrutinised the complexities associated with using TSR as a means to measure gains or losses in shareholder wealth and also as a frame of reference for long-term incentive compensation and proxy voting by shareholders. The research concludes that the quality of TSR can be accurately interpreted by introducing various metrics, such as economic profit (EP), return on invested capital (ROIC) and future value (FV).

The research by Pandya (2014) scrutinised the correlation of TSR with various other metrics, such as created shareholder value (CSV), market value added (MVA) and EP, in the context of the Indian banking system. The study reveals that CSV, together with MVA and EP, can explain the variations of total shareholder value in Indian banks.

Pandya (2014) evaluated the correlation of TSR and excess return with accounting measures. The research concluded that, on average, pharmaceutical companies have generated positive TSR and excess return, thus significantly benefiting shareholders.

The study by Snyders (2017) sampled companies listed in the Johannesburg Stock Exchange that had been growing through acquisitions during the period 2007–2016 to scrutinise whether such businesses have demonstrated better TSR figures than companies employing organic or mixed growth strategies. Analysis reveals that mergers and acquisitions events ultimately lead to the value destruction of businesses.

Combined with a three-year horizon, TSR has the potential to be dangerous – payouts to executives may reward short-to mid-term stock price volatility rather than sustained long-term TSR performance. The analysis by Hosken and Makridis (2015) raised questions about the appropriateness of 3 years as a performance period for relative TSR plans and suggested a few possibilities for action.

The research by Murekefu and Ouma (2012) sought to establish the relationship between dividend payout and firm performance among listed firms on the Nairobi Securities Exchange. Regression analysis was carried out to establish the relationship between dividend payouts and firm performance. The findings indicated that dividend payout was a major factor affecting firm performance.

The study by Osamwonyi and Lola-Ebueku (2016) examined the effect of dividend policy on firm's returns using the data of 17 manufacturing firms listed on the Nigerian Stock Exchange. One lagged dividend payout (previous dividend payout), cash flow and leverage have positive but not significant influence on Earnings Per Share (EPS), while the impact of size is negative and not significant.

Share repurchases, rather than dividend payments, are increasingly becoming the globally favoured payout method. This has prompted a renewed interest in the field and raises questions about the actual motivation for share repurchases and whether companies are now repurchasing shares in preference to investing in future growth. Share repurchases were found to be a popular payout method, especially in the more recent periods covered in the study. Aspects unique to the South African regulatory environment, however, resulted in the South African share-repurchase experience not fully mirroring current global practices. The main constraint in the South African share-repurchase environment is that comprehensive, actual time-based share-repurchase data are not available (Wesson et al., 2015).

However, if we believe that TRAS provides an average return for all shareholders, and TR calculates an IRR for a subset of shareholders, then we believe that there is a way to calculate an IRR for other shareholders. This problem has not been sufficiently studied by many researchers.

3. Materials and Methods

3.1 Difference between Total Return (TR) and Total Return for All Shareholders (TRAS)

The impact of a dividend is significant on TR indices. 'Total return' is the result of reinvesting all dividends back into the index or portfolio. In the short term, the contribution of dividends to TR performance may not be visible. Over time, however, the difference in accumulated wealth is significant due to the reinvestment of income.

The level of the TR index is adjusted according to the amount of dividends paid in by index constituent companies. When a company issues a dividend, the price of the equity drops in the exact amount of the per-share dividend amount. Leaving aside subsequent market movements of the equity price, the direct impact of a dividend on an index is a drop in the price of the index. However, the TR index is adjusted for the issuance of dividends by reinvesting them. In most cases, Refinitiv will reinvest the gross dividend amount on the ex-date in the TR indices (there are some exceptions to this rule due to local market conventions).

The TR index is computed as follows:

$$Index Price_{t} = \frac{\sum_{i=1}^{n} p_{i,t} q_{i,t} r_{i,t} + Div_{i,t} q_{i,t} r_{i,t}}{Divisor_{t}}, \qquad (1)$$

where p_{it} – price of equity $i = \overline{1,n}$ at time $t = \overline{0,T}$;

n – the number of equities in the index;

 $q_{i,t}$ – shares held in index for equity i at time t;

 $r_{i,t}$ – exchange rate from local currency to index currency for equity i at time t;

DIV_i, – per-share dividend on ex-date¹.

All quantities in the equation above are end-of-day quantities. The numerator is computed as per the ex-date for any dividends. The divisor is also adjusted for TR indices on the day following the dividend ex-date. This is done to ensure that the index does not fall back down to previous levels (prior to dividend ex-date). This adjustment is done by calculating an adjusted market cap

¹ Refinitiv Equity Indices, Corporate Action Methodology, April 2020. Refinitiv Limited. https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/corporate-actions-methodology.pdf

for the TR index immediately after the dividend ex-date. The adjusted market cap is the price-only market cap as on the dividend ex-date (i.e. excluding index dividend). Once this is divided by the TR index value as on dividend ex-date, we get an adjusted divisor, which is used for calculations from the next day onwards.

TSR is a measure of financial performance, indicating the total amount an investor reaps from an investment – specifically, equities or shares of stock. To arrive at its total, usually expressed as a percentage, TSR factors in capital gains and dividends from a stock might also include special distributions, stock splits and warrants. Whichever way it is calculated, TSR means the same thing: the sum total of what a stock has returned to those who have invested in it.

TSR is most useful when measured over time, as it shows the long-term value of an investment, the most accurate metric for gauging success for most individual investors.

TSR is a good gauge of an investment's long-term value, but it is limited to past performance, requires an investment to generate cash flows and can be sensitive to stock market volatility.

TSR is calculated as the overall appreciation in the stock's price per share plus any dividends paid by the company during a particular measured interval; this sum is then divided by the initial purchase price of the stock to arrive at the TSR²:

$$TSR = \frac{(Current Price - Purchase Price) + Dividends}{Purchase Price},$$
 (2)

The TR, also called 'return including dividends' and 'Total Index Return' provides the theoretical return of a share, assuming that dividends are reinvested to purchase additional shares. TRAS is the return that all the shareholders of a company had in a period. It is also the return of a shareholder that always had a constant proportion (i.e. 0.1%) of the shares. It takes into account not only the dividends, but also the share repurchases and the capital increases (Table 1).

Table 1. Different assumptions in Total Return (TR) and Total Return for All Shareholders (TRAS) calculations

	TR	TRAS
Dividend payment	Dividends are reinvested to purchase additional shares.	Dividends are collected. No purchase of additional shares.
Share repurchases	Nothing happens.	Shares are sold to keep a constant proportion of the shares of the company.
Capital increase, Rights offering	Rights are sold and the money obtained is reinvested to purchase additional shares.	Rights are sold and the money obtained is reinvested to purchase additional shares.
Equity offering at market price	Nothing happens.	Buy new shares to keep a constant proportion of the company shares.

² Investopedia. https://www.investopedia.com/terms/t/tsr.asp

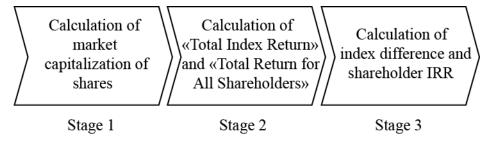


Figure 1. Number of steps required for t he study

Table 2. Company that repurchases shares and does not pay dividends (In year 1: repurchase of 60 shares at \$5/share)

No dividends	Year						
No dividends	0	1	2				
Number of shares	100	40	40	IRR			
Price / share	5	5	10				
Market capitalisation	500	200	400				
TR	-5	0	10	41.4%			
TRAS	-500	300	400	24.3%			

Figure 1 shows the number of steps required for the study.

Table 2 presents an easy example: A company that repurchased shares in year 1. The TRAS (TRAS = 24.3%) is substantially lower than the TR (TR = 41.4%), the annual return of a shareholder that maintained a share both years (41.4%).

3.2. Definitions provided by Datastream

Data about indexes TR and TSR (TRAS) is taken from the Datastream site.³

PRICE – Datatype (P) represents the official closing price. This is the default datatype for all equities. The prices taken at the close of the market are stored each day. These stored prices are adjusted for subsequent capital actions, and this adjusted figure then becomes the default price offered on all research programmes. The actual historical prices can be accessed using the unadjusted price datatype (UP). Prices are generally based on 'last trade' or an official price fixing. For stocks that are listed on more than one exchange within a country, default prices are taken from the primary exchange of that country (note that this is not necessarily the 'home' exchange of the stock). For Japan and Germany, prices from the secondary markets can be obtained by qualifying the price datatype with an exchange code.

Total return index – a return index is available for individual equities and unit trusts. This shows a theoretical growth in the value of a share holding over a specified period, assuming that dividends are reinvested to purchase additional units of an equity or unit trust at the closing price applicable on the ex-dividend date.

³ Trading solutions: refinitiv. https://solutions.refinitiv.com/datastream-macroeconomic-analysis/

Table 3. TR and TRAS of the companies in the S&P100 during December 2004 – April 2020

		Annual return 2004–2020 Annual return 201					14–2020
	2004–2020	TR	TRAS	Differ-	TR	TRAS	Differ-
		IK	IKAS	ence	1 IX		ence
1	BLACKROCK	15.6%	11.7%	-3.9%	9.3%	9.2%	-0.1%
2	HOME DEPOT	14.0%	11.3%	-2.7%	17.5%	17.7%	0.2%
3	MICROSOFT	15.6%	13.6%	-2.0%	31.5%	30.9%	-0.6%
4	AMGEN	10.4%	8.5%	-2.0%	10.8%	9.8%	-1.0%
5	SALESFORCE.COM	26.8%	24.9%	-1.9%	20.7%	20.2%	-0.6%
6	BOOKING HOLDINGS	31.0%	29.2%	-1.8%	5.0%	6.2%	1.2%
7	LOWE'S COMPANIES	10.5%	8.7%	-1.8%	10.2%	10.2%	0.0%
8	UNITEDHEALTH GROUP	14.3%	12.5%	-1.8%	23.9%	24.1%	0.1%
9	ELI LILLY	10.6%	8.9%	-1.7%	19.2%	18.5%	-0.7%
10	ABBOTT LAB	12.5%	10.8%	-1.7%	16.8%	17.5%	0.7%
11	ALLSTATE ORD SHS	7.1%	5.5%	-1.6%	9.2%	9.0%	-0.2%
12	INTEL	9.3%	7.8%	-1.5%	12.9%	12.3%	-0.6%
13	ALPHABET A	18.8%	17.3%	-1.4%	19.1%	19.0%	-0.1%
14	TARGET	7.4%	6.0%	-1.3%	10.7%	9.3%	-1.4%
15	TEXAS INSTRUMENTS	12.9%	11.6%	-1.3%	18.7%	18.8%	0.2%
16	NVIDIA	27.3%	26.1%	-1.2%	66.4%	63.5%	-3.0%
17	WALMART	7.9%	6.8%	-1.1%	9.4%	8.3%	-1.0%
18	LOCKHEED MARTIN	16.8%	15.8%	-1.0%	17.1%	17.2%	0.1%
19	THERMO FISHER SCIENTIFIC	17.3%	16.5%	-0.8%	20.6%	20.5%	-0.1%
20	QUALCOMM	6.5%	5.7%	-0.7%	4.7%	2.5%	-2.2%
21	VERIZON COM	8.2%	7.5%	-0.7%	8.9%	8.9%	0.0%
22	NETFLIX	42.9%	42.2%	-0.7%	49.7%	49.4%	-0.3%
23	ADOBE (NAS)	17.1%	16.5%	-0.6%	34.5%	34.5%	0.0%
24	PFIZER	6.5%	5.9%	-0.6%	7.8%	8.2%	0.4%
25	CISCO SYSTEMS	7.1%	6.5%	-0.6%	11.8%	12.7%	0.9%
26	MEDTRONIC	6.5%	5.9%	-0.6%	8.0%	8.2%	0.1%
27	BIOGEN	10.8%	10.2%	-0.6%	-1.0%	-1.4%	-0.5%
28	JOHNSON & JOHNSON	8.8%	8.2%	-0.6%	9.9%	9.8%	-0.1%
29	COSTCO WHOLESALE	15.0%	14.5%	-0.5%	18.2%	18.0%	-0.1%
30	BRISTOL MYERS SQUIBB	10.0%	9.4%	-0.5%	3.3%	3.6%	0.3%
	BANK OF NEW YORK MELLON	2.5%	2.1%	-0.5%	0.6%	1.7%	1.1%
32	PROCTER & GAMBLE	8.2%	7.7%	-0.5%	8.4%	7.7%	-0.7%
33	AMERICAN TOWER	19.3%	18.9%	-0.4%	20.2%	20.1%	-0.1%
34	NEXTERA ENERGY	16.2%	15.9%	-0.3%	18.8%	18.8%	0.0%
35	AT&T	6.7%	6.5%	-0.3%	4.0%	4.4%	0.5%
36	NIKE 'B'	15.8%	15.5%	-0.3%	13.1%	13.1%	0.0%
37	DANAHER	14.4%	14.2%	-0.2%	19.6%	19.3%	-0.3%
38	STARBUCKS	12.1%	11.9%	-0.2%	14.4%	14.9%	0.5%
39	PEPSICO	9.2%	9.0%	-0.2%	9.6%	9.6%	-0.1%
40	SOUTHERN TO SOUTHERN	8.4%	8.3%	-0.1%	7.6%	7.3%	-0.2%
41	JP MORGAN CHASE & CO.	8.9%	8.8%	-0.1%	11.4%	12.5%	1.1%
42	AMERICAN EXPRESS	5.7%	5.6%	-0.1%	1.3%	0.8%	-0.5%
43	WALT DISNEY	10.8%	10.7%	-0.1%	4.0%	4.1%	0.1%
44	ACCENTURE CLASS A	15.4%	15.4%	-0.1%	16.8%	16.9%	0.0%
45	COMCAST A	9.9%	9.8%	0.0%	7.0%	7.5%	0.4%
46	APPLE	32.4%	32.3%	0.0%	22.1%	20.9%	-1.2%

Table 3 (continued)

		Annua	l return 200	04-2020	Annual return 2014–2020			
	2004–2020	TR	TRAS	Differ-	TR	TRAS	Differ-	
				ence			ence	
47	CVS HEALTH	8.4%	8.4%	0.0%	-5.7%	-6.1%	-0.4%	
48	MERCK & COMPANY	10.1%	10.2%	0.1%	9.7%	9.5%	-0.2%	
49	3M	6.8%	6.9%	0.1%	1.2%	1.8%	0.5%	
50	UNITED PARCEL SER. 'B'	3.5%	3.6%	0.1%	0.1%	0.2%	0.1%	
51	ORACLE	10.2%	10.5%	0.2%	4.8%	4.4%	-0.5%	
52	BERKSHIRE HATHAWAY 'B'	7.9%	8.1%	0.3%	4.2%	4.2%	-0.1%	
53	MONDELEZ INT. CL.A	8.1%	8.4%	0.3%	8.8%	8.9%	0.1%	
54	COCA COLA	8.5%	8.8%	0.3%	4.9%	4.9%	0.0%	
55	RAYTHEON TECHNOLOGIES	7.4%	7.7%	0.4%	1.4%	1.2%	-0.3%	
56	WALGREENS BOOTS	2.6%	3.0%	0.4%	-8.1%	-6.6%	1.4%	
57	AMAZON.COM	30.0%	30.4%	0.4%	47.6%	47.2%	-0.4%	
58	HONEYWELL INTL.	12.4%	12.8%	0.4%	10.0%	10.6%	0.6%	
59	CATERPILLAR	8.7%	9.1%	0.4%	8.0%	8.0%	-0.1%	
60	FEDEX	2.4%	2.8%	0.4%	-4.8%	-4.4%	0.4%	
61	UNION PACIFIC	18.1%	18.6%	0.5%	8.0%	7.2%	-0.8%	
62	EXELON	2.7%	3.2%	0.5%	3.5%	3.8%	0.3%	
63	COLGATE–PALM.	9.3%	9.9%	0.6%	2.7%	2.7%	-0.1%	
64	MCDONALDS	15.5%	16.0%	0.6%	17.0%	17.7%	0.7%	
65	EMERSON ELECTRIC	6.3%	6.9%	0.6%	1.7%	1.6%	-0.1%	
66	GENERAL DYNAMICS	8.5%	9.1%	0.6%	1.1%	2.1%	0.9%	
67	DUKE ENERGY	9.3%	10.0%	0.7%	4.6%	4.5%	-0.1%	
68	US BANCORP	3.9%	4.8%	0.8%	-1.3%	-0.2%	1.1%	
69	GOLDMAN SACHS GP.	5.1%	6.0%	0.9%	0.5%	0.8%	0.3%	
70	GILEAD SCIENCES	17.0%	18.0%	1.0%	0.5%	-0.1%	-0.6%	
71	INTERNATIONAL BUS.MCHS.	4.1%	5.3%	1.1%	-0.7%	-0.6%	0.1%	
72	CAPITAL ONE FINL.	-0.3%	0.9%	1.2%	-2.6%	-2.2%	0.5%	
73	METLIFE	2.4%	3.6%	1.2%	-2.1%	-1.2%	0.9%	
74	CHEVRON	7.5%	9.0%	1.6%	0.3%	0.5%	0.2%	
75	BOEING	9.3%	11.1%	1.8%	4.1%	7.9%	3.8%	
76	MORGAN STANLEY	0.8%	2.7%	1.9%	2.7%	3.2%	0.5%	
77	SCHLUMBERGER	-2.4%	-0.4%	2.0%	-23.7%	-22.5%	1.2%	
78	FORD MOTOR	-3.8%	-1.3%	2.5%	-13.9%	-12.6%	1.3%	
79	CONOCOPHILLIPS	4.8%	7.5%	2.7%	-6.4%	-6.0%	0.4%	
80	WELLS FARGO & CO	2.4%	5.2%	2.8%	-8.4%	-6.0%	2.4%	
81	GENERAL ELECTRIC	-7.3%	-4.5%	2.8%	-19.3%	-16.4%	2.9%	
82	BANK OF AMERICA	-2.2%	0.8%	3.0%	7.5%	8.4%	0.9%	
83	EXXON MOBIL	2.2%	5.5%	3.3%	-8.6%	-7.9%	0.7%	
84	SIMON PROPERTY GROUP	4.4%	7.9%	3.5%	-13.6%	-12.0%	1.6%	
85	ALTRIA GROUP	12.6%	18.0%	5.4%	0.6%	2.2%	1.6%	
86	OCCIDENTAL PTL.	-0.1%	5.7%	5.8%	-21.3%	-20.7%	0.6%	
87	CITIGROUP	-12.4%	-4.6%	7.8%	-0.5%	1.5%	2.0%	
88	AMERICAN INTL.GP.	-20.8%	-10.3%	10.5%	-11.8%	-8.4%	3.4%	
	Average	9.6%	9.9%	0.3%	7.8%	8.0%	0.2%	
	Maximum	42.9%	42.2%	10.5%	66.4%	63.5%	3.8%	
	Minimum	-20.8%	-10.3%	-3.9%	-23.7%	-22.5%	-3.0%	

Source: https://solutions.refinitiv.com/datastream-macroeconomic-analysis/

4. Results

4.1. TR and TRAS of the companies in the S&P100 during December 2004–April 2020

We analysed 88 companies that were in the S&P100 in April 2020 and had trading records since December 2004.

Table 3 contains the shareholder returns (TR and TRAS) of the 88 companies during the period December 2004–April 30, 2020.

For 18 companies, annual TR exceeded annual TRAS in more than 1% (i.e. Blackrock 3.9%, Microsoft 2%). For 19 companies, annual TRAS exceeded annual TR in more than 1% (i.e. Citigroup 7.8%, Altria 5.4%). We believe that there is a way to calculate the IRRs for some and other shareholders individually.

The returns that we found in databases correspond to investors that hold the shares for the whole period and: a) did not subscribe new shares when the company increased capital and b) reinvested in shares all the dividends.

The most relevant return for an investor is, of course, their own return.

When we analyse companies, TRAS provides the most comprehensive average of individual returns. The return with a unique shareholder and the return of a shareholder that always holds a constant percentage of the outstanding shares were also sufficient.

TR provides the theoretical return of a precise shareholder: one who bought shares and did not receive any cash flow until the end of their investments. The dividends were reinvested to purchase additional shares.

5. Discussion

The results were split almost evenly between the two groups, and their explanations provide greater clarity, intrigue and interest.

One explanantion is the 'Buffett Index,' however, with one peculiarity: TR does not take into account transaction costs or taxes and is not realistic. TR only exists if the money stays in society's box and is not distributed. If distributed, the account of (i) income tax (Impuesto sobre la Renta de las Personas Físicas, IRPF) and (ii) repurchase costs must be taken. The only realistic index is TRAS because money comes out of the box, and that is the fact. The other is an estimate, because it does not take into account costs. Buffett has memorable paragraphs about why, when a company is doing well, it is much better for the shareholder that the money remains in society to be distributed.

If we think of TRAS as providing an average return for all shareholders, then TR calculates an IRR for a subset of shareholders. We purport that there is a way to calculate an IRR for other shareholders, and assume that if TR > TRAS, then the return for these 'other' shareholders is < TRAS.

This problem was also investigated by other researchers who obtained the following results.

For repurchases announced by 'glamour' stocks, where undervaluation is less likely to be an important motive, no positive drift in abnormal returns was observed (Ikenberry et al., 1995).

Guay and Harford (2000) found that post-shock cash flows of dividend-increasing firms exhibit less reversion to pre-shock levels compared to repurchasing firms.

The results by Bezawada and Tati (2017) indicated that there is a negative non-linear association between the market value of a share and dividend yields.

Burgman and Van Clieaf (2012) concluded that the quality of TSR can be accurately interpreted by introducing various metrics such as EP, ROIC and FV.

The research by Pandya (2014) scrutinised the correlation of TSR with various other metrics, such as CSV, MVA and EP, in the context of the Indian banking system. The study revealed that CSV, together with MVA and EP, can explain the variations of total shareholder value in Indian banks.

The analysis by Hosken and Makridis (2015) raised questions about the appropriateness of 3 years as a performance period for relative TSR plans and suggests a few possibilities for action.

Share repurchases were found to be a popular payout method, especially in the more recent periods covered in the study. Aspects unique to the South African regulatory environment, however, resulted in the South African share-repurchase experience not fully mirroring current global practices. The main constraint in the South African share-repurchase environment is that comprehensive, actual time-based share-repurchase data are not available (Wesson et al., 2015).

However, these authors did not calculate the IRR for subgroups of shareholders. We believe that there is a way to calculate the IRRs for certain shareholders individually.

Thus, emerging capital markets provide new information to investors on how to better manage equity.

6. Conclusion

TR, also called 'return including dividends' and 'Total Index Return', provides the theoretical return of a share, assuming that dividends are reinvested to purchase additional shares.

TRAS is the return that all the shareholders of a company had in a given period. It is also the return of a shareholder that always had a constant proportion (i.e. 0.1%) of the shares. It takes into account not only the dividends but also the share repurchases and the capital increases.

We calculated both returns for the S&P100 companies during December 2004–April 2020. For 18 companies, annual TR exceeded annual TRAS in more than 1% (i.e. Blackrock 3.9%, Microsoft 2%). For 19 companies, annual TRAS exceeded annual TR in more than 1% (i.e. Citigroup 7.8%, Altria 5.4%).

Most databases provided TR valid for shareholders that reinvested 100% of the dividends, did not sell any shares in repurchases and did not subscribe any new shares when the company increased capital.

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The article was submitted 1.05.2021, approved after reviewing 21.06.2021, accepted for publication 1.07.2021.

Статья поступила в редакцию 1.05.2021, одобрена после рецензирования 21.06.2021, принята к публикации 1.07.2021.

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SECTION 2

ENTERPRISES AND THE SUSTAINABLE DEVELOPMENT OF REGIONS

РАЗДЕЛ 2

ПРЕДПРИЯТИЯ И УСТОЙЧИВОЕ РАЗВИТИЕ РЕГИОНОВ

Research article

DOI: https://doi.org/10.48554/SDEE.2021.2.2

INNOVATION AND RESOURCE POTENTIAL ON KEY PERFORMANCE INDICATORS OF WATER SUPPLY ENTERPRISES

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Abstract

he article analyses the innovation and resource potential of an enterprise as the basis for its sustainable development. The factors of structure, assessment and impact of this potential on individual resulting performance indicators are considered. This study identified the natural links between innovation and resource potential and the indicators of profit, revenue, costs, volumes of water losses and consumption. Thus, the probable links between potential and the financial, environmental and social components that characterise the activities of an enterprise are elucidated. The study used expert assessments and regression analyses on data from the SUE 'Vodokanal of St. Petersburg'. The value of innovation and resource potential was determined by summing up the values of constituent elements (subpotentials): educational and personnel, research, information and technological, production and technical, socioenvironmental, financial and economic as well as organisational and managerial. For each subpotential, a system of indicators was developed. Calculations of indicators were done for data from 2010-2020. Indicators were ranked by degree of importance. After determining the value of the innovation and resource potential, six regression models were built, reflecting the impact of potential on key performance indicators of the water supply enterprise. The results of the study demonstrated profit, revenue and cost indicators' direct dependence on innovation and resource potential and the inverse dependence of water loss and consumption. Studying indicators characterising a particular subpotential and selecting resulting indicators for modelling and assessing the impact of innovation and resource potential remain problematic. The results show that subpotential improvement can be achieved by identifying indicators, such as personnel and technological support that depend on innovation and resource potential for major advancements. This can improve the effectiveness and efficiency of water supply enterprises, making this an important area of scientific inquiry.

Keywords: innovation and resource potential, subpotentials, water supply enterprise, sustainable development, regression analysis, regression model.

Citation: Furtatova, A., Victorova, N., Konnikov, E., 2021. Innovation and resource potential on key performance indicators of water supply enterprises. Sustainable Development and Engineering Economics 2, 2. https://doi.org/10.48554/SDEE.2021.2.2



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Научная статья

УДК 338.45

DOI: https://doi.org/10.48554/SDEE.2021.2.2

ОЦЕНКА ВЛИЯНИЯ ИННОВАЦИОННО-РЕСУРСНОГО ПОТЕНЦИАЛА НА КЛЮЧЕВЫЕ ПОКАЗАТЕЛИ ДЕЯТЕЛЬНОСТИ ПРЕДПРИЯТИЙ **ВОДОСНАБЖЕНИЯ**

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Аннотация

татья посвящена инновационно-ресурсному потенциалу предприятия как основе его устойчивого развития. В ней рассмотрены вопросы структуры, оценки и влияния потенциала на отдельные результирующие показатели деятельности применительно к предприятиям водоснабжения. Цель исследования состоит в выявлении закономерных связей между инновационно-ресурсным потенциалом и показателями прибыли, выручки, затрат, объемов потерь и потребления воды. Таким образом, в исследовании обозначены вероятные связи потенциала с финансовой, экологической и социальной компонентами, характеризующими деятельность предприятия. Исследование выполнено на материалах ГУП «Водоканал Санкт-Петербурга». В работе использованы метод экспертных оценок и регрессионный анализ. Значение инновационно-ресурсного потенциала определено путем суммирования величин его составных элементов (субпотенциалов): образовательно-кадрового, научно-исследовательского, информационно-технологического, производственно-технического, социально-экологического, финансово-экономического, организационно-управленческого. Для каждого субпотенциала разработана система показателей. Расчеты показателей произведены за период 2010-2020 гг. Показатели проранжированы по степени значимости. После определения значения инновационно-ресурсного потенциала построено шесть регрессионных моделей, отражающих влияние потенциала на ключевые показатели деятельности предприятия водоснабжения. Результаты исследования показали прямую зависимость от инновационно-ресурсного потенциала показателей прибыли, выручки и затрат, и обратную зависимость потерь и потребления воды. Дискуссионными остались вопросы выделения в исследовании показателей, характеризующих тот или иной субпотенциал, а также отбора результирующих показателей для моделирования и оценки влияния на них инновационно-ресурсного потенциала. В заключении исследования предложены направления совершенствования субпотенциалов. Интерес для будущих научных разработок представляет выявление зависимости инновационно-ресурсного потенциала и показателей, характеризующих кадровое и технологическое обеспечение деятельности предприятия водоснабжения.

Ключевые слова: инновационно-ресурсный потенциал, субпотенциалы, предприятие водоснабжения, устойчивое развитие, регрессионный анализ, модель.

Цитирование: Фуртатова, А., Викторова, Н., Конников, Е., 2021. Оценка влияния инновационно-ресурсного потенциала на ключевые показатели деятельности предприятий водоснабжения. Sustainable Development and Engineering Economics 2, 2.

https://doi.org/10.48554/SDEE.2021.2.2



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1. Introduction

Given the conditions of limited water resources and environmental problems, the issue of the effectiveness of water supply enterprises is becoming more important. Some territories are characterised by a shortage of fresh water and other territories by its low quality. Even if these indicators are normal, problems of water loss arise. However, on a global scale, all these problems coexist, so special attention needs to be paid to the management of water resource potentials through the analysis of water consumption.

Water is the greatest natural resource involved in the human economy. In terms of annual use, it exceeds all key extracted resources. Water is a vital resource; it participates in the manufacturing of goods and services, the development of energy, industry and agriculture (Furtatova and Kamenik, 2018).

The United Nations world water development report 2020: water and climate change noted that over the past hundred years, global water use has increased sixfold, and every year this indicator has increased by 1% due to a number of factors, including demographic growth, economic development and changing patterns of water consumption (UNESCO, 2020).

To date, according to *The Sustainable Development Goals Report 2020*, 2.2 billion people around the world do not have safe and organised access to drinking water, which is 28% of the world's population (DESA, 2020). This situation has developed not only for geographical reasons, but also due to population growth, urbanisation, economic development, climate change and the high level of pressure on water resources, which arose as a result of previous ineffective management.

Globally, the load on water resources is 17%, indicating a generally safe level of freshwater use today; however, this figure varies significantly between regions (DESA, 2020).

The situation of water losses as a result of its transportation is also problematic. The average value of this indicator among Western European enterprises is 10.8 m³/km per day, and in Russia, it is 29.4 m³/km per day (EBC, 2018).

The global international studies and statistics presented above justify the need to revise the management model of water supply enterprises, including the management of their potential.

2. Literature Review

Many scientists around the world are devoted to studying potential and its characteristics, properties and methods of determination. From the socioeconomic aspect, the assessment of potential sets itself the goal of ensuring the sustainable development of a country, industry or enterprise. Depending on the territorial, economic, political, cultural and other features of economic objects, researchers analyse the potential by dividing it into its constituent elements or considering its integrated essence. A variety of tools are used for this.

Canci (2021) assessed the innovative potential of the United States over the past decades. It proved the association between innovation and the state of the national economy. As a result of the growth of the innovative potential of the United States, labour productivity has improved, and the influence of the market economy and capitalism has increased. The increase in the use of scientific technologies and developments in various fields has ensured the sustainable innovative development of the country's economy (Rudskaia and Rodionov, 2018).

Fallah-Alipour et al. (2018) studied potential in the agricultural industry by assessing potential based on a system of environmental, social, economic and other indicators. The tools for this

system's implementation were sustainability maps, diagrams and a barometer of sustainability. The results allowed the formulation of recommendations for effective land use, ensuring sustainable development of the country.

Scientists have also used various approaches to study potential. Nehrebecka (2018) assessed the financial potential of an enterprise based on modelling using regression logarithmic equations. The effective use of financial potential was compared here with the indicator of the probability as default. The study concluded that the lowest risk of bankruptcy was observed in the pharmaceutical industry, and the highest risk of bankruptcy was in the mining sector.

Stewart et al. (2018) used a model to assess the life cycle of an enterprise as determined by its sustainable development based on data from more than 45 000 corporate reports. The model included the main tasks, opportunities and recommendations for expanding the potential of the enterprise.

A non-trivial approach to managing sustainable innovative development of an enterprise proposed by Vasilieva et al. (2020) assessed innovative potential using the specialised software CASI-F created by Popper et al. (2017). They conducted a meta-analysis of roadmaps compiled through CASI-F. The applied methodology allowed the authors to identify strengths and weaknesses, as well as opportunities and threats in assessing the sustainable innovative development of the enterprise.

Abouhamad and Abu-Hamd (2020) assessed the potential of one of the innovative technologies in the construction industry using the Athena Impact Estimator program. Furthermore, Graciano et al. (2018) assessed the environmental and economic potential of one of the innovative biotechnologies.

Martins et al. (2018) constructed a model for assessing the potential of electric power generation companies in Portugal in the context of their life cycle. The results of the simulations allowed them to develop avenues for the effective management of such enterprises, including the reduction of greenhouse gas emissions as a result of the introduction of 'green' technologies. In a continuation of the issue of assessing the potential of a country's electric power industry, Hulio et al. (2017) substantiated the need for the calculation and economic assessment of the potential of wind energy. In the paper, the authors proved (through the application of mathematical statistics and the coefficient of determination of the model) the expediency of using power plants operating on wind energy.

Along with assessing the potential of the country, industry, enterprise and technology, studies have assessed other types of potential. For example, the potential of waste (Iacovidou et al., 2017) and the potential of products (plastic parts) used in automotive production (Dobransky, 2019) have also been assessed.

However, the works of greatest interest in this study are the works that assessed water potential. Specifically, Moro et al. (2019) compared the national innovation potential of European countries and China in the water sector. They concluded that this potential is higher in European countries and that the development of primarily environmental innovations determines the level of national water innovation potential.

Researchers from South Korea (Park and Kim, 2021) estimated the predicted potential of using groundwater sources in the country using big data. The authors emphasised the need to create groundwater potential maps for the effective management of groundwater sources' potential.

Bertuzzi and Ghisi (2021) assessed the potential of the use of rainwater in the technological process in the enterprises of Brazil. The authors simulated the enterprise's future demand for water for technological purposes and revealed that it is twice the current consumption. Thus, technology for using rainwater was proposed, including its additional purification before use, which ensures the quality of the resource, and the economic feasibility of introducing this technology was also estimated.

Regardless of the object (country, technology, enterprise, industry, products, etc.) considered by researchers, the assessment of each potential is aimed at ensuring the sustainable development of the relevant object and emphasises the importance of considering the environmental factor, the primary factor of production (natural resource capital). However, the assessment of innovation and resource potential of water supply enterprises and its influence on the resulting performance indicators have been insufficiently covered in the literature. This problem is therefore the focus of this article.

3. Materials and Methods

This study develops a methodology for assessing water supply enterprises and their activities' (financial, environmental and social) dependence on innovation and resource potential. The objectives of the study (in relation to the specifics of the type of activity under consideration) include 1) the determination of the innovation and resource potential of the enterprise and its constituent elements (subpotentials); 2) the development of a system of indicators for assessing each type of subpotential; 3) the assessment of innovation and resource potential and 4) the construction of models reflecting the influence of innovation and resource potential on the results of the financial, environmental and social activities of the enterprise.

Research hypotheses:

- 1) Innovation and resource potential affect the income and profit of a water supply enterprise as a business entity and is not significant in cost processes.
- 2) Since one of the main goals of the water supply enterprise is to provide the population with water, it can be assumed that of all three components selected for the study that characterise the results of the enterprise's activities, innovation and resource potential has the greatest impact on the social component.

For the purposes of this study, innovation and resource potential is understood as a complex integral indicator reflecting the qualitative characteristics of the current and future capabilities of an enterprise. The object of the study is the water supply enterprise SUE 'Vodokanal of St. Petersburg'. The empirical base for the study was formed over 11 years during the period from 2010 to 2020 on the basis of data from the annual reports of SUE 'Vodokanal of St. Petersburg' and its divisions.

The research methodology is as follows.

- 1. The value of the innovation and resource potential of the water supply enterprise is calculated.
- 1.1. Innovation and resource potential is divided into its constituent elements (subpotentials).
- 1.2. A system of indicators is developed for each subpotential.
- 1.3. The significance of each indicator is determined using the ranking method and expert assessments.
 - 1.4. The size of each subpotential (integral value) is calculated.
 - 1.5. The integral value of innovation and resource potential is determined.
 - 2. The dependence of a water supply enterprise on its innovation and resource potential is assessed.
 - 2.1. The resulting indicators for constructing models are selected, and models are formed.
- 2.2. The reliability and significance of the constructed models are checked using the coefficient of determination, approximation error, P-level and regression coefficient (Smith, 2015; Georgiev et al., 2018; Furtatova and Kamenik, 2019).

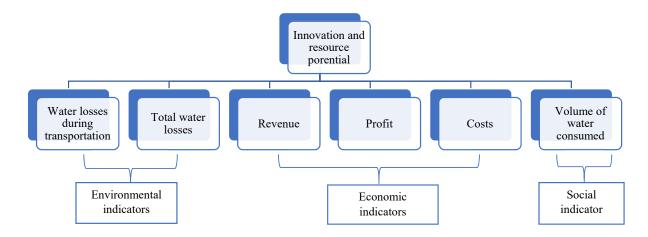


Figure 1. Conceptual model for constructing regression models.

The methodology for identifying the dependencies of the resulting performance indicators of the water supply enterprise on innovation and resource potential is based on regression analysis. Below is a conceptual diagram of the relationships between the indicators used to build regression models in the study (Fig. 1).

As the resulting indicators for modelling, indicators characterising the sustainability of the development of the water supply enterprise were chosen as follows: 1) group of environmental indicators (water loss during transportation and total water loss); 2) group of economic indicators (profit, costs and revenue) and 3) social indicator, provision of consumers with drinking water (volume of water consumed; Furtatova and Kamenik, 2019). The data are shown in Table 1.

Year	Water loss	Total water loss	Revenue	Profit	Profit	Volume
	during	(thousand m ³)	(thousand	(thousand	(thousand	of water
	transportation		rubles)	rubles)	rubles)	consumed
	(thousand m ³)					(thousand m ³)
2010	104806.24	276205.14	9425693.50	2525945.50	6899748.00	623240.16
2011	98577.91	242951.61	9583548.70	2658912.20	6924636.50	603295.59
2012	91265.20	230683.60	9486346.10	2521985.70	6964360.40	587032.10
2013	89090.30	243298.30	9632589.20	2507219.50	7125369.70	570134.40
2014	81005.10	213103.80	9789586.50	1987436.90	7802149.60	544120.90
2015	77492.00	211357.90	10899258.40	2149134.60	8750123.80	519498.20
2016	71645.80	209433.50	11250988.20	1351862.90	9899125.30	512487.30
2017	62443.44	193226.64	12937890.20	2739125.60	10198764.60	505476.06
2018	57572.05	182273.65	14279390.80	4106666.60	10172724.20	504936.05
2019	53243.48	174187.48	15112625.90	5247537.70	9865088.20	504305.72
2020	51859.17	154340.77	15963124.50	6199561.90	9763562.60	504142.13

Table 1. Initial data for building regression models

All calculations of regression analysis were done in MS Excel.

4. Results

Based on previously conducted research by domestic and foreign researchers, in terms of the types of potential inherent in an organisation in relation to water supply enterprises, the following subpotentials must be considered: educational and personnel, research, information and technological, production and technical, socioenvironmental, financial and economic, organisational and managerial subpotentials (Furtatova and Viktorova, 2020).

The authors developed a system of indicators characterising each type of subpotential. In general, 62 indicators were included in the calculation process (Table 2); all indicators were relative, calculated as the ratio of the specific indicator of the subpotential under consideration of the total indicator for the subpotential under study.

Table 2. List of indicators for assessing subpotentials of innovation and resource potential of a water supply enterprise

Subpotential name	Relative indicators reflecting the specific element of the subpotential
Educational and personnel	1. Staff education / 2. Staff professional literacy / 3. Professional growth of employees / 4. Interest of graduates in the enterprise as an employer / 5. Rejuvenation of the team / 6. Employment of graduates / 7. Activity of employees / 8. Involvement of employees in the development of the enterprise / 9. Success of employees / 10. Merit of employees / 11. Merit of employees within the enterprise / 12. Merit of employees at the city level.
Research	1. Intellectual property of the water supply enterprise / 2. Intensity of use of intellectual property of the enterprise / 3. Intensity of use of the acquired intellectual property of the enterprise / 4. Introduction of innovative technologies by third-party organisations / 5. Involvement of research organisations in conferences held at the enterprise / 6. Involvement of commercial organisations in the conferences held at the enterprise.
Information and technological	1. Provision of software products to production departments of the water supply enterprise / 2. Provision of software products to non-production departments of the water supply enterprise / 3. Continuity of the software functioning in the production departments of the water supply enterprise / 4. Continuity of the software functioning in the non-production departments of the water supply enterprise / 5. Automation of technological operations within the technological process of production departments of the water supply enterprise / 6. Automation of technological processes in the production departments of the water supply enterprise / 7. Automation of operations within the process of non-production departments of the water supply enterprise / 8. Automation of processes in the non-production departments of the water supply enterprise.
Production and technical	1. Use of key production equipment / 2. Wear of key production equipment / 3. Use of auxiliary equipment / 4. Wear of auxiliary equipment / 5. Renewal of key production equipment / 6. Renewal of auxiliary equipment / 7. Intensity of modernisation of objects of the water supply enterprise / 8. Intensity of reconstruction of objects at the water supply enterprise / 9. Intensity of new construction of objects at the water supply enterprise / 10. Intensity of repair of objects at the water supply enterprise / 11. Use of resource-saving technologies by the water supply enterprise / 12. Use of resource-intensive technologies by the water supply enterprise

Table 2. (continued)

Subpotential name	Relative indicators reflecting the specific element of the subpotential
Socioenvironmental	1. Supply of water from the water source / 2. Water consumption for servicing the water supply grids / 3. Water consumption in the production process / 4. Taxes for the negative environmental impact / 5. Economy of water resources by the employees of the water supply enterprise / 6. Satisfaction of employees with the working conditions of the water supply enterprise / 7. Satisfaction of the employees with the quality of water supply services of the enterprise / 8. Awareness of the population of the activities of the water supply company
Financial and economic	1. Financial independence of the water supply enterprise / 2. Share of borrowed funds in the capital of the water supply enterprise / 3. Share of budget funds in the capital of the water supply enterprise / 4. Accounts receivable of the water supply enterprise / 5. Accounts payable of the water supply enterprise / 6. Financing activities of the water supply enterprise with its own funds / 7. Budget financing activities of the water supply enterprise / 8. Credit financing activities of the water supply enterprise / 9. Investment in the implementation of activities of the water supply enterprise / 10. Implementation of public—private partnership mechanisms at the water supply enterprise.
Organisational and managerial	1. Subordination of personnel at the water supply enterprise / 2. Share of workers in the personnel of the water supply enterprise / 3. Share of specialists in the personnel of the water supply enterprise / 4. Share of managers in the personnel of the water supply enterprise / 5. Career growth of the employees of the water supply enterprise / 6. Additional education of managers at the water supply enterprise.

Furthermore, based on expert assessments, each indicator was assigned a weight coefficient. To this end, the company has selected groups of experts responsible for the formation of a specific type of subpotential. Experts ranked the indicators by their importance, which made it possible to calculate the weight coefficient for each of the indicators. In Table 3, using the organisational and managerial subpotential as an example, such a calculation is provided.

Table 3. Assignment of weight coefficients to indicators of organisational and managerial subpotential

	Indicators of evaluation of organisational and managerial subpotential							
Expert	Subordination of personnel at the water supply enterprise	Share of workers in the personnel of the water supply enterprise	Share of specialists in the personnel of the water supply enterprise	Management structure at the water supply enterprise	Career growth of employees of the water supply enterprise	Additional education of managers at the water supply enterprise		
Director of the water supply enterprise	4	2	1	6	5	3		
Deputy director for general affairs	5	1	2	5	3	6		
Senior management specialist	6	5	4	3	2	1		
Senior specialist for coordination of work of the manager	3	2	1	6	4	5		

Table 3. (continued)

	Indicators of evaluation of organisational and managerial subpotential							
Expert	Subordination of personnel at the water supply enterprise	Share of workers in the personnel of the water supply enterprise	Share of specialists in the personnel of the water supply enterprise	Management structure at the water supply enterprise	Career growth of employees of the water supply enterprise	Additional education of managers at the water supply enterprise		
Senior referent-coordinator	2	3	4	5	6	1		
Chief operations specialist	6	2	5	4	1	3		
Head of systems analysis of services	4	6	5	3	2	1		
Leading specialist of the office management service	1	3	2	6	4	5		
Deputy director for human resources policy and corporate communications	4	1	2	6	5	3		
Leading specialist of HR administration department	1	3	2	4	5	6		
Sum	36	28	28	48	37	34		
Weights	0.171	0.133	0.133	0.227	0.175	0.161		

Then, the integral values for each subpotential were calculated by multiplying the weight coefficients by the corresponding values of the subpotential indicators (Table 4).

Table 4. Estimated values of subpotentials and innovation and resource potential of the water supply enterprise

Subpotential	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Educational and personnel	0.268	0.294	0.293	0.298	0.303	0.309	0.302	0.300	0.296	0.289	0.291
Research	0.312	0.316	0.323	0.320	0.319	0.316	0.311	0.314	0.315	0.319	0.321
Information and technological	0.472	0.485	0.517	0.529	0.539	0.532	0.543	0.556	0.563	0.569	0.575
Production and technical	0.365	0.367	0.389	0.383	0.379	0.386	0.385	0.386	0.379	0.378	0.380
Socioenvironmental	0.611	0.612	0.617	0.613	0.630	0.629	0.623	0.640	0.644	0.642	0.651
Financial and economic	0.284	0.284	0.288	0.285	0.275	0.276	0.259	0.279	0.299	0.311	0.328
Organisational and managerial	0.299	0.292	0.306	0.328	0.329	0.322	0.336	0.339	0.337	0.337	0.331
Innovation and resource potential	2.610	2.651	2.733	2.756	2.775	2.769	2.761	2.814	2.834	2.844	2.876

Further, six regression models were constructed to describe the relationship between the innovation and resource potential with a specific indicator reflecting the result of the activities of the water supply enterprise. X is the value of the innovation and resource potential, and $Y_1...Y_n$ (where n=6) is the value of the resulting indicator.

Model 1. The influence of innovation and resource potential on water loss during transportation (Fig. 2).

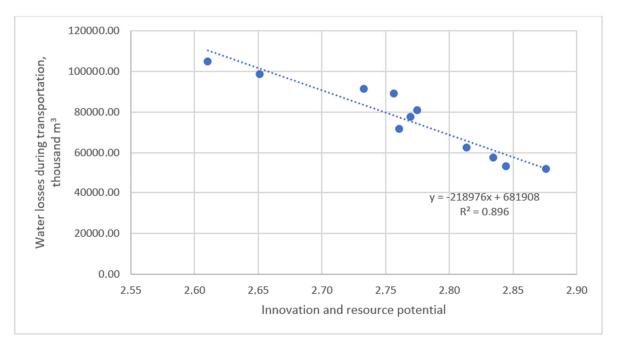


Figure 2. Relationship between indicators of innovation and resource potential and water loss during transportation

The highest coefficient of determination was obtained by selecting a linear function (89.6%). Thus, 89.6% of changes in the value of the indicator 'water loss during transportation' can be described by the value of innovation and resource potential.

The practical significance of this approximation error indicator is interpreted as follows: on average, the constructed model when predicting the indicator 'water loss during transportation', calculated on the basis of the value of innovation and resource potential, is erroneous by 8.23%.

The value of the F-criterion is equal to the p-value, since these are equations of pair regressions, demonstrating the degree of reliability of the model and proving that the value of the innovation and resource potential affects the indicator under consideration.

Model 2. The influence of innovation and resource potential on the total water loss at the water supply enterprise (Fig. 3).

This model is reliable, based on the P-level and the approximation error, the value of which was 5.61%.

The coefficient of determination was almost 90%; that is, the compiled model explained 90% of the described variance.

The vector of influence in this case took a negative value. Thus, with an increase in innovation and resource potential, total water loss would decrease. This could be achieved through repairs, reconstruction and new construction of water supply facilities.

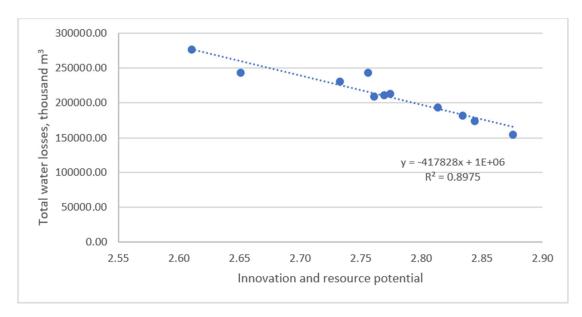


Figure 3. Relationship between indicators of innovation and resource potential and total water loss

Model 3. The influence of innovation and resource potential on revenue from the sale of services (Fig. 4).

The P-level = 99% and standard error =12.45% for the model, meaning that 69% of the obtained variance of the studied indicator can be explained by a change in the innovation and resource potential.

In this model, the vector of influence took a positive value: an increase in the innovation and resource potential would increase revenue. However, with such an approximation error, this effect would be achieved gradually.

Model 4. The influence of innovation and resource potential on profit (Fig. 5).

When constructing a linear equation of the 'Profit' indicator, the coefficient of determination was 0.374; thus, the innovation and resource potential described 37.4% of the changes in the resulting indicator under consideration, which is insufficient for the analysis of the model. In addition,

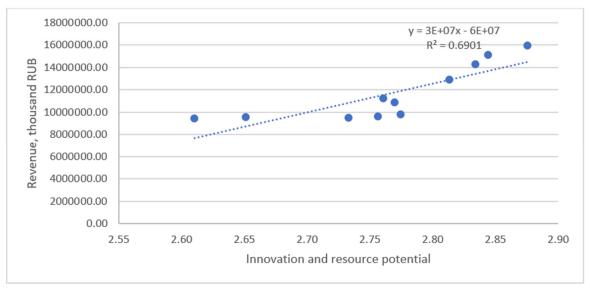


Figure 4. Relationship between indicators of innovation and resource potential and revenue

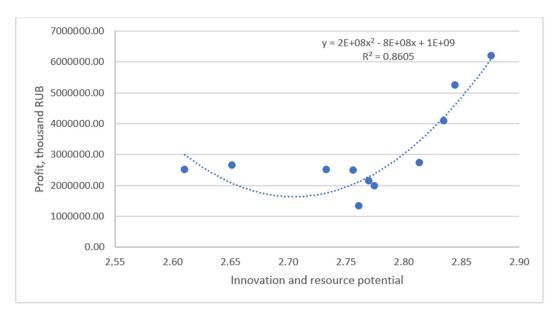


Figure 5. Relationship between indicators of innovation and resource potential and profit

the value of the F-criterion was 0.04561, and the value of the approximation error was 39.82%, which shows the low degree of reliability and practical quality of this model.

To describe the influence of innovation and resource potential on profit, the equation of the polynomial of the second degree is chosen (Song and Li, 2021). In this model, the coefficient of determination was 86%, but the standard error was almost 20%, which indicates that the model is unreliable. However, the importance of the F-criterion indicates that the value of innovation and resource potential has a significant impact on the profit of a water supply enterprise.

It is worth noting here that the value of the standard error was 19.94%, so we can conclude that with an increase in innovation and resource potential, the return on profit would be observed a little later.

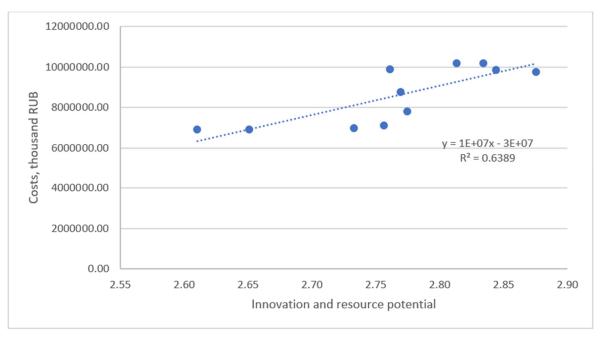


Figure 6. Relationship between indicators of innovation and resource potential and costs

According to the obtained model, increasing the innovation and resource potential from 2.61 to 2.73, the profit value decreased markedly. In this period, the basis for further increment of the economic result (construction of new capacities, reconstruction of existing facilities, etc.) is formed. At the end of this period, the importance of innovation and resource potential increased, thereby indicating an increase in the economic effect at the enterprise (profit growth).

Thus, the value of innovation and resource potential equal to 2.73 is the value of this indicator, up to which the increment of innovation and resource potential is vital for the functioning of the water supply enterprise, and after the transition of the value to 2.73, an increase in the profit of the enterprise will be noticeable.

Model 5. The influence of innovation and resource potential on costs (Fig. 6).

According to the results of the linear regression model, the following data were obtained: 1) the value of the determination coefficient was 63.9%, which is significant (more than 50%) for the object under study and the existing environment; 2) the value of the standard error was 10.67%; that is, the model on average was wrong by almost 11% and 3) the significance of the F-criterion emphasised the model's high degree of reliability.

However, the influence vector had a positive value; that is, with an increase in the value of innovation and resource potential, the costs would also increase.

This conclusion is generally natural, since measures to increase innovation and resource potential require significant costs (introduction of resource-saving technologies, increase in costs for research and development, etc.) but contradicts the goals of the enterprise to reduce costs and increase profits.

To determine the quantitative relationship between the innovation and resource potential and the resulting economic indicator (costs) under consideration, the elasticity coefficient was calculated. Its value was 4.66%, which means the following: with an increase in innovation and resource potential by 1%, costs would increase by 4.66%.

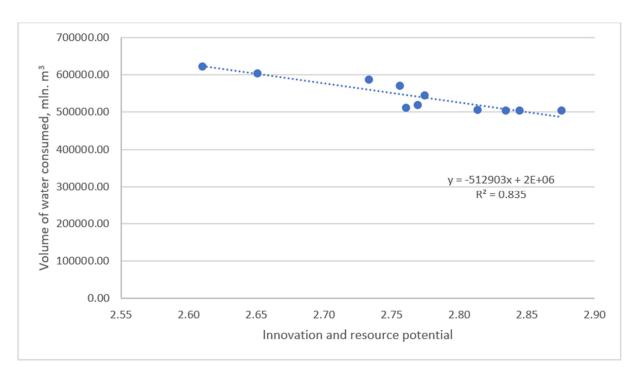


Figure 7. The relationship between indicators of innovation and resource potential and the volume of water consumed

This increase in costs would be compensated for by a significant increase in revenue, for which elasticity was also calculated. According to the results of the calculation, an increase in the innovation and resource potential by 1% would entail an increase in the company's revenue by 6.1%, which in turn confirms the effect of profit growth.

Model 6. The influence of innovation and resource potential on the volume of water consumed (Fig. 7).

This model is reliable and practically significant (the coefficient of determination exceeded 83%, and the standard error was 3.53%).

However, in this case, the impact vector (regression coefficient) had a negative value. Thus, with an increase in innovation and resource potential, the volume of water consumed would decrease.

5. Discussion

According to the results of the study, the first hypothesis was partially confirmed. That is, the impact of innovation and resource potential on profit was unambiguous. However, the modelling data indicated a temporary delay in the return on profit with the growth of innovation and resource potential, and accordingly, the absence of a clear correlation between the indicators when considering them in dynamics.

The second hypothesis was fully confirmed. Moreover, the reverse influence of the innovation and resource potential on water consumption was proven. This conclusion is logical, since the goal of the water supply enterprise is the rational use of water resources through the introduction of resource-saving technologies (closed-loop technologies, equipment with frequency regulation, flow meters, etc.). Moreover, water supply enterprises promote environmental policies and work with the public to rationalise water use. Therefore, the growth of innovation and resource potential will contribute to the reduction in water consumption.

Based on the analysis of the constructed regression models and the identification of the relationship between the innovation and resource potential and the resulting indicators, a set of recommendations and proposals aimed at improving and developing water supply enterprises was developed.

It should be noted that there is a problem with assessing innovation and resource potential, specifically the selection of indicators characterising a particular subpotential. For example, personnel indicators are present in the educational and personnel as well as organisational and managerial subpotentials, while technological indicators affect the information and technological as well as production and technology subpotentials. In the present study, the rationale for linking an indicator to a particular type of subpotential was related to the specifics of the activities of departments that primarily form such a subpotential. Therefore, subpotential assessments were focused on the expert opinions of the employees of these departments. Such a problem is inherent in complex studies of potential (Rudskaia and Rodionov, 2018; Fallah-Alipour et al., 2018) and does not arise in subject research (Nehrebecka, 2018; Stewart et al., 2018; Vasilieva et al., 2020; Popper et al., 2017).

The issue of selecting the resulting indicators for modelling and assessing the impact of innovation and resource potential is also debatable. The study took the most logical indicators from the point of view of the consequences of modelling and for the type of activity under consideration. The-following scientists turned to some of them in their studies. Nehrebecka (2018) in his work assessing the financial potential of enterprises applied the dynamic econometric model, arguing that the financial constraints of the enterprise affect the level of sales in foreign markets and the behaviour

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Subpotential	Directions of subpotential development
Educational and	Improve the professional and qualification level of employees involved in the process
personnel	of water treatment, transportation and water consumption through advanced training
	programs, additional higher education, competitions of professional skill, etc.
Research	Increasing the volume of positive results of research and development used to optimise
	the processes of water treatment, transportation and consumption in the forms of
	patents for inventions, descriptions of inventions, utility models, industrial designs,
	license agreements, etc.
Production and	Modernise equipment and structures, ensuring the replacement of old machinery
technical	and technologies in all divisions of the enterprise (main, auxiliary, servicing and
	management)
Information and	Automate most processes at the stages of water treatment, transportation and water
technological	consumption based on modern computer support
Financial and	Ensure the rational use of sources of financing of projects for modernisation
economic	(reconstruction) of water supply facilities and attraction of external investors (based
	on concession agreements and public-private partnerships)
Socioenvironmental	Ensure the stable quality of water supply services provided to consumers through
	the introduction of advanced achievements of scientific and technological progress
	(introduction of closed-cycle technologies to rationalise the use of resources at all
	stages of the water supply process); form a culture of careful water consumption
	among consumers of drinking water
Organisational and	Improve the management system through the organisation of additional training
managerial	programs for senior management and improve missions, vision, values and culture of
	the water supply enterprise aimed at rationalising the use of resources

Table 5. Approaches to increase the efficiency of the use of innovation and resource potential

of potential exporters. Vasilieva et al. (2020) evaluated development projects at chemical enterprises using key performance indicators, such as net discounted income, internal rate of return, profitability index and discounted payback period, to improve the efficiency of development and implementation of innovative products. Stewart et al. (2018) analysed the sustainable development of large companies, focusing on assessing the combined economic, social and environmental successes of a business.

However, in general, the results of the study showed the impact of innovation and resource potential on the selected financial, social and environmental indicators of the water supply enterprise.

6. Conclusion

The contributions of this study are as follows:

- 1. The key indicator reflecting the current and future capabilities of the enterprise is its potential. Under constant change and uncertainty from the external environment for the sustainable development of an enterprise, including water supply enterprises, it is advisable to consider innovation and resource potential and evaluate it.
- 2. The most complete idea of the innovation and resource potential of the enterprise can be given by an integral indicator that includes different types of potential (subpotentials). For the example of the water supply enterprise, seven subpotentials were selected, each of which characterises its own system of indicators developed by the authors. The study assessed the integral indicator.
- 3. The regression models constructed in the study showed the direct influence of the innovation and resource potential of the water supply enterprise on such effectiveness indicators as profit

and revenue and the reverse effect on the indicators of water loss during transportation and total water loss, costs and the volume of water consumed.

4. Of interest for further research is the assessment of the impact of human potential and automation on the potential of water supply enterprises. Since there is currently a rivalry between the educational and personnel as well information and technological potentials, the problem of the role of man in the future has become more relevant than ever.

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The article was submitted 2.05.2021, approved after reviewing 29.06.2021, accepted for publication 10.07.2021.

Статья поступила в редакцию 2.05.2021, одобрена после рецензирования 29.06.2021, принята к публикации 10.07.2021.

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SECTION 3

SUSTAINABLE DEVELOPMENT OF REGIONAL INFRASTRUCTURE

РАЗДЕЛ 3

УСТОЙЧИВОЕ РАЗВИТИЕ РЕГИОНАЛЬНОЙ ИНФРАСТРУКТУРЫ Research article

DOI: https://doi.org/10.48554/SDEE.2021.2.3

RANKING THE REGIONS OF THE NORTHWESTERN FEDERAL DISTRICT AS A SUSTAINABLE DEVELOPMENT POLICY TOOL

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Abstract

he study reported in this paper ranked the regions of the Northwestern Federal District according to the degree of their socio-economic development to evaluate such regions' sustainable development. It used a ranking algorithm to calculate the socio-economic development indices. The index of economic development of a region is calculated not only through the given average per capita values but also through the average values of the financial indicators, considering the number of employed individuals in the region. The index is an integral one, calculated as the sum of the partial integral indices. In this method, various difficult-to-compare indicators can be analysed to measure the degree of sustainable development achieved by the regions. The algorithm relies on balancing the importance of social and economic development. Striking such balance is essential for maintaining sustainable development in the long term. Thus, to calculate the final index of socio-economic development considering both social and economic development, equal shares are assigned to the components of the index, such as the index of the maturity level of the region's economy and the index of the maturity level of the social sphere. However, if each index is calculated separately, a different set of indicators with various specific weights is used. For example, to measure the index of economic maturity, the index of the industrialisation level in the region and the index of enterprise financial status are considered, and in this case, a greater specific weight is assigned to industrialisation. To calculate the index of the social sphere, the following indicators are considered: the index of the monetary income of the population in the region and the index of the quality of the social situation in the region. All these indices have an additional division according to the method described in the book Investment Potential of the Russian Economy by Bard, Buzulukov, Drogobytsky and Shchepetova (2003). Using the algorithm for calculating the indices of socio-economic development, we can judge the state of the economy and the social sphere at a specific time (in our case, we studied the 2018 data) and their potential for achieving sustainable economic development in the end. The result of the study is the ranking of the regions of the Northwestern Federal District, which considers their socio-economic development and how favourable their climate is for achieving the sustainable development of the territories. The regions that received above-average index values were St. Petersburg, Leningrad Region, Kaliningrad Region and Murmansk Region.

Keywords: region, socio-economic development index, ranking, algorithm for the regional ranking of the socio-economic indices, sustainable economic development.

Citation: Zaborovskaia, O, Zhogova, E., Alamshoev, A., 2021. Ranking of the regions of the Northwestern Federal District as a Sustainable Development Policy Tool. Sustainable Development and Engineering Economics 2, 3. https://doi.org/10.48554/SDEE.2021.2.3



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Научная статья

УДК 332.14

DOI: https://doi.org/10.48554/SDEE.2021.2.3

РАНЖИРОВАНИЕ РЕГИОНОВ СЕВЕРО-ЗАПАДНОГО ФЕДЕРАЛЬНОГО ОКРУГА КАК ИНСТРУМЕНТ ПОЛИТИКИ УСТОЙЧИВОГО РАЗВИТИЯ

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Аннотация

татья посвящена ранжированию регионов СЗФО по их социально-экономическому развитию. Новизна данного исследования заключается в том, что для ранжирования применен алгоритм расчета индексов социально-экономического развития, при этом индекс развития экономики региона рассчитывается с учетом не только среднедушевых значений, но и средних значений финансовых показателей с учетом числа трудоустроенных в регионе. Рассчитываемый индекс является интегральным и строится как сумма частных интегральных индексов. Метод позволяет использовать различные трудносопоставимые показатели. Данный алгоритм построен на сбалансированной важности как социального, так и экономического развития, в связи с этим при расчете итогового индекса социально-экономического развития, объединяющего обе эти сферы, его составным частям, а именно индексу уровня развития экономики региона и индексу уровня развития социальной сферы присвоены равный удельный вес. Однако для расчета каждого индекса в отдельности применены различный набор показателей с различными удельными весами, такими как для индексу уровня развития экономики: индекс уровня развития производства в регионе и индекс финансового состояния предприятий, в данном случае больший удельный вес присвоен уровню производства, для расчета индекса социальной сферы рассматриваются показатели: индекс уровня денежных доходов населения в регионе и индекс качества социальной обстановки, все указанные выше индексы имеют дополнительное подразделение согласно методики описанной в книге «Инвестиционный потенциал Российской экономики» Бард В.С., Бузулуков С.Н., Дрогобыцкий И.Н., Щепетова С.Е. Алгоритм расчета индексов социально-экономического развития позволяет выявить уровень состояния экономики и социальной сферы на конкретный момент времени (в нашем случае изучались данные 2018 года), рассчитанных на основе формализованных показателей. Результатом исследования стал рейтинг регионов СЗФО по их социально-экономическому развитию, а именно регионами, получившими значения индекса выше среднего, стали Санкт-Петербург, Ленинградская область, Калининградская область, Мурманская область.

Ключевые слова: регион, индекс социально-экономического развития, ранжирование.

Цитирование: Заборовская, О., Жогова, Е., Аламшоев, А., 2021. Ранжирование регионов Северо-Западного федерального округа как инструмент политики устойчивого развития. Sustainable Development and Engineering Economics 2, 3.

https://doi.org/10.48554/SDEE.2021.2.3

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1. Introduction

Today, to encourage the sustainable economic development of a territory, many factors that interact with each other and are simultaneously influenced by the global and virtual environment have to be considered. Accordingly, the parameters that reflect these changes and also the weaknesses and strengths of territories need to be identified.

The study reported in this paper (our study) was about measuring the sustainable development of a region and was based on the research on the region's social and economic spheres. In particular, it focused on deciding how to choose the factors to be included in the analysis of the statistical data of the region in terms of their validity and specific weights. Accordingly, the object of our study was the analysis of the possibility of achieving sustainable socio-economic development in a region using an algorithm for calculating integral indices.

Extensive statistical data are used to study the dynamics of change in the state of the so-cio-economic environment of a region, considering the relationships existing between them. The results obtained can be matched with the global economic changes, and the possibility of implementing government programs aimed at sustainable socio-economic development can be explored. However, the data array as such is neutral, and it is the research method that determines the results it can demonstrate. Hence, a problem arises regarding how to select a specific range of indicators that will reflect the changes taking place in the economic and social spheres and that can be used to balance the economically and socially significant factors with specific weights attached to them.

Foreign and national studies suggest that regional government bodies should track a region's rank in the national and world economy (Yakimchuk et al., 2021) in accordance with the available resources. The quantitative estimates obtained should be used for making informed management decisions, reducing the negative consequences and maximising the opportunities for the region's sustainable development (Andra-Madalina, 2014). Furthermore, the focus in studying regional inequality shifts from the economic factors to the social ones and to the ways of more effectively influencing the development of the regional economy through the better living standards of the population and an improved social sphere. It is essential to analyse the factors affecting the regional economy in the long term (Lvov et al., 2004). Therefore, some algorithms have to be created for the integral assessment of the socio-economic state of the region, with the indicators selected being well balanced in relation to each other so that the economic situation in the region can be realistically reflected.

2. Literature review

Investigating the socio-economic states of regions and ranking them on the basis of the results obtained is one way of deciding on the scope of sustainable development programs for a particular territory and of choosing the sustainable development policy priorities for the targeted financial support of the regions to be provided by the federal government.

Regional socio-economic systems are affected by many factors. These factors are interconnected and are influenced by both the global and virtual environments, which causes changes in the operation of the economic entities in the regions (Zuti, 2018). Accordingly, the parameters that reflect these changes must be identified and the weaknesses and strengths of regions must be assessed and considered in the formulation of the sustainable development policies of regions.

The changes occurring in the state of regional socio-economic systems can be evaluated if the dynamics of the statistical data are analysed. Such analysis can also determine the impact of the global environment and world trends on the region.

A number of research algorithms can be used to generalise and structure statistical data so that the various economic aspects of the sustainable development policies being pursued in different territories can be studied using a list of concrete indicators.

In our study, statistical indicators were the bases of the algorithm that was used for calculating the index of socio-economic development of the regions of the Northwestern Federal District (NWFD). This algorithm involves calculating the indices of maturity of the economy and social sphere of the region¹.

It is important to study the socio-economic development of regions because it is the 'socio-economic modernization' of the economy that can result in an increase of some indicators in the region, such as income and employment (Obasaju et al., 2021). The sustainable socio-economic development of the region, however, is a major issue (Martin and Sunley, 2015).

A number of Russian and foreign researchers have brought up the question of what the drivers of regional development² are in the context of sustainable development policy. One of such drivers can be an agglomeration effect (Wu et al., 2014) and the cluster approach (Kourtit and Gordon, 2019). In addition, we agree that the key driver can be the possibilities of human capital (Gordon and Kourtit, 2020; McCool and Kruger, 2003). Human capital is also quite important in the transformation processes occurring in a country (and in a region as its integral part) caused by new economic realities and innovations (Smetkowski, 2015).

In addition, it is highlighted that there is a need to separate the power and responsibilities for socio-economic development and the priority areas of the region's sustainable development policy not only at the federal level but also at the regional and municipal levels (Yakimchuk et al., 2021; Tatarkin, 2016). It is important to decide on the priorities for the economic development of the country as a whole and of a concrete territory therein in particular, according to the priorities that have been chosen.²

The aforementioned hypothesis is confirmed in the book *Strategic Management: Region, City, Enterprise* written by Lvov, Granberg et al. (2004). According to the said book, it is reasonable to relate global problems with local ones, such as problems arising in the social sphere of a city (Lvov et al., 2004). Thus, if local problems are investigated, the economic problems existing in a particular territory and in a specific industry can be studied in a more in-depth way.

Some national studies have pointed out that it is hard to analyse the state of the regions because of various factors, which are multidimensional and multidirectional. Thus, regional statistics should be considered to identify and evaluate the scales and directions of internal processes. After that, priority areas should be chosen by comparing, ranking and grouping the development levels of the region according to the characteristics selected (Pascariu et al., 2020). The method suggested in this study relies on the synthesis of the results of the analysis of objective (regional) factors (the geography and history of the region) and the specific development conditions in the region (economic, social, financial and other components) to carry out a summary assessment of the state of the region.

Some authors highlight the need for sustainable development policies to be based on the predicted general economic, sectoral and regional proportions. For example, when the country's development is projected, an indicator that characterises the standard of living of the population in each specific region,

¹ Bard, V.S., Buzulukov, S.N., Drogobytsky, I.N., Schepova, S.E., 2003. The Investment Potential of the Russian Economy. Moscow: Examen. URL: https://search.rsl.ru/ru/record/01002355429

² Chernyak, V.Z., Chernyak, A.V., Dovdienko, I.V., 2010. The Economy of a City. Moscow: KNORUS.

etc., should be considered to a certain degree (Tyutin et al., 2019). In addition, the development forecast should take into account the micro and macro constraints, such as inflation, unemployment, poverty and social factors. It is pointed out that the factors of social and individual development have a great impact on the level of the country's economic potential and on the degree of sustainability of its development in the long run. Regional government bodies need to objectively evaluate the region's position vis-à-vis other territories and given the available resources. They should use objective quantitative data to manage the risks and to minimise the effects of negative factors.

Some studies have acknowledged the need for a region to choose its own model of economic behaviour given its competitive advantages. At the same time, the federal centre should aim at minimising the differences in the living standards of the people in various regions, taking into account their economic development level and unique natural resources.

Some foreign studies have focused on studying regional inequality, its causes and the factors leading to its growth. Sustainable development of territories is the key to achieving high living standards. This opinion is widespread both in Russia and abroad (Yakimchuk et al., 2021). It is stated in particular that the state needs to monitor the dynamics of the changes in the causes of these differences and to assess the influence of political institutions (distribution of power among the regional government bodies and tax deductions among the regions), world trade and the ability of economic entities to make a profit in a particular region, depending on the economic conditions in such region (Kim, 2008).

The review of foreign studies in our study was partially based on classical models used to evaluate the causes of regional inequality. The key factors are the geographic location of the region, the maturity of its infrastructure and the production costs. Today, these ideas are supplemented by the investigation of the social indicators of the people's living standards because these can significantly expand the production potential of the region due to the growth of the quality of human capital (Capello and Nijkamp, 2009).

Previous studies have described the methods used for assessing the statistical indicators and investigating the dynamics and structure of the gross regional product (GRP), consumption indicators, unemployment rate, labour migration and availability of social services (Zhogova et al., 2020). We should clearly highlight the statements about the different interpretations of the values of the indicators and their dynamics in the long and short run (Zhalsaraeva and Dugarzhapova, 2020). Thus, in the short run, the dynamics can be interpreted as negative (Song et al., 2019). However, if we assess, for example, the ratio of labour productivity, the development of education and the introduction of new technologies (Yu et al.), the results in the long term can be interpreted as diametrically opposite (Magomedov et al., 2020).

The significance of the social factors of regional development can be evaluated on the basis of a range of indices, such as the Labor Force Survey (LFS), the Statistics on Income and Living Conditions, the Inclusive Society Index and other indices aimed at measuring the population's income level, health-care level, environmental indicators, and other factors. These factors must be considered when assessing regional development because the people's high standard of living is a catalyst for economic growth (Medgyesi et al., 2017).

3. Methodology

The algorithm for calculating the indices of socio-economic development can be used to identify the levels of the economy and the social sphere at a specific time (in our case, the 2018 data were studied). The indices are calculated using formalised indicators, and help us assess the chances that a sustainable development policy will be pursued in a given territory. The index to be calculated is integral and represents the sum of partial integral indices. Various hard-to-compare indicators can be used in this method.

The indices consider the development level of the region and that of the national economy as a whole (this value is considered equal to 1).¹

The aforementioned method uses the indices demonstrating the level of socio-economic development of regions (I_{Ej}); in this study, the regions of the NWFD in Russia. The index is the sum of the indices indicating the development levels of the social sphere and the economy of a particular region. Each of the indices is assigned an equal specific weight amounting to 0.5.

In turn, each of the sub-indices, which are used to calculate the indices of the social sphere and economic development, is the sum of the relative values estimated from the statistics of the region and has a certain specific weight. For example, to calculate the Economic Development Index, we have to count the Production Index (Ii_j) and the Enterprise Financial Status Index (If_j) . The Production Index consists of the sum of the following indicators per capita: industrial production of region (I_j) , construction (C_j) , agricultural produce (AX_j) , and retail goods turnover (T_j) . The Financial Status Index consists of the volume of indicators, such as the amounts of profit (loss) made by the enterprises (P_j) in the region and the amounts of overdue receivables and payables (Z_j) per employed person. The initial method used indicators per employable person, but we believe that if the indices are calculated given the number of employed people, it can paint a better picture of the region being studied because the values obtained pertain to the people engaged in the economy of the region (e.g. production of goods, work and services), and correspondingly, we can indirectly measure how effectively the human resources are used in the region's economy.

All the above values were calculated in this study as a ratio of the regional values to the all-Russian ones. The following specific weights were assigned: 0.33 for the Financial State Index and 0.67 for the Industrialization Index. The index values were calculated according to the basic method, and were not changed.¹

The levels of economic development of the Russian regions as of year 2018 are presented in Table 1.

To compute the Social Sphere Index (Is_j), we calculated the Social Environment Index (Ie_j) and the Population Monetary Income Index (Im_j). The prevailing specific weight (0.65) was assigned to the Monetary Income Index while the other index was appraised as 0.35.

The indices are calculated given the deviations of the regional values along the country as a whole. Income $(I\partial_j)$ and average salary (Sc_j) are calculated given the values per capita and the size of the regional minimum wages. The Social Environment Index consists of the indicators of housing provision H_j , unemployment rate U_j , and crime rate C_j . Here, the specific weights remain unchanged according to the basic method, and are evenly distributed among the indicators.

4. Results

We chose the NWFD in the context of its regions as the object of our study. The range of the main indicators used in the analysis included the volumes of industrial production, construction, production of the main types of agricultural products and retail goods turnover; the indicators of companies' financial performance and the size of overdue receivables and payables. The indicators were calculated given the population size of every region while some indicators considered the size of the employed population in the region. Then the indicators of the NWFD regions were compared to the data for Russia as a whole³.

According to the above indicators, the constituent indicators of the Industrialization Index and Financial Status Index of enterprises in the NWFD were calculated (Figure 1).

³ Committee for Economic Development and Investment Activities in Leningrad Region URL: https://lenobl.ru

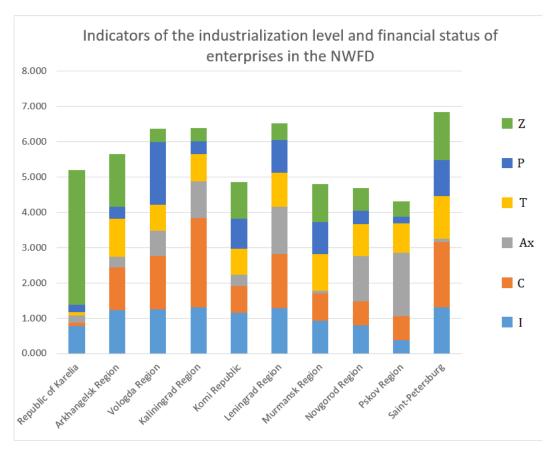


Figure 1. Industrialisation level and financial status of enterprises in the regions of the Northwestern Federal District. Source: compiled by the authors.

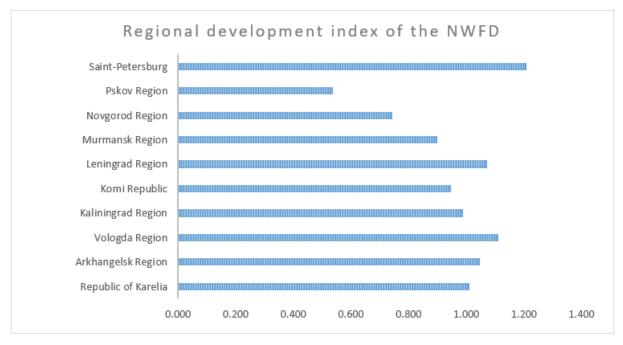


Figure 2. Regional Development Index of the Northwestern Federal District. Source: compiled by the authors

The indices were interpreted according to the 'Investment Potential of the Russian Economy' method worked out by Bard, Buzulukov, Drogobytsky and Schepetova (2003). All the indicators were based on the calculation of the ratio between the regional and Russian indicators: I was the volume of industrial production per capita, C the volume of construction per capita, Ax the volume of agricultural produce per capita, C the volume of retail goods turnover, C the amount of profits to losses from all types of economic activity per employed person and C the amount of overdue receivables and payables calculated per employed person.

Then, according to the calculation algorithm, the values of the Industrialization Index (I_{i_j}) , Enterprise Financial Status Index (I_{f_j}) and Final Regional Development Index (I_{E_j}) ; this unites the data of the first two aforementioned indices) indicators were given. The intermediate values of indices (I_{i_j}) and (I_{f_j}) were united in the bar chart of the ranked NWFD regions according to the indicators of the Regional Development Index (I_{E_j}) presented in Figure 2.

Thus, according to the above data, St. Petersburg is in the first place, followed by Leningrad Region in the second place and Vologda Region in the third place.

Leningrad Region has higher indicators, but given the larger size of its population (1 867 000) against Vologda Region's 1 167 700, the gap turned out to be insignificant because the indicators were relative rather than absolute.

Then, to compute the development level of the NWFD regions' social sphere, the indicators shown in Figure 3 were calculated.

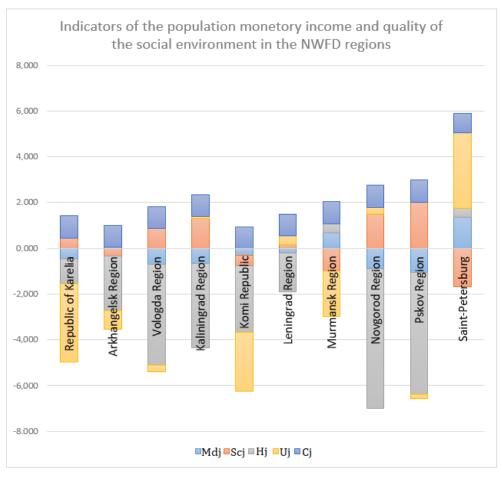


Figure 3. Population monetary income and quality of social environment in the Northwestern Federal District regions. Source: compiled by the authors

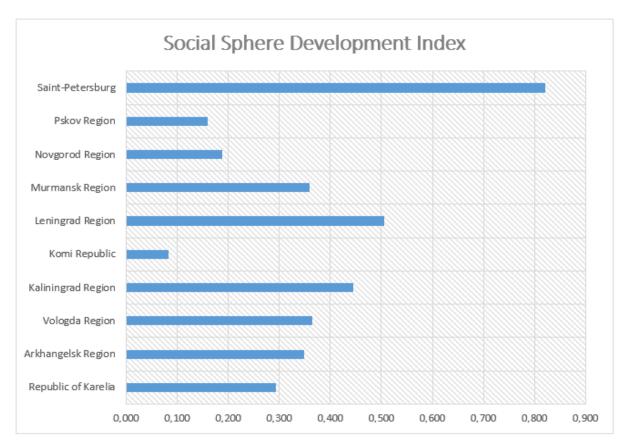


Figure 4. Social sphere development index of the Northwestern Federal District regions. Source: compiled by the authors

As mentioned earlier, the indices were interpreted according to the 'Investment Potential of the Russian Economy' method worked out by Bard, Buzulukov, Drogobytsky and Schepetova (2003). With regard to the following indicators, the values of the region deviated from the Russian values: housing provision per capita (H_j) , unemployment rate (U_j) , crime rate (C_j) , ratio of monetary income per capita to minimum wage $(M\partial_j)$ and ratio of average salary (given the debt) to minimum wage (Sc_i) .

Then based on the given data, we calculated the Social Sphere Development Index of regions *Is_j*. To rank the NWFD regions by the indicators of the Social Sphere Development Index, the results obtained were given in the form shown in Figure 4.

Thus, according to the above data, St. Petersburg is in the first place, and all the others regions are far behind. Leningrad Region is in the second place, Kaliningrad Region is in the third and Murmansk and Vologda Region are in the fourth.

Once again, it must be noted that the figures may differ from the absolute statistical values because they are based on mathematical calculations of the regions' indicators per capita and indicators per employed person.

To assess the validity of the study results obtained, the socio-economic indicators of the NWFD must be briefly reviewed.

Figure 5 shows the specific weights of the land areas of the NWFD regions.

Figure 5 presents the indicators of the distribution of the population size across the NWFD. The consolidated figure of the district's population size was used as a basis, and the specific weight of each region was calculated.

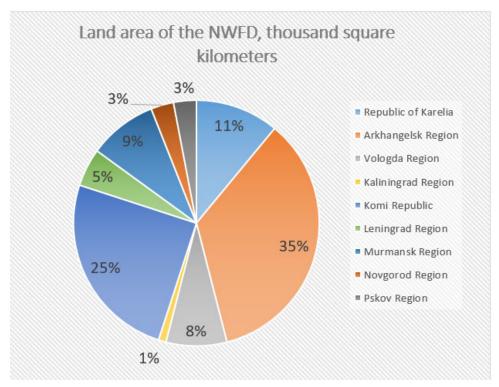


Figure 5. Land area of the Northwestern Federal District, thousand square kilometres. Source: Federal State Statistics Service⁴

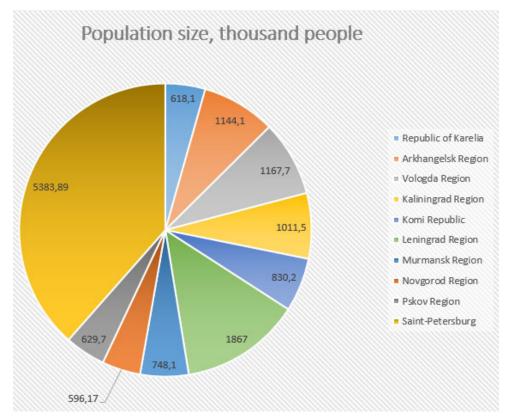


Figure 6. Population of the Northwestern Federal District as of 2018. Source: Federal State Statistics Service.⁴

⁴ Statistics. https://rosstat.gov.ru

Table 1. Socio-economic indicators for 2018, million rubles

Northwestern Federal District regions	Volumes of industrial production, mln. rub.	Volumes of construction, mln. rub.	Volumes of major agricultural produce	Volumes of retail goods turnover
Republic of Karelia	226 673.90	3 582.10	4 347.20	12 439.80
Arkhangelsk Region	668 166.00	77 910.00	12 703.30	262 434.80
Vologda Region	691 100.00	100 981.30	28 870.40	185 839.00
Kaliningrad Region	621 030.00	146 465.90	36 718.00	168 930.30
Komi Republic	527 714.00	42 461.00	11 189.80	154 311.00
Leningrad Region	1 125 100.00	159 950.00	86 800.00	387 800.00
Murmansk Region	327 370.40	32 932.20	1 860.80	169 676.60
Novgorod Region	222 080.70	23 032.90	26 935.50	115 300.00
Pskov Region	113 642.60	24 412.70	39 394.90	112 140.50
SPB	3 301 428.00	572 871.00	15 900.00	1 396 600.00
RF	69 086 000.00	8 385 700.00	5 119 800.00	31 579 000.00

Source: Federal State Statistics Service.4

In addition to the population size, we should consider the data on the major socio-economic indicators given in the statistical digest of the Russian regions' socio-economic indicators for the year 2018 (Table 1).

The statistics that do not consider the social sphere of the NWFD indicate the primacy of St.Petersburg, for example, in terms of industrial production. It is followed by Leningrad Region (second place), Vologda Region (third place), and Arkhangelsk and Kaliningrad Region (fourth and fifth places).

As for the indicators of the social sphere, the following statistics can be presented for the year 2018 (Table 2).

Table 2. Socio-economic indicators for 2018

Northwestern Federal District regions	Population monetary income per capita, rub.	Ratio of average salary (given the debt) to minimum wage	Housing provision indicator, sq. m. per capita	Unemploy- ment rate, %	Crime rate,
Republic of Karelia	29 150.00	4.56	26.90	8.2	4%
Arkhangelsk Region	33 831.00	4.59	28.20	10.6	6%
Vologda Region	26 982.00	4.13	30.20	5.1	5%
Kaliningrad Region	27 461.00	3.72	28.20	4.7	4%
Komi Republic	30 100.00	4.74	28.70	7.4	5%
Leningrad Region	31 341.00	4.86	29.00	4.4	7%
Murmansk Region	41 564.00	4.47	25.40	6.8	4%
Novgorod Region	25 292.00	3.51	31.90	4.5	3%
Pskov Region	23 880.00	3.00	31.10	5	2%
SPB	44 999.00	6.68	25.40	1.5	16%
RF	33 178.00	5.01	25.80	4.80	1.00

Source: Federal State Statistics Service.⁴

⁴ Statistics. <u>https://rosstat.gov.ru</u>

According to the data in Table 7, it can be concluded that in terms of the population monetary income, for instance, St. Petersburg, Murmansk Region and Arkhangelsk Region occupy the leading positions. Correspondingly, the indicators of the social and economic spheres approximate the results of our study.

Let us now analyse the GRP of the NWFD regions and rank them according to this indicator (Figure 7).

According to the data presented in Figure 7, in terms of GRP, St. Petersburg and Leningrad Region are in the first place in the NWFD. Correspondingly, the results of our study are quite realistic, except for an error in the relative indicators and the human factor, and can serve as the bases for learning about the development trends in the territory being studied.

The results of our study include the calculated index of the level of socio-economic development of the NWFD regions. In essence, this index is a comprehensive indicator consisting of indices that take into account the level of economic development and the index of development of the social sphere in the regions. The indicators of the indices can be used to rank the regions, comparable to the ranking built according to the indicators of socio-economic analysis using non-aggregated statistics.

Which weights to assign to the indicators at each stage when this algorithm is calculated, however, are debatable. Assigning a specific weight of 0.5 for the socio-economic development indices of the regions is explainable for the final stage of the calculation because most studies aim to find the golden mean between investing in the economy and investing in social programs. However, the other weights in the algorithm, which we took entirely from the basic method, without any change (Bard, Buzulukov, Drogobytsky, & Shchepetova, 2003), are controversial and have to be substantiated in some way depending on the priority level of a particular indicator.

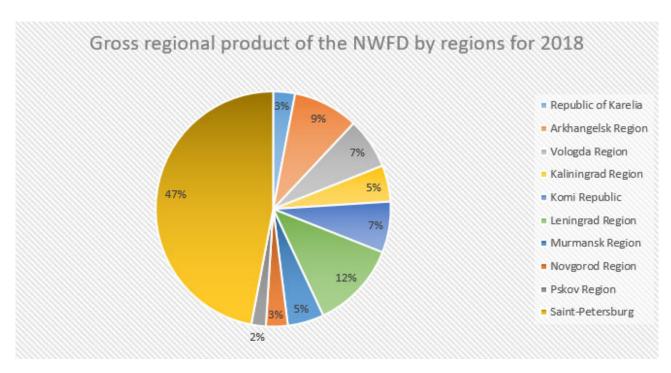


Figure 7. Gross regional product of the Northwestern Federal District by region for 2018. Source: Federal State Statistics Service.⁴

⁴ Statistics. https://rosstat.gov.ru

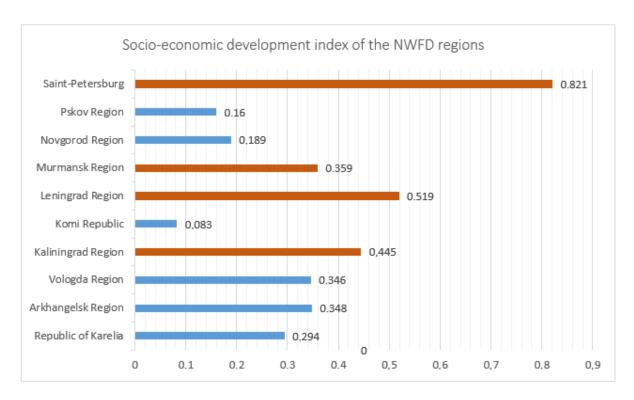


Figure 8. Socio-economic development index of the Northwestern Federal District regions. Source: compiled by the authors

In our analysis, we left all the indices unchanged. The only change that was introduced was that some indicators were calculated not per employable person but per employed person, which slightly changed the study's final results. Nevertheless, at the end of the analysis, the socio-economic development index of each NWFD region (I_j) was calculated, so it is possible to rank the regions by their socio-economic development level and to draw certain conclusions about such regions' potential for achieving sustainable development and for working on the priority areas of the sustainable development policy within the federal state program (Figure 8).

The result of our study can be the following aggregated ranking of the NWFD regions with the greatest potential for pursuing the sustainable development policy priorities. The regions whose index values are above the average (0.356) are considered the most successful in the context of their social and economic development levels. These are St. Petersburg, Leningrad Region, Kaliningrad Region and Murmansk Region. Those that fall below the threshold value are considered successful regions (Arkhangelsk Region and Vologda Region). All the other regions are in a less favourable position and will need more resources to follow the sustainable development policy because their index values are below the average threshold values.

The analysis results in our study approximate reality and can be used to consider incomparable factors, such as the economic and social spheres, to evaluate the level of sustainable economic development of territories.

5. Conclusion

It can be concluded from our study that the causes of the inequality among regions have to be investigated further. Here, both the economic factors and the results of the analysis of the social sphere should be taken into account because it is essential to eliminate the factors leading to a decline in the economic development of a region to be able to adopt a sustainable economic development policy.

The findings of some studies conducted by scientists from various countries show that the growing social satisfaction and security of a region's population can become a more effective leverage for the productive potential of the regional economy than the singular potential for using the factors of geographical location and the calculation of the production cost level (Zhogova et al., 2020; Malgorzata et al., 2018). Moreover, a better standard of living within the context of global trade can further stabilise the socio-economic situation in the region (Medvedev, 2018) and drive its sustainable development, and can lead to progress in the innovative environment (Babskova, 2017). The outcome of this can be the higher morale of the public, economic entities and the country as a whole during times of crisis not only in the economy but also in politics.

It should also be noted that it is essential to establish some common criteria and priorities for the development not only of a region but also of the country as a whole, and to implement the sustainable development programs of a territory at the international level (Bobylev, 2017).

Some studies have shown that gross domestic product growth may not always sufficiently reflect the growth of the Russian economy. It may just be the evidence of increasing prices in the raw materials sector and may not reflect the stagnation of the regional economy (Bobylev, 2017). It is the analysis of the sustainable development of each specific region that will allow the state to choose and implement the sustainable development policy priorities at both the federal and municipal levels in the most efficient way.

The results of the ranking herein analysed according to the indicators of the socio-economic development index of the NWFD regions allowed us to highlight the regions with the greatest potential for implementing the sustainable development policy priorities. The regions with index values above the average are considered the most successful ones at the social and economic levels and include St. Petersburg, Leningrad Region, Kaliningrad Region and Murmansk Region. Those that ended up just below the threshold value, Arkhangelsk and Vologda Region, are also considered successful regions.

In general, the results we obtained in our study approximate reality. The proposed algorithm is suitable for analysing the socio-economic sphere of regions and for deciding if sustainable development can be achieved. It can also be used to consider incomparable factors such as economic and social ones.

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The article was submitted 18.05.2021, approved after reviewing 13.07.2021, accepted for publication 23.07.2021.

Статья поступила в редакцию 18.05.2021, одобрена после рецензирования 31.07.2021, принята к публикации 23.07.2021.

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Research article

DOI: https://doi.org/10.48554/SDEE.2021.2.4

ECONOMIC SECURITY AND INNOVATIVE COMPONENT OF A REGION: A COMPREHENSIVE ASSESSMENT

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Abstract

This article is devoted to designing a comprehensive assessment of the level of economic security of a region, taking into account its innovative component. The relevance of the study is supported by the need for a more detailed consideration of certain aspects of economic security to improve the efficiency of the functioning of the subjects of the Russian Federation and create favourable conditions for their economic development from a strategic perspective. The goal of this article is to determine a comprehensive assessment of the level of economic security of the subjects belonging to the Northwestern Federal District of the Russian Federation, as well as analysing the contribution of each region to ensuring national and economic security. To design a comprehensive assessment of the level of economic security of a region, it is proposed to average the normalized values of all indicators employing the simple average method. The method used is the basis of the rating approach of the European Commission employed for designing a comparative assessment of the level of innovative development of the EU regions, which makes it possible to adapt it to the Russian conditions, taking into account the specifics of the domestic economic system. As a result of the study, the criterion boundaries of the integral indicator for assessing the level of economic security were established, which allowed comparing the territorial entities within the region under consideration and identifying the level of secure development of the territory in the economic sphere. The result of the implementation of the proposed methodology was an assessment of the economic security level of regions. The proposed methodology for a comprehensive assessment of the economic security of the territory is characterized by efficiency, simplicity, and accessibility and also takes into account the innovative aspect of the development of a territory. The results obtained enable one to use the developed methodology to solve a wide range of issues to ensure the economic security of a region.

Keywords: sustainable development of a region, indicators of economic security, threshold parameters, regional infrastructure, innovative component of a region, assessment of economic security.

Citation: Zaytsey, A., Sun, P.K., Elkina, O., Tarasova, T., Dmitriev, N., 2021. Economic security and innovative component of a region: a comprehensive assessment. Sustainable Development and Engineering Economics 2, 4. https://doi.org/10.48554/SDEE.2021.2.4



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Научная статья

УДК 332.14

DOI: https://doi.org/10.48554/SDEE.2021.2.4

ЭКОНОМИЧЕСКАЯ БЕЗОПАСНОСТЬ И ИННОВАЦИОННАЯ СОСТАВЛЯЮЩАЯ РЕГИОНА: КОМПЛЕКСНАЯ ОЦЕНКА

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Аннотация

анная статья посвящена построению комплексной оценки уровня экономической безопасности региона с учетом ее инновационной составляющей. Актуальность исследования подтверждается необходимостью более детального рассмотрения отдельных аспектов экономической безопасности для повышения эффективности функционирования субъектов РФ и создания благоприятных условий их экономического развития в стратегической перспективе. Цель статьи заключается в определении комплексной оценки уровня экономической безопасности субъектов РФ Северо-Западного федерального округ, а также в проведении анализа вклада каждого региона в обеспечение национальной и экономической безопасности. Для определения комплексной оценки уровня экономической безопасности региона предлагается произвести усреднение нормализованных значений всех показателей индикаторов методом простого среднего. Использованный метод лежит в основе рейтингового подхода Европейской комиссии для определения сравнительной оценки уровня инновационного развития регионов ЕС, что позволяет адаптировать его к российским условиям, учитывая специфику отечественной экономической системы. В результате исследования были установлены критериальные границы интегрального показателя оценки уровня экономической безопасности, которые позволили провести сопоставление территориальных образований, входящих в анализируемый регион, и выявить уровень безопасного развития территории в экономической сфере. Представленная методика комплексной оценки экономической безопасности территории характеризуется действенностью, простотой и доступностью, а также учитывает инновационный аспект развития территориального образования. Полученные результаты позволяют использовать выработанную методику для решения обширного круга вопросов обеспечения экономической безопасности региона.

Ключевые слова: экономическая безопасность региона, устойчивое развитие региона, показатели экономиче-ской безопасности, пороговые параметры, региональная инфраструктура, инновационная со-ставляющая региона, оценка экономической безопасности.

Цитирование: Зайцев, А., Сун, П.К., Елкина О., Тарасова Т., Дмитриев, Н., 2021. Экономическая безопасность и инновационная составляющая региона: комплексная оценка. Sustainable Development and Engineering Economics 2, 4.

https://doi.org/10.48554/SDEE.2021.2.4



© Зайцев, А., Сун, П.Х., Елкина, О., Тарасова, Т., Дмитриев, Н., 2021. Издатель: Санкт-Петербургский политехнический универ¬ситет Петра Великого

1. Introduction

Despite the adoption of national and economic security (ES) strategies in the Russian Federation, the fragmented essence of the measures implemented within the framework of these documents is clearly visible. Firstly, it should be noted that there are a number of unresolved problems in the field of ES management of regions: ES indicator systems of development of the subjects of the Russian Federation and municipal entities and their threshold parameters have not been approved, and monitoring studies on the management of ES of territorial entities are imperfect (Moros, 2020). These conditions increase the relevance of creating effective and accessible methodological approaches to assessing the ES of a territory in the system of its ensuring at the regional level.

The purpose of this study is to design a comprehensive assessment of the level of ES of the subjects of the Russian Federation within the Northwestern Federal District (NWFD), taking into account the innovative component, as well as analysing the contribution of each region to ensuring ES at the national level. To this end, the following tasks were solved:

- A system of indicators for assessing the level of ES of a region has been formed, which should contain a minimum list of indicators for a specific time interval (one year in this study), available for processing and corresponding to socioeconomic indicators of the region's development.
- Threshold parameters for the indicators of the ES of a subject of the Russian Federation within the NWFD were established.
- A comprehensive assessment of the level of ES of the subjects of the Russian Federation within the NWFD was designed.

The object of the study is the subjects of the Russian Federation within the NWFD. The subject of the study is the ES of the subject of the Russian Federation. To build an analytical base, the data of the Federal State Statistics Service of the Russian Federation of the NWFD on the socioeconomic situation of the subjects were tested.

2. Literature review

The transformation of economic relations and institutional transformations dictate the need to rebuild the economic system, and the key role in improving economic efficiency belongs to the innovative potential (Rakhmeeva, 2020). In the context of globalization, a powerful innovative potential is needed to ensure the ES of territories, which prevents the emergence of not only traditional but also non-traditional threats: slave trade, international terrorism, shadow international sector activities, production and sale of drugs, cyberattacks, piracy, water shortages, environmental disasters, pandemics, etc. (Greiman, 2015). The increasing importance of intangible assets at the entrepreneurial level also affects the functioning of higher levels of management, including regional structures. Intellectualization as a way of creating innovative capacity is already a driving force for progress and creation of conditions for maintaining the ES (Dmitriev et al., 2020b). However, current ES assessment methodologies are not sufficiently suitable for working out the role of innovative elements in strategic support.

The essence of the ES of the subjects of the Russian Federation lies in ensuring it through the actions of regional authorities and management by effectively employing the socioeconomic potential of the territory, including its innovative potential, which will lead to the acceleration of economic growth,

boost the competitiveness of the region, and ultimately improve the quality of life of the population. The key influence of these elements and the innovative potential itself on the ES indicators of a region has been considered in a number of studies, for example, in Pak et al. (2017), Ivleva et al. (2016), and Pak et al. (2018). The results obtained made it possible to judge the possibility of drawing parallels between the assessment of the safety of socioeconomic development and the effective use of the economic potential of the region, which allows taking into account an expanded number of indicators in the process of improving the quality of the ES indicator system.

Thus, to improve the existing system of ensuring the ES of the region, it is advisable to develop indicator and monitoring systems, which cannot be done without an appropriate integrated assessment apparatus (Denezhkina and Suzdaleva, 2011). The complex assessment of the ES should contain the elements of sustainable development, as without it, forming the approaches and methods of strategic development of a territory in the current macroeconomic environment becomes impossible.

The relationship between sustainable and safe development of the territory is confirmed in many studies, for example, in the work of Kirshner (1998), which necessitates the solution of an entire range of issues related to ensuring the ES of regions, including the problem of assessing its level. Also, his colleagues Neu and Volk are among the few Western authors who, at the end of the last century, noted in their works that one of the main components of national security is socioeconomic security (Neu and Volk, 1994).

A study of current methodological approaches to the assessment of ES showed that most of them employ a list of indicators and threshold values based on the assumption that the value of the corresponding indicator outside the established parameter indicates the emergence of threats to the economic interests of the region (Chernogorskiy et al., 2020; Chueva et al., 2017; Ionova, 2017). From the point of view of the authors, the analysis of the state of ES requires methods that utilize indicators that can provide a more multifaceted assessment and evaluate the qualitative aspects of the negative impact.

In this context, the methodology for assessing negative impacts, based on the tools of probability theory, in which the relationship between the financial resources of the region and business entities is noted, is prospective. However, the complexity of the algorithm for calculating a comprehensive assessment – due to the use of a large amount of information on the state of socioeconomic development of the region, forecasting, and assessing the consequences of negative impacts – complicates its practical implementation and operational management of the region (Feofilova, 2014; Leksin and Profiryev, 2017). A multifaceted methodology for assessing the ES, proposed by Syupova and Bondarenko (2019), which defines the components of the ES of a region – production, scientific and technical, investment, and social and demographic security with the appropriate indicators – is also worth noting. With the simplicity of calculations, the downside of many practical methods lies in the complexity of their implementation due to a significant volume of information.

Many researchers (Dyuzhilova and Vyakina, 2015; Mityakov et al., 2013; Rodionov et al., 2018) have based the formation of ES indicators on the postulate that ES is determined by its potential, ability to ensure protection and sustainable development. Other authors (Cheremisina, 2013; Mojseyenko et al., 2013) have noted that in the assessment of the ES of the region, it is necessary to take into account the level of sustainable growth of the economy, the financial system, the development of scientific potential, etc. In the work of Dyuzhilova and Vyakina (2015), when assessing the ES, "pain points" that can become a source of threats to the region are identified.

In the practice of forming a system of indicators for assessing the level of ES of a territory, scientists do not always include indicators that characterize the innovative level of development of the region, i.e. the innovative component of the ES. Such a flaw is noteworthy since it is the innovative

component that is the key element in the transition of the economy from the extractive path of development to the innovative one, which is important for the Russian economic system. In particular, the need to highlight the innovative component was defined in the "National Security Strategy of the Russian Federation: Decree of the President of the Russian Federation" (2017).

The study of existing methodologies allows us to conclude that there is no universally recognized method for assessing the ES of a region. Therefore, it is advisable to start the search for a complex approach to determining the level of ES of a region, which will enable stakeholders to judge the investment and innovation attractiveness of the region and compare the subjects of the Russian Federation by the level of their ES to determine the contribution of each subject of the Russian Federation in strengthening the ES development of the Federal District and the country as a whole. These conditions are a logical continuation of the research (Pak et al., 2017, 2018).

3. Materials and methods

3.1. Methodology of the study

The study proposes a comprehensive assessment of the level of ES of a region, which is most often used in similar works and meets the requirements presented.

The algorithm for calculating a comprehensive assessment consists of the following stages:

1. Normalization (level of significance) of each indicator will be carried out by determining the ratio of the actual indicator to the threshold parameter (coefficient) if an increase in the corresponding indicator is desirable; if a decrease in the indicator is desirable, then the threshold parameter is correlated with the actual one (e.g. for the level of unemployment, crime, etc. indicators); i.e. the threshold parameter is taken as a unit. The result is an opportunity to move away from the ES assessment by simply analysing the quantities and bringing them to a comparable level relative to the specified thresholds.

In this manner, a type of grouped indicator comparable in strategic areas provides an opportunity to conduct a comparative analysis and determine criteria that reflect the state of regional security. Meanwhile, normalizing and determining the level of significance is possible on the basis of various criteria, the formation of which is built both on the basis of an in-depth analysis of particular indicators and by constructing integral metrics. At the same time, the ratio of actual and threshold values will facilitate a systematic approach to the assessment of indicators that have mathematically determined units of measurement and allow normalization relative to the threshold value, which is taken as a unit.

2. A comprehensive assessment of the level of ES of a region is determined by averaging the normalized values of all indicators using the simple average method. This method is the basis of the rating approach of the European Commission for designing a comparative assessment of the level of innovative development of the regions of the European Union.

The scale of the proposed integrated assessment of the level of ES of a region is adaptive and can be subject to significant dynamics depending on the average values at the interregional level. At the same time, this approach allows taking an objective look at the essence of ES, highlighting the problematic position of the attributes of regional stability. The obtained values provide an opportunity to design mechanisms for identifying and responding to real and potential threats in the ES system, determining the presence of interval deviations from the reference values of ES (Shokhnekh et al., 2020). A comprehensive assessment is based on a number of coefficients that can be changed to provide more complete calculations of sustainability and security at the regional level (Edmonds et al., 2017).

The methodological basis for determining the sustainability and safety of territorial development is the use of specified indicators and integral criteria. At the same time, indicators should be considered through an analysis of growth rates since obtaining quantitative data may not always lead to the possibility of developing objective recommendations. In many respects, integral criteria provide a fairly clear and rational management basis, which is useable for mathematical calculations of the ES. However, the integral criteria are not sufficiently developed in the methodology – only in the case of the correct adjustment of the coefficients, it becomes possible to obtain a balanced assessment and identify bottlenecks in the ES (Senatro et al., 2015; Foltin, 2017). Thus, the study of the ES of a region determines the relevance of studying a broad range of indicators, which, through the calculation of indicators, provides specific information on key aspects of the socioeconomic state of the territory. Making this model more complex will provide the opportunity to calculate the ES of both the region as a whole and its individual component indicators, the monitoring of which, to a greater extent, reveals the nature of the ongoing processes and reflects the causes or consequences of existing threats. Consequently, the complications of a comprehensive assessment by analytical and information indicators strongly complement the overall picture of the state of the ES of regions and the course of processes.

3.2. Innovative development index (IDI) calculation method

The study employs the IDI of a region, which is determined through the rating method. This method is a product of the collective work of the Association of Innovative Regions of Russia (AIRR), the Ministry of Economic Development of the Russian Federation, and the administrations of the subjects of the Russian Federation¹. The method is based on determining the level of innovative development of a region using 29 indicators and is used by the regions as a real management tool. The basis for the formation of this rating is the methodological approach of the European Commission, using which a comparative assessment of the level of innovative development of the EU regions is determined. The methodology for forming the rating of innovative subjects of the Russian Federation is scientifically substantiated and uses official statistical data of the Federal State Statistics Service.

The methodology consists of the following blocks:

- 1. The "research and development" block consists of indicators, the main of which are the following: internal costs for research and development as a percentage of gross regional product (GRP), %; share of funds of business organizations in the total volume of internal expenditures on research and development, %; the number of articles published in journals indexed in WoS (Web of Science) to the number of researchers; the number of international PCT (Patent Cooperation Treaty) applications submitted to the workforce numbers (EAN economically active population), etc.
- 2. The "innovative activity" block consists of the following indicators: the share of organizations that carried out technological innovations in the total number of organizations, %; the share of innovative goods, works, services in the total volume of shipped goods, works, services, the volume of revenues from the export of technologies in relation to GRP; the intensity of expenditure on technological innovations, %, etc.
- 3. The "socioeconomic conditions of innovative activity" block consists of the following indicators: the coefficient of renewal of fixed assets; GRP per person employed in the economy; the share of people employed in high-tech activities in the total number of people employed in the economy; the share of products of high-tech industries in the GRP, %; the share of organizations that used the Internet at a speed of at least 2 Mbit/s in the total number of surveyed organizations, etc.

¹ Rating of Innovative Regions of Russia [WWW Document], 2018. Association of Innovative Regions of Russia. Available at: http://www.gks.ru

4. The "activity of the region in the innovation sphere" block consists of the following indicators: the volume of budget investments (federal budget) in the regional innovation sphere to the volume of GRP; the level of innovative activity of the authorities and management of the constituent entities of the Russian Federation; the degree of participation of corporate structures in the development of clusters and technoparks, etc.

According to the rating results, the group of strong innovators is headed by St. Petersburg. In total, this group includes eight subjects of the Russian Federation: St. Petersburg, the Republic of Tatarstan, Moscow, Tomsk, Novosibirsk, Kaluga, the Moscow Region, and the Nizhny Novogorod Region. The Ulyanovsk, Lipetsk, Samara, Tyumen Regions, the Republics of Bashkortostan and Mordovia, the Perm and Krasnoyarsk Territories, and others (a total of 21 subjects of the Russian Federation) make up a group of medium-strong innovators. Altai, Stavropol, Krasnodar Territories, Irkutsk, Kirov, Leningrad, Arkhangelsk, Kursk and Kurgan Regions, and others (a total of 21 subjects of the Russian Federation) make up a group of medium innovators. Sevastopol, the Republic of Crimea, the Khanty-Mansi Autonomous Okrug-Yugra, and others (a total of 26 subjects of the Russian Federation) represent a group of medium-weak innovators. The group of outsiders is headed by the Nenets and Chukotka Autonomous Okrugs and the subjects of the North Caucasus.

The top three in sub-rankings are the following:

- 1. Moscow, St. Petersburg, and Tomsk region in the field of research and development
- 2. Republic of Tatarstan, Nizhny Novgorod region, and St. Petersburg in the field of innovative activities of organizations
- 3. Moscow, Kaluga region, and St. Petersburg in the field of creating socioeconomic conditions for innovation
- 4. Novosibirsk and Tomsk regions and the Republic of Tatarstan in the field of innovative activity of the subject of the Russian Federation

The presented analytical tool for determining the level of innovative development of the region clearly shows the regional authorities and management, the strengths and weaknesses of innovation systems, and the directions and dynamics of innovative development in all established indicators. It is also possible to determine that the innovation component plays a strategic role in ensuring ES and implementing the concept of sustainable development of the territories of the Russian Federation. Nevertheless, in the ongoing studies of assessing the level of ES, this aspect is practically not taken into account, which creates inaccuracies in making organizational decisions on the management of territories.

3.3. Approaches to solving problems

To assess the level of ES of a region, a number of indicators and threshold parameters from the methods of Abalkin (2002) and Glazyev (1997, 2015), ES indicators of Oleynikov (2014), and socioeconomic indicators presented in the Strategy of Economic Security of the Russian Federation for the period up to 2030 and the Strategy for Socioeconomic Development of the Northwestern Federal District² are used. Aggregation of various indicators allows justification of the most significant parameters for characterizing a particular region by the level of its ES. At the same time, within the framework of the study, it is proposed to construct the author's approach on the basis of the use of generally accepted and well-established scientific tools. However, calculation of the ES is often carried out to determine the state of economic insecurity, for example, by forming index metrics and identifying problem states

² On approval of the Strategy of Socio-economic Development of the North-Western Federal District for the period up to 2020: Order of the Government of the Russian Federation N 2074-r, 2011.

(Hacker et al., 2014). Improving metrics and departing from the standardized integral approach allow forming a new potential for "convolution" of indicators that can be interchanged, which will provide certain opportunities for reduction of correlation influence of one of the normalized indicators and will ensure its full compensation through the allocation of new values of normalized indicators, setting their high importance for obtaining a comprehensive assessment.

These include the following indicators:

- 1. GRP per capita. This reflects the level of the economic potential of the region. A multi-criteria security assessment includes an assessment of the economic potential of the region and determines the effectiveness of its application. The economic potential determines the material base for the secure development of the territory. When determining the effectiveness of using the economic potential of the territory, a search for reserves by the main factors affecting the level of security of the region's development is conducted (Ivleva et al., 2016). The threshold parameter is the highest value of this indicator among the regions (GRP per capita of the Nenets National District); i.e. the method of analogies (comparison of indicators with reference values) is used.
- 2. Industrial production index (IPI). It characterizes the dynamics of industrial production and reflects the change in production volumes in key industries, such as mining, electric power, gas and water supply, and manufacturing industries. The added value of these industries is the GRP of the region. Consequently, when the growth rate of the IPI is greater than the growth rate of the GRP and the GDP, then these industries are increasing the volume and production rates; otherwise, the industries are in the stage of reducing the growth rate of production. The threshold parameter is taken as the highest IPI among the regions of the Russian Federation (115% in the Krasnodar Territory).
- 3. Labour productivity index (LPI). It is the main indicator of the effectiveness of a region's management, which significantly affects the pace of economic growth. In accordance with the methodology of the Federal State Statistics Service³, it represents the ratio of the GRP physical volume index to the total labour cost index for the region. Stakeholders pay special attention to this indicator. The threshold parameter is the highest LPI among the regions (113% in the Jewish Autonomous Region).
- 4. Degree of depreciation of fixed production assets. This is one of the key indicators of industrial safety; therefore, an important problem in managing the socioeconomic development of the region is the determination of the optimal ratio of investments in fixed assets, which is directed to the expansion, reconstruction of the main production, and new construction, since the degree of depreciation of funds can be used to judge the competitiveness of the industrial complex of the region. The threshold parameter is 60% (Glazyev, 1997).
- 5. The ratio of investments to the GRP. Investments in fixed assets determine the efficiency of the real sector of the economy. On the one hand, an increase in the volume of investments in fixed assets increases the volume and growth rate of the GRP; on the other hand, the growth in the volume of the GRP creates conditions for future investments. Also, the growth in the volume of investments in fixed assets is the main factor in the technological development of the industrial complex of the region. The threshold parameter is 25% (Glazyev, 1997).
- 6. Innovative development index (IDI). Using the IDI, the level of innovative development of the region is determined. As a real management tool, the IDI is defined using 29 indicators, which are grouped into the following blocks: research and development, innovative activity, socioeconomic conditions of innovation activity, and activity of the region in the innovation sphere. The threshold parameter is the highest IDI (0.68 in St. Petersburg).

³ On approval of the methodology for calculating the indicator "labour productivity index": Order of Rosstat, 2018.

- 7. Unemployment rate. This determines the threat to the ES of the region in the social sphere. This indicator can be used to judge not only the state of the labour market but also the state of social health of the population living in the region. The unemployment rate is the ratio of the number of unemployed to the number of workforces (EAN) in percentage. The threshold parameter is 8% (according to the research of the International Labour Organization).
- 8. Fund ratio. This determines the level of social stratification. A sharp differentiation of the incomes of the population in the regions of the Russian Federation negatively affects the economic growth of the territories. This indicator is determined by the ratio of the average level of monetary incomes of 10% of the population with the highest incomes to 10% of the population with the lowest incomes. The threshold parameter is 10:1, based on international comparisons (Mityakov et al., 2013).
- 9. Share of population living below the poverty line. As one of the negative factors of the ES of a region, this creates conditions for the emergence of social conflicts in society. This indicator is determined by the ratio of the number of people whose incomes are below the subsistence minimum to the total number of the population in percentage. The threshold parameter is 10%, based on international comparisons (Mityakov et al., 2013).
- 10. Crime rate. This is one of the negative factors of the ES of a region. The increase in the crime rate is influenced by the growth in the number of people living below the poverty line and the number of unemployed. This indicator is determined by the sum of the crimes committed and their participants per certain population, for example, per 100 thousand people. The threshold parameter is 5 thousand crimes per 100 thousand people (Glazyev, 1997).
- 11. Life expectancy at birth. It is a social indicator of the ES used to assess public health. Life expectancy at birth is the number of years that an average person from the generation of births would have to live, provided that, throughout the life of this generation, age-related mortality remains at that level (Glazyev, 1997). The threshold value is 70 years.
- 12. Level of debt burden. The growth of this indicator indicates the emergence of a threat to the ES. In the Strategy of Economic Security of the Russian Federation until 2030, this indicator is absent; however, the high level of the debt burden creates conditions for the emergence of threats to the financial security of the region. This indicator is the ratio of the region's public debt to its own budget revenues in percentage. As a threshold parameter, we use the lowest value of this indicator among the regions (2.8% in the Leningrad region).

The above list of indicators can be used in the system of indicators for assessing the level of ES of a region since they fully reflect the specifics of the activities of the territories. The number of proposed indicators corresponds to the recommended standards for conducting reasonable calculations without unduly complicating the calculation system. At the same time, it is advisable to expand the methodology for taking into account the parameters of the region in the future, in particular, by taking into account specialization and differentiating states; however, such an approach will lead to a complication of the methodology and will not allow obtaining brief data for comparative analysis. The main advantage of the presented minimum indicators is the possibility of their rapid processing by specialists, practitioners, and novice researchers without the use of special technical means, which will allow us to assess the socioeconomic development of a region in the time interval under consideration and draw conclusions for comparative analysis without excessive in-depth study.

	Threshold	Complex ass	essment of the Republic of	Table 1. Complex assessment of the level of ES of the subjects of the Kussian Federation in the NWFD for 2019 threshold Republic of Republic of Arkhangelsk Vologda Kaliningrad Leningrad Murmansk Novgorod F	or the subje Vologda	cts of the Kuss Kaliningrad	sian rederat Leningrad	ion in the N	W FD Tor 20	Pskov	,
	parameter	Karelia	Komi	Region	Region	Region	Region	Region	Region	Region	St. Petersburg
GRP per capita, % of the highest in the Russian	100	90:0	0.108	0.102	0.068	0.067	0.085	0.094	0.070	0.038	0.116
IPI, %	115	0.90	0.885	0.860	0.917	0.893	0.910	0.909	0.883	0.890	0.914
LPI, %	113	0.92	0.881	0.921	0.909	0.910	0.934	0.904	0.927	0.919	0.888
Degree of depreciation of fixed assets, %	09	1.15	1.220	1.169591	1.156069	1.899	1.351	1.357	1.3071895	1.3071895	1.500
Ratio of investment to the GRP, %	25	0.65	0.882	1.029	1.176	1.250	1.934	1.297	0.886	0.827	0.773
IDI	89.0	0.49	0.515	0.603	0.544	0.559	0.603	0.500	0.662	0.456	1.000
Unemployment rate, %	∞	0.92	1.096	1.250	1.569	1.702	1.951	1.176	1.905	1.404	5.333
Fund ratio	10	1.06	0.800	0.800	0.980	0.952	0.893	0.952	1.020	0.990	0.680
The share of the population living below the poverty line, %	10	0.64	0.671	0.741	0.735	0.730	1.190	1.010	0.725	0.588	1.515
Crime rate, amount of crimes per 100 000 people	2000	2.60	2.513	2.914	3.294	3.621	4.184	3.117	2.786	3.997	5.203
Life expectancy at birth, years	70	1.01	1.015	1.030	1.020	1.042	1.044	1.024	1.004	1.002	1.085
Debt burden level, %	2.8	0.04	0.079	0.052	0.092	0.049	1.000	0.089	0.041	0.036	0.528
Complex assessment of the level of ES of the subject of the Russian Federation		0.87	0.89	96.0	1.04	1.14	1.34	1.04	1.02	1.04	1.63

4. Results

The results of the analysis are summarized in Table 1, which presents a comprehensive assessment of the level of ES of a region and the normalized values of indicators.

- 1. St. Petersburg, the leader among all regions of the country in IDI (0.68), holds the first place in terms of the ES level. It is taken as a threshold parameter for this indicator. A high IDI has a positive impact on the value of the comprehensive assessment. This once again confirms that the innovative component is one of the key factors in ensuring ES. A sharp differentiation of federal districts by the level of economic development demonstrates that a high degree of innovative development is observed only in the locomotive regions (Moscow, the Moscow Region, the Republic of Tatarstan, the Kaluga Region, etc.): in the Central, Northwestern, and Volga Federal Districts. The IDI, together with the lowest unemployment rates, poverty, and crime in the NWFD and the highest life expectancy and the lowest level of debt burden, puts St. Petersburg in the first place in terms of ES.
- 2. The second place is occupied by the Leningrad region. This region, in difficult economic conditions for the country, has maintained social stability and positive dynamics of development. During the analysed year, the main task of the budget policy of the Leningrad region - ensuring balance and maintaining financial stability - was successfully implemented. Since 2002, this region has been a financial donor. However, the following indicators of the ES level (5 out of 12) do not meet the established threshold parameters: 1. The volume of GRP per capita, its percentage of the highest indicator for the Russian Federation, is only 8.52%; 2. IPI, 104.6% against the threshold parameter of at least 115% (the highest IPI among the regions of the Russian Federation); 3. LPI, 105.5% against the threshold parameter of 113% (the highest LPI among the regions of the Russian Federation); 4. IDI, 0.41 against the threshold parameter of 0.68 (the highest IDI among the regions of the Russian Federation); 5. the ratio of funds is 11.2:1 against the threshold parameter of 10:1. The region has one of the lowest debt burden indicators, which significantly affects the value of the comprehensive assessment. The region is the leader in the ratio of investments to GRP indicator. In recent years, the region has been in the top 10 in terms of investment. The share of investments in GRP is a record 48% in 2019 (e.g. in newly industrialized countries, it exceeds 30%). The Leningrad region is in the top 10 in terms of investment per capita. The remaining indicators correspond to the set threshold parameters.
- 3. The third place is occupied by the Kaliningrad region, which has the lowest degree of depreciation of fixed production assets, 31.6% against the established threshold parameter of 60%. This indicates the competitiveness of the industrial potential of the region and the growth of investments in fixed assets. The ratio of investments in fixed assets to GRP is above the established threshold parameter. The regime of the special economic zone, which has been in force since the 1990s and is extended until 2031, creates all the necessary conditions for attracting investment. The implementation of priority areas for the development of the Kaliningrad region is reflected positively in the level of unemployment and crime, reducing the degree of social stratification of the population and increasing life expectancy. Despite the growth of human capital and the stimulation of scientific and innovative activities, the poverty level has exceeded the threshold. The volume of GRP per capita, LPI, IPI, IDI, and the level of debt burden did not reach the established threshold parameter.

The fourth place is occupied by three subjects of the Russian Federation: the Vologda Region, the Murmansk Region, and the Pskov Region.

- 4.1. Vologda Region. It ranks fourth in the country in terms of investment growth. In terms of investment activity, the region is among the 10 leading regions. Over the past five years, the volume of investments has increased by 1.75 times. The ratio of investments to the GRP exceeds the established threshold of 29.4. The volume of investments in fixed assets is growing annually, but the degree of depreciation of fixed assets is still high, especially in industries such as pulp and paper, mechanical engineering, and chemical. This indicator is still within the limits of the set parameter and is 51.9%. In the region's economy, production is modernized on the basis of the cluster approach. In the region, there are such support clusters as forestry, construction, agriculture and food, and recreational. The development of the cluster complex of the region created conditions for reducing unemployment, crime, significant differentiation of incomes of the population, and increasing the life expectancy of the population of the region. Nevertheless, a number of indicators, such as the volume of GRP per capita, LPI, IPI, IDI, and the level of debt burden, have not reached the established threshold, and the poverty level exceeds the threshold.
- 4.2. Murmansk Region. The main vector of the development of the region's economy is the Arctic. The port of Murmansk and its water areas in the spring of this year will receive the status of a territory of advanced development. In terms of GRP per capita, the region ranks 5th in the district and 17th among the subjects of the Russian Federation. In the GRP structure, the share of industry is 35%, including the share of extractive industries, which is more than 50%. More than 171 billion rubles of investments in fixed assets were allocated for the development of the economy and social sphere of the Murmansk region in 2019, including the own capital of businesses, accounting for more than 46% of this investment volume. More than 80% of the volume of investment is directed to the sphere of industry and transport. Fixed assets in key industries are being actively upgraded in the region. The degree of depreciation of fixed assets of the region is lower than in many regions of the district and does not exceed the threshold parameter, which affects the ratio of investments in fixed assets to the GRP indicator, which exceeds the established threshold. This is the only region in the county where the values of social indicators are within the set parameters.
- 4.3. Pskov Region. The industrial complex includes 199 large and medium-sized enterprises. The basis of the complex is made up of enterprises of "processing industries." The growth rate of industrial production has been increasing since 2015. The cluster approach in industry is the main direction for the strategic development of its industry. Although the indicators of the degree of depreciation of fixed assets, the ratio of investments in fixed assets to GRP, the level of unemployment, crime, and the coefficient of funds correspond to the established threshold parameter, the region is characterized by high levels of poverty and debt burden among the subjects of the Russian Federation within the NWFD.

Other regions of the NWFD:

5. Novgorod Region. In the region, the volume of industrial production is growing consistently (above the national average). There are several new projects for the development of industry, which should improve the employment situation in the region. Historical problems include low standard of living, outflow of population from the region, and lack of newly created jobs. The volume of investments in 2019 decreased compared to the previous year (mainly in processing). The ratio of investment to the GRP indicator has not reached the established threshold parameter (25%); it is 22%. The index of innovative development is quite high. The region ranks second in this indicator among the regions of the NWFD of the Russian Federation. The value of indicators of the degree of depreciation of fixed assets, the level of unemployment, crime, social stratification of the population, and life expectancy do not go beyond the values of the established threshold parameter. The remaining ES indicators do not meet the set threshold.

- 6. Arkhangelsk Region. Indicators of the ES of the region, such as the degree of depreciation of fixed assets, the ratio of investments to the GRP, the unemployment rate, crime, and life expectancy, do not go beyond the established threshold. Nevertheless, this region is characterized by a low level of renewal of fixed assets (the value of their depreciation indicator approaches the established threshold value), and unemployment is growing (6.4% against the established 8%).
- 7. Komi Republic. The value of ES indicators, which do not go beyond the values of the established threshold parameters, is inherent in indicators such as the degree of depreciation of fixed assets, the level of unemployment, crime, and life expectancy. Despite this, it should be noted that the unemployment rate (7.3%) is approaching the threshold parameter (8%); in terms of the number of crimes committed, the republic ranks first among the regions of the district; it has the lowest LPI. The republic has a large proportion of the poor population. According to this indicator, the region ranks second among the subjects of the Russian Federation in the district. The positive aspect is that in terms of GRP per capita, it ranks second among the subjects of the Russian Federation in the district.
- 8. Republic of Karelia. The basis of the region's economy is the mining and processing industries. In terms of GRP per capita, the republic ranks ninth among the regions of the district. The region has the lowest comprehensive assessment of the level of ES. Only the values of four indicators (the degree of depreciation of fixed assets, the coefficient of funds, life expectancy, and crime rate) do not go beyond the established threshold. The region has the highest unemployment rate (according to the experts' opinion, the main reason is that the level of qualification of the unemployed does not correspond to the proposed vacancies), respectively, the high level of poverty; in terms of the number of crimes committed and the level of debt burden (the budget of the subject of the Russian Federation is very dependent on transfers from the federal budget), it ranks second among the regions of the NWFD. The ratio of investments in fixed assets to the GRP indicator is the lowest compared to other regions of the district. The main reasons for the low investment activity of the region are the proximity of investment-attractive territories (Finland, St. Petersburg); high costs of construction and doing business are associated with the fact that the republic belongs to the territories of the Far North; constant outflow of the population; undeveloped deposits of minerals necessary for the development of the industry; and low level of energy supply in the region.

According to the established criterion boundaries of the integral indicator, St. Petersburg (1.63), Leningrad Region (1.34), and Kaliningrad Region (1.14) have a high level of ES of the region (comprehensive assessment is over 1.05). The Vologda, Murmansk, and Pskov regions have the same score, 1.04, with the Novgorod Region being at 1.02. Assessment of secure development of these subjects is included in the established limit of 1–1.04, which describes them as regions with a normal level of secure development in the economic sphere. The remaining subjects of the Russian Federation (the Republic of Karelia, the Komi Republic, and the Arkhangelsk Region) belong to regions with a low (pre-crisis) level of ES (comprehensive assessment ranges within 0.70–0.99).

The application of the proposed comprehensive indicator to the assessment of the level of ES demonstrates additional opportunities for identifying relationships between indicators and determining priority areas for the development of territories. As a justification for the need to include the IDI in the comprehensive assessment of the ES of a region, confirming our conclusions, we conducted a correlation analysis of the relationship between the integrated assessment of ES and ES indicators (Table 2).

Table 2. Close relationship between the complex assessment of ES of the region and indicators of ES

	Correlation	Number of degrees	t-Student's	Statistical significance of
	ratio (r)	of freedom (f)	criterion	feature dependence (p)
GRP per capita, % of the				
highest in the Russian	0.307	1.125	2.306	0.297499
Federation				
IPI, %	0.512	1.686	2.306	0.135651
LPI, %	-0.148	0.422	2.306	0.685686
Degree of depreciation of fixed assets, %	0.468	1.500	2.306	0.177364
Ratio of investment to GRP, %	0.272	0.800	2.306	0.449987
IDI	0.829	4.195	2.306	0.004061
Unemployment rate, %	0.910	6.193	2.306	0.000448
Fund ratio	-0.477	1.536	2.306	0.168391
The share of the population living below the poverty line, %	0.902	5.907	2.306	0.000596
Crime rate, amount of crimes per 100 000 people	0.935	7.474	2.306	0.000140
Life expectancy at birth, years	0.887	5.428	2.306	0.000979
Debt burden level, %	0.729	3.014	2.306	0.19560

The presented results indicate that there is a strong correlation with the level of ES of the region of the following indicators: the IDI; the unemployment rate; the share of the population living below the poverty line; crime rate; and life expectancy. Consequently, the models on the basis of which the integrated assessment of ES of a region is based should include, along with socioeconomic indicators of the region's development, the IDI.

The application of the method of averaging the normalized values of all indicators using the simple average method allows us to bring all the indicators of the ES of a region to comparable values and determine the directions in which the region should develop. In particular, our correlation analysis determines a close relationship between the level of innovative development and the unemployment rate in the region, the share of the population living below the poverty line, and life expectancy (Table 3).

Table 3. Close relationship between the IDI and other indicators of ES

	Correlation ratio (r)	Number of degrees of freedom (f)	t-Student's criterion	Statistical significance of feature dependence (p)
Unemployment rate	0.957	9.334	2.306	0.000034
The share of the population living below the poverty line	0.800	3.768	2.306	0.007003
Life expectancy at birth	0.819	4.033	2.306	0.004974

5. Discussion

Despite the high importance of ensuring ES, there is a serious lack of scientific and practical materials focusing on it, especially from the point of view of creating innovative potential at the regional level. This problem does not allow the design of tools to influence the ES and develop effective management methods. From the authors' point of view, a comprehensive assessment should be only the first step before the formation of strategic support mechanisms for ES with a parallel build-up of the territory's innovative capabilities. In a market economy, the key subjects of ensuring ES are entrepreneurial structures, but the ability to use the corporate segment to achieve innovative goals does not always contribute to the interests of enterprises and society.

At the same time, the lack of an unambiguous understanding of the innovative component of ES is characteristic of both domestic and foreign experiences. In particular, Cable (1995) notes that the basis for ensuring ES is market regulators and cooperation between countries, and business structures are a secondary element that exist in the market space created by the state. At the same time, in addition to the macroeconomic influence, attention should be paid to the creation of innovative potential in the microeconomic environment since it is at the micro-level that the formation of intellectual resources that determine innovative development takes place. Thus, the business sector ensures the creation and redistribution of intellectual rent, which was considered in the literature (Dmitriev et al., 2020a; Ilchenko et al., 2020). Intellectual competitiveness ensures the strategic superiority of not only enterprises but also the territories of their operation, which increases the role of intellectual rent from the position of creating a sufficient level of ES.

Murdoch (2012) notes that a security threat occurs when there are changes in income, employment, inflation, reduced access to the market, raw materials, etc., in violation of economic sovereignty. In this context, it is advisable to use innovative potential for the development of the domestic market and the prevention of innovative intervention from outside. Orlova (2012) notes that the ES provides a state of the economy in which it is protected, primarily by economic means, from serious threats to its security arising from the influence of international factors. At the same time, attention should be paid not only to international and other macrofactors but also to the domestic state of resources, for which it is rational to ensure the regulation of market demand and social aspects of the functioning of society. To achieve this goal, it is possible to ensure the development of labour potential by providing fair wages based on rating tools (Rodionov et al., 2020). The intellectual aspects of creating ES through the formation of innovative potential are poorly developed, but it is human resources and intangible assets that prove their performance in conditions of increasing macroeconomic dynamics and the growing uncertainty of the geopolitical background. In particular, Jiang (2008) notes that ES has two aspects: competitiveness and independent economic sovereignty. Thus, innovation should be considered a strategic resource for the sustainable development of regions and the country as a whole.

The toolkit for assessing the ES of a region should provide a comprehensive account of the issues of territorial and industrial specification, as well as ensuring the identification of promising industries in the region that determine the possibilities for increasing the level of ES. Taking this fact into account allows for further improvement of the proposed methodology, but at the same time, it can significantly complicate its algorithms – due to the need for a comprehensive fundamental analysis of the territory – and reduce its quality. For example, in practice, one of the most significant security indicators is taking into account the agroindustrial potential of the territory and the potential for technical renewal of the agricultural sector (Kiritsa et al., 2021). In this context, taking it into account in the metrics of the assessment of the ES of a region should ensure that the complication

of the methodology is not significant, but at the same time, its apparatus should be developed in accordance with the ever-increasing instability of objective reality of the environment.

Considering industrial and regional specialization will allow us to take a fresh look at setting the threshold values in the future and improving the basis for calculating the existing metrics. In particular, it is possible to construct digital conditions for improving the system of using the socioeconomic indicators of a particular region – it is necessary to ensure their interconnection with the approved scheme for analysing indicators. At the same time, a more complex variation of the scorecard should be compatible with the current accounting and forecasting system. As a result, there appears to be an objective opportunity to assess security in the context of its use to reduce the impact of destabilizing factors. It is proposed to direct the analysis of threshold values towards the minimization of indicators to increase the accessibility and simplify the interpretation of the values obtained.

The existing practical approaches to the implementation of ensuring ES at the regional level do not allow determination of their strengths and weaknesses. In Russian practice, the formation of a system of economic indicators and threshold parameters and the improvement of monitoring studies contribute to solving this problem. It is possible to use a number of generally recognized methods for assessing the ES (NORDSTAT DTLR, etc.); however, these methods do not allow establishing threshold values for indicators of ES of regions and assessing the level of ES of a region, taking into account the assessment of the innovative component (Iancu et al., 2014). At the same time, the methodology proposed by the authors allows for a comprehensive assessment of the ES of the region, taking into account the formation of a rating of innovative subjects of the Russian Federation. The use of this methodology allows us to compare information about the state of the regions from the point of view of innovative development to identify areas that should be key from the standpoint of the growth points of the regions. The presented methodology made it possible to normalize each indicator to make it comparable and design a comprehensive assessment of the ES of a region. This methodology enables one to obtain reliable comparative estimates of the level of ES of 10 regions, taking into account their innovative potential. Based on the data obtained, it is possible to design qualitative measures to strengthen ES.

6. Conclusions

The results of the research conducted can be characterized by the following aspects:

- 1. The list of ES indicators of the region is minimal, accessible, and corresponds to the socio-economic indicators of the regional development.
- 2. The proposed methodology is easy to implement and allows us to comprehensively assess the level of ES of regions and determine the contribution of each subject of the Russian Federation to strengthening the ES development of its Federal District and the country as a whole. Stakeholders, based on the results of the study, can choose the region most attractive in the investment and innovation spheres.
- 3. The proposed system of indicators takes into account the indicators of innovative development. Currently, when assessing the level of ES of the territory, the innovative component is not always singled out, while it is one of the main factors in ensuring the ES. The IDI should be included in the comprehensive assessment of the level of ES of a region. The results of the correlation analysis show that there is a close relationship between the IDI and the main ES indicators. It is an innovative development that determines the quality of life of the population of a particular region.

- 4. The index of innovative development is the highest in St. Petersburg, which is the leader in this indicator not only among the regions of the district but also in the whole country. IDI is quite high in the Arkhangelsk Region, Leningrad Region, and Novgorod Region. The lowest IDI is in the Pskov Region.
- 5. The implementation of the proposed methodology for assessing the level of ES of a region made it possible to determine that in the NWFD, only three subjects of the Russian Federation (the Republic of Karelia, the Republic of Komi, and the Arkhangelsk Region) belong to regions with a low (pre-crisis) level of ES. They are characterized by a significant degree of depreciation of fixed production assets and a high level of unemployment, poverty, and debt burden. Most of the subjects of the Russian Federation are regions with high and normal levels of ES.
- 6. For the regions of the NWFD, in the field of ES, it is typical not to achieve the established threshold parameters for a number of indicators: the volume of GRP per capita, the LPI, the IDI, and the level of the debt burden.

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The article was submitted 1.06.2021, approved after reviewing 18.07.2021, accepted for publication 28.07.2021.

Статья поступила в редакцию 1.06.2021, одобрена после рецензирования 18.07.2021, принята к публикации 28.07.2021.

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SECTION 4

MANAGEMENT OF KNOWLEDGE AND INNOVATION FOR SUSTAINABLE DEVELOPMENT

РАЗДЕЛ 4

УПРАВЛЕНИЕ ЗНАНИЯМИ И ИННОВАЦИЯМИ В ИНТЕРЕСАХ УСТОЙЧИВОГО РАЗВИТИЯ

Research article

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

DEVELOPMENT OF INNOVATIVE INDUSTRIAL CLUSTER STRATEGY USING COMPOUND REAL OPTIONS

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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



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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

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Аннотация

редметом 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 HH». 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

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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.

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:

$$E[S_0] = \frac{S_{1,\text{opt}} \cdot p_{\text{opt}} + S_{1,\text{pes}} \cdot p_{\text{pes}}}{1 + W\Delta CC}, \tag{1}$$

where $S_{1,\rm opt}$ and $S_{1,\rm pes}$ are optimistic and pessimistic values of future cash receipts, reduced to their start value (rubles); $p_{\rm opt}$ and $p_{\rm pes}$ 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 NPV_{old} of the basic variant of the cluster strategy – i.e., without options or with existing options:

$$NPV_{old} = E[S_0] - K, (2)$$

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):

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

$$APV = PV + P = \sum_{t=0}^{n-1} CF_t \left(\frac{1 - p_{pes}}{1 + WACC} \right)^t + \frac{CF_n}{\left(1 + WACC \right)^t} + \sum_{t=0}^{n-1} L_t p_{pes} \left(\frac{1 - p_{pes}}{1 + r_f} \right)^t, \tag{4}$$

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); t is the planning horizon (number of years); t is the liquidation value in years t i.e., the forecasted total discounted value of the shares of the core company (rubles); t 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):

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

where pseudo-probability p is calculated as

$$p = \frac{r_f - r_d}{r_u - r_d} \,; \tag{6}$$

 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

$$C_t^A = \max\left\{S_t - K_t, 0\right\},\tag{7}$$

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 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: $172714 \ln x + 197637$, $R^2 = 0.00222704$;

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

polynomial of the third degree: $27473.4x^3 - 286123x^2 + 851635x - 353127$, $R^2 = 0.0125885$.

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

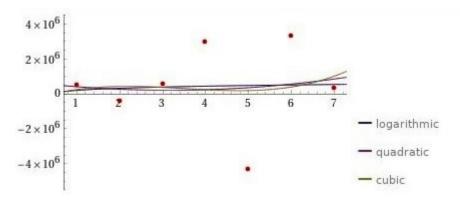


Figure 1. Forecast cash flow functions of TNS Energy NN PJSC

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;
- $S_{1,pes} = 2358870$ thousand rubles, in the pessimistic scenario.

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

$$E[S_0] = \frac{8770806 \cdot 0.5 + 2358870 \cdot 0.5}{1.1256} = 4943886$$
 (thousand rubles),

$$NPV = 4943886 - 2233864 = 2710022$$
 (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:

$$\begin{aligned} \text{APV} &= 556\ 786 + 577\ 128 \cdot \frac{1 - 0.5}{1.1256} + 595\ 326 \cdot \left(\frac{1 - 0.5}{1.1256}\right)^2 + 611\ 787 \cdot \left(\frac{1 - 0.5}{1.1256}\right)^3 + \frac{626\ 815}{1,1256^4} + \\ &+ 2\ 514\ 437 + 2\ 830\ 251 \cdot \frac{1 - 0.5}{1.0421} + 3\ 1185\ 730 \cdot \left(\frac{1 - 0.5}{1.0421}\right)^2 + 3\ 585\ 858 \cdot \left(\frac{1 - 0.5}{1.0421}\right)^3 = \\ &= 1\ 374\ 728 + 5\ 001\ 847 = 6\ 376\ 575\ \text{ (thousand rubles)}, \\ \text{E}[S_0] &= \frac{8\ 770\ 806 \cdot 0.5 + 6\ 376\ 575 \cdot 0.5}{1.1256} = 6\ 728\ 581\ \text{ (thousand rubles)}, \end{aligned}$$

$$NPV = 6728582 - 2233864 = 4494717$$
 (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

$$\Delta P_0 = 4494717 - 2710022 = 1784695$$
 (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:

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

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

$$NPV = 6936086 - 2233864 = 4702222$$
 (thousand rubles),

where the premium for a given call option according to formula (3) will amount to $\Delta C^0 = 4702222 - 4494717 = 207505$ (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 data², amounted to

$$\Delta K = K_{\text{Rostov}} - K_{\text{NN}} = 6708617 - 2540079 = 4168538$$
 (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:
$$720\ 254\ lnx - 486\ 173$$
, $R^2 = 0.318403$;

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

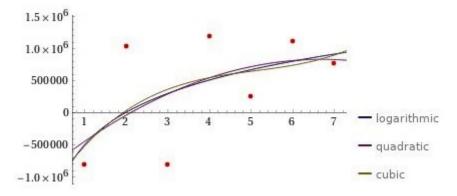


Figure 2. Forecast cash flow functions of TNS Energo Rostov-on-Don PJSC

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 $S_{1,\rm opt}$ = 10 481 385 (thousand rubles). Then for TNS energo NN PJSC,

$$C_{1 \text{ pes}} = 556786 + 10481385 - 4168538 = 6869633$$
 (thousand rubles).

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

$$E[S_0] = \frac{9 \cdot 237 \cdot 942 \cdot 0.5 + 6869 \cdot 633 \cdot 0.5}{1.1256} = 7 \cdot 155 \cdot 106 \text{ (thousand rubles)},$$

$$NPV = 7\ 155\ 106 - 2\ 233\ 864 = 4\ 921\ 242$$
 (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:

$$\Delta C_0 = 4921242 - 4702222 = 219020$$
 (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

	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
l-p	0.98563	0.975513	0.966462	0.956909

Table 6. Calculation of pseudo-probabilities of two technologies

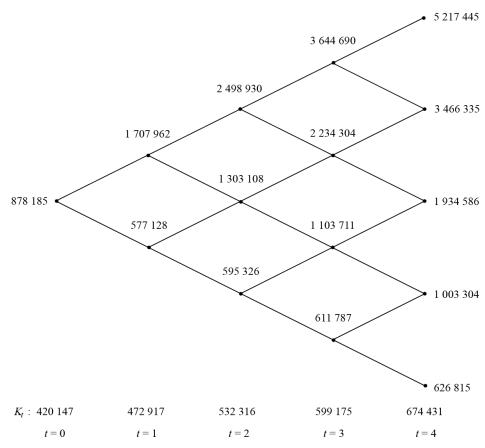


Figure 3. Change in cash flows of two technologies (thousand Rubles)

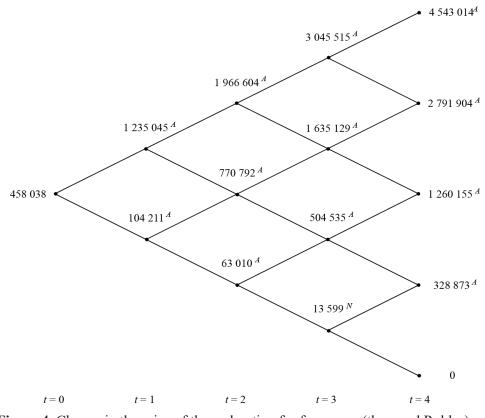


Figure 4. Change in the price of the real option for four years (thousand Rubles)

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:

$$C_{1,\text{pes}} = 6\ 869\ 633 + 458\ 038 = 7\ 32\ 7671$$
 (thousand rubles),
$$E[S_0] = \frac{91237\ 942 \cdot 0.5 + 7\ 327\ 671 \cdot 0.5}{1.1256} = 7\ 358\ 570 \text{ (thousand rubles)},$$

$$NPV = 7358570 - 2233864 = 5124706$$
 (thousand rubles).

The premium for the analysed call option would amount to

$$\Delta C_0 = 5\ 124\ 706 - 4\ 921\ 242 = 203\ 464$$
 (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.'

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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.

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