Saint Petersburg 2024

volume 3 issue 2

An international journal

TECHNO ECONOMICS

TECHNO ECONOMICS

An international journal

EDITORS OFFICE PUBLISHER
Executive Secretary: *Olga Voronova*
Development Manager: *Anastasia Levina*
Layout designer: *Dayana Gugutishvili*

PUBLISHER
Peter the Great St. Petersburg Polytechnic University
Corresponding address: 29 Polytechnicheskaya st.,
Saint-Petersburg, 195251, Russia

CONTACTS
Email: *technoeconomics @spbstu.ru*
Web: *https://technoeconomics.spbstu.ru/en*

Saint Petersburg
2024

CONTENTS

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 4–21.
Техноэкономика. 2024, Том 3, № 2 (9). С. 4–21.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.1

ELEMENTARY IMAGE OF THE KOLMOGOROV-GABOR POLYNOMIAL IN ECONOMIC MODELING

Sergey Svetunkov ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ sergey@svetunkov.ru

Abstract. Today, neural networks are actively used in modeling complex nonlinear dependencies. Amid such a rapid growth of interest in this powerful tool for modeling various objects and processes, research in the natural sciences and engineering, the work on the application of neural networks in economics is vanishingly small. This is explained both by the complexity of the modeling tool itself - neural networks, and by the object of modeling - the evolving economy. At the dawn of the development of neural networks, the method of modeling processes using Kolmogorov-Gabor polynomials (or Wiener series) was considered as an alternative. For various reasons, this method lost the competitive battle, and neural networks prevail. The article presents a method and technique for constructing an elementary image of the Kolmogorov-Gabor polynomial and shows that today it can be used as an alternative to neural networks in modeling of economic processes.

Keywords: economic and mathematical modeling, nonlinear processes, multidimensional dependencies, neural networks, Kolmogorov-Gabor polynomial, N. Wiener series

Funding: The work was carried out with the financial support of the Russian Science Foundation, grant No. 19-010-00610\19 “Theory, methods and techniques for forecasting economic develop-ment using autoregressive models of complex variables.”

Citation: Svetunkov S. Elementary image of the Kolmogorov-Gabor polynomial in economic modeling. Technoeconomics. 2024. 3. 2 (9). 4–21. DOI: https://doi.org/10.57809/2024.3.2.9.1

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.1

ЭЛЕМЕНТАРНЫЙ ОБРАЗ ПОЛИНОМА КОЛМОГОРОВА-ГАБОРА В МОДЕЛИРОВАНИИ ЭКОНОМИКИ

Сергей Светуньков ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ sergey@svetunkov.ru

Аннотация. Сегодня при моделировании сложных нелинейных зависимостей активно используют нейронные сети. На фоне такого бурного роста интереса к этому мощному инструменту моделирования различных объектов и процессов исследования естественно-научных и технических наук работы по применению нейронных сетей в экономике исчезающе малы. Это объясняется как сложностью самого инструмента моделирования - нейронные сети, так и объекта моделирования – эволюционирующая экономика. На заре становления нейронных сетей в качестве альтернативы им рассматривался метод моделирования процессов с помощью полиномов Колмогорова-Габора (или рядов Винера). По разным причинам этот метод проиграл конкурентную борьбу и нейронные сети превалируют. В статье приводится метод, и методика построения элементарного образа полинома Колмогорова-Габора и показывается, что он сегодня вполне может использоваться как альтернатива нейронным сетям в моделировании экономических процессов.

Ключевые слова: коэффициент корреляции, номинальные данные, коэффициент Юла, коэффициент Пирсона, корреляционные связи

Финансирование: Работа выполнена при финансовой поддержке Российского фонда фундаментальных исследований, грант № 19-010-00610\19 «Теория, методы и методики прогнозирования экономического развития авторегрессионными моделями комплексных переменных».

Для цитирования: Светуньков С. Элементарный образ полинома Колмогорова-Габора в моделировании экономики // Техноэкономика. 2024. Т. 3, № 2 (9). С. 4–21. DOI: https://doi.org/10.57809/2024.3.2.9.1

Introduction

From the very beginning of the emergence of the task of modeling complex interrelationships, scientists have used mathematical statistics to LSM to solve it, directing their efforts to identify causal relationships between variables and to explicitly determine the form of these identified interrelations.

This form of interrelation took the form of one of the elementary functional dependencies of the indicator y on the factors xi. It was believed that a correctly chosen function, if it does not express the mathematical expectation of the process, is its best approximation.

The main problem that scientists faced when constructing and using a regression model or a set of models was precisely the difficulty of determining the type of functions describing the mathematical expectation, since an error made in this case leads to incorrect modeling results. In the univariate case, this task is solved with a certain degree of success using correlation and regression analysis.

However, in multivariate dependencies, determining the form and nature of the influence of

each factor on the result is a very difficult and rarely successfully solved problem.

Let's demonstrate the complexity of this task with a simple example by generating data for a conditional example. Let the influencing factors change as follows:

$x_{1i} = i, x_{2i} = 0,5x_{1i} + \varepsilon_i = 0,5i + \varepsilon_i, x_{3i} = x_{2i}\cos(x_{1i})^{0,1} + x_{1i}$

And now let's generate the resulting feature using the specified three variables by the formula:

$y_i = x_{1i} + 2x_{2i} + 0,1x_{3i}^2$ (1)

We are faced with a nonlinear multifactorial functional dependency, and since it does not contain a random component, we can expect a definitive determination of the form of this dependency. We will change i from 1 to 50 and generate data for a hypothetical task based on this.

Now let's assume that the form of this dependency is unknown to us and, based on the available statistical data about the factors and the modeled variable, it is necessary to find this dependency. The first thing to do is to calculate the correlation matrix. We will obtain the following.

Table 1. Correlation matrix for a conditional example

	x_{1i}	x_{2i}	x_{3i}	y_i
x_{1i}	1			
x_{2i}	0,8103	1		
x_{3i}	0,9931	0,8674	1	
y_i	0,9746	0,8907	0,9823	1

What conclusion will the researcher draw from these data? Since the pairwise correlation coefficients are above 0.80, these data should be described using a linear multifactorial model. The LSM estimates of such a model based on the available data will give the following form of the model:

$\hat{y}_i = 13,16x_{1i} + 5,56x_{2i} - 9,67x_{3i} - 11,34$ (2)

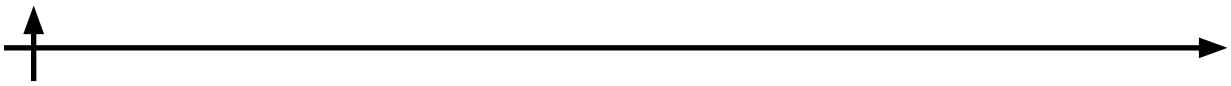
It has excellent statistical characteristics, which tell the researcher about its significance. However, the obtained model terribly described the original formula (1) and does not correspond at all to the law it describes! And yet, many economists, having received an econometric model of type (2), will try to give an economic interpretation to each coefficient obtained, for example, that an increase of the third factor by one unit will reduce the result by 9.67 units. From the true situation, which is modeled by (1), follows a completely different influence of the third factor – its increase will nonlinearly enhance the result. That is, mathematical statistics have yielded a result opposite to what is the case.

If we now take a closer look at the data in Table 1, we can notice that there is a strong and almost linear relationship between the first and third factors, as the pairwise correlation coefficient between them is r = 0.9931. Therefore, the effect of multicollinearity may be present in the modeling results. One of these two correlated factors should be discarded when building the model. Let it be the factor x1i.

Then, the econometric model, which takes multicollinearity into account, will look like this:

$\hat{y}_i = 1,38x_{2i} + 4,47x_{3i} - 18,79$ (3)

It also has excellent statistical characteristics, indicating its statistical significance. But it is as far from the truth as model (2). And if we now give an economic interpretation to the new



model (3), we can say that an increase of the third factor by one unit leads to an increase in the result by 4.47 units, which is far from the real influence and opposite to the conclusions of model (2).

It is impossible to find the form of the real dependency (1) using methods of mathematical statistics.

These methodological difficulties in applying structural regression models in economic modeling have been understood for a long time, but there was no alternative until cybernetics appeared. Cybernetics took various steps away from regression, proposing as an alternative the 'black box' model, into which certain factors xi are fed, and the values yare observed at the output. How the input is transformed into the output is of no interest to anyone. In managing the 'black box,' the task was set as follows: to select such values of factors xi that the output y observed would be close to a predetermined Y. Methods for selecting optimal values of xi were developed in cybernetics.

In parallel with the tasks of optimal control of complex systems, cybernetics solved another problem – pattern recognition. It differed from the task of optimal control in that, given the input parameters xi and known values of the output parameter y, it was necessary to adjust the 'black box' so that this correspondence between input and output matched the given pattern Y. Here, the object of adjustment was not the data, but the 'black box' model, or rather – its coefficients.

Scientists proposed various mathematical models of this 'black box,' and over time, the model of artificial neurons combined into a single neural network proved to be the most accurate and convenient. Inside the 'black box' - the neural network - when solving the task, a multi-iterative recalculation of the network's coefficients occurs so that the output result is obtained with the specified accuracy. The obtained values of the neural network coefficients are of no interest, as they are not statistical characteristics of the process but are parameters of the 'black box.'

With the help of neural networks, many diverse tasks have been solved, and we have come close to the task of creating artificial intelligence. However, examples of successful application of neural networks in economics are exceedingly rare.

This can be explained by two main reasons.

The first is that building and using neural networks requires the specialist to have a deep knowledge of several narrowly specialized sections of mathematics and programming. Typically, scientists engaged in economic research do not possess such knowledge. Therefore, at best, they apply templates of existing neural networks to one or another forecasting object. The basis for applying such a template is the known number of inputs (factors) and outputs (indicators).

The second reason is due to the specific properties of the economy as an object of research. The fact is that neural networks were developed as a method of modeling complex objects operating under conditions of homogeneity, characterized by a finite set of properties and features. In contrast, economic processes are mostly heterogeneous and evolving – the set of properties and features of these processes changes over time and is not finite. The exception is perhaps financial and consumer markets under conditions of stable economic conjuncture. Here neural networks show very good results. But such periods of relative stability are eventually interrupted by some external influences on the markets, and the processes become heterogeneous, evolutionary, and chaotic. In such situations, neural networks stop working well.

Thus, the task of modeling complex economic objects is more successfully solved by methods of mathematical statistics than by neural networks or their analogs. Therefore, the task of creating a simple and understandable alternative to neural networks is relevant.

Materials and Methods

A neural network consists of a collection of j interconnected neurons, each of which represents a superposition of linear and non-linear functions:

$$\widehat{y_j} = f(a_0 + \sum_{i=1}^{n} a_i x_i) \quad (4)$$

Here:

y_j – output signal of j-th neuron;

f – activation function or transfer function;

a_i – weight of the i-th signal (factor);

x_i – i-th component of the input signal or the factor itself;

i = 1, ..., n – neuron input number;

n – number of neuron inputs;

a_0 – coefficient characterizing the displacement.

To avoid problems that may arise with the scales of variables when working with neural networks, all variables are preliminarily normalized.

Two aspects are fundamentally important for the neural network: the form of the function f and the structure of the neural network, that is, the number of neurons (4) and their interconnection with each other.

At the very beginning of the use of neural networks, the computational capabilities of their implementation were not high, so the function f was often considered as the possibility of activation y = 1 or non-activation y = 0 of the output from the neuron, and in the case when it was necessary to quantitatively transform the input values xi, a linear or piecewise-linear function was used. Today, the logistic (sigmoid) function is most often used, allowing for a nonlinear transformation of input signals into output. The logistic is also convenient because its first derivative is easily calculated and computed, which is important when estimating the coefficients of all neurons (4) by numerical methods, since one of the gradient methods (Yunze, 2022) is most often used for this.

LSM or other methods of mathematical statistics are not directly suitable for solving this task. Indeed, for example, in a simple two-layer neural network, the variables xi are considered as inputs to the first layer of m neurons of the network. In each neuron of the first layer (4), they are transformed into outputs yj (j = 1, 2, ..., m), which are inputs to the second layer neural network. At the output of the second layer, the following is obtained:

$$\hat{y} = f(b_0 + \sum_{j=1}^{m} a_j \widehat{y_j}) \quad (5)$$

If we now substitute (4) into (5), we obtain the following superposition of functions:

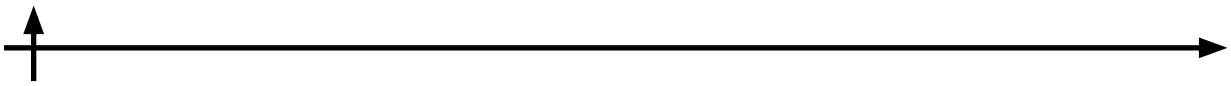
$$\hat{y} = f(b_0 + \sum_{j=1}^{m} a_j f_j(a_{0j} + \sum_{i=1}^{n} a_{ij} x_i)) \quad (6)$$

Real values are described by this model with some error:

$$\varepsilon = y - \hat{y} \quad (7)$$

the minimization of whose squares will give LSM estimates. But it is not possible to directly estimate the coefficients of such a simple two-layer neural network in the case of a nonlinear form of the transfer function, since the calculation of the gradients of the error function (7) by the model coefficients (6) represents a complex task, leading to the need to solve a system of complex nonlinear equations. It is significantly easier and more convenient to solve this problem using numerical methods, most often using the gradient method.

As can be seen from the simple explanation of the essence of building neural networks, their use requires a good knowledge of mathematics and programming skills, as training a neural network is a multi-iterative procedure with many parameters being estimated simultaneously,



which can only be done using some advanced programming language.

When a neural network, trained on a sample from the general population, is tested on a validation set from this general population, it should give good results. If this does not happen, the network is complicated and trained again. And this continues until the network is well 'tuned'.

If non-stationary and irreversible processes are modeled, then neural networks demonstrate their inadequacy. And it is such processes that are many of the processes occurring in the economy. Today many scientists are trying to solve this problem by improving neural networks. One of such directions is the theory of neuro-Bayesian methods (Volterra, 1930), but this theory so far cannot boast any tangible results and admits that: 'now this area is only at the very beginning of the path and is waiting for new researchers' (Lusia, 2018). Some hopes in this direction are pinned on recurrent neural networks (Mekhovich, 2014). In traditional neural networks, it is assumed that the input factors and output factors are independent, and recurrent neural networks take into account the presence of some influence of previous observations on current observations due to feedback between some neurons.

One of the first publications on this topic among Russian economists is the article by Astrakhantseva I.A., Astrakhantsev R.G., and Kutuzova A.S. (Astrakhantseva, 2020). Having identified potential factors of inflation in the Russian Federation, the authors conducted a correlation-regression analysis and determined that inflation can be described by two factors: the exchange rate of the dollar to the ruble and the growth of citizens' debt excluding currency revaluation. A simple recurrent neural network built by them on this data set predicts inflation well for one observation and very poorly predicts all subsequent values.

Physicists Kondratenko V. and Kuprin Y. built a recurrent neural network capable of predicting the sign of price increases in the foreign exchange market with a probability of success just over 50% (Kiselev, 2018). For this, they used the logarithm of the ratio of the current price to the previous price of exchange rates of the American dollar, Japanese yen, Swiss franc, British pound, and euro.

Among the few foreign publications on this topic, several articles can be highlighted. Yunze Tao, Xia Sheng presented a method for predicting the exchange rate of the euro to the US dollar using a simple recurrent neural network in which the factors were past daily exchange rates of the euro and the US dollar (Yunze, 2022). It is difficult to assess how well this network works, as no comparison with other forecasting methods is provided in the article.

Zhiguo Qiu, Emese Lazar, and Keiichi Nakata showed comparative results of using models based on recurrent neural networks with state tracking, feedforward neural networks, as well as VAR vector autoregressions and exponential smoothing models [30]. Six asset return time series were modeled over a period of more than 20 years. Recurrent models showed the best results.

Ruofan Liao, Petchaluck Boonyakunakorn, Napat Harnpornchai, and Songsak Srioonchitta used a recurrent neural network to predict the exchange rate of the US dollar to the yuan from 12 other indicators, shifted up to d lags back plus the indicator itself, shifted up to d lag (Wiener, 1958). They compared this network with ARIMA and showed that if ARIMA gave an average forecast error square of 0.211, then their neural network - 0.010.

These results are encouraging but not impressive.

Returning to the origins of the formation of neural networks, it should be noted that the director of the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR A.G. Ivakhnenko in the 1970s proposed another path of unstructured modeling of complex objects using complex polynomials. In this regard, he proposed an interesting method of decomposing many complex tasks, the essence of which can be understood from a simple example (Gabor, 1961).

Suppose there is a need to build a model of a high-degree polynomial on a small number of

observations:

$$\widehat{y_t} = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 \quad (8)$$

It is proposed to divide this polynomial into a system of three series.

The first row is:

$$\widehat{y_{1t}} = b_0 + b_1 t + b_2 t^2 \quad (9)$$

The second row is:

$$\widehat{y_{2t}} = c_1 t^3 + c_2 t^4 \quad (10)$$

It is easy to notice that the first row is a model that includes the first three terms of polynomial (8), and the model of the second row includes two other components of this polynomial.

The coefficients of models (9) and (10) can be easily estimated, for example, using LSM. To form the overall polynomial (8), it is proposed to estimate the coefficients of the third row model using LSM:

$$\widehat{y_t} = d_0 + d_1 \widehat{y_{1t}} + d_2 \widehat{y_{2t}} \quad (11)$$

Into this model, as you can see, the calculated values of the variable are substituted, which are computed according to (9) and (10). What does this mean? If we substitute into (11) not the calculated values, but the formulas by which they are obtained, that is, models (9) and (10), then we get:

$$\widehat{y_t} = d_0 + d_1(b_0 + b_1 t + b_2 t^2) + d_2(c_1 t^3 + c_2 t^4) =$$
$$(d_0 + d_1 b_0) + d_1 b_1 t + d_1 b_2 t^2 + d_2 c_1 t^3 + d_2 c_2 t^4 \quad (12)$$

From where it is easy to determine the relationship between the coefficients of the original polynomial (8) and the coefficients of the multi-row system (9) - (11):

$$a_0 = d_0 + d_1 b_0, \;\; a_1 = d_1 b_1, \;\; a_2 = d_1 b_2, \;\; a_3 = d_2 c_1, \;\; a_4 = d_2 c_2 \quad (13)$$

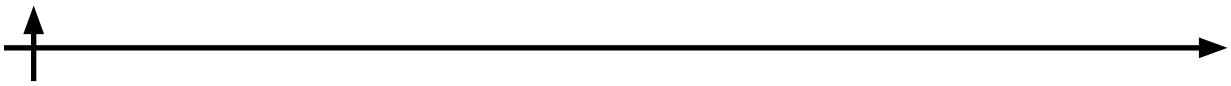
Since the multi-row procedure for estimating the coefficients of the polynomial is a linear superposition of functions linear with respect to unknown coefficients, the estimates (13) will coincide with the LSM estimates applied directly to (9). This decomposition method proposed by A.G. Ivakhnenko was suggested for constructing various nonlinear models, and most often it was proposed to use a finite polynomial decomposition of the nonlinear dependency into additive components.

In 1930, V. Volterra published the work 'Theory of Functionals and of Integral and Integro-Differential Equations' where he derived series that allow the study of systems with soft inertial nonlinearities (Zhiguo, 2024). These series are actively used today in solving technical and engineering tasks of modeling nonlinear processes (Ivakhnenko, 1984). In 1958, N. Wiener in the monograph 'Nonlinear Problems in the Theory of Random Processes' published a modification of the Volterra series. He proposed a method of approximating a nonlinear dependency, starting with simple elements, to which new and new nonlinear terms are successively added: 'Our decomposition differs from the usual Fourier decomposition, as we have a countable set of functionals, but the overall task remains the same' (Schmidhuber, 2015). Today, mathematicians call this decomposition the Wiener series, and for the discrete case, this series will take the form:

$$y = a_0 + \sum_{i=1}^{m} a_i x_i + \sum_{i=1}^{m}\sum_{j=1}^{m} a_{ij} x_i x_j + \sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{k=1}^{m} a_{ijk} x_i x_j x_k + \ldots \quad (14)$$

The same problem was independently solved in 1956 by A.N. Kolmogorov and in 1961 by D. Gabor (Gabor, 1961). Since A.G. Ivakhnenko, who first used series (14), called it the Kolmogorov-Gabor polynomial, this name prevails in domestic science today, and we will also adhere to this naming convention.

Series (14) is indeed very convenient for modeling nonlinear systems with weak nonlinearity based on available statistical data. Moreover, like a neural network, it connects the input



variables xi with the output ywithout defining the nature and form of the relationship between them, that is, it does so in an unstructured way, just like neural networks, which allows it to be considered as an alternative to neural networks. However, unlike neural networks, the structure of the polynomial is fixed and strictly defined. Any researcher with m input variables will always construct the same polynomial (14). Neural networks can connect variables xi with the output y in many ways – they can be single-layer or multi-layer, vary the connections between neurons, add recursive connections, etc. This means that the dependency between xi and y can be described using neural networks in many ways – better or worse, simpler or more complex. With series (14), this relationship can only be modeled in the same way.

And if we compare (14) with (6), we can notice an important advantage of the polynomial over the neural network: it represents a linear function in terms of parameters, whose coefficients can be easily found by any statistical method directly, without resorting to numerical methods, by solving a system of linear equations with unknown coefficients.

In the 60s and 70s of the 20th centuries, when the polynomial (14) competed with neural networks in pattern recognition tasks, calculations were performed on analog machines. These machines consisted of electrical devices that transformed electrical signals similarly to mathematical operations. For example, about the first neural networks, A.G. Ivakhnenko reported: "In the first design of the perceptron, automatic potentiometers with servomotors were used as associating elements. The machine used 512 such potentiometers. They were too large and expensive. Now in the perceptron, so-called biaks are used – magnetic elements with ferrite cores. Functionally, biaks reproduce the actions of a two-position polarized relay or trigger (Dyachkov, 2017).

At that historical moment in the development of computing technology, simple multipliers and adders in computers for the use of artificial neurons were simpler and cheaper than nonlinear converters for the use of the Kolmogorov-Gabor polynomial, which were also less reliable in operation. This predetermined that neural networks became the main tool for pattern recognition, and the Kolmogorov-Gabor polynomial is only occasionally used for modeling nonlinear dependencies. Mainly these are works in the field of engineering sciences (Balasanyan, 2016). Such works are not encountered in economics. Conditionally economic can be considered only the article with the results of modeling the relationship between electrical power and a set of technical and economic indicators of the operation of the Ryazan GRES (Belov, 2008), as well as the article on the application of (14) for clustering industrial enterprises (Kiselev, 2018). In all these works, not the Kolmogorov-Gabor polynomial is used, but the method of sequential approximation to it - MGUA as developed by A.G. Ivakhnenko.

Unfortunately, the Kolmogorov-Gabor polynomial has a significant drawback: as the number of i variables x, describing the behavior of the variable y, increases, the number of terms N in the polynomial (14) sharply increases. Indeed, if for $i = 2$ the number of terms in series (14) will be equal to $N = 6$, then for $i = 5$ it becomes equal to $N = 252$. And this is a sharp increase in the dimensionality of the problem being solved.

For example, if modeling the dependence of several variables yj on x, then for $i = 5$ and $j = 4$ we get $N = 1008$ unknown coefficients of the polynomial. And when using a two-layer fully connected feedforward neural network to solve this problem, it is necessary to estimate from twenty to forty unknown coefficients.

Precisely because of the high dimensionality of the problem, this tool is practically not used in solving real modeling tasks. Thus, I.I. Sulyaev, mentioning the Kolmogorov-Gabor polynomial when setting the task of modeling the process of mixing oxygen and air for the oxidation of sulfide copper-nickel raw materials in a metallurgical furnace, pointed out the enormous size

of this polynomial and subsequently used a neural network (Sulyaev, 2014).

Pointing out the enormous dimensionality of the problem with many initial variables, A.G. Ivakhnenko proposed a method of step-by-step decomposition of the model - "formation of a multi-row system", the essence of which was outlined earlier in (8) − (13).

For the case of three factors, the full Kolmogorov-Gabor polynomial will be written as follows (Ivakhnenko, 1971):

$$\hat{y} = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_1^2 + a_5x_2^2 + a_6x_3^2 + a_7x_1x_2 + a_8x_1x_3 + a_9x_2x_3 + a_{10}x_1^3 + a_{11}x_2^3 + a_{12}x_3^3 + a_{13}x_1^2x_2 + a_{14}x_1^2x_3 + a_{15}x_1x_2^2 + a_{16}x_2^2x_3 + a_{17}x_1x_3^2 + a_{18}x_2x_3^2 + a_{19}x_1x_2x_3 \quad (15)$$

At the first stage, it is proposed to use partial (support) polynomials with two factors, each of which approximates the modeled indicator ywith its own approximation error ε_i:

$$y = \widehat{y_1} + \varepsilon_1 = b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2 + \varepsilon_1 \quad (16)$$

$$y = \widehat{y_2} + \varepsilon_2 = c_0 + c_1x_1 + c_2x_3 + c_3x_1^2 + c_4x_3^2 + c_5x_1x_3 + \varepsilon_2 \quad (17)$$

$$y = \widehat{y_3} + \varepsilon_3 = d_0 + d_1x_2 + d_2x_3 + d_3x_2^2 + d_4x_3^2 + d_5x_2x_3 + \varepsilon_3 \quad (18)$$

Using the method of least squares, one can easily find the coefficients (16) - (18). After that, using the calculated values of the variables obtained from (7) − (9) as factors, one can find the coefficients of another polynomial using the method of least squares:

$$y = \widehat{y_4} + \varepsilon_4 = e_0 + e_1y_1 + e_2y_2 + e_3y_3 + e_4y_1y_2y_3 + \varepsilon_4 \quad (19)$$

And now, substituting (16), (17) and (18) into (19), we get:

$$z = e_0 + e_1(b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2) + e_2(c_0 + c_1x_1 + c_2x_3 + c_3x_1^2 + c_4x_3^2 + c_5x_1x_3) + e_3(d_0 + d_1x_2 + d_2x_3 + d_3x_2^2 + d_4x_3^2 + d_5x_2x_3) + e_4(b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2) \cdot (c_0 + c_1x_1 + c_2x_3 + c_3x_1^2 + c_4x_3^2 + c_5x_1x_3) \cdot (d_0 + d_1x_2 + d_2x_3 + d_3x_2^2 + d_4x_3^2 + d_5x_2x_3) \quad (20)$$

If we now compare the resulting expression with (15), we can see that the coefficient a0 corresponds to a combination of coefficients of the equations:

$$a_0 = e_0 + e_1b_0 + e_2c_0 + e_3d_0 + e_4b_0c_0d_0 \quad (21)$$

In the same way, correspondences can be found for other coefficients of the complete Kolmogorov-Gabor polynomial (15):

$$a_1 = e_1b_1 + e_2c_1 + e_4b_1c_0d_0 + e_4b_0c_1d_0,$$

$$a_2 = e_1b_2 + e_2c_2 + e_3d_1 + e_4b_2c_0d_0 + e_4b_0c_0d_1,$$

...

$$a_{19} = e_4(b_1c_2d_1 + b_2c_1d_2 + b_5c_2d_0 + b_2c_5d_0 + b_1c_0d_6 + b_0c_1d_5 + b_5c_0d_2 + b_0c_5d_1). \quad (22)$$

Some scientists suggest considering this correspondence as estimates of the Kolmogorov-Gabor polynomial. However, (20) is not identical to (15), since in addition to the 20 terms of the Kolmogorov-Gabor polynomial, polynomial (20) contains many other terms that are not present in (15). If we expand the brackets (20) and group the resulting terms of the polynomial, we will obtain a significantly more complex formation. In order not to clutter the description of the obtained polynomial with its coefficients, let's assume that in the final polynomial they are all equal to one. Then we will get:

$$z = 1 + x_1 + x_2 + x_3 + x_1^2 + x_2^2 + x_3^2 + x_1^3 + x_2^3 + x_3^3 + x_1^4 + x_2^4 + x_3^4 +$$
$$x_1x_2 + x_1x_3 + x_2x_3 + x_1x_2^2 + x_1x_3^2 + x_1x_2^3 + x_1x_3^3 + x_1x_2^4 + x_1x_3^4 + x_1^2x_2 + x_1^2x_3 +$$
$$x_1^2x_2^2 + x_1^2x_3^2 + x_1^2x_2^3 + x_1^2x_3^3 + x_1^2x_2^4 + x_1^2x_3^4 + x_1^3x_2 + x_1^3x_3 + x_1^3x_2^2 + x_1^3x_3^2 +$$
$$x_1^3x_2^3 + x_1^3x_3^3 + x_1^3x_2^4 + x_1^3x_3^4 + x_1^4x_2 + x_1^4x_3 + x_1^4x_2^2 + x_1^4x_3^2 + x_1^4x_2^3 + x_1^4x_3^3 +$$
$$x_2x_3^2 + x_2x_3^3 + x_2x_3^4 + x_2^2x_3 + x_2^2x_3^2 + x_2^2x_3^3 + x_2^2x_3^4 + x_2^3x_3 + x_2^3x_3^2 + x_2^3x_3^3 + x_2^3x_3^4 + x_2^4x_3 + x_2^4x_3^2 + x_2^4x_3^3 +$$
$$x_1x_2x_3 + x_1x_2^2x_3 + x_1x_2x_3^2 + x_1x_2^3x_3 + x_1x_2x_3^3 + x_1x_2^4x_3 + x_1x_2x_3^4 + x_1x_2^2x_3^2 + x_1x_2^2x_3^3 + x_1x_2^3x_3^2 +$$
$$x_1^2x_2x_3 + x_1^2x_2^2x_3 + x_1^2x_2x_3^2 + x_1^2x_2^2x_3^2 + x_1^2x_2^3x_3 + x_1^2x_2x_3^3 +$$
$$x_1^3x_2x_3 + x_1^3x_2^2x_3 + x_1^3x_2x_3^2 + x_1^4x_2x_3 + x_1x_2x_3^2x_2^2 + x_1x_2^2x_3x_2^2$$

(23)

This polynomial contains 80 terms, unlike the Kolmogorov-Gabor polynomial (15), which has 20 terms. That is, using the approach of A.G. Ivakhnenko, the researcher constructs not the Kolmogorov-Gabor polynomial, but a new polynomial with a different structure, which has four times more terms. A.G. Ivakhnenko wrote that under certain conditions "... the coefficients of non-existent real connections turn out to be zero (or very small)" (Ivakhnenko, 1963). However, it turned out that this is not the case: "Testing the classical GMDH (Group Method of Data Handling) by solving control tasks with artificially formed initial data shows that its selecting abilities are not high enough: in some examples, arguments not included in the formula defining the process were in the list of arguments of the model of the process" (Belov, 2008).

A.G. Ivakhnenko later abandoned the idea of multi-stage estimation of the coefficients of the Kolmogorov-Gabor polynomial as a whole and considered another task - the sequential complication of models, starting with reference polynomials, and gradually complicating the form of the model, approaching the form of the full Kolmogorov-Gabor polynomial, but not reaching it. At each stage of complicating the model, its statistical characteristics (for example, the variance of the approximation error) are evaluated, which are compared with the same characteristics of less complex models. The process of complicating the model stops when the measured statistical characteristic ceases to improve. This method was named by him "Group Method of Data Handling" (GMDH) and it is used today in solving some practical problems (Artemenko, 2016), including in combination with neural networks (Ivakhnenko, 1973; Svetunkov, 2024).

Research has shown that the Kolmogorov-Gabor polynomial in terms of accuracy can actively compete with neural networks used in economics, especially today with the availability of different computational capabilities than fifty years ago (Nikolenko, 2022), but for this, an effective method is needed to overcome the "curse of dimensionality". The Ivakhnenko method (16) − (22) does not solve this problem.

A simple method for constructing the full Kolmogorov-Gabor polynomial, which overcomes the "curse of dimensionality," is outlined below.

Let's consider this method first on the example of the dependence of y on three factors x1, x2, and x3 (15), and then make the necessary generalizations.

At the first stage, for example, using the method of least squares, it is necessary to find the coefficients of a simple linear model that includes all factors:

$$\hat{y}' = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \quad (24)$$

And at the second and last stage, the same least squares method should be used to estimate the coefficients of the cubic polynomial, substituting the calculated values into it as a factor (24).

$$\hat{y} = c_0 + c_1\hat{y}' + c_2(\hat{y}')^2 + c_3(\hat{y}')^3 \quad (25)$$

It's all. The model is built. If we now substitute (24) into (25), we get:

$$\hat{y} = c_0 + c_1(b_0 + b_1x_1 + b_2x_2 + b_3x_3) + c_2(b_0 + b_1x_1 + b_2x_2 + b_3x_3)^2 + c_3(b_0 + b_1x_1 + b_2x_2 + b_3x_3)^3 \quad (26)$$

Opening the brackets and grouping, we obtain complete correspondence of the structure of the polynomial (26) to the structure of the Kolmogorov-Gabor polynomial (15) - it contains exactly 20 terms.

Now we can find the correspondence of coefficients (25) - (26) to the coefficients of the Kolmogorov-Gabor polynomial (15):

$$a_0 = c_0 + c_1b_0 + c_2b_0^2 + c_3b_0^3,$$
$$a_1 = c_1b_1 + 2c_2b_0b_1 + 2c_2c_3b_0^2b_1,$$
$$\ldots$$
$$a_{19} = 2c_3(b_1 + b_2 + b_3) \quad (27)$$

It should be noted that with such a simple method, we will not obtain the true values of the polynomial coefficients. The least squares estimate (LSE) applied directly to the Kolmogorov-Gabor polynomial (15) and the LSE applied to the proposed method of stepwise decomposition (25) - (26) will differ from each other. This is easily understood because, in the first case, 20 independent coefficients are estimated, while in the second case, 8 coefficients are estimated, of which only 4 coefficients of the linear multifactor model (25) are completely independent of the other coefficients.

Therefore, a simplified model of the Kolmogorov-Gabor polynomial is obtained, which we will call the "elementary form" of the Kolmogorov-Gabor polynomial.

Is it possible to obtain a more accurate representation of the Kolmogorov-Gabor polynomial? Yes, it is.

In relation to the task at hand, the process of constructing such a more complete representation will consist of three stages.

At the first stage, a multifactor linear model (24) is constructed.

At the second stage, a multifactor nonlinear quadratic model is constructed:

$$\hat{y}'' = c_0 + c_1x_1^2 + c_2x_2^2 + c_3x_3^2 \quad (28)$$

And based on these two models, the coefficients of the final model are estimated:

$$\hat{y} = d_0 + d_1\hat{y}' + d_2(\hat{y}')^2 + d_3(\hat{y}')^3 + d_4y'' \quad (29)$$

After substituting (24) and (28) into (29) and grouping the terms, the image of the Kolmogorov-Gabor polynomial is obtained again, in the construction of which not 4, but 8 independent coefficients (24) and (28) are estimated, as well as five dependent coefficients (29). Of course, the new image will be somewhat more accurate than the elementary image (26), and at the same time, the estimation of its parameters is still simpler than the direct estimation of the coefficients of the Kolmogorov-Gabor polynomial (15). The feasibility of using the elementary or full images of the Kolmogorov-Gabor polynomial is determined by practical needs.

This simple method of constructing images of the Kolmogorov-Gabor polynomial can be extended to the case of any number of variables xi, i=1, 2, ..., m. For the elementary image of the Kolmogorov-Gabor polynomial of degree m we obtain:

$$\begin{cases} \hat{y}' = b_0 + b_1x_1 + b_2x_2 + \ldots + b_mx_m, \\ \hat{y} = c_0 + c_1\hat{y}' + c_2(\hat{y}')^2 + \ldots + c_m(\hat{y}')^m \end{cases} \quad (30)$$

As can be seen, it is necessary to estimate step by step (m+1) unknown coefficients, which

is a routine task. Therefore, the "curse of dimensionality," which A.G. Ivakhnenko repeatedly pointed out, is completely overcome, and with the help of the indicated method, an elementary image of the Kolmogorov-Gabor polynomial can be constructed for any m.

The system (30) can be represented in a more compact mathematical form:

$$\hat{y} = b_0 + \sum_{j=1}^{m} b_j (a_0 + \sum_{i=1}^{m} a_i x_i)^j \quad (31)$$

If a researcher is interested in a more accurate approximation to the Kolmogorov-Gabor polynomial, then its full image at xi, i=1, 2, ..., m will be formed like this:

$$\begin{cases} \hat{y}' = b_0 + b_1 x_1 + b_2 x_2 + ... + b_m x_m, \\ \hat{y}'' = c_0 + c_1 x_1^2 + c_2 x_2^2 + ... + c_m x_m^2, \\ ... \\ \hat{y}^{m-1} = w_0 + w_1 x_1^{m-1} + w_2 x_2^{m-1} + ... + w_m x_m^{m-1} \\ \hat{y} = z_0 + z_1 \hat{y}' + z_2 (\hat{y}')^2 + ... + z_2 (\hat{y}')^m + ... + z_m \hat{y}^{m-2} + z_{m+1} \hat{y}^{m-1} \end{cases} \quad (32)$$

Research conducted on numerous hypothetical and real examples confirms the conclusion that the elementary image of the Kolmogorov-Gabor polynomial models various nonlinear processes only slightly worse than the full image of this polynomial. Since the Kolmogorov-Gabor polynomial is suitable for describing dependencies with weak nonlinearity (Ruofan, 2022), which most of the nonlinear multifactor economic processes are, the elementary image can be used as the primary model for describing economic nonlinear dependencies.

A.G. Ivakhnenko, having defined the Kolmogorov-Gabor polynomial as a certain limit, believed that there is no particular sense in reaching it, since the partial polynomials (the first parts of the Kolmogorov-Gabor polynomial) can cope with the task of modeling nonlinearity quite successfully and there is no need to "multiply entities beyond necessity." To find a model of optimal complexity, he proposed the "Group Method of Data Handling" (GMDH), which involves the sequential complication of the model, following the structure of the Kolmogorov-Gabor polynomial for this set of variables.

It is quite possible that the elementary image of the Kolmogorov-Gabor polynomial may also be excessively complex for the modeled object, and therefore it also makes sense to find a polynomial of optimal complexity through the sequential use of partial elementary images, starting with the simplest linear image.

For this, the first equation of system (30) is initially constructed - a multifactor linear model, which is considered as a partial image of the first-degree polynomial. The coefficients found for this model are the basis for calculating the variance σ_1^2.

Then, the coefficients of the partial image of the second-degree Kolmogorov-Gabor polynomial are estimated, which has the form:

$$\hat{y}_2 = c_{02} + c_{12} \hat{y}_1 + c_{22} \hat{y}_1^2 \quad (33)$$

For it, the variance σ_2^2 is also calculated.

If $\sigma_1^2 \leq \sigma_2^2$, then complicating the polynomial is pointless, and a simple linear multifactor model should be used for modeling. However, if this condition is not met and a reduction in variance is observed, the process of complicating the polynomial image continues, and a partial image of the third-degree polynomial is constructed:

$$\hat{y}_3 = c_{03} + c_{13} \hat{y}_1 + c_{23} \hat{y}_1^2 + A_{33} \hat{y}_1^3 \quad (34)$$

and its variance σ_3^2 is estimated. It is compared with the previous variance σ_2^2.

If the condition $\sigma_2^2 \le \sigma_3^2$ is satisfied again then the model becomes more complicated until a complete elementary image of the Kolmo-Gorov-Gabor polynomial is constructed:

$$\widehat{y_m} = c_{0m} + c_{1m}\widehat{y_1} + c_{2m}\widehat{y_1^2} + ... + c_{mm}\widehat{y_1^m} \quad (35)$$

with dispersion σ_m^2.

Results and Discussion

Let's demonstrate with an example how this procedure can be used to select the optimal image of the Kolmogorov-Gabor polynomial. Suppose that for some research purposes, it became necessary to model the dependence of the number of divorces in the Russian Federation from 1999 to 2022 based on five factors: population size, birth rate, GDP per capita, cost of one square meter of housing, as well as the number of marriages and divorces. These data can be taken from the open statistics of the Russian Federation and are not provided here to save space.

Since a nonlinear dependence of one indicator on six is being modeled, the full Kolmogorov-Gabor polynomial that could be constructed from these data should contain 954 coefficients that need to be estimated from the available statistical data. Constructing such a polynomial is a complex task. However, constructing an elementary image of this polynomial is a simple task. Let's find the partial image of the Kolmogorov-Gabor polynomial of optimal complexity using the procedure described above.

The linear multifactor model of this dependence has the maximum variance of all, which we will take as 100%. How the variance of the approximation error of this dependence changes with the complication of the partial images of the Kolmogorov-Gabor polynomial is shown in Table 2.

Table 2. Change in the variance of the approximation error with a change in the complexity of the elementary image of the Kolmogorov-Gabor polynomial

View of the elementary image of the Kolmogorov-Gabor polynomial	Approximation error variance, % of maximum variance
Particular elementary image of a polynomial of a first degree	100,00
Particular elementary image of a polynomial of a second degree	98,78
Particular elementary image of a polynomial of a third degree	95,62
Particular elementary image of a polynomial of ta fourth degree	82,07
Particular elementary image of a polynomial of a fifth degree	72,83
Elementary image of a polynomial	72,84

The model of optimal complexity for the considered example is a partial elementary image of a fifth-degree polynomial. In the artificial neuron (4), the first stage involves a linear convolution of the input variables into a single parameter s, which is then transformed into the output y through the transfer function f(s) at the second stage.

In the elementary image of the polynomial (31), the first stage also involves a linear convolution of the same input variables into the calculated value y_1. However, here, unlike the neuron model, the first adjustment of the image occurs when the function of the discrepancy between the result of the linear convolution and the actual value y is minimized. The second stage involves "fine-tuning" the image in the form of a simple power series.

The strength of neural networks is determined by the fact that its neurons are interconnected

according to the principle: the output from one neuron simultaneously becomes the input to the next neuron (or several subsequent neurons). The number of neurons is determined by the researcher, and by varying them, the researcher can complicate the network until it begins to describe the modeled dependence between input and output in the best way.

Elementary images of the polynomial can also be combined into a certain network when the output from one elementary image of the polynomial simultaneously becomes the input to the next elementary image of another polynomial (or several subsequent elementary images of polynomials). Then a network of polynomials is formed, which describes the dependence between input and output data differently and with different accuracy than a neural network. Let's call such a network polynomial.

It is important to note one very important difference between the polynomial network and the neural network. In the neuron model, only the form of the transfer function f(s) can change. It can be logistic, linear, piecewise-linear, or hyperbolic tangent. Other types of transfer functions in the neuron are rare and can be called exotic. But all these transfer functions model the same type of sigmoidal nonlinear transformation: linear and piecewise-linear functions somewhat worse, logistic and hyperbolic tangent better. Replacing the type of transfer function during the training process is impossible – the type of transfer function determines the mathematical algorithms for training the network.

In the model of the elementary image of the polynomial, the fine-tuning function does not necessarily have to represent the full elementary image of the Kolmogorov-Gabor polynomial. These can be partial elementary images, ranging from a simple linear to a full elementary image of the polynomial. When training such a network, you can change these very fine-tuning functions – complicating them from simple to full or vice versa – simplifying them from full to simple. Thus, polynomial networks acquire an additional training tool without changing the network structure.

What should we expect from the new polynomial network compared to neural networks? Since the computational power of an artificial neuron is significantly lower than the computational power of the elementary image of the polynomial, more accurate modeling results can be expected from the polynomial network.

Let's confirm this statement with a simple example. Let's build a neural network and a polynomial network based on data from 1990 to 2022 about the GDP of the United Kingdom (y) depending on the gross capital accumulation (x_1), the size of the economically active population (x_2), expenditures on scientific research and development (x_3), and the size of the UK's GDP for the previous period (x_4).

Since the influence of the first three factors on the indicator is approximately the same, and the influence of the GDP of the previous period on the current value is somewhat different, let's build a neural network and a polynomial network in such a way.

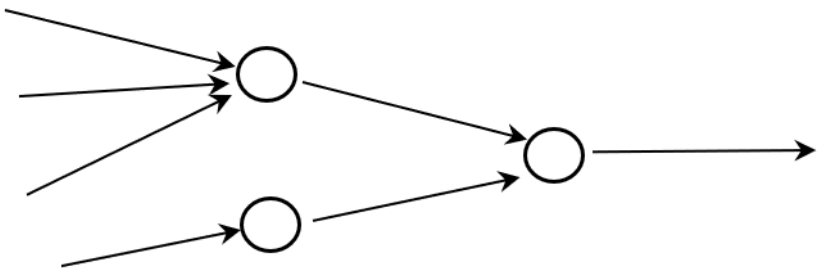


Fig. 1. Graphical model of neural network and polynomial network

Here, for the neural network, each circle represents an artificial neuron, and for the polynomial network – an elementary image of the Kolmogorov-Gabor polynomial. We have before us a simple two-layer feedforward model, the complexity of which is optimal for the considered example. Since after nor-malization the original data become both negative and positive, the transfer function of the last neuron was represented as a hyperbolic tangent, which allows working with negative values.

Let's include in the list of models for comparison of the neural and polynomial networks also an el-ementary image of the Kolmogorov-Gabor polynomial. The comparison results are presented in Table 3.

Table 3. Results of approximation of UK data (1990 – 2020)

Model type	Neural network	Elementary image of the Kolmogorov-Gabor polynomial	Polynomial network
Average sum of squares	0,01388	0,00865	0,00846

Conclusion

As can be seen from the table, the neural network gave the worst results out of the three models, while the network of elementary images of the Kolmogorov-Gabor polynomial gave the best result. This, of course, does not mean that neural networks will always be worse than polynomial networks. Moreover, it was previously discussed that recurrent neural networks are best suited for modeling economics, not feedforward networks. But our task was not to build the best model with the available data, but to com-pare the neural network and the polynomial network. And the given example suggests that polynomial networks can be a worthy alternative to neural networks, and if necessary, polynomial networks can also be made recurrent.

But another conclusion follows from the example: the elementary image of the Kolmogorov-Gabor polynomial showed very good approximating properties. Its average sum of squares of approximation er-ror is less than that of a simple neural network and slightly worse than that of a polynomial network. This once again confirms the conclusion that in a sufficiently large number of cases of modeling nonlinear economic interrelations, the elementary image of the Kolmogorov-Gabor polynomial copes well with this task, and it is possible to do without forming a polynomial network.

REFERENCES

Artemenko M.V., Kalugina N.M., Shutkin A.N. 2016. Formation of a set of informative indicators based on the approximating Kolmogorov–Gabor polynomial and the maximum gradient of functional differences. Proceedings of the South-West State University 1 (18), 116 – 124.

Astrakhantseva I.A., Kutuzova A.S., Astrakhantsev R.G. 2020. Recurrent neural networks for fore-casting regional inflation. Scientific works of VEO of Russia: Materials of MA-EF-2020 223, 420 – 431. doi: 10.38197/2072/2060-2020-223-3-420-431

Balasanyan S.Sh., Gevorgyan E.M. 2016. Comparative analysis of regression methods and group accounting of arguments in modeling mineral processing processes. Georesources Engineering 327 (4), 23–34.

Belov V.V., Chistyakova V.I. 2008. Modeling and forecasting business processes using algorithms for self-organization of formal descriptions. Business-Informatics 4 (6), 37–45.

Busgang J.J, Ehrman L., Graham J.W. 1974. Analysis of Nonlinear Systems with Multiple Inputs. IEEE 62, 1088.

Dyachkov M.Yu. 2017. Inductive modeling of objects and phenomena by the method of group ac-counting of arguments: shortcomings and ways to eliminate them. Bulletin of the

Russian Peoples' Friendship University. Series: Mathematics. Computer science. Physics 25 (4), 323–330.

Gabor D., Wilby W.R., Woodcock R.A. 1961. A universal nonlinear filter, predictor and simulator which optimizes itself by a learning process. Proc. Inst. Electr. Engrs. 108 (40), 85—98.

Geets V.M. ., Klebanova T.S., Chernyak O.I., Ivanov V.V., Kizim M.O., Dubrovina N.A., Stavitsky A.V. 2008. Models and methods of socio-economic forecasting. Kh.: VD "INZHEK", 396 p.

Ivakhnenko A.G. 1963. Self-learning systems with positive feedback, 328.

Ivakhnenko A.G. 1971. Systems of heuristic self-organization in technical cybernetics, 372.

Ivakhnenko A.G. 1975. Long-term forecasting and control of complex systems, 312.

Ivakhnenko A.G., Muller J.A. 1984. Self-organization of predictive models, 223.

Kiselev A.V., Petrova T.V., Degtyaryov S.V., Rybochkin A.F., Filist S.A., Shatalova O.V., Mishustin V.N. 2018. Hybrid deciding modules with virtual streams for classification and prediction of functional state of complex systems. Proceedings of the Southwest State University 22(4), 123-134. doi:10.21869/2223-1560-2018-22-4-123-134

Kondratenko V. V., Kuperin Yu. A. Using Recurrent Neural Networks To Forecasting of Forex. Papers cond-mat/0304469, arXiv.org

Lusia D.A., Ambarwati A. 2018. Multivariate Forecasting Using Hybrid VARIMA-Neural Network in JCI Case, Proceedings of SAIN, 11-14.

Maas S. 2000. What you need to know about the method of analysis based on Volterra series. Engineering micro-electronics 1. 45–51.

Mekhovich S.A., Akhiezer E.B., Dunaevskaya O.I. 2014. Economic and mathematical model of zoning of industrial enterprises. Energy saving, energy, energy audit, 8 (126), 39-49.

Neal R.M. 1993. Probabilistic inference using. Technical Report CRGTR,140.

Nikolenko S.I., Kadurin A.A., Arkhangelskaya E.O. 2022. Deep learning, 480.

Patterson D. 2018. Deep learning from a practitioner's perspective, 482.

Petrov K.E., Deineko A.A., Chalaya O.V., Panferova I.Yu. 2020. Method for ranking alternatives during the procedure of collective expert evaluation. Radioelectronics, informatics, management 2, 84-94.

Ruofan L., Petchaluck B. 2020. Forecasting the Exchange Rate for USD to RMB using RNN and SVM. Journal of Physics: Conference Series 1616, 012050. doi:10.1088/1742-6596/1616/1/012050

Schmidhuber J. 2015. Deep learning in neural networks: An overview. Neural Networks 61, 85-117.

Sulyaev I.I. 2014. Neuromodel of the technological process of preparing an oxygen-air mixture as a control object. News of St. Petersburg Electrotechnical University "LETI" 7, 20 – 25.

Svetunkov S.G. 1993. Econometric methods for demand forecasting 183.

Svetunkov S.G., Chernyagin A.S. 2024. Neural network and Kolmogorov-Gabor polynomial in modeling complex economic processes. Modern Economy Success 4, 153 – 157.

Volterra V. 1930. Theory of Functionals and of Integral and Integro-differential Equations, 226.

Wiener N. 1958. Nonlinear problems in random theory, 138.

Yunze T., Sheng X. 2024. Exchange rate forecast between Euro and US dollar based on recurrent neural network. Highlights in Science, Engineering and Technology 85, 663 – 669.

Zhiguo Q., Emese L., Keiichi N. 2024. VaR and ES forecasting via recurrent neural network-based stateful models. International Review of Financial Analysis 92, 103102.

СПИСОК ИСТОЧНИКОВ

Артеменко М.В., Калугина Н.М., Шуткин А.Н. 2016. Формирование множества информативных показателей на основании аппроксимирующего полинома Колмогорова-Габора и максимального градиента функциональных различий. Известия Юго-Западного государственного университета. Серия: Управление, вычислительная техника, информатика. Медицинское приборостроение 1 (18), 116 – 124.

Астраханцева И.А., Кутузова А.С., Астраханцев Р.Г. 2020. Рекуррентные нейронные сети для прогнозирования региональной инфляции. Научные труды Вольного

экономического общества России 223, 420 − 431. doi: 10.38197/2072/2060-2020-223-3-420-431

Balasanyan S.Sh., Gevorgyan E.M. 2016. Comparative analysis of regression methods and group accounting of arguments in modeling mineral processing processes. Georesources Engineering 327 (4), 23−34.

Белов В.В., Чистякова В.И. 2008. Моделирование и прогнозирование бизнес-процессов с помощью алгоритмов самоорганизации формальных описаний. Бизнес-информатика 4 (6), 37−45.

Busgang J.J, Ehrman L., Graham J.W. 1974. Analysis of Nonlinear Systems with Multiple Inputs. IEEE 62, 1088.

Дьячков М.Ю. 2017. Индуктивное моделирование объектов и явлений методомгруппового учёта аргументов: недостатки и способы их устранения. Вестник Российского университета дружбы народов. Серия: Математика. Информатика. Физика 25 (4), 323−330.

Gabor D., Wilby W.R., Woodcock R.A. 1961. A universal nonlinear filter, predictor and simulator which optimizes itself by a learning process. Proc. Inst. Electr. Engrs. 108 (40), 85—98.

Geets V.M. ., Klebanova T.S., Chernyak O.I., Ivanov V.V., Kizim M.O., Dubrovina N.A., Stavitsky A.V. 2008. Models and methods of socio-economic forecasting. Kh.: VD "INZHEK", 396 p.

Ивахненко А.Г. 1963. Самообучающиеся системы с положительными обратными связями, 328.

Ивахненко А.Г. 1971. Системы эвристической самоорганизации в технической кибернетике, 372.

Ивахненко А.Г. 1975. Долгосрочное прогнозирование и управление сложными системами, 312.

Ивахненко А.Г., Мюллер Й.А. 1984. Самоорганизация прогнозирующих моделей, 223.

Киселев А.В., Петрова Т.В., Дегтярев С.В., Рыбочкин А.Ф., Филист С.А., Шаталова О.В., Мишустин В.Н. 2018. Нейросетевые модули с виртуальными потоками для классификации и прогнозирования функционального состояния сложных систем. Известия Юго-Западного государственного университета 22(4), 123-134. doi:10.21869/2223-1560-2018-22-4-123-134

Kondratenko V. V., Kuperin Yu. A. Using Recurrent Neural Networks To Forecasting of Forex. Papers cond-mat/0304469, arXiv.org

Lusia D.A., Ambarwati A. 2018. Multivariate Forecasting Using Hybrid VARIMA-Neural Network in JCI Case, Proceedings of SAIN, 11-14.

Maas S. 2000. What you need to know about the method of analysis based on Volterra series. Engineering micro-electronics 1. 45−51.

Мехович С.А., Ахиезер Е.Б., Дунаевская О.И. 2014. Экономико-математическая модель зонирования промышленных предприятий. Энергосбережение. Энергетика. Энергоаудит 8 (126), 39-49.

Neal R.M. 1993. Probabilistic inference using. Technical Report CRGTR,140.

Николенко С.И., Кадурин А.А., Архангельская Е.О. 2022. Глубокое обучение, 480.

Patterson D. 2018. Deep learning from a practitioner's perspective, 482.

Petrov K.E., Deineko A.A., Chalaya O.V., Panferova I.Yu. 2020. Method for ranking alternatives during the procedure of collective expert evaluation. Radioelectronics, informatics, management 2, 84-94.

Ruofan L., Petchaluck B. 2020. Forecasting the Exchange Rate for USD to RMB using RNN and SVM. Journal of Physics: Conference Series 1616, 012050. doi:10.1088/1742-6596/1616/1/012050

Schmidhuber J. 2015. Deep learning in neural networks: An overview. Neural Networks 61, 85-117.

Суляев И.И. 2014. Нейромодель технологического процесса подготовки кислородно-воздушной смеси как объекта управления. Известия СПбГЭТУ ЛЭТИ 7, 20 − 25.

Светуньков С.Г. 1993. Эконометрические методы прогнозирования спроса 183.

Светуньков С.Г. 2024. Нейронная сеть и полином Колмогорова-Габора в моделировании сложных экономических процессов. Modern Economy Success 4, 153 − 157.

Volterra V. 1930. Theory of Functionals and of Integral and Integro-differential Equations, 226.

Wiener N. 1958. Nonlinear problems in random theory, 138.

Yunze T., Sheng X. 2024. Exchange rate forecast between Euro and US dollar based on recurrent neural network. Highlights in Science, Engineering and Technology 85, 663 – 669.

Zhiguo Q., Emese L., Keiichi N. 2024. VaR and ES forecasting via recurrent neural network-based stateful models. International Review of Financial Analysis 92, 103102.

INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

SVETUNKOV Sergey G. – Professor, Doctor of Economic Sciences
E-mail: sergey@svetunkov.ru
СВЕТУНЬКОВ Сергей Геннадьевич – профессор, д.э.н.
E-mail: sergey@svetunkov.ru
ORCID: https://orcid.org/0000-0001-6251-7644

Статья поступила в редакцию 13.05.2024; одобрена после рецензирования 24.05.2024; принята к публикации 27.05.2024.

The article was submitted 13.05.2024; approved after reviewing 24.05.2024; accepted for publication 27.05.2024.

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 22–33.
Техноэкономика. 2024, Том 3, № 2 (9). С. 22–33.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.2

ASSESSMENT OF REQUIREMENTS OF REGULATORY DOCUMENTS ON THE USE OF ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION

Maria Skatova ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ grigorianma@yandex.ru

Abstract. This scientific article is devoted to the systematization of the requirements of domestic standards and other international regulatory documents in the field of application of artificial intelligence technologies in higher education. The research includes analysis of the main standardizing domestic and international documents, identification of drivers and goals of higher education institutions in the use of artificial intelligence technologies in educational processes. The article also presents a model of motivational extension within the TOGAF concept using the ArchiMate enterprise architecture modelling language, which allows to systematize both the requirements of standards and the motivations of higher education institutions to use artificial intelligence. The results of the study can contribute to a more effective integration of artificial intelligence technologies in higher education, taking into account the current standards and needs of educational institutions.

Keywords: artificial intelligence, higher education, higher education institution, standards, documents, requirements, educational processes, motivation extension, ArchiMate, TOGAF

Citation: Skatova M. Assessment of requirements of regulatory documents on the use of artificial intelligence in higher education. Technoeconomics. 2024. 3. 2 (9). 22–33. DOI: https://doi.org/10.57809/2024.3.2.9.2

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.2

АНАЛИЗ ТРЕБОВАНИЙ НОРМАТИВНЫХ ДОКУМЕНТОВ К ИСПОЛЬЗОВАНИЮ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В СФЕРЕ ВЫСШЕГО ОБРАЗОВАНИЯ

Мария Скатова ✉

Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия

✉ grigorianma@yandex.ru

Аннотация. Настоящая научная статья посвящена систематизации требований отечественных стандартов и других международных регламентирующих документов в области применения технологий искусственного интеллекта в сфере высшего образования. Исследование включает анализ основных стандартизирующих отечественных и зарубежных документов, выявление драйверов и целей высших учебных заведений в использовании технологий искусственного интеллекта в образовательных процессах, а также в статье представлена модель мотивационного расширения в рамках концепции TOGAF с использованием языка моделирования архитектуры предприятия ArchiMate, что позволяет систематизировать как требования стандартов, так и мотивы вузов к применению искусственного интеллекта. Результаты исследования могут способствовать более эффективной интеграции технологий искусственного интеллекта в высшее образование, учитывая текущие стандарты и потребности образовательных учреждений.

Ключевые слова: коэффициент корреляции, номинальные данные, коэффициент Юла, коэффициент Пирсона, корреляционные связи. искусственный интеллект, высшее образование, высшее учебное заведение, стандарты, документы, требования, образовательные процессы, мотивационное расширение, ArchiMate, TOGAF

Для цитирования: Скатова М. Анализ требований нормативных документов к использованию искусственного интеллекта в сфере высшего образования // Техноэкономика. 2024. Т. 3, № 2 (9). С. 22–33. DOI: https://doi.org/10.57809/2024.3.2.9.2

Introduction

In today's world, when artificial intelligence (hereinafter referred to as AI) is revolutionizing many industries, higher education should also keep up with the change and implement the potential of AI to improve the educational process and increase the efficiency of administrative tasks. The possibility of increasing the efficiency of information resources use in an organization appears if a unified information space is built and an IT infrastructure is created, based on modern methods and models of building information systems, data and knowledge exchange systems and relevant information and communication technologies (Ilyin, Shirokova, 2022). Education should become multi-format and personalized (Dyatlova, 2023). This can be realized by introducing new information systems into the structure of higher education institutions (hereinafter referred to as HEI) processes.

The relevance of this research article is as follows. Standards and regulatory documents play a key role in ensuring the correct and ethical application of AI in any field, including higher education. Standards establish requirements, constraints and guidelines that help to ensure that AI technologies are used effectively, safely and for the benefit of all stakeholders. However,

there is a challenge in that AI standards and regulations can be very numerous, complex and frequently updated due to the rapid development of AI technologies. This creates challenges for higher education institutions to understand and comply with all relevant requirements.

Moreover, the goals and needs of HEIs in the context of AI application may differ depending on the specific institution, educational programs and administrative processes. It is important to identify the drivers and motivations that encourage HEIs to apply AI, as well as to understand the constraints and requirements that set standards to ensure successful integration of AI into the educational environment. The realization of the strategic goals of the enterprise should be ensured by a flexible and effective management system (Ilin, 2022).

The article aims to help higher education institutions understand the complex landscape of standards, identify drivers and constraints in the context of AI applications, and ultimately successfully integrate AI technologies into educational and administrative processes.

Purpose of the study: systematization of the requirements of domestic standards and other foreign regulatory documents in the field of application of artificial intelligence technologies in higher education.

Objectives:

– to analyze the main standardizing domestic standards and foreign regulatory documents in the field of application of AI technologies in higher education;

– to identify the drivers and goals of higher education institutions in the context of the application of AI technologies in educational processes/processes of organization and support of the educational process, as well as to identify the limitations and requirements of standards and other regulatory documents in the field of application of AI technologies in higher education;

– to create a model of motivation extension within the TOGAF methodology to systematize the requirements of domestic standards and other foreign regulatory documents in higher education, as well as to systematize the drivers and motives that encourage HEIs to apply AI technologies.

Subject of the research: regulating, standardizing, normative and other documentation in the field of implementation of artificial intelligence technologies in educational processes and processes of support and organization of educational process in higher education institution.

Object of the research: educational processes and processes of support and organization of educational process in higher education institution.

Materials and Methods

The following materials and methods were used to fulfil the aim and objectives of this research article:

1. Analyzing standards and regulatory documents.

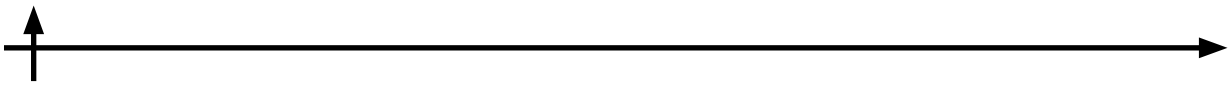
First, the main domestic standards, such as 'GOST R 59895-2021' and 'GOST R 70946-2023', as well as foreign regulatory documents, such as guidelines from the UNESCO Institute, were analyzed.

The general provisions, terminology, functional subsystem of learner performance management, test methodology and other aspects related to the application of AI technologies in education were studied.

2. Identification of drivers, goals and constraints of higher education institutions.

For this purpose, research was conducted into the motives that may encourage universities to apply AI technologies in educational processes.

The goals and drivers in the context of using AI in the organization and support of the educational process were identified, as well as the limitations and requirements established by



standards and other documents.

3. Modelling a model of motivation extension within the TOGAF methodology.

To systematize the requirements of standards and other regulatory documents, the modeling of the motivation extension model was used.

TOGAF methodology was used to organize and classify drivers and motives that stimulate higher education institutions to use AI technologies.

Thus, the paper used analytical methods to analyze the standards, exploratory methods to identify the drivers and goals of universities, and modelling within the TOGAF methodology to systematize the requirements and motivations for the application of AI technologies in higher education.

Results and Discussion

The introduction of AI technologies into educational processes requires the use of unified concepts and definitions to ensure a uniform understanding and exchange of information between specialists in the field. One of the breakthrough technologies in solving automation challenges is artificial intelligence (Abdukhalilova, 2023). A digital strategy requires IT tools capable of supporting its development, implementation and evaluation (Maidanova, 2023).

Standard GOST R 59895-2021 «Artificial Intelligence Technologies in Education. "General provisions and terminology" is a fundamental standard that defines key terms and concepts in the field of AI use in education. Thanks to the standardization of terminology, it becomes possible to effectively implement new technologies, as well as to exchange experience and transfer knowledge between participants of the educational process.

The document consists of three main sections:

1. "Scope of application".

2. "Terms and definition": terms related to artificial intelligence; terms related to the educational process; terms related to the use of artificial intelligence technologies in education.

3. "Use of artificial intelligence technologies in education": computer vision technologies; technologies of natural language processing, speech recognition and synthesis; technologies of intellectual decision-making support; promising artificial intelligence technologies; use of the totality of described artificial intelligence technologies.

The document introduces specialized terms that apply exclusively in the context of the use of AI in education, which distinguishes it from other standards. While most standards cover a wide range of applications of AI without reference to a specific subject area or domain, this document focuses exclusively on the educational domain.

It is worth mentioning important advantages of GOST R 59895-2021 standard, which can be taken into account when implementing AI technologies in the system of support and organization of the educational process:

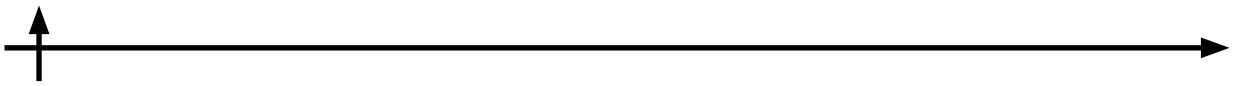
1. Standardization and unification of terminology in the field of application of AI technologies in higher education helps to ensure a common understanding of AI concepts among all participants of the educational process.

2. Clarity of terminology provides developers with clear criteria for creating educational AI systems.

3. The possibility to avoid misunderstandings and legal disputes related to the use of AI technologies in education.

The digitalization of activities generates an increasing amount of data that requires further processing. It is data that is at the heart of digital transformation (Morozevich, 2022). In this regard, it is necessary to have some document prescribing the requirements for testing this data.

The next document for analysis is the standard GOST R 70946-2023 «Artificial Intelligence



Technologies in Education. Functional subsystem for managing the progress of students on bachelor's and specialist's programs. General provisions and test methodology». This standard defines the general provisions and test methodology of AI technologies used in the management of learning achievement of students on undergraduate and specialist programs within the framework of the relevant functional subsystem of a higher education institution.

The document is organized into seven main sections:

1. "Scope of application".
2. "Normative references".
3. "Terms and definitions".
4. "General Provisions". It is important to note that this section states that in order to ensure confidence in artificial intelligence systems (hereinafter referred to as AIS) used to implement learning progress management, the test methodology set out in this standard should be applied. For the realization of other functions arising within the functional subsystem under consideration, the test methodology set out in this standard is also applicable, provided that it is transformed to take into account the peculiarities of the applied AI technologies. In other words, it means that the test methodology described in this standard can also be applied to other modules of the system, including those mentioned earlier, but it needs to be adapted to the specific AI technologies. This means that it is possible to scale and use it not only for testing the module of learning progress accounting with the help of AI technologies, but also for testing any different functions of organization and support of the educational process of HEI.
5. "Test Methodology". It is one of the main sections. This section describes the following points: who are the participants of the tests, the responsibilities of the customer and the test laboratory during the tests, the essential conditions of operation, the formation of the test data set, as well as the formulas for calculating the classification and approximation indicator (the choice of one of the indicators is set by the customer), which will be subsequently calculated by the test laboratory and recorded in the test report.
6. "Examples of intelligent systems and tasks for managing the progress of students on bachelor's and specialist programs".
7. "Description of the basic demonstration dataset".

Let us describe the advantages of using the GOST R 70946-2023 standard when implementing AI technology in the system of support and organization of the educational process:

1. Providing a unified approach to testing of the AI system when implementing it in the processes of support and organization of the educational process in the sphere of higher education;
2. Ensuring consistency in the assessment of compliance of the stated requirements to the system with the actual functions of the system and identification of inconsistencies for their subsequent elimination.

The economy, which had started to recover, was again caught in the crucible of another crisis - COVID-19 (Vinichenko, 2020). Educational organizations were forced to restructure the system of personnel training, switch to distance learning and, in general, completely restructure their business processes in the shortest possible time. In this regard, there was no doubt that sooner or later higher education institutions would need to integrate artificial intelligence into their processes.

The use of international standards in the implementation of AI technologies in the system of support and organization of the educational process in higher education is of great importance. AI technologies have a serious potential for implementation in the field of science and higher education and nowadays successful results are already observed in the international practice. For successful implementation of new technologies, it is necessary to take into account possible and available international experience (Alexandrov, 2021). Modern education is impossible without

the use of digital technologies (Kolesnikova, 2021), in particular, without the evaluation and application of international best practices in the field of implementation of AI technologies in the educational process.

"Guidance for Generative AI in Education and Research" is a document developed by the UNESCO Institute to provide guidance on the use of generative AI in education and research. The document covers issues such as the ethical, social and educational aspects of the use of generative AI and offers recommendations for its application in teaching and research environments. It also analyses the existing problems and challenges associated with the use of generative AI in education and research and suggests ways to address them. In addition, the document provides recommendations and best practices for integrating generative AI into curricula, research projects and other educational and research activities. The importance of this approach to organizational development is now understood by almost everyone (Mokaeva, 2021).

The document is organized into six main sections:

1. "What is generative AI and how does it work?".
2. "Controversies about generative AI and their implications for education".
3. "Regulating the use of generative AI in education".
4. "Towards a policy framework for the use of generative AI in education and research".
5. "Promoting the creative use of generative AI in education and research".
6. "Generative AI and the future of education and research".

AI co-operates with humans in various fields of activity, including education (Petrova, 2021). The report of the UNESCO Institute for Information Technologies in Education, reveals the main provisions of the application of AI systems in the field of education. The report focuses on the advances in technology in the educational environment, the capabilities of AI systems at the moment, as well as some prospects for this technology in the future (Chagilov, 2021). Artificial intelligence is a huge resource that opens up rich opportunities for improving the educational process (Radugin, 2021).

The document "Guidance for Generative AI in Education and Research" provides valuable recommendations on the use of generative AI in education and research. These recommendations may be particularly useful for Russian higher education institutions that are seeking to introduce AI technologies into the educational process. The main recommendations include the following:

1. Ethical principles. The UNESCO guidelines emphasize the need for ethical standards in the use of AI, which helps Russian HEIs to develop and implement AI technologies that respect the rights and freedoms of students and teachers.

2. Transparency and accountability. The UNESCO guidelines emphasize the need for transparency of algorithms and accountability for their results, which is important for building trust in AI systems in the academic environment.

3. Quality of education and educational process organization. By providing methodologies for integrating AI into the educational process, the UNESCO guidelines contribute to improving the quality of education, allowing students to have a personalized and adaptive learning experience and university staff to organize their work more efficiently.

In the period of digital transformation, artificial intelligence technologies are being actively developed and implemented in the processes of various organizations (Blinnikova, 2020). This trend extends to the educational and administrative processes of higher education institutions.

As a result of the analysis of the selected documents that can help IT specialists in the possible implementation of artificial intelligence technologies in the system of support and organization of the educational process in higher education institution, it is possible to compile and

systematize the main requirements that each of them puts forward:

1. Standard GOST R 59895-2021 “Artificial Intelligence Technologies in Education. General provisions and terminology”. The main requirement put forward by the standard: Application of standardized and unified terminology in the field of implementation of AI technologies in educational processes/processes of organization and support of educational process in higher education institution.

2. Standard GOST R 70946-2023 “Artificial Intelligence Technologies in Education. Functional subsystem for managing the progress of students on bachelor's and specialist's programs. general provisions and test methodology”. The main requirement put forward by the standard: Application of a unified approach to testing of functional modules of the AI system when it is implemented in educational processes/processes of organization and support of the educational process in higher education institution.

3. “Guidance for Generative AI in Education and Research”. The main requirement of the standard: Compliance with international practices and trends in the field of implementation of AI technologies in educational processes/processes of organization and support of educational process in higher education institutions.

Now, with a clear systematized set of document requirements, it seems possible to generate a motivation extension model within the TOGAF methodology using the ArchiMate modelling language, which will achieve the following objectives:

– identify the drivers and goals that higher education institutions have in implementing AI technologies in their processes;

– identify the constraints and requirements that standards and other regulatory documents impose on the application of AI technologies in higher education.

In the description of enterprise architecture, one of the most popular tools is ArchiMate - a tool for integrated high-level modelling and analysis of various enterprise domains and dependencies between domains. Within the discipline of Enterprise Architecture, the concept of motivation extension is used, which is understood as a model of external forces (stakeholders, drivers of situations, constraints, requirements, assessments) that influence the emerging business architecture (Ilyin, Levina, 2019). Motivation extension is an extremely important feature of ArchiMate because it is an effective tool for describing goals, drivers, interaction principles, business requirements and business constraints (Voronova, 2021).

Let us describe in more detail each of the components of motivation extension: stakeholders, drivers, driver evaluations, goals, outcomes, constraints and requirements.

The main stakeholder is the higher education institution. It is also the customer.

Drivers are the main interests of the stakeholder in the system (Mapping methodological concepts using the ArchiMate language).

Drivers:

1. The need for the HEI's IT infrastructure to keep up with the latest cutting-edge technologies in higher education.

2. The need to support the competitiveness of HEI IT support in the market of educational services.

3. Growing volume of information and the need of educational and support staff to quickly process and analyze it.

Assessment is the result of analyzing the state of affairs in an enterprise in relation to a driver (Elements of motivation).

Assessments:

1. The existing IT infrastructure of the HEI does not meet the latest advanced technologies

in higher education.

2. Low competitiveness of HEI on the market of educational services.

3. Low current speed of analyzing and processing information by the teaching and support staff.

A goal is a high-level statement about the intentions, direction of development, or desired end state of an organization and its stakeholders (ArchiMate 3.1 Specification).

Goals:

1. Update and modernize IT infrastructure, implement new technologies and IT solutions.

2. High competitiveness in the market of educational services due to effective IT support of the educational process.

3. Development of IT infrastructure to ensure high speed and efficiency of information processing.

The overall goal is «Introduction of AI technologies into educational processes/system of support and organization of educational process in HEI».

An outcome is a desired or achieved result that affects the motivation of stakeholders and determines the strategic goals of the organization (ArchiMate. Motivation Layer).

Outcome:

1. Improving the efficiency of the educational process and formation of the modern image of the HEI.

2. Increasing the attractiveness of HEI for future and current students and potential partners.

3. Improving the efficiency of decision-making processes of the teaching and support staff and responsiveness to students' requests.

Constraints:

1. Standard GOST R 59895-2021 «AI technologies in education. General provisions and terminology».

2. Standard GOST R 70946-2023 «AI Technologies in Education. Functional subsystem for managing the progress of students in undergraduate and specialist programs. General provisions and test methodology».

3. Guidance for Generative AI in Education and Research.

Requirements:

1. Application of standardized and unified terminology in the field of implementation of AI technologies in educational processes/processes of organization and support of educational process in higher education institution.

2. Applying a unified approach to testing the functional modules of the AI system during its implementation in educational processes/processes of organization and support of educational process in higher education institution.

3. Compliance with international practices and trends in the field of implementation of AI technologies in educational processes/processes of organization and support of educational process in higher education institution.

The model of motivation extension for higher education institutions when introducing artificial intelligence technologies in educational processes and processes of support and organization of educational process in higher education institution is presented in figure 1.

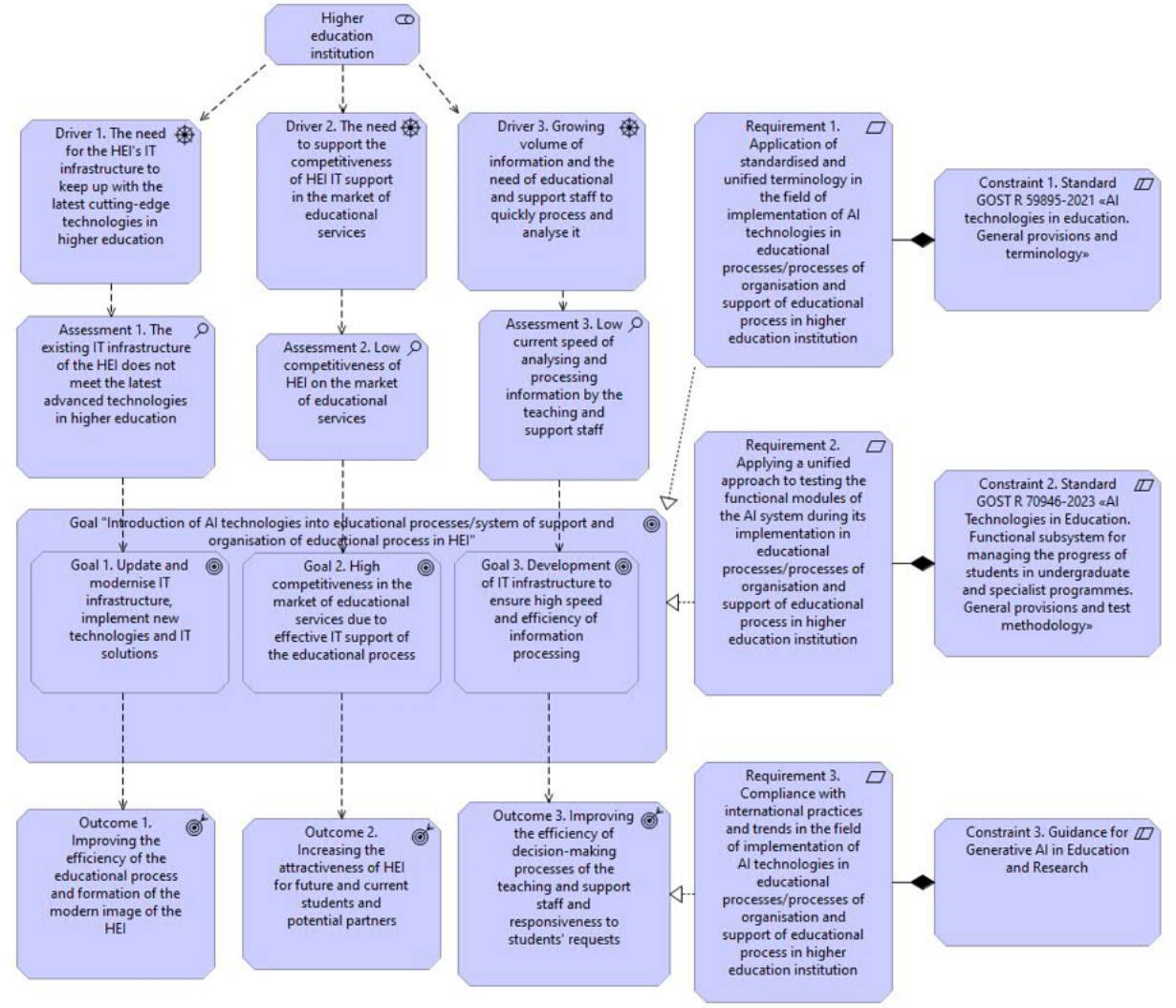


Fig. 1. Model of motivation extension for higher education institutions when introducing artificial intelligence technologies in educational processes and processes of support and organization of the educational process

The proposed model of motivation extension will allow further qualitative modelling of the model of the current state of the organization 'AS-IS', identify bottlenecks in the work of the organization and model the model of the target state of the organization 'TO-BE', which, ultimately, will help IT specialists in understanding the complex landscape of processes of higher education institutions and will contribute to the successful integration of artificial intelligence technologies into the educational and administrative processes of higher education institutions.

Conclusion

In conclusion, it should be noted that the systematization of the requirements of standards and other regulatory documents in the field of application of AI technologies in higher education is an important and urgent task. Proper and effective application of AI technologies in the educational process can bring significant benefits and improve the quality of higher education.

In the course of this study, the main standardizing domestic standards and foreign regulatory documents concerning the application of AI technologies in higher education have been analyzed, namely the standard GOST R 59895-2021 «Artificial Intelligence Technologies in Education. General provisions and terminology», standard GOST R 70946-2023 «Artificial Intelli-

gence Technologies in Education. Functional subsystem for managing the progress of students on bachelor's and specialist's programs. general provisions and test methodology», the guidelines from the UNESCO Institute «Guidance for generative AI in education and research». This made it possible to identify general trends, requirements and limitations that should be taken into account by higher education institutions when implementing AI technologies.

One of the key aspects of the study was to identify the drivers and goals of higher education institutions in the context of the application of AI in educational processes and their relationship to the requirements of standards. It was found that HEIs are interested in using AI to improve the quality of education, personalize learning, increase the efficiency of administrative tasks and many other goals. These drivers and goals play an important role in motivating HEIs to implement AI technologies.

In addition, a motivation extension model within the TOGAF methodology was modelled using the ArchiMate modelling language to systematize the requirements of standards and other regulatory documents and visualize the link between them and the drivers and goals of higher education institutions when implementing AI technologies. This model provides a structured approach to understanding and complying with the requirements of the standards, ensuring successful integration of AI into educational processes and processes of organization and support of the educational process. The result of the formation of a motivation extension to update and modernize the IT infrastructure, increase competitiveness through effective IT support of the learning process and develop the speed and efficiency of information processing can be the transformation of a higher education institution into a modern educational institution with an attractive offer for students and partners.

REFERENCES

Abdukhalilova L., Ilyashenko O., Alchinova D. 2023. Application of machine learning methods in electronic document management systems. Technoeconomics 4 (7), 61-71. doi: https://doi.org/10.57809/2023.2.4.7.6

Alexandrov N.D. 2021. International experience of introduction of artificial intelligence in the branches of science and higher education. Scientific Proceedings of the Free Economic Society of Russia 229 (3), 391-401. doi:10.38197/2072-2060-2021-229-3-391-401

Blinnikova A.B. 2020. Utilisation of artificial intelligence in the processes of human resource management 7, 14-21. doi:10.26425/1816-4277-2020-7-14-21

Chagilov V.R. 2021. Artificial intelligence in education: potential scale of optimisation of educational process. Scientific Bulletin of the State Autonomous Educational Institution of Higher Education 'Nevinnomyssk State Humanitarian-Technical Institute' 3, 30-34.

Dyatlova D.D., Krotov E.Yu. 2023. Smart university: global challenges or local tasks? Technoeconomics 2 (5), 36-44. doi: https://doi.org/10.57809/2023.2.2.5.3

Ilin I.V. 2022. Integration of information and management technologies. Technoeconomics 1 (1), 24-32. doi: https://doi.org/10.57809/2022.1.1.2

Ilyin I.V., Levina A.I., Ilyashenko V.M., Ilyashenko O.Y. 2019. A model of motivation extension of the digital transformation of Russian business. Science and business: ways of development 8 (98), 127-131.

Ilyin I.V., Shirokova S.V., Lyovina A.I., Rostova O.V. et al. 2022. Information Technologies in Business Management. Politech-press, 215.

Kolesnikova A.P. 2021. Artificial intelligence in the educational process: possibilities of application. Poisk 3 (76), 20-23.

Maidanova S.A., Ilyin I.V. 2023. Development of digital transformation strategy in the context of enterprise architecture. Technoeconomics 1 (4), 64-75. doi: https://doi.org/10.57809/2023.2.1.4.6

Mokaeva A.K. 2021. Artificial intelligence in business processes. Naukosphere 5 (2), 198-202.

Morozevich E.S., Korotkikh V.S., Kuznetsova E.A. 2022. Development of the model of formation of individual educational trajectories using machine learning methods. Business Informatics 16 (2), 21-35. doi: 10.17323/2587-814X.2022.2.21.35

Petrova A.K. 2021. Artificial intelligence in the automation of educational processes. Modern education: content, technology, quality 1, 58-61.

Radugin A.A. 2021. Application of artificial intelligence in the educational process of higher education institution: technologies, potential and problems. Bulletin of Voronezh State University. Problems of higher education 4, 84-87.

Vinichenko M.B. 2020. Changes in the quality of learning in higher education using digital technologies and artificial intelligence in the conditions of COVID-19 pandemic. Scientific Notes of the Russian State Social University 4 (157), 137-144. doi:10.17922/2071-5323-2020-19-4-137-144

Voronova O.V., Ilyin I.V., Sheleiko V.A. 2021. Development of structural-functional approach to detailing of motivation extension of Archimate for realisation of branch architectural solutions. Izvestiya St. Petersburg State University of Economics 5 (131), 120-128.

ArchiMate 3.1 Specification. URL: https://pubs.opengroup.org/architecture/archimate31-doc/chap06.html (accessed 27.05.2024).

Archimate. Motivation Layer. URL: https://habr.com/ru/companies/otus/articles/722134/ (accessed 28.05.2024).

Elements of motivation. URL: https://www.businessstudio.ru/help/docs/current/doku.php/ru/manual/archimate (accessed 26.05.2024).

Mapping methodological concepts using the ArchiMate language. URL: https://www.hostco.ru/news/otobrazhenie-metodologicheskikh-kontseptsiy-s-pomoshchyu-yazyka-archimate/?ysclid=lwp014skgx827703388 (accessed: 25.05.2024).

СПИСОК ИСТОЧНИКОВ

Abdukhalilova L., Ilyashenko O., Alchinova D. 2023. Application of machine learning methods in electronic document management systems. Technoeconomics 4 (7), 61-71. doi: https://doi.org/10.57809/2023.2.4.7.6

Александров Н.Д. 2021. Международный опыт внедрения искусственного интеллекта в отрасли науки и высшего образования. Научные труды Вольного экономического общества России 229 (3), 391-401. doi:10.38197/2072-2060-2021-229-3-391-401

Блинникова А.В. 2020. Использование искусственного интеллекта в процессах управления человеческими ресурсами 7, 14-21. doi:10.26425/1816-4277-2020-7-14-21

Чагилов В.Р. 2021. Искусственный интеллект в образовании: потенциальный масштаб оптимизации учебного процесса. Научный вестник Государственного автономного образовательного учреждения высшего образования "Невинномысский государственный гуманитарно-технический институт" 3, 30-34.

Dyatlova D.D., Krotov E.Yu. 2023. Smart university: global challenges or local tasks? Technoeconomics 2 (5), 36-44. doi: https://doi.org/10.57809/2023.2.2.5.3

Ilin I.V. 2022. Integration of information and management technologies. Technoeconomics 1 (1), 24-32. doi: https://doi.org/10.57809/2022.1.1.2

Ильин И.В., Левина А.И., Ильяшенко В.М., Ильяшенко О.Ю. 2019. Модель мотивационного расширения цифровой трансформации российского бизнеса. Наука и бизнес: пути развития 8 (98), 127-131.

Ilyin I.V., Shirokova S.V., Lyovina A.I., Rostova O.V. et al. 2022. Information Technologies in Business Management. Politech-press, 215.

Kolesnikova A.P. 2021. Artificial intelligence in the educational process: possibilities of application. Poisk 3 (76), 20-23.

Maidanova S.A., Ilyin I.V. 2023. Development of digital transformation strategy in the context of enterprise architecture. Technoeconomics 1 (4), 64-75. doi: https://doi.org/10.57809/2023.2.1.4.6

Мокаева А.К. 2021. Искусственный интеллект в бизнес-процессах. Наукосфера 5 (2), 198-202.

Морозевич Е.С., Коротких В.С., Кузнецова Е.А. 2022. Разработка модели формирования индивидуальных образовательных траекторий с использованием методов машинного обучения. Бизнес Информатика 16 (2), 21-35 doi: 10.17323/2587-814X.2022.2.21.35

Петрова А.К. 2021. Искусственный интеллект в автоматизации образовательных процессов. Современное образование: содержание, технологии, качество 1, 58-61.

Radugin A.A. 2021. Application of artificial intelligence in the educational process of higher education institution: technologies, potential and problems. Bulletin of Voronezh State University. Problems of higher education 4, 84-87.

Виниченко М.В. 2020. Изменение качества обучения в вузе, использующем цифровые технологии и искусственный интеллект, в условиях пандемии COVID-19. Ученые записки Российского государственного социального университета 4 (157), 137-144. doi:10.17922/2071-5323-2020-19-4-137-144

Воронова О.В., Ильин И.В., Шелейко В.А. 2021. Разработка структурно-функционального подхода к детализации мотивационного расширения ARCHIMATE для реализации отраслевых архитектурных решений. Известия Санкт-Петербургского государственного экономического университета 5 (131), 120-128.

ArchiMate 3.1 Specification. URL: https://pubs.opengroup.org/architecture/archimate31-doc/chap06.html (accessed 27.05.2024).

Archimate. Motivation Layer. URL: https://habr.com/ru/companies/otus/articles/722134/ (accessed 28.05.2024).

Elements of motivation. URL: https://www.businessstudio.ru/help/docs/current/doku.php/ru/manual/archimate (accessed 26.05.2024).

Mapping methodological concepts using the ArchiMate language. URL: https://www.hostco.ru/news/otobrazhenie-metodologicheskikh-kontseptsiy-s-pomoshchyu-yazyka-archimate/?ysclid=lwp014skgx827703388 (accessed: 25.05.2024).

INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

SKATOVA Maria M. – student.
E-mail: grigorianma@yandex.ru
СКАТОВА Мария Михайловна – студент.
E-mail: grigorianma@yandex.ru

Статья поступила в редакцию 28.05.2024; одобрена после рецензирования 10.06.2024; принята к публикации 13.06.2024.

The article was submitted 28.05.2024; approved after reviewing 10.06.2024; accepted for publication 13.06.2024.

Technoeconomics. 2024, Vol. 3, No. 1 (8). Pp. 34–49.
Техноэкономика. 2024, Том 3, № 1 (8). С. 34–49.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.3

INTERACTIVE INFORMATION SYSTEMS IN THE HOSPITALITY INDUSTRY

Olga Voronova, Ekaterina Novikova ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ qckmnh@icloud.com

Abstract. In the changing landscape of the hospitality industry, the integration of modern consumer interaction technologies has become a must for hotels to remain competitive and meet the changing expectations and needs of guests. Thus, more and more collective accommodation facilities are implementing innovative solutions to enhance comfort, safety and personalization of service. This article is devoted to analyzing the possibilities of interactive systems in the enterprises of the hospitality industry. The study considers the main information systems of hospitality enterprises, methods and options for providing an interactive map, identifies functional requirements for project implementation in ArchiMate, and determines the socio-economic effect of implementing additional interactive information systems.

Keywords: interactive map, information technology, hospitality industry, mobile application, interaction interface

Citation: Voronova O., Novikova E. Interactive information systems in the hospitality industry. Technoeconomics. 2024. 3. 2 (9). 34–49. DOI: https://doi.org/10.57809/2024.3.2.9.3

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.3

ИНТЕРАКТИВНЫЕ ИНФОРМАЦИОННЫЕ СИСТЕМЫ В ИНДУСТРИИ ГОСТЕПРИИМСТВА

Ольга Воронова, Екатерина Новикова ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ qckmnh@icloud.com

Аннотация. В условиях постоянно меняющегося ландшафта индустрии гостеприимства интеграция современных технологий взаимодействия с потребителями стала обязательным условием для отелей, чтобы оставаться конкурентоспособными и соответствовать меняющимся ожиданиям и потребностям гостей. Таким образом, все больше коллективных средств размещения внедряют инновационные решения, направленные на повышение комфорта, безопасности и персонализации обслуживания. Данная статья посвящена анализу возможностей интерактивных систем на предприятиях индустрии гостеприимства. В исследовании рассмотрены основные информационные системы гостиничных предприятий, методы и варианты предоставления интерактивной карты, выявлены функциональные требования к осуществлению проекта в ArchiMate, а также определен социально-экономический эффект внедрения дополнительных интерактивных информационных систем.

Ключевые слова: интерактивная карта, информационные технологии, индустрия гостеприимства, мобильное приложение, интерфейс взаимодействия

Для цитирования: Воронова О., Новикова Е. Интерактивные информационные системы в индустрии гостеприимства // Техноэкономика. 2024. Т. 3, № 2 (9). С. 34–49. DOI: https://doi.org/10.57809/2024.3.2.9.3

Introduction

In an evolving marketplace, businesses in the hospitality industry need to focus on information systems in order to remain competitive. The key technologies that are most prevalent at the moment are discussed below.

Smart rooms represent a fundamental advancement in the solutions used by hotels to meet the needs of their guests. These technologically advanced rooms use IoT (Internet of Things) to create an immersive and personalized customer experience. Equipped with built-in smart sensors and devices, these rooms allow guests to control various aspects of the environment, including lighting, air temperature and more, from a central control unit. The smart room can function with the help of a tablet tethered to the system or a voice assistant. Innovations were also reflected in the way the rooms are opened. In most hotels, traditional keys have given way to electronic cards, simplifying the process of opening a room. These cards, equipped with RFID or NFC technology, allow guests to access their rooms with a simple touch.

In addition, it is worth mentioning biometric technologies such as facial recognition and fingerprint scanning. These are being incorporated into hotel systems to open a room without the need for handy tools, which is certainly a convenient solution, so that a guest can leave the room without having to take a key or access card with them. Despite concerns about privacy and data security, hotels that implement biometric technology often prioritize transparency and

compliance to ensure guest trust and loyalty.

Interactive maps have also become an indispensable tool for guests to comfortably navigate areas of modern hotel complexes. Integrating augmented reality (AR) technology and the use of geolocation, these maps offer guests a dynamic and interactive way to explore hotel facilities, amenities and nearby attractions. Guests can use their smartphones or in-room tablets to access interactive maps that provide all the information they need in real time. This solution helps to increase self-management of vacations, which is increasingly valued by guests (Types of interactive maps, 2024).

The emergence of virtual concierge services, in turn, has completely changed the concept of providing support during a hotel stay. Chatbots, accessible via mobile apps or in-room devices, instantly respond to guest queries, provide various recommendations on request, and facilitate the booking of additional services.

Not to be overlooked are another IoT devices, such as smartwatches and wristbands, which have also found their way into the hospitality industry to enhance guest convenience. They can perform a number of functions at the same time and serve as electronic room keys, allowing guests unhindered access to rooms and other secured areas.

Some forward-thinking hotels are already implementing robotics to enhance the guest experience. Robots equipped with artificial intelligence can perform routine tasks such as delivering food to the room, assisting with quick check-in and check-out of guests, and booking services.

Having reviewed the existing methods used for consumer interaction with various systems, it is worth noting that the hospitality industry will undoubtedly master more innovative and exciting technologies as they emerge. It is important to emphasize that in order to be successful, collective accommodation facilities must remain flexible, regularly introducing new solutions that meet the preferences of modern travelers and contribute to not only a comfortable but also memorable stay for guests.

Materials and Methods

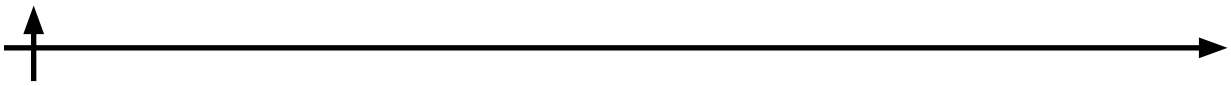
The research adopts a mixed-methods approach, blending qualitative and quantitative data to comprehensively analyze the effects of implementation of interactive information systems in hospitality industry. Central to the study is an extensive literature review, encompassing academic papers, government reports, and industry analyses, to understand the current dynamics of hospitality. Quantitative data collection focuses on key results related to the implementation of information technologies in hospitality industry

A descriptive analysis method is employed to present a clear picture of current hospitality landscape, highlighting its reliance on information technologies. The study also incorporates case studies of successful projects providing practical examples of theoretical strategies in action.

Results and Discussion

An interactive map is a digital mapping tool that allows users to actively engage and interact with geographic information in real time. Unlike static maps, interactive maps allow for dynamic exploration, customization, and integration of different data layers, providing a more immersive and personalized spatial experience. In addition to the information conveyed to users through traditional map exploration, interactive maps contain hidden data that becomes available through certain user actions, such as hovering over an object.

An interactive map can also significantly improve the efficiency of resort management by employees. Decision-making based on data obtained from the program can optimize the management of resources and operational processes in the resort complex. The key technologies and functionalities of interaction of the interactive map with other services of the hotel enterprise



aimed at guests are presented in Table 1.

Table 1. Functionality of the interactive map aimed at guests

Function	Description
Geo-spatial view	A visual representation of the hotel grounds, including buildings, room locations and outdoor spaces; Interactive zooming and panning features that allow users to explore various hotel facilities in more detail.
Points of interest (POI)	Identification and highlighting of key points of interest within the hotel, such as restaurants, lounge areas, fitness centers and meeting rooms; Clickable icons or labels that provide additional information about each point of interest.
Information on rooms	Integration with the hotel's reservation system, allowing guests to view each individual room and its location in the building, check availability, view rates and make reservations (seamless transition between the interactive map and the reservation process); Real-time updates on room availability.
Navigation and route finding	Step-by-step instructions and a standard set of several itinerary options for first familiarization with the area will help guests spend their time productively and get from one place to another with ease.
Information on events and activities	Map display of scheduled events, conferences and activities taking place at the hotel with location; Integration with event calendars and promotion of events within the hotel.
Guest-oriented offers	Integration of an AI questionnaire that provides an opportunity for guests to customize their vacation by indicating preferences for amenities and services of interest, which will subsequently be highlighted on a map and a personalized route will be generated to reach them.
Booking	Integrating service reservations directly through the interactive map, this could represent a reservation for a table in a hotel complex restaurant, spa services, tennis court and so on.
Local attractions and places of interest	Some interactive maps go beyond the hotel and show nearby attractions, restaurants, shopping centers and other points of interest, so integration with external data sources allows guests to get comprehensive information about the surrounding area.

Based on this table, it can be seen that interactive maps interacting with hospitality businesses provide a variety of functionality to improve the customer experience.

The key technologies and functionalities aimed at hospitality enterprise employees are summarized in Table 2.

Table 2. Interactive map functionality aimed at employees

Function	Description
Operational efficiency: Staff guiding	Interactive maps help staff as well as guests to navigate the hotel territory, especially in large properties. This is especially valuable for new employees during the adaptation process.
Facility Management: Maintenance and cleaning	Interactive maps can be integrated with maintenance and cleaning systems to help staff identify areas that need attention. This contributes to faster response times and quality service
Event planning and organization: Conferences and banquet services	At hotels with event services, interactive maps can help event organizers coordinate logistics, organize exhibits, and manage conferences or banquets more visually
Resource allocation: Staff deployment	By integrating visualization of occupancy and demand in different areas of the hotel, management can optimize staff performance, ensuring that staff are allocated where they are most needed at any given time
Emergency planning: Evacuation routes	In the event of an emergency, employees can use interactive maps to access predetermined evacuation routes and emergency assembly points, ensuring a quick and organized response to critical situations
Improved communication: Interaction between departments	Interactive maps can serve as a centralized platform for interdepartmental communication, facilitating collaboration and information sharing between different departments within the hotel
Data-driven decision making: Feedback analytics	Data from guest interactions with interactive maps (namely integrated feedback on the points and services marked on the map) can be analyzed to identify areas for improvement, allowing the hospitality company to improve itself

Based on this table, it can be noted that collective accommodation facilities can derive many benefits from the implementation of interactive maps, in addition to the convenience for guests. These benefits extend to internal operations and, consequently, the efficiency of the organization's management. It is important to note that interactive maps also include the ability to integrate processes to organize work activities. In this way, hospitality businesses using electronic maps for personal purposes can optimize their internal processes, improve communication between departments and, as a result, improve overall productivity and management performance (Cooper, 2021).

For the purpose of this study, the Park Hotel Lazurniy Bereg was selected as the case study. It is a four-star resort complex located in the suburban village of Dzhemete, in the resort area of Pionersky Avenue, in the north of Anapa.

The Lazurniy Bereg resort complex features a small number of technological solutions aimed at consumer interaction, including electronic cards for opening a room, smart watches for entering the gym and spa area, and a "smart room" system for higher room categories.

In addition, for the convenience of the guests of the resort complex they have introduced a technological solution in the form of smart bracelets, which provide access to such free areas of the hotel as a gym and spa zone, as well as work as a "payment meter" for the tennis court and air hockey, which records the time of entry and exit from the territory of the service and allows guests to comfortably spend their leisure time and pay afterwards at any convenient time.

Moreover, in the nearest future the hotel company is going to introduce the bracelet payment system also in the bar areas by the pool and the sea on the territory of the resort complex "Azure Coast", so that the guests are not forced to carry valuable things with them and can enjoy their vacation feeling that the hotel cares about the personal belongings of the clients and their safety.

These bracelets are integrated with the access and identification system using IoT (Internet of

Things) technology, which allows guests to freely use the amenities of the resort complex without having to carry additional items, which is often inconvenient. As the statistics of reviews on various booking sites show, this innovative approach is very much appreciated among guests and is often noted in customer feedback.

It should also be noted that for guests choosing higher category suites, the Azure Beach resort complex offers a unique "smart room" system, which includes not a wide but sufficient range of features, including automated control of lighting and temperature in the room, as well as audio system. This is controlled via a tablet that each top-tier room has, which is a practical solution and does not require guests to install a separate app on their smartphone.

Nevertheless, despite the sufficient number of successfully functioning technologies of interaction with the consumer in the hotel "Lazurniy Bereg", in the reviews on various booking platforms in the feedback section there is a pattern of frequent complaints about the complex infrastructure of the resort complex, the lack of signs on the territory of the hotel and the general layout of facilities.

Taking into consideration the shortcomings observed, which undoubtedly affect the overall impression of guests from their vacation at Azure Coast Hotel, it is recommended to implement an interactive map to improve the experience of guests and facilitate their orientation in the complex. Such an innovative solution contributes to providing visitors with more convenient access to information about the various places provided for recreation and leisure activities, presenting a detailed layout of the location of facilities and travel routes.

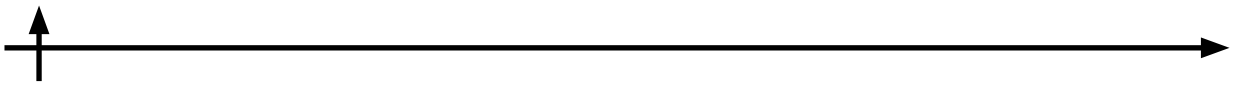
The interactive map, available in one of the options: in electronic format via a mobile application, on the hotel website or on the installed information stands in the main points of the resort complex, will allow guests to easily find the objects of interest, and not only to familiarize themselves with the services and entertainment offered, but also to book them. This approach will significantly reduce the time of searching for a place of interest, thus reducing the number of complaints about the complex infrastructure of the large territory of the Park-Hotel "Azure Coast" and increasing the overall satisfaction of guests.

The introduction of the interactive map also helps to increase the attractiveness of the resort complex for potential visitors, allowing them to plan their stay more efficiently and feel comfortable during their stay. This innovative approach to providing convenience and information to guests is in line with modern requirements for service in the hotel business and contributes to improving the reputation and competitiveness of "Lazurniy Bereg" in the market of resort services.

To ensure the smooth operation of all the above innovation solutions it is necessary to understand the positive and negative sides of each technology used in the hotel in order to identify in advance both the threats and in general the necessity of functioning of this or that system both for consumers and for the enterprise.

Table 3. Evaluation of information technologies of interaction with the consumer in the resort complex "Lazurniy Bereg"

Advantages	Disadvantages
Implemented technologies	
Electronic card	
Ability to control access and set time limits	Dependence on power supply
Increased security	Problems with card demagnetization
An attractive element of modern guest service	Not all guests may be familiar with the use of electronic devices
Easy to make additional copies for one room	



Advantages	Disadvantages
Smart bracelet	
Can be integrated with other hotel systems	Technological disruptions
Ability to customize access depending on the individual preferences of the guest	A lost or stolen smart wristband can lead to guest billing issues
No need to carry extra things with you on vacation	The ability to track entry and exit from the property may raise privacy concerns for guests
Ability to track who entered or left the territory and at what time	
Smart room	
Allowing guests to customize their in-room environment to suit their preferences	Continuous updating of software and replacement of obsolete equipment
The use of room control technology gives the hotel a modern and innovative look	Hotel staff should be trained to maintain and solve possible problems with the use of tablets
Increases demand for upgraded rooms	Software failures that cause malfunctions in smart number management
Can be integrated with other hotel systems	
Planned technologies	
Interactive map	
Increasing the convenience for guests to find the location of facilities and services in the hotel	Requires regular updates and technical support for up-to-date information and correct operation
Improved visualization of the hotel infrastructure to guests	Difficulty in use by guests unfamiliar with technology
Ability to personalize information for each guest based on their preferences and requests	Risk of technical failures in the system
Ability to integrate with other hotel systems	

Based on this table, we can conclude that the main negative factors of using these innovative solutions are the risk of technical failures in the system and the need for their constant updating and monitoring of their work for timely troubleshooting. Also among the minuses can be seen "human factor" - not all guests may have an understanding and mastery of modern technologies, which will make it difficult for them to use the above systems. It is worth noting that these threats can be circumvented by allocating a separate position to constantly monitor the operation of these devices to prevent possible problems before they occur. Staff should also be trained on the basics of interacting with innovative devices so that they can provide further instruction to guests who need it.

Nevertheless, it is also worth noting the number of positives, which include the ability to integrate each device with other hotel systems, making their use even more convenient and justifiable for a business to utilize. Also, undoubtedly, each of the technologies gives the hotel a modern look and increases its competitiveness. It is impossible not to mention the fact that the decision to implement a smart room system increases the demand for the "luxury" category, which brings more profit to the resort complex due to a competent approach to modernization of rooms of high categories.

The introduction of an interactive map in the Lazurniy Bereg plays an important role in the endeavor to provide a comfortable and informative stay for every visitor. Thus, the right choice of how to provide maps becomes a key factor in meeting the needs and expectations of guests.

As it was established earlier, the use of interactive maps as a means of navigation and information provision for guests of the resort complex leads to increased convenience in planning leisure activities on the territory of the hotel, as well as optimization of time resources

of visitors. Therefore, the main emphasis should be made on this factor when determining the methodology.

Resort hotel complexes can provide their guests with interactive maps in various ways, depending on the technological capabilities and needs of customers. Undoubtedly, at the present stage the most effective way is a mobile application. Creating a special mobile application of the resort complex, in which guests can access an interactive map, as well as book some services. The application can be available for download on smartphones and tablets.

The initial stage is the classification of requirements, which allows structuring information, prioritizing and dividing requirements into main categories, which provides a more efficient development process and also contributes to meeting the users' need in the best possible way (Voronova, 2020; Klimova, 2022).

Table 4. Requirements for a mobile application with an interactive map of a resort complex

Type of requirements	Detailed requirements
Business requirements	– Increasing the attractiveness of the resort complex for potential clients – Increasing the competitiveness of the complex on the market – Improving guest service and customer satisfaction – Efficient use of company resources to maximize profits
User requirements	– Ability to view an interactive map of the resort complex with the display of objects (cottages and buildings, restaurants, swimming pools, sports grounds, etc.). – Ability to search for and create routes to specified points – Access to information about current events and activities on the territory of the complex – Ability to book services and activities through the application – Notification system about important events and offers at the resort – Personal user account to manage reservations and view booking history, as well as to create individual vacation offers – Intuitive and simple interface for easy use even by inexperienced users
System requirements	– The application must be available for installation and use on mobile devices running iOS and Android operating systems – The system should support working on different screen resolutions of devices – Optimized use of resources (memory, processor) to reduce the load on devices and extend battery life – Secure and reliable methods of storing data on the server – Backup and restore data to prevent data loss – Interaction with services (service booking system) – Integration with geolocation services to determine the user's location and display it on the map of the resort complex
Functional requirements	– User registration and authentication – Personal cabinet with the ability to view booking history, edit profile and notification settings – Display of an interactive map of the resort complex with markup of objects – Possibility to zoom in and zoom out the map – Search for objects on the map by name or category – Plotting an optimal route from the user's current location to a selected point on the map – Information about each object on the map (name, description, contact information, working hours) – Functionality of booking various services (restaurant tables, SPA procedures, sports grounds, etc.) through the application – Booking confirmation with notifications sent to the user – Notification system about important events on the territory of the complex

Non-functional requirements	– Convenience and ease of interaction with the interface, attractive and functional design – Reliability and guarantee of long-term operation without malfunctions – Optimal performance even with a large number of simultaneous users – Ability to remain productive after changes in system size and volume
Requirements of the subject area	– The application should have up-to-date and accurate map data of the resort complex – Ensured that resort data is updated and updated in real time – Accessibility for users with limited skills in using mobile applications is ensured and various instructions for use are prescribed – Ability to choose the language of the application interface for the convenience of users from different countries and regions – Provision of information in a language understandable to the target audience (Russian and English)
Product requirements	– The application should load quickly, response time to user requests should be minimized – Optimize the use of device resources to reduce power consumption and data traffic – Intuitive interface with easy access to the main functions of the application – Easy navigation through maps and resort facilities – Accessibility for users with different skill levels – Minimize the likelihood of glitches and errors when using all app features
Organizational requirements	– Compliance with all company policies related to software development and data protection – Implementing security and privacy measures in accordance with company requirements – Regular monitoring of application performance, timely updates and support
Integration requirements	– Preliminary development of test scenarios to verify the operation of the application – Provide for the possibility of integration with the reservation systems of the resort complex – Define data exchange standards and protocols for integration with existing company systems – Conduct integration testing with existing systems to verify data exchange

This structuring is an important element in the further development of the mobile application and contributes to the competent modeling of the system taking into account all the identified and considered requirements.

Let's consider the functionality of each of the services in Table 5 to study the necessity of API application in detail.

Table 5. Main functions of API services for a mobile application with an interactive map

Service	Areas of responsibility	Main fuctions
Geo-location service	Responsible for providing information about the current geographical position of the user or object based on GPS coordinates	Determination of geographical position by IP address, monitoring and tracking of object movement in real time
Mapping and geo-data service	Responsible for providing cartographic data	Map display in various modes (satellite images, topographic maps, etc.), conversion of addresses or place names to geographic coordinates and vice versa
Object search service	Responsible for providing the ability to search for various objects and locations on the interactive map	Search on the map by various criteria such as names, categories, addresses, etc., filtering search results
Routing service	Responsible for building optimal routes between given points	Determining the fastest and most optimal path between two or more points on the map, providing several route options for the user to choose from

Service	Areas of responsibility	Main fuctions
Reservation management service	Responsible for managing and coordinating the booking process for various services through the mobile app	Providing functionality for users to book various services, displaying free windows for specific dates and times, the ability to view, edit and cancel existing reservations by the user
User data analysis service	Responsible for processing and analyzing users' personal data obtained from questionnaires to provide personalized recommendations	Analyzing user responses when filling out a preference questionnaire, classifying users by specific interests, providing users with individual recommendations
User behavior analysis service	Responsible for collecting and analyzing data about user actions in the application	Determining the category of the most frequently requested objects when searching on the map in the application, generating reports and statistics on user behavior in the application
Service for sending notifications	Responsible for organizing and sending notifications to mobile app users based on various news events and other conditions related to the interactive map	Scheduling and sending notifications to inform about important events
Local geo-data storage service	Responsible for storing and managing geographic data to enable offline navigation capabilities	Caching map data on the device for access without a network connection, building routes between points on saved maps that do not require an Internet connection
Data synchronization service	Responsible for automatically updating local data from the server when an Internet connection is available	Providing the latest downloaded maps and routes for quick access when the internet is not available

Thus, based on this table we can see that each API service fulfills an important role in the aggregate representing a powerful tool for navigation and interaction with geographical information for users of the mobile application.

Realization of the project on implementation of mobile application with interactive map, as well as any innovation, requires detailed financial planning. Calculating the costs of implementing and operating an interactive map allows you to determine the effectiveness of investment, anticipate potential risks, and develop a strategy to maximize the return on investment.

Let's start with a detailed analysis of the one-time costs required to develop and implement the interactive map. This stage represents a key moment in the project realization process. The following specialists will be involved in the development of the mobile application:

1. Project Manager - responsible for planning, control and coordination of the team's work, management of resources and project timelines;

2. UI/UX designer - develops user interface design and determines how users will interact with the map;

3. Frontend developer - creates the client side of the application, where the interactive map will be displayed. 4. Backend developer - creates the client side of the application, where the interactive map will be displayed;

4. Backend developer - develops the server part of the application, which provides processing and storage of data required for the map operation;

5. Tester (QA engineer) - tests the application for errors and faults, as well as checks the correctness of the interactive map.

Thus, based on the data on the current situation in the labor market and average salaries, let's calculate the approximate salary for specialists in Table 6.

Table 6. One-time salary costs for specialists

Development of the application		
Position	Amount per month (rubles)	Amount per 7 months (rubles)
Project manager	90 000	90 000 * 7 = 630 000
UI/UX designer	80 000	80 000 * 4 = 320 000
Frontend-developer	90 000	90 000 * 6 = 540 000
Backend-developer	95 000	95 000 * 6 = 570 000
Tester (QA engineer)	60 000	60 000 * 1 = 60 000
Total	415 000	2 120 000

Based on this table, it can be noted that the total salary for all the listed specialists will amount to 2,120,000 rubles for 7 months. It is important to emphasize that each of the presented specialists will work a certain amount of time necessary to perform their main task. For example, the project manager is needed at all stages of development, the designer - only the first 4 months, frontend-developer and backend-developer all the time, except for the first month from the beginning of the project, the tester is needed only at the final stage and will perform his duties 1 final month.

Buying a server for a mobile app plays a key role in ensuring its stable and reliable operation, so it is more preferable than renting hosting. To summarize, it serves to store and manage data, so the mobile app can update, sync data across devices, and provide personalized content to users. Let's look at the data in Table 7.

Table 7. One-time server purchase costs

Server	
Type	Amount at purchase (rubles)
Server (Datadase)	110 000
Linux (operating system license)	0
Total	110 000

Based on the data in the table, it is important to emphasize that Linux was chosen as the operating system for the server, which is a free solution. Thus, the total costs will amount to 110,000 rubles, which will be allocated solely for the purchase of server equipment.

The next one-time cost is the placement of the mobile application on a platform that allows users to download it. The data is shown in Table 8.

Table 8. One-time costs of placing the mobile application on the platform

Placement on the platform	
Platform	Amount at placement (rubles)
Play Market	2 300 (25$) singular pay at registration
App Store	9 500 ($99) at registration and every year
Total	11 800

Based on the figures in the table, the total cost of registering a mobile application on the two main platforms will be 11,800 rubles. In aggregate, the cost is quite low due to the fact that the developed mobile application will be provided to users free of charge, so the platforms will not charge an additional commission on top of the main fee. However, unlike the Play Market, placement in the App Store requires not only payment when registering the application, but also each subsequent year, which will be further reflected in the table with the current costs.

Thus, it is possible to calculate the total cost of developing an application with an interactive map:

$$2\ 120\ 000 + 110\ 000 + 11\ 800 = 2\ 241\ 800 \text{ rub.} \quad (1)$$

It is worth noting that the main share of costs is the salary of specialists, whose professionalism is critical for the development of a high-quality interactive system, so it is not recommended to save money at this stage.

Next, let's move on to the consideration of current costs required to maintain stable and uninterrupted operation of the mobile application, we will also start with the consideration of specialists.

The following specialists are needed in maintaining the functioning of the application with an interactive map:

1. Information Engineer - responsible for setting up and monitoring the infrastructure, including server provisioning (server maintenance) and application upgrades;

2. System administrator - provides information security support and protection of local networks and infrastructure, is responsible for creating database backups and preparing for possible failures, eliminates current failures;

3. Data Analyst - collects and analyzes data on the application usage by users to identify possible problems and improve its functionality.

Thus, also based on the available information on the average salary of these specialists, let us calculate their salary for the year in Table 9.

Table 9. Current expenditures on salaries of specialists

Application maintenance		
Position	Amount per month (rubles)	Amount per year (rubles)
Information engineer	65 000	65 000 * 12 = 780 000
System administrator	65 000	65 000 * 12 = 780 000
Data analyst	60 000	60 000 * 12 = 720 000
Total	190 000	2 280 000

Based on the data in the table, we can see that the total amount for employee salaries is 190,000 rubles per month and 2,280,000 rubles per year.

Further in Table 10 we will consider the current costs of the platforms through which users have access to download the application.

Table 10. Current costs of hosting a mobile application on a platform

Placement on the platform	
Platform	Amount per year (rubles)
Play Market	-
App Store	9 500
Total	9 500

As mentioned earlier, placement in the Play Market is paid for once when registering a mobile app, while the recurring cost in the App Store is 9,500 rubles per year.

In order for the application to function, it is also worth considering the need for API services, which are required to interact with various external resources and systems. These services provide access to external databases, geolocation services, and other functional components, extending the capabilities of the application and thus enriching its functionality. Consider the data in Table 11.

Table 11. Current costs for API services licenses

API license	
Type	Amount per year (rubbles)
Yandex MapKit SDK	150 000
SmartGeo	80 000
Yandex Maps Geocoder	150 000
Nexign API Gateway	150 000
AppMetrica.Yandex	0
Ngrow	0
Gravitec REST API	0
Yandex DataSync API	0
Total	530 000

Based on this table, we can point out that exactly half of the selected API services provide their services for free, which is undoubtedly a significant advantage. Thus, the total amount for a license is 530,000 rubles per year.

To summarize, let's calculate all the current costs for one year:

$$2\ 280\ 000 + 9\ 500 + 2\ 819\ 500 \text{ rub.} \quad (2)$$

It is important to note that this amount is acceptable for the hotel enterprise "Lazurniy Bereg" and will ensure the quality functioning of the application and a high level of service for guests.

Conclusion

The key objective of each collective accommodation facility is to maintain the reputation of the organization and distinguish it in the hotel market. To achieve this result requires continuous improvement of service, as well as careful control by the management.

Social positive factors from the implementation of the interactive map are present for both top managers and customers. The area of interest of the enterprise includes such aspects as a significant increase in the competitiveness of the enterprise, as well as increasing the level of loyalty of visitors. In addition, the interactive map helps to stimulate the interest of guests to explore various facilities and amenities at the resort, which indirectly affects the increase in hotel revenue from the sale of additional services (visiting restaurants, spa services, paid sports grounds). It is also necessary to note the factor of optimization of staff workload by reducing the number of requests to the staff from guests about routes and locations on the territory of the complex.

The social factors for the consumer are increased satisfaction with the accommodation, as well as an improved overall experience of participation and involvement in the life of the resort, which guarantees a more interesting pastime. In addition, it is important to emphasize that the

implementation of an interactive map has a significant impact on reducing the level of stress and uncertainty when visiting an unfamiliar resort, as well as contributing to the reduction of time spent searching for facilities at the resort and, consequently, frustration due to problems with orientation in a large area. Not to be overlooked, this project contributes significantly to increasing the sense of a unique and personalized experience for each visitor.

To summarize, the implementation of a mobile application with an interactive map in the Lazurniy Bereg provides both social and economic justification. Undoubtedly, this project has the potential to significantly increase the competitiveness of the company in the hotel market, creating a positive image as an innovative and modern place for recreation with a high-tech level of service.

REFERENCES

Cooper A., Reiman R., Cronin D. 2021. Interface. Fundamentals of interaction design. Creating a quality interface: principles and patterns, 190-200.

Klimova T.B. 2022. Hotel business enterprise architecture: business process model. Technoeconomics 2 (2), 64–76. DOI: https://doi.org/10.57809/2022.2.2.6

Voronova O.V., Ilyin I.V., Khareva V.A. 2020. Economics of enterprises, regions and industries. Methodological bases for the formation of a system of requirements for the architecture of services of network trading companies, 119.

Types of interactive maps. URL: https://vinchi-interactive.ru/journal/top-5-vidov-interaktivnikh-kart/ (accessed 04.02.2024).

Concierge service URL: https://hot-link.ru/concierge-online-/ (accessed 04.02.2024).

Interactive map. URL: https://dic.academic.ru/dic.nsf/ruwiki/641413 (accessed10.02.2024).

What is human-computer interaction (HCI)? URL: https://dovetail.com/product-development/human-computer-interaction/ (accessed10.02.2024).

Information architecture in design: key aspects and principles. URL: https://traff.ink/design/informacionnaya-arhitektyra-v-dizaine/ (accessed 10.02.2024).

Creating custom interactive maps. URL: https://appmaster.io/ru/blog/sozdavat-pol-zovatel-skie-interaktivnye-karty (accessed 11.02.2024).

Dealing with interactive maps. URL: https://cartetika.ru/tpost/ec7d1eeu11-vzaimodeistvie-s-interaktivnimi-kartami (accessed 11.02.2024).

Park-hotel "Lazurny Bereg". URL: https://anapa-lazurnyy.ru/ (accessed 20.02.2024).

Services. URL: https://anapa-lazurnyy.ru/services (accessed 20.02.2024).

Contractor of "Park Hotel Lazurny Bereg". URL: https://www.audit-it.ru/contragent/1182375008287_ooo-park-otel-lazurnyy-bereg (accessed 23.02.2024).

Competitors and competitive environment of the hotel. URL: https://hoteladvisors.ru/blog-2/Konkurenty-i-konkurentnoe-okruzhenie/ (accessed 23.02.2024).

Hotels of Anapa. URL: https://101hotels.com/main/cities/anapa?in=&out=&adults=2 (accessed 23.02.2024).

Organizational structure of the enterprise: types and schemes. URL: https://kontur.ru/articles/4197 (accessed 27.02.2024).

Linear organizational structure of enterprise management. URL: https://galyautdinov.ru/post/linejnaya-organizacionnaya-struktura (accessed 27.02.2024).

Advantages and disadvantages of a linear management structure. URL: https://dzen.ru/a/Y_c1s3KXv3wye21I (accessed 27.02.2024).

Map of the territory. URL: https://anapa-lazurnyy.ru/karta-territorii (accessed 06.03.2024).

Fundamentals of ArchiMate. URL: https://cors.su/eto-interesno/dlya-chego-analitiku-znanie-archimate/ (accessed 12.03.2024).

Costs of application development. URL: https://workspace.ru/blog/5-non-obvious-costs-when-developing-an-application/ (accessed 14.04.2024).

СПИСОК ИСТОЧНИКОВ

Купер А., Рейман Р., Кронин Д. 2021. Об интерфейсе. Основы проектирования взаимодействия. Создание качественного интерфейса: принципы и шаблоны, 190–200.

Klimova T.B. 2022. Hotel business enterprise architecture: business process model. Technoeconomics 2 (2), 64–76. DOI: https://doi.org/10.57809/2022.2.2.6

Воронова О.В., Ильин И.В., Харева В.А. 2020. Экономика предприятий, регионов и отраслей. Методологические основы формирования системы требований к архитектуре сервисов сетевых торговых компаний, 119.

Виды интерактивных карт. URL: https://vinchi-interactive.ru/journal/top-5-vidov-interaktivnikh-kart/ (дата обращения 04.02.2024).

Concierge service URL: https://hot-link.ru/concierge-online-/ открытый (дата обращения 04.02.2024).

Интерактивная карта. URL: https://dic.academic.ru/dic.nsf/ruwiki/641413 (дата обращения 10.02.2024).

What is human-computer interaction (HCI)? URL: https://dovetail.com/product-development/human-computer-interaction/ (дата обращения 10.02.2024).

Информационная архитектура в дизайне: ключевые аспекты и принципы. URL: https://traff.ink/design/informacionnaya-arhitektyra-v-dizaine/ (дата обращения 10.02.2024).

Создание пользовательских интерактивных карт. URL: https://appmaster.io/ru/blog/sozdavat-pol-zovatel-skie-interaktivnye-karty (дата обращения 11.02.2024).

Взаимодействие с интерактивными картами. URL: https://cartetika.ru/tpost/ec7d1eeu11-vzaimodeistvie-s-interaktivnimi-kartami (дата обращения 11.02.2024).

Парк-отель «Лазурный берег». URL: https://anapa-lazurnyy.ru/ (дата обращения 20.02.2024).

Услуги. URL: https://anapa-lazurnyy.ru/services (дата обращения 20.02.2024).

Контрагент ООО "ПАРК-ОТЕЛЬ ЛАЗУРНЫЙ БЕРЕГ". URL: https://www.audit-it.ru/contragent/1182375008287_ooo-park-otel-lazurnyy-bereg (дата обращения 23.02.2024).

Конкуренты и конкурентное окружение гостиницы. URL: https://hoteladvisors.ru/blog-2/Konkurenty-i-konkurentnoe-okruzhenie/ (дата обращения 23.02.2024).

Отели Анапы. URL: https://101hotels.com/main/cities/anapa?in=&out=&adults=2 (дата обращения 23.02.2024).

Организационная структура предприятия: виды и схемы. URL: https://kontur.ru/articles/4197 (дата обращения 27.02.2024).

Линейная организационная структура управления предприятием URL: https://galyautdinov.ru/post/linejnaya-organizacionnaya-struktura (дата обращения 27.02.2024).

Преимущества и недостатки линейной структуры управления URL: https://dzen.ru/a/Y_c1s3KXv3wye21I (дата обращения 27.02.2024).

Карта территории URL: https://anapa-lazurnyy.ru/karta-territorii (дата обращения 06.03.2024).

Основы ArchiMate. URL: https://cors.su/eto-interesno/dlya-chego-analitiku-znanie-archimate/ (дата обращения 12.03.2024).

Затраты при разработке приложения URL: https://workspace.ru/blog/5-non-obvious-costs-when-developing-an-application/ (дата обращения 14.04.2024).

INFORMATION ABOUT AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

VORONOVA Olga V. – Associate Professor, Candidate of Economic Sciences
E-mail: ilina.olga@list.ru
ВОРОНОВА Ольга Владимировна – доцент, к.э.н.
E-mail: ilina.olga@list.ru
ORCID: https://orcid.org/0000-0003-1032-7173

NOVIKOVA Ekaterina – student
E-mail: qckmnh@icloud.com
НОВИКОВА Екатерина – студент
E-mail: qckmnh@icloud.com

Статья поступила в редакцию 10.05.2024; одобрена после рецензирования 20.05.2024; принята к публикации 24.05.2024.

The article was submitted 10.05.2024; approved after reviewing 20.05.2024; accepted for publication 24.05.2024.

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 50–61.
Техноэкономика. 2024, Том 3, № 2 (9). С. 50–61.

Scientific article
UDC 330.15
DOI: https://doi.org/10.57809/2024.3.2.9.4

ASSESSMENT OF ICT IMPLEMENTATION IN AGRICULTURE

Carlean Chingovo ✉

Land & Larder

✉ carleanchingovo@gmail.com

Abstract. The article looks into the role IT plays in modern agriculture, focusing specifically on its abilities to enhance efficiency, productivity and sustainability. It seeks to answer the question: How does technology empower farmers and what influences their uptake of these innovations? The assessment analyzes various IT uses in agriculture that include precision farming, sensor networks, agricultural robotics, data analytics and mobile applications. The research emphasizes the usefulness of these technologies for efficient resource allocation; waste reduction; increase crop production; better disease management and facilitated market access. Additionally, it explores some factors that may hinder or facilitate ICT adoption in agriculture such as access to technology, digital literacy levels, affordability of terms among others mentioned here. Finally, key strategies are identified that promote broad based technology adoption stressing the importance of collaboration among farmers, policy makers as well as technology developers and research institutions. This all-inclusive analysis is aimed at providing valuable insights to stakeholders engaged with agricultural development by drawing attention to how information technology has the potential for transformative change in agriculture leading to improved farm incomes and fostering sustainable agricultural practices.

Keywords: agriculture, information and communication technology (ICT), market, Internet of Things (IOT), robotics, remote sensing, improved efficiency

Citation: Chingovo C. Assessment of ICT implementation in agriculture. Technoeconomics. 2024. 3. 2 (9). 50–61. DOI: https://doi.org/10.57809/2024.3.2.9.4

Научная статья
УДК 330.15
DOI: https://doi.org/10.57809/2024.3.2.9.4

ОЦЕНКА ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ В СЕЛЬСКОМ ХОЗЯЙСТВЕ

Карлин Чингово ✉

Land & Larder

✉ carleanchingovo@gmail.com

Аннотация. В статье рассматривается роль информационных технологий в современном сельском хозяйстве. Особое внимание уделяется их способности повышать эффективность, производительность и устойчивость. Целью данного исследования является ответ на вопрос: как технологии расширяют возможности фермеров, и что влияет на внедрение этих инноваций? В статье анализируются различные варианты использования ИТ в сельском хозяйстве, включая точное земледелие, сенсорные сети, сельскохозяйственную робототехнику, анализ данных и мобильные приложения. В исследовании подчеркивается полезность этих технологий для эффективного распределения ресурсов; уменьшения отходов; увеличения урожайности сельскохозяйственных культур; улучшения борьбы с болезнями и облегчения доступа к рынку. Кроме того, в нем исследуются некоторые факторы, которые могут препятствовать или способствовать внедрению ИКТ в сельском хозяйстве, такие как доступ к технологиям, уровень цифровой грамотности, доступность и др. Наконец, в результате проведенного исследования были определены ключевые стратегии, которые способствуют широкому внедрению технологий, подчеркивая важность сотрудничества между фермерами, политиками, а также разработчиками технологий и исследовательскими институтами. Комплексный анализ направлен на предоставление ценной информации заинтересованным сторонам, участвующим в развитии сельского хозяйства, путем привлечения внимания к тому, как информационные технологии могут привести к трансформационным изменениям в сельском хозяйстве, ведущим к увеличению доходов фермеров и развитию устойчивых методов ведения сельского хозяйства.

Ключевые слова: сельское хозяйство, информационные и коммуникационные технологии (ИКТ), рынок, Интернет вещей (IOT), робототехника, дистанционное зондирование, повышенная эффективность

Для цитирования: Чингово К. Оценка использования информационных технологий в сельском хозяйстве // Техноэкономика. 2024. Т. 3, № 2 (9). С. 50–61. DOI: https://doi.org/10.57809/2024.3.2.9.4

Introduction

There are multitudinous delicate problems in ultramodern farming. Our earth's evolving requirements, as well as those of regulators, customers, food processors, and merchandisers, must be met by growers. Climate change, field mapping, biodiversity loss, which lowers productivity, as well as customers' shifting food preferences and worries about how it is produced, are all sources of growing pressure. Therefore, it is possible to argue that agriculture is a grueling, changeable assiduity. Agriculturists also struggle to keep up with changing profitable conditions, meet the need for more food of exceptional quality while safeguarding the environment, and embracing and understanding new technology. Lack of digitization and crucial communication infrastructure is one of these issues. Technology, on the other hand, is furnishing solutions to

some of these problems in agriculture, indeed though ultramodern agriculture is defying enormous problems. One can therefore concur with robotics engineer George Kantor of Carnegie Mellon University in Pittsburgh, Pennsylvania, who claims that "there is a potential for intelligent robots to change the economic model of farming so that it becomes feasible to be a small producer again"

For instance, if a farmer wanted to map a large field to determine biodiversity, he would need to scout the entire area, which would take time. Nevertheless, with the arrival of technology, similar as satellite imagery and aerial drones, one can map the entire field quickly and identify which fields are under stress. Consequently, it can be said that technology is resolving the issue of low yields by furnishing farmers with strong genetics and field mapping analysis. As a result, if a farmer places the genetics on bettered soil conditions, the yield will be better. Thus, it may be said that technology in agriculture has enabled farmers to increase agricultural yields while lowering labor expenses. By enabling farmers to work smarter, not harder, green house automation technology can help farmers become more productive. Hence, workers might spend lower time on some tasks and further time on other parts of the farm that necessitate surplus attention. Despite the fact that contemporary agriculture offers a wide range of alternatives the results aren't always the same because every farm is different due to its own geomorphology, soils, technologies, and prospective yields.

The primary objective of this study is to assess the major issues that farmers deal with and how technology is delivering solutions in the field of agriculture.

This study aims to identify the features of Information Technology in Agriculture and provide an analysis of their effectiveness in research development, implementation, food and crop production due to the importance of ICT role in various aspects of agriculture and its application in increasing performance of farmers' activity and satisfying consumers' expectations.

Materials and Methods

The research adopts a mixed-methods approach, blending qualitative and quantitative data to comprehensively analyze the effects of ICT implementation in agriculture. Central to the study is an extensive literature review, encompassing academic papers, government reports, and industry analyses, to understand the current dynamics of agricultural sector. Quantitative data collection focuses on key results related to the implementation of ICT in agriculture.

A descriptive analysis method is employed to present a clear picture of current agricultural landscape, highlighting its reliance on information and communication technologies.

The study also incorporates case studies of successful ICT projects providing practical examples of theoretical strategies in action.

Results and Discussion

What does agriculture information technology entail?

“The Harvard Business Review coined the term information technology to make a distinction between purpose-built machines designed to perform a limited scope of functions, and general-purpose computing machines that could be programmed for various tasks” (What is IT/OT convergence, 2024) however, Information and communication technology in agriculture (ICT in agriculture), commonly referred to as e-agriculture, focuses on improving agricultural and rural development through enhanced information and communication processes. E-agricultural is more particularly the conceptualization, design, development, testing, and implementation of novel information and communication technologies (ICTs) in the rural domain, with a strong focus on agriculture. Information technology, as shown in Figure 1 below, covers every layer of every system in a company, from the physical hardware to the operating systems, applications,

databases, storage, servers, and more.

Fig. 1. Shows what IT encompasses

Technology in Agriculture and Its Importance

The way modern farms and agricultural enterprises operate differs greatly from how they did a few decades ago, largely due to technological developments in the form of sensors, machinery, devices, and information technology. Robots, temperature and moisture sensors, aerial photographs, and GPS technology are all frequently used in modern agriculture. Businesses can become more successful, productive, safe, and environmentally friendly thanks to these cutting-edge equipment, robotic systems, and precision agriculture techniques. Thus, the widespread adoption of information and communication technology is essential for the advancement of agriculture in the twenty-first century.

Examples of several technologies are provided below.

The aerial drones and the Netherlands

The latest disruption is the introduction of agricultural drones, and technology advancements have nearly entirely changed agricultural operations. Drones are utilized for plant health evaluations, field analysis, crop monitoring, and agricultural spraying. Based on the real-time data that the drone technology provides, the farming sector has rapidly grown and changed. Thermal sensor-equipped drones locate the areas where irrigation has to be adjusted. For example, sensors calculate the vegetation index after the crops have started to grow and display their health. Agriculture has become more automated and industrialized since the industrial revolution. Artificial intelligence increases automation even more. The use of Artificial intelligence has implications for what is now known as "precision agriculture." Increasing yields while utilizing less water, fertilizer and herbicides is the aim. The Netherlands is well recognized for using unmanned aircraft for a range of uses, including aerial agricultural inspection. Important data about the condition of the soil and the condition of crops can be gleaned from aerial images. Trimble is an agricultural drone manufacturer, an American company that provides services to numerous transnational sectors including farming, construction and transportation. In 1978, Charles Trimble established the business. Robert Painter leads the company as CEO (Agricultural solutions, 2024; Zagazezheva, Berbekova, 2021).

Yamaha Industrial Unmanned Helicopters are a compact, economically viable helicopter UAV that can be utilized to satisfy Japan's needs for agricultural dusting and spraying. The "R-50" from Yamaha Aero Robot is an artificial helicopter that can carry 20 kg of goods effectively.

Recent years have seen problems plaguing the Japanese agriculture sector, including the aging of the labor force and a lack of younger generation successors. The interest in the Yamaha artificial-use unmanned helicopters is due to the fact that they are cutting-edge agricultural instruments that are both economical and environmentally benign. They are now heavily used for crop dusting (Sato, 2003).

Fig. 2. Process of a drone spraying

The use of drones has grown significantly in the Netherlands in the past few years. Every farm owner in the nation of Holland who raises fresh produce may use a drone to spray his crops in the future. A drone being utilized for spraying is shown in Figure 2.

Driverless agricultural machines in Germany and Israel

A high-tech business has quickly emerged from agriculture. Robotic technology enables efficient crop management and monitoring. Because of its use, the crop is produced more safely and effectively. Precision farming, as the name implies, also helps to lower food prices and minimizes the negative impacts on the environment by carefully applying fertilizer or pesticides to the correct plant. Additionally, farming robotic arms are enhancing farmers' crop production in a variety of ways. One of the most popular robotic uses within agriculture consists of harvesting and collecting because of the degree of precision and quickness that robots can achieve. As a result, there will be a higher yield along with decreased crop residue from crops that are left in the field after harvesting (Stoces, 2016). However, automating some applications could be challenging. For instance, a robotic system intended to choose apples has various challenges. In challenging circumstances, such as the presence of dust, changing light intensity and motion caused by the wind, optical systems must locate and assess the apple's ripeness. Nevertheless, gathering fruits and vegetables still calls for more than only highly developed vision technologies. A robotic arm must travel through environments with a similar number of risks in order to deftly grasp and arrange a fruit or vegetable. Thus, it can be said that the agro robotic arm must be precise enough to choose the crops without harming them and flexible enough to adapt to changing environmental conditions (Muchiri, Kimathi, 2022).

Fig. 3. Autonomous planting robot in use (Germany and Japan)

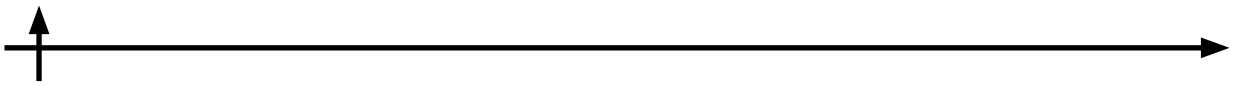
To provide an example of current work, a robotic system for harvesting sweet peppers was created as part of the EU projects Crops and follow-up SWEEPER. The primary goal of SWEEPER is to commercialize the first generation of greenhouse harvesting robots. By automating the harvest, SWEEPER optimizes the farming system. Crop models will be employed to pinpoint the peppers' general location in order to enhance the robot's cognitive capabilities. Fruit identification will be enhanced and sped up by this "model-based vision." Only the gripper will be equipped with sensors, in line with the lessons learned from the CROPS project (Arad, 2020). Hence one can concur with the notation that robotization of labor is pivotal in the field of greenhouse horticulture. The number of workers willing to complete monotonous duties in adverse rainfall conditions is steadily abating. In addition, the automation of these repetitive jobs opens up a wide range of cutting-edge technological advancements.

Another example is the Siberian Tiger, a new Russian agricultural robot from Agrirobot that could enter the market as early as 2024 and is scheduled to start field trials in 2021. A separate team of Russian scientists created the 172x172 centimeter robot to control plant disease. Using a collection of cameras and sensors, Siberian Tiger is built to traverse around fields while keeping an eye on the crops and soil. A neural network receives the gathered data and processes it for further analysis (Uskova, 2021).

Online farmer marketplaces in Uganda and India

For case, Ugandan growers vend their products at the Agro Market only during request days at specific times and locales. Due to the necessity of conserving goods, transport it to requests, and engage mediators to do so, growers face advanced costs during request days. On a market day, a farmer might not be suitable to vend all of his yield (Building a digital marketplace for agriculture in Uganda, 2024). A mobile app that eliminates mediators and factual requests by connecting buyers and merchandisers directly could affect how profitable husbandry is for growers. This Application called Agromarket day was made in Uganda by students at Makerere University. The farmer uploads images of his yield to the app along with its price, position, and phone number. A buyer browses the application's product rosters, and if he decides he wants to buy a certain item, he phones the dealer to set up the deal (Devi, Venugopal, 2022).

The Napanta App was created in India. The establishment, which is backed and fostered by AIP- ICRISAT and IIIT- Hyderabad, enables growers to incontinently pierce any type of agrarian information they bear. This digital platform was made to help agriculturists in stream-



lining their agrarian operations, boosting profitability, and getting better results. The agriculturists only need a straightforward mobile internet connection. Additionally, NaPanta provides agriculturists with comprehensive information on the vacuity, makeup, and operation styles of fungicides and germicides as well as aids in the organized tracking of their charges. Moreover, it provides connections for agro-dealers in the two states as well as a five- day rainfall forecast, details on crop insurance, and the locales of soil laboratories and cold storehouse facilities. The operation also contains offline functionality with data regarding crop and pest operation strategies for further than 100 crops for agriculturists who find it delicate to always have an internet connection (Naredla, 2018).

ET Agricultural Brain used for asset management by farmers in China

Alibaba Cloud, the Alibaba Group's cloud computing division, was founded in 2009 and is currently ranked as one of the top three IaaS providers globally and the largest provider of public cloud services in China by IDC. Alibaba Cloud offers a full range of cloud computing services to companies around the world, including start-ups, corporations, and governmental agencies, as well as merchants conducting business on marketplaces operated by the Alibaba Group (The Alibaba Cloud Intelligence Brain, 2024). The International Olympic Committee's official cloud services partner is Alibaba Cloud. Human farmers are a source of inefficiency in an optimized world. They make decisions differently because they are human and are susceptible to informational and temporal limitations. So, the reasoning goes, why not swap them out with AI models that have unlimited access to data and computing time?

The answers offered by Alibaba Cloud are designed to help agriculturists manage their resources and cover their crops more effectively. Under the term ET Agricultural Brain, they combine a number of AI approaches, speech and image recognition, climate vaticination models, and satellite data collection. Alibaba Cloud, the data intelligence arm of the Alibaba Group, asserted that the revolution of China's agricultural business was significantly told by its agricultural technology results, Agricultural Brain. ET Agricultural Brain helps agriculturists increase farmstead produce, manage healthier animals, and save labor costs to maximize return on investment. The foundation for all of this is its cloud computing structure (Bagnall, 2021).

To add on, animal products and natural resources of advanced quality have long been in demand in China. In response, ET Agricultural Brain has been working to change the agrarian industry. The system incorporates multitudinous AI algorithms, including image identification, speech recognition, and real- time monitoring of environmental data, to insure the healthy development of animals in a well- maintained environment. Thanks to the data processing and machine learning algorithm model training done by ET Agricultural Brain, livestock producers may remotely and in real time cover their farms and animals. ET Agricultural Brain can also induce high- quality milk at cheap operating costs, exclude feed waste by conforming feeds, and keep an eye on livestock conditions using image and sound recognition technologies. Several detectors are put in place to ameliorate the terrain for herd growth and to reduce human error in the breeding process (Plaksin, Trifanov, 2018).

Along with Tequ Group, other early adopters of ET Agricultural Brain include the top agricultural establishment Haisheng Group, which oversees 55 vineyards with a combined area of further than 4000 hectares, and Guoqiang Modern Farming, a rural collaborative with a base in Shaanxi that focuses on producing decoration melons (At the Shanghai Computing Conference, Alibaba Cloud launches ET Agricultural Brain, 2024). The AI program has enhanced fruit and vegetable growing for these two agriculturists. About 10,000 acres of apple trees in Haisheng have their development parameters automatically gathered by the ET Agricultural Brain, saving the farm an estimated RMB 20 million in operating costs annually.

GIS, or geographic information systems

The development of a system known as a geographic information system (GIS) was made specifically for the purpose of gathering, storing, deploying, processing, and displaying geographic data. This practice has proven to be effective in the agriculture sector in a number of ways. To make it simpler to study the soil, digital maps of the land are made and material geodetic data, such as topography and contours, are combined with other statistical data. GIS is used to determine what and where to plant using historical data and sampling (King, 2017). Thus, it should be noted that utilizing agriculture GIS tools, you may determine the vegetation levels in your field or any of its regions. Based on this knowledge, agricultural machinery can then be used to alter the quantum of seeds, nutrients, herbicides, and fertilizer for each plot. Furthermore, more intricate spatial analyses for agriculture may compare elements like soil type, wind direction, rainfall summations, slope, aspect, topography, or elevation to help with crop oversight, site suitability, drainage planning, and threat reduction from disease, flood tide, drought, and erosion. GIS can thus help an agriculturist in conforming to these various variables, tracking the health of specific crops, estimating yields from a specific field, and maximizing crop production (Ren, 2020).

IoT, or the Internet of Things

The different devices used in the field to monitor and assess the work done are connected by the Internet of effects. Cellphones have access to all data, including information on irrigation pumps, water meters, weather stations, and soil moisture levels. Sensors have been employed in agricultural activities for a while now. But the problem with the traditional approach of using detector technology was that we could not get the real- time data from the sensors (Kootstra, 2021). The sensors preliminarily stored the information in their internal memory, from which we could latterly prize it. The advent of industrial IoT has led to the usage of much more advanced sensors in agriculture. The devices with sensors are presently connected to the cloud through a cellular or satellite network (Tzounis, 2017). We may use it to get sensor data instantly and make wise decisions. From bitsy to large farms, the internet of things facilitates quick planning and decision making (Zhao, 2010).

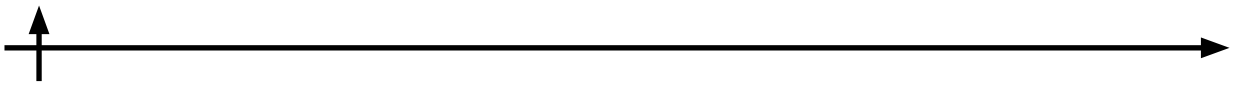
Factors that have an impact on how farming technology is used

Expensive machinery and High upkeep costs

One of the negatives of farm technology is the high upkeep costs. The high upkeep expenses of the equipment present a problem for agriculturists and small businesses. Ultramodern technological machines and gadgets are expensive to maintain that's why agriculturists are unable to keep up with them. The vast majority of agriculturists in Africa live in rural areas, where they warrant the means to maintain this premium machinery. Because they cannot afford the high upkeep expenses of new specialized equipment, farmers struggle to stay current with technology. For farmers, and extension workers to effectively communicate and share information in a cost-effective manner, the adoption of these cutting-edge technologies needs to be encouraged (Bhusal, Sagar, Khatri, 2021). However, the high cost of ICT serves as a deterrent for using ICT services. The impoverished farmers cannot afford such gadgets because android cell phones are more useful for gaining access to ICT services. For instance, in Tanzania and Nepal, the cost of adopting ICTs by farmers in the agricultural sector was the biggest obstacle to adoption. Poor and disadvantaged farmers in these two countries lack access to high-quality information on agricultural production.

Lack of Education among Agriculturalists

Since most agriculturists warrant knowledge, it might be delicate for them to understand how to use ultramodern farming technologies. Due to their traditional farming practices and limited understanding of the advantages and downsides of agricultural technology, these agriculturists



find it delicate to use it. Not everyone can profit from ultramodern agricultural technology, which is another one of its failings. Most agriculturists are unfit to duly operate ultramodern technological tools and machinery. Rural residents are prevented from using ICT due to a lack of education and understanding. Utilizing various ICT resources and getting exposed to them aid in developing a good attitude about their effects. People who utilize it frequently become aware of its advantages and adopt a positive outlook. Higher educated people have access to cutting-edge technology that allows them to study more effectively and quickly while also understanding its significance. When using ICT, a person with a greater degree of education perceives more information than a person with a lower level of education (Bhusal, Sagar, Khatri, 2021).

Health-related implications

Multitudinous research has shown that using pesticides and fertilizers exorbitantly has a dangerous impact on health. Overuse of pesticides has the drawback of eradicating salutary soil organisms that support plant growth. The topsoil could also come contaminated, away from that. Nothing additional will grow for the time being. Both pesticides and fertilizers are known to be dangerous to human health; indeed, a small quantum of skin contact with some of them can result in excruciating agony. Also, it has the potential to pollute near rivers and soils, as has been seen in Brazilian rivers. Even though the water seems harmless, it's actually veritably dangerous (Machado, 2016).

Deterioration of the environment

The majority of technical tools and innovations degrade our environment, which is veritably dangerous to people. Overuse of tractors, trucks, and other large machinery results in the release of carbon dioxide and dangerous chemical pollutants into the atmosphere. As a result, our environment has become toxic and dangerous for both humans and other living creatures. As a result, certain countries in Europe, including the UK, have developed rules regarding the use of heavy machinery on farms. Consequently, there is a major reduction in soil fertility as a result of this. The excessive use of technology in the fields reduces soil fertility. One of the most disastrous outcomes of agricultural technology is the loss of soil fertility. The soil in the fields is damaged and loses fertility due to the inordinate use of technology. Both Brazilian and American agribusiness are dealing with this. Although chemicals and fertilizers can boost productivity, they also have the eventuality to deplete soil fertility. Therefore, one can contend while a chemical or toxin might boost agrarian productivity, it can also sluggishly erode the soil's fertility, hence the overuse of agrarian chemicals like pesticides and fertilizers can harm the soil (Da Silveira, Lermen, Amaral, 2021; Imangali, Bekturganova, 2024).

Unemployment

As technology in agriculture is encouraged in the agricultural sector, agriculturists ' incomes are anticipated to increase. Robotization in agriculture will suddenly enhance farmers' income while lowering their expenditures. The output will increase coincidently with a drop in employment due to agriculture automation. As a result of the adoption of various technical advancements in agriculture, workers' services are being substituted by machines. Some of these technologies drastically dwindle the need for human workers, which is bad for society because it leads to the growth of unemployment (Da Silveira, Lermen, Amaral, 2021).

Conclusion

Due to the world population's exponential rise, the loss of agricultural land, and the shrinkage of limited natural resources, there's a critical need to increase farm yields. Our lives are impacted by technology, which is altering every element of contemporary life, including agriculture. The application of new technology developments in farming is extremely beneficent to

farmers. Developing farming technology is a pivotal approach for elevating agricultural product, establishing food sufficiency, and reducing poverty and food instability especially among smallholder farmers in sub-Saharan Africa. The high- tech equipment presently being employed in agriculture ensures that the food we consume today gets to us more snappily. Additionally, it's further nutritional, fresher, and more affordable. The food sector is witnessing a metamorphosis thanks to agricultural technology, which will only advance in the coming years. Agriculturists can work more successfully and efficiently thanks to it. There are many technological tools and devices used in agriculture. It saves a great deal of time and effort for farmers in agriculture. Thanks to ultramodern technology, agriculturists can complete a lot of work in a short period of time. Ultramodern technology results to centuries-old challenges have been applied to agriculture with the backing of IoT. This has made it easier to reconcile product, quality, and yield. Rapid action and minimized damage to the crops are assured by data collected by obtaining and integrating information from multitudinous devices for immediate use or keeping in a database for after use. On the other hand, we must recognize that technology has some adverse effects. Before using technology, we need to be apprehensive of how much damage it causes. Agriculturists must acclimatize to these changes while contemporaneously reducing the greenhouse gas emissions caused by agriculture by enforcing climate-smart techniques. The downsides of technology must be conceded, nevertheless. We must consider how much detriment technology does before employing it.

REFERENCES

Arad B. et al. 2020. Development of a sweet pepper harvesting robot. Journal of Field Robotics 37 (6), 1027-1039. doi:10.1002/rob.21937

Bagnall D.K. et al. 2021. Soil health considerations for global food security. Agronomy Journal 113 (6), 4581-4589. doi:10.1002/agj2.20783

Bhusal A., Sagar G.C., Khatri L. 2021. A review article on the role of information communication technology in agriculture and factors affecting its dissemination in Nepal. Journal of Applied Biotechnology and Bioengineering 8 (3), 81-85. doi:10.15406/jabb.2021.08.00257

Da Silveira F., Lermen F.H., Amaral F.G. 2021. An overview of agriculture 4.0 development: Systematic review of descriptions, technologies, barriers, advantages, and disadvantages. Computers and electronics in agriculture 189, 106405. doi: 10.1016/j.compag.2021.106405

Devi V.R., Venugopal M. 2022. The Role of Social Media in Rural Development—A Study in Telangana State. Journal of Rural Development, 136-152. doi: 10.25175/jrd/2022/v41/i1/172467

Imangali Zh., Bekturganova M. 2024. Sustainable growth in Kazakhstan: green economy, decarbonization and energy transition. Technoeconomics 3, 1 (8). 14—25. DOI: https://doi.org/10.57809/2024.3.1.8.2

King A. 2017. Technology: The future of agriculture. Nature 544 (7651), 21-S23. doi:10.1038/544S21a

Kootstra G. et al. 2021. Selective harvesting robotics: current research, trends, and future directions. Current Robotics Reports 2, 95-104. doi:10.1007/s43154-020-00034-1

Machado C.S. et al. 2016. Chemical contamination of water and sediments in the Pardo River, Sro Paulo, Brazil. Procedia engineering 162, 230-237. doi:10.1016/j.proeng.2016.11.046

Muchiri GN, Kimathi S. 2022. A review of applications and potential applications of UAV. Proceedings of the Sustainable Research and Innovation Conference, 280-283. doi:10.3390/su13041821

Naredla S.K. et al. 2018. Uniquely addressing customer pain points-The case study of AgRITEch app. International Journal of Mechanical Engineering and Technology 9 (11), 2306-2314.

Plaksin I.E., Trifanov A.V. 2018. Analysis of the application of automated and robotic complexes in agriculture. AgroEcoEngineering 4 (97), 73-83. doi:10.24411/0131-5226-2018-10091

Ren Q. et al. 2020. Application and development of new drones in agriculture. IOP conference series: Earth and environmental science 440 (5), 052041. doi: 10.1088/1755-1315/440/5/052041

Sato A. 2003. The RMAX helicopter UAV. National Technical Information Service, 0011.

Stoces M. et al. 2016. Internet of things (IOT) in agriculture-selected aspects. Agris on-line Papers in Economics and Informatics 8 (1), 83-88. doi:10.7160/aol.2016.080108

Tzounis A. et al. 2017. Internet of Things in agriculture, recent advances and future challenges. Biosystems engineering 164, 31-48. doi: 10.1016/j.biosystemseng.2017.09.007

Uskova O. 2021. On Russian Farms, the Robotic Revolution Has Begun: Hundreds of Aftermarket AIs are Harvesting Grain. IEEE Spectrum 58 (9), 40-45. doi:10.1109/MSPEC.2021.9531014

Zagazezheva O.Z., Berbekova M.M. 2021. Main trends in the development of robotic technologies in agriculture. Proceedings of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences 5 (103). doi:10.35330/1991-6639-2021-5-103-11-20

Zhao J. et al. 2010. The study and application of the IOT technology in agriculture. IEEE 2, 462-465. doi: 10.1109/ICCSIT.2010.5565120

Agricultural solutions. URL: https://www.trimble.com/en/solutions/industries/agriculture (accessed 10.05.2024).

At the Shanghai Computing Conference, Alibaba Cloud launches ET Agricultural Brain. URL: https://shorturl.at/mFOP4 (accessed 11.05.2024)

Building a digital marketplace for agriculture in Uganda. URL: https://www.atai-research.org/building-a-digital-marketplace-for-agriculture-in-uganda/ (accessed 15.05.2024)

The Alibaba Cloud Intelligence Brain. URL: https://www.alibabacloud.com/solutions/intelligence-brain (accessed 12.05.2024)

What is IT/OT convergence. URL: https://www.techtarget.com/searchdatacenter/definition/IT (accessed 10.05.2024).

СПИСОК ИСТОЧНИКОВ

Arad B. et al. 2020. Development of a sweet pepper harvesting robot. Journal of Field Robotics 37 (6), 1027-1039. doi:10.1002/rob.21937

Bagnall D.K. et al. 2021. Soil health considerations for global food security. Agronomy Journal 113 (6), 4581-4589. doi:10.1002/agj2.20783

Bhusal A., Sagar G.C., Khatri L. 2021. A review article on the role of information communication technology in agriculture and factors affecting its dissemination in Nepal. Journal of Applied Biotechnology and Bioengineering 8 (3), 81-85. doi:10.15406/jabb.2021.08.00257

Da Silveira F., Lermen F.H., Amaral F.G. 2021. An overview of agriculture 4.0 development: Systematic review of descriptions, technologies, barriers, advantages, and disadvantages. Computers and electronics in agriculture 189, 106405. doi: 10.1016/j.compag.2021.106405

Devi V.R., Venugopal M. 2022. The Role of Social Media in Rural Development—A Study in Telangana State. Journal of Rural Development, 136-152. doi: 10.25175/jrd/2022/v41/i1/172467

Imangali Zh., Bekturganova M. 2024. Sustainable growth in Kazakhstan: green economy, decarbonization and energy transition. Technoeconomics 3, 1 (8). 14—25. DOI: https://doi.org/10.57809/2024.3.1.8.2

King A. 2017. Technology: The future of agriculture. Nature 544 (7651), 21-S23. doi:10.1038/544S21a

Kootstra G. et al. 2021. Selective harvesting robotics: current research, trends, and future directions. Current Robotics Reports 2, 95-104. doi:10.1007/s43154-020-00034-1

Machado C.S. et al. 2016. Chemical contamination of water and sediments in the Pardo River, Sro Paulo, Brazil. Procedia engineering 162, 230-237. doi:10.1016/j.proeng.2016.11.046

Muchiri GN, Kimathi S. 2022. A review of applications and potential applications of UAV. Proceedings of the Sustainable Research and Innovation Conference, 280-283. doi:10.3390/su13041821

Naredla S.K. et al. 2018. Uniquely addressing customer pain points-The case study of AgRITEch app. International Journal of Mechanical Engineering and Technology 9 (11), 2306-2314.

Плаксин И.Е., Трифанов А.В. 2018. Анализ применения автоматизированных и

роботизированных комплексов в сельском хозяйстве. АгроЭкоИнженерия 4 (97), 73-83. doi:10.24411/0131-5226-2018-10091

Ren Q. et al. 2020. Application and development of new drones in agriculture. IOP conference series: Earth and environmental science 440 (5), 052041. doi: 10.1088/1755-1315/440/5/052041

Sato A. 2003. The RMAX helicopter UAV. National Technical Information Service, 0011.

Stoces M. et al. 2016. Internet of things (IOT) in agriculture-selected aspects. Agris on-line Papers in Economics and Informatics 8 (1), 83-88. doi:10.7160/aol.2016.080108

Tzounis A. et al. 2017. Internet of Things in agriculture, recent advances and future challenges. Biosystems engineering 164, 31-48. doi: 10.1016/j.biosystemseng.2017.09.007

Uskova O. 2021. On Russian Farms, the Robotic Revolution Has Begun: Hundreds of Aftermarket AIs are Harvesting Grain. IEEE Spectrum 58 (9), 40-45. doi:10.1109/MSPEC.2021.9531014

Загазежева О.З., Бербекова М.М. 2021. Основные тренды развития роботизированных технологий в сельском хозяйстве. Известия Кабардино-Балкарского научного центра РАН 5 (103). doi:10.35330/1991-6639-2021-5-103-11-20

Zhao J. et al. 2010. The study and application of the IOT technology in agriculture. IEEE 2, 462-465. doi: 10.1109/ICCSIT.2010.5565120

Agricultural solutions. URL: https://www.trimble.com/en/solutions/industries/agriculture (accessed 10.05.2024).

At the Shanghai Computing Conference, Alibaba Cloud launches ET Agricultural Brain. URL: https://shorturl.at/mFOP4 (accessed 11.05.2024)

Building a digital marketplace for agriculture in Uganda. URL: https://www.atai-research.org/building-a-digital-marketplace-for-agriculture-in-uganda/ (accessed 15.05.2024)

The Alibaba Cloud Intelligence Brain. URL: https://www.alibabacloud.com/solutions/intelligence-brain (accessed 12.05.2024)

What is IT/OT convergence. URL: https://www.techtarget.com/searchdatacenter/definition/IT (accessed 10.05.2024).

INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

CHINGOVO Carlean – student.
E-mail: carleanchingovo@gmail.com
ЧИНГОВО Карлин – студент.
E-mail: carleanchingovo@gmail.com

Статья поступила в редакцию 01.06.2024; одобрена после рецензирования 05.06.2024; принята к публикации 07.06.2024.

The article was submitted 01.06.2024; approved after reviewing 05.06.2024; accepted for publication 07.06.2024.

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 62–71.
Техноэкономика. 2024, Том 3, № 2 (9). С. 62–71.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.5

METHODS OF ONLINE REPUTATION MANAGEMENT IN ENTERPRISES

Viktoria Sheleyko, Anastasia Krestnikova ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ nkrestnikova@list.ru

Abstract. Today, reputation management is one of the most important components of successful business. This research is devoted to the study of the factors of formation of company reputation in the Internet, as well as the development of measures to improve the management of online reputation of enterprises. In the course of the study, the authors analyzed the methods of assessing the online reputation of enterprises, identified the tools for managing the reputation of companies in the digital environment, and put forward a number of proposals to improve online reputation management.

Keywords: online reputation, business reputation, reputation management, ORM, SMM, cost per click (CPC), cost per mille (CPM), cost per action (CPA)

Citation: Sheleyko V., Krestnikova A. Methods of online reputation management in enterprises . Technoeconomics. 2024. 3. 2 (9). 62–71. DOI: https://doi.org/10.57809/2024.3.2.9.5

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.5

МЕТОДЫ УПРАВЛЕНИЯ ОНЛАЙН-РЕПУТАЦИЕЙ ПРЕДПРИЯТИЙ

Виктория Шелейко, Анастасия Крестникова ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ nkrestnikova@list.ru

Аннотация. На сегодняшний день репутационный менеджмент является одной из важнейших составляющих успешного бизнеса. Данное исследование посвящено изучению факторов формирования репутации предприятий в сети Интернет, а также разработке мероприятий по совершенствованию управления онлайн-репутацией предприятий. В ходе исследования был проведен анализ методов оценки онлайн-репутации предприятий, определены инструменты управления репутацией компаний в диджитал среде, а также выдвинут ряд предложений по совершенствованию управления онлайн-репутацией.

Ключевые слова: онлайн-репутация, деловая репутация, репутационный менеджмент, ORM, SMM, CPC, CPM, CPA

Для цитирования: Шелейко В., Крестникова А. Методы управления онлайн-репутацией предприятий // Техноэкономика. 2024. Т. 3, № 2 (9). С. 62–71. DOI: https://doi.org/10.57809/2024.3.2.9.5

Introduction

Reputation management is one of the most important components of a successful business; through competent management it is possible to make a company attractive to customers, investors and other stakeholders (Fombrun, 1990). While originally the term "reputation management" referred to the field of public relations, nowadays the development of computer technology, the Internet and social media has made reputation dependent on search engine results. Online marketplace services have long become commonplace and in demand in the business environment, which has found application in the field of corporate reputation management as well. In other words, online reputation management or ORM (online reputation management) is an effective marketing technology, thanks to which a positive image of the company is formed in the network.

Figure 1 shows the operations that the reputation management technology implies.

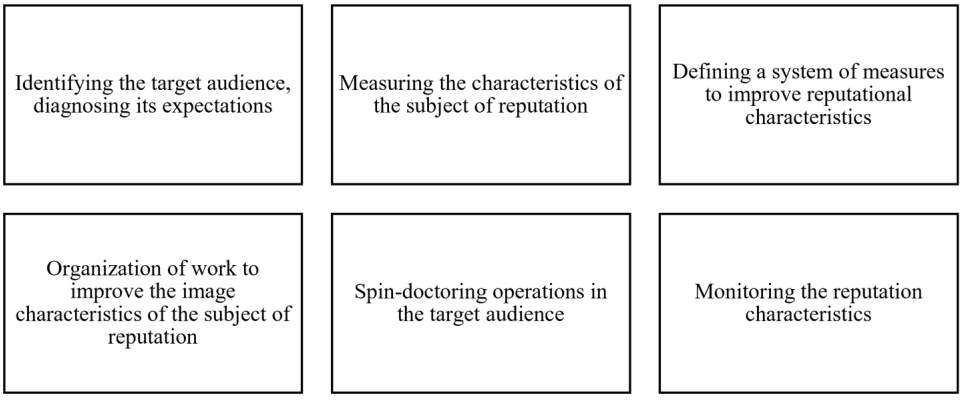


Fig. 1. Technology of reputation management

When defining the target audience, it is necessary to form its structure, to define expectations in relation to a particular company and its reputation, i.e. it is necessary to build an expected reputation model.

When measuring the characteristics of the subject, the main parameters that form the reputation model are identified. During the definition of the system of measures to improve the characteristics of reputation, the real model of reputation and the expected one are compared, then those whose indicators are noticeably worse than the others are singled out. Corrective measures are formed for them, ways of attracting investments are thought over (Sharkov, 2015; Markov, 2023).

During the organization of works on the optimization of the subject's image characteristics, a point-by-point adjustment of the fundamental indicators is carried out to make them comply with the normative ones.

Spindoctoring is the correction of data already covered in the media, which are not favorable for the organization. At this stage, corrective work is carried out to change the established negative attitudes about the subject of reputation, previously unknown positive information and qualities of the company are disclosed.

Speaking about monitoring the state of the reputation subject's characteristics, we are talking about comparing the current reputation characteristics of the company and comparing them with the target audience's perceptions of their values. If the difference in the compared characteristics falls below an acceptable level, a number of corrective measures are taken.

Let's proceed to the consideration of techniques and means of reputation management and its formation.

1. Preemptive tactics by revealing negatives ahead of time.

The essence of this tactic is the company's demonstration of its own mistakes or disclosure of information that can be negatively perceived by the society. Following this, the company announces that corrective actions are underway and every effort is being made to correct the error. Due to the company's openness and honesty, the public does not perceive the negative consequences as something bad, and people also have confidence that "work on the mistakes" is already underway.

Alfa Bank can be cited as an example. In 2010, a shortage was discovered in one of its branches, but the company did not let this happen and waited for the local media to discover this information. The bank decided to self-disclose the problem and talked about cooperating with law enforcement (Kozlova, 2011). The management staff stated that the bank's customers were completely safe and the fact of the shortage would not affect them in any way.

2. Spin-doctoring operations in reputation management.

There are situations when a company either does not adhere to the previous strategy or does not manage to self-report an incident before the media. In such a case, negative consequences for the organization will come anyway, even though the company may be innocent. For example, in 2002 in one of the products of "Ochakovo" was distributed information about the presence of sodium benzonate, the carcinogenic effect of which on the human body has been proven. A little later the company denied this information, but by that time the company's sales had already decreased by more than 1/8. In order to restore the business reputation of the brand, the company decided to file a lawsuit in court to protect its own reputation, as a result of the court hearing the lawsuit was satisfied.

3. Policy of ignoring public opinion.

This policy is directly opposite to the previous two - instead of reacting in advance or after media publications, companies choose the tactic of complete silence of the situation. One of the organizations that chose this tactic is the Moscow toy factory Pineapple Toys. Mercury impuri-

ties were found in their products, so all toys were thoroughly checked by regulatory authorities before being sent for sale. The mass media actively agitated to refrain from buying the goods of this company. For its part "Pineapple Toys" decided to completely refrain from any comment on this situation, which caused significant damage to the reputation and profits of the firm.

4. Use of suggestibility.

Effective reputation management is based on adequate interaction with the target audience, excluding the use of manipulative methods. The preference is given to the audience, corresponding to the norms and values, because in the marginal environment preservation of stable reputation is difficult. It is possible to create an attractive image quickly, but reputations are built over the long term, and aggressive methods can harm rather than improve reputations.

5. Use of opinion leaders in reputation management.

One of the peculiarities of opinion leaders' activities is that they bring together people from different groups. That is why companies use their services to create pressure groups. During reputation enhancement activities, it is impossible to ignore these pressure groups, as some of them can make a significant contribution to the improvement or deterioration of the company's reputation. More often than not, these groups conduct targeted promotions on online platforms or in the media, which cannot go unnoticed by investors, potential customers and other stakeholders.

Figure 2 shows the most common behavioral tactics of pressure groups.

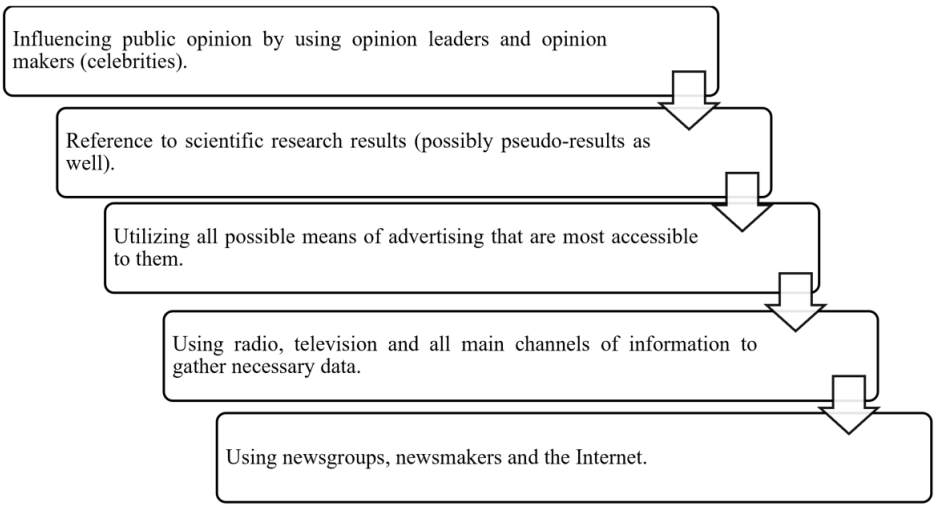


Fig. 2. Main behavioral tactics of pressure groups

There is no point in conflicts with groups of influence, as they do not bear any losses. However, there is also a scheme for working with them - you should try to attract them as key groups for an alliance with shareholders.

There is no point in conflicts with pressure groups - they have nothing to lose. If possible, you should try to involve them as key groups for an alliance with shareholders. Adopting a declaration on a contentious issue is one possible method of managing this activist movement. Other key actions may include negotiating with pressure groups to find common ground and ways to cooperate.

Due to the rapid development of the Internet, there has been a recent transformation of the media market. Due to the fact that content and information can be published simultaneously on several platforms and the time of publication takes seconds, there is an increase in the number of users reached, which is why this communication channel prevails over other methods of mass

communication.

Initially the concept of "reputation management" was related to public relations, at the moment, due to the increasing influence of IT-technologies, "reputation management" directly depends on the results of search engine results. Digital space, online stores have already entered the daily life of users, which is also embodied in the reputation management of companies.

Materials and Methods

The work uses various research methods, including: theoretical analysis of literature, comparison, study of statistical information, etc. When collecting the data necessary to perform the work, the search engines Yandex, Google were used. The following programs were used in data processing: ArchiMate, Figma. In the course of the work were considered tools and methods of online reputation management, factors that are influenced by the reputation of companies in the digital environment, currently implemented strategy of online reputation management at the enterprise, presented ways to assess the reputation on the Internet. The state of online reputation was also assessed using the Ex-index.

Results and Discussion

Online reputation is a system of subjective opinions of CA (target audience) about the company, its activity in the market, which is reflected in digital space based on both objective and subjective information. Online reputation management from the point of view of marketing is the impact on users, carried out through the development and implementation of marketing tools, in order to establish long-term relationships, create loyalty to the company, increase profits and, finally, increase the value of reputational capital (Shulgina, 2017; Gimadeev and Abdukhalilova, 2023).

Reputation management in the digital space or Online Reputation Management (ORM) in a different way can be interpreted as the process of creating a company's image attractive to consumers, investors or other stakeholders on online platforms, carried out through the implementation of marketing technology.

Today, online reviews are considered more authoritative when making a purchase of a product or service compared to the opinions of family and friends. Bright Local, which studies the relationship of online reviews with making purchases, found that a large proportion of users resort to online opinions in order to find information about local businesses.

Today, the communication hierarchy for building a company's brand and for thinking about and producing content has changed, with users embedded in almost every stage.

The AIDA model has also undergone a number of innovations. Earlier it consisted of four components (attention, interest, desire, action), but now it is modified to AIDAS, where S stands for share. Share or "to share" means the user's desire to inform about the made purchase and tell about personal impressions on the Internet.

If the company's management does not pay proper attention to social networks and their influence on the public's opinion and loyalty, reputational losses can be very serious and, consequently, the company's profits will decrease.

This is why it is important for any organization to create an effective online reputation management tool to both increase the number of loyal customers and to increase return on assets.

One of the components of Online Reputation Management is Search Engine Reputation Management or SERM. The focus of SERM is on search engine optimization, predominantly Yandex or Google. Despite the fact that the range of coverage of both platforms is very large, reputation management subordinates itself to many more aspects. Reputation management consists of all the ways and methods of promoting the company on the web, which is why the mar-

keting department, in particular the specialist responsible for PR or SMM, must be in constant contact with other departments.

Figure 3 shows the main factors that influence a company's reputation in the digital space.

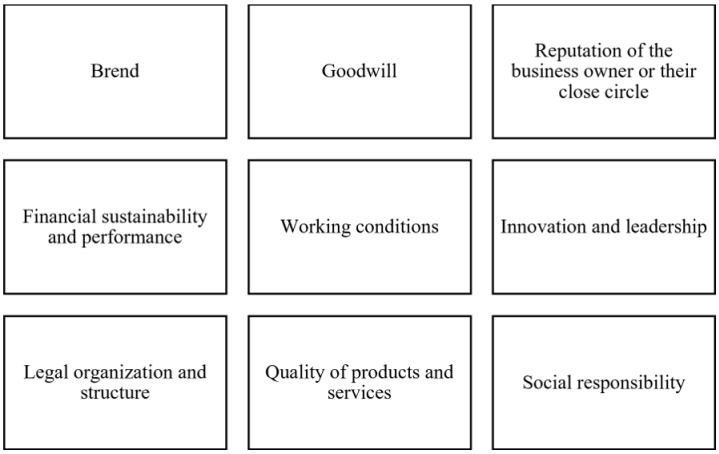


Fig. 3. Factors influencing the company's reputation in the digital space

Mostly reviews, comments and ratings are collected in the company's groups in social networks, official websites, review sites, personal blogs. The company rating has a direct impact on the preferences of potential customers.

Predominantly subjective user-generated information about the company is made available through the following communication channels:

1. Personal blogs, official websites, groups in social networks directly owned by the owners of the company.
2. Channels leased by the company (contextual and targeted advertising, sponsorship).
3. Self-dissemination of information about the product or service by customers, called the word-of-mouth effect.

Let's depict the main strategic techniques used in reputation management in digital space in Figure 4.

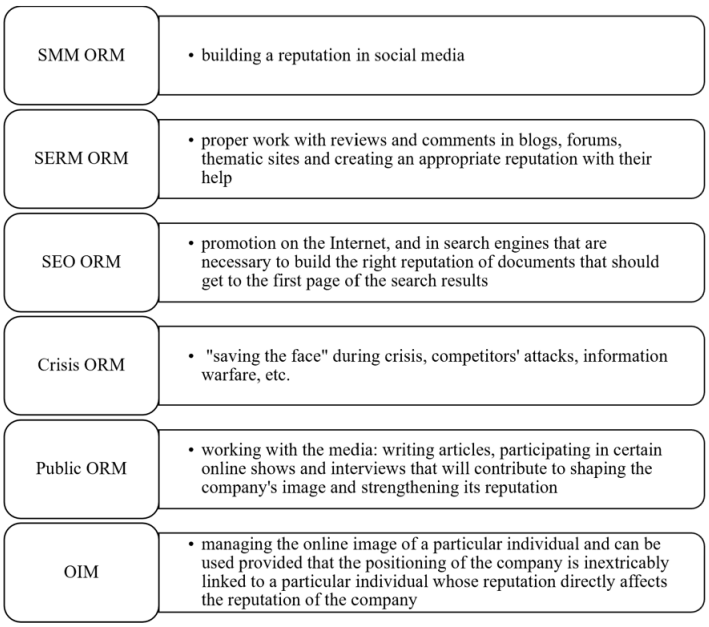


Fig. 4. Strategic techniques used in reputation management in the digital space

Suggestions for improving online reputation from a SERM ORM perspective should be considered.

1. Service integration to automate the process of responding to reviews.

To organize seamless responses to reviews, it is suggested to implement TrustYou CXP - a service (for hospitality companies, for example) that helps organizations to manage service quality, collect and analyze reviews from various platforms.

The main focus of this service is on working with reviews, which is a useful tool for enterprises. Separately, we would like to emphasize the use of AI (artificial intelligence), which is able to independently generate a suitable response to an individual review. This aspect of the service has a number of positive aspects, namely:

– personalization of the response;
– saving time;
– reduction of personnel costs;
– independent setting of response parameters (tone, length);
– the possibility of making corrections to the response created by the service.

TrustYou CXP has three usage rates: "Light", "Base" and "Pro". At first it is recommended to choose in favor of the "Light" version for gradual adaptation to the service and avoid unnecessary costs.

When using the proposed version of the service, the company will be able to collect feedback from various aggregators. In addition, thanks to the tariff there will be an opportunity to place a widget with ratings of reviews on the official website, which can positively affect the reputation of the company.

The creator of the service is Big Tree, which has more than 125 years of experience in the hotel business. Among the company's clients are such hotel chains as Kempinski, ParkInn, HYATT, Cosmos and others.

Besides TrustYou service it is recommended to pay attention to Medialogy service, the implementation of which can be realized together with the above-mentioned service. Since Medialogy focuses mainly on the reputation of social networks and media mentions, the services will not duplicate, but complement each other.

A distinctive feature of Medialogy is that as soon as a new mention of the hotel appears on the supported platforms, real-time notifications are sent to the responsible employee.

1. Motivation of the currently employed employees to write reviews by awarding a corporate gift for "Review of the Month"

An important task is to obtain feedback from currently employed employees who are able to point out positive aspects of their work at the company.

Material motivation in the form of a prize for the best review is an effective influence tool. The following criteria will be taken into account when selecting the winning review:

– originality of the review. An automatically generated review is characterized by its "boilerplate" and is quite often easily recognizable by users. If potential guests recognize an "inanimate" review, it will have a negative impact on the hotel's reputation;
– the volume of the review. Reviews that are too small are often uninformative, while reviews that are too long are hard to read. A "golden mean" in terms of text size is important, so a 500-700 word review is considered optimal;
– the tone of the review. Since, based on the analysis performed, employee reviews are predominantly colored negatively, it is necessary to "interrupt" them with positive ones. That is why employees who left a positive comment on the Internet can claim to receive a bonus;
– literacy and compliance with spelling norms. Employees of the company - its face, so compliance with the rules of the Russian language, the use of normative vocabulary will posi-

tively affect the online reputation of the hotel;

– honesty when writing a review. The situation that the employee describes in the review must necessarily be real and ever happened to the employee. Telling what happened to another employee (or not at all) is falsification. Such reviews are not allowed to participate in the contest.

According to the Civil Code of the Russian Federation (Clause 1, Article 575), the value of a gift in monetary terms should not exceed three thousand rubles, so this factor must necessarily be taken into account when making a selection.

Suggestions for activities within the SMM ORM framework include the following:

1. Work with VKontakte group:

a) Compiling a content plan.

b) A SMM specialist should take a course on creativity in content marketing.

Conclusion

Business reputation forms the image of the enterprise, thus affecting its image in the eyes of potential customers, and has a direct impact on the profit from the activity. The relevance of online reputation at the present stage is due to the growing influence of the Internet and social networks on all sectors of people's lives and their economic activity, which can positively affect the activities of enterprises in various spheres of activity.

When forming measures to maintain and develop online reputation, it is necessary to take into account the techniques of reputation management, allowing to positively affect the image of the company in the eyes of customers. Among them we can emphasize the following:

1. Preemptive tactics by means of advance exposure of negatives;
2. Spindoctor operations in reputation management;
3. The use of suggestibility;
4. Policy of ignoring public opinion (negative influence);
5. The use of opinion leaders in reputation management.

Due to the fact that online reputation management has a number of peculiarities, it is necessary to emphasize the main components of ORM (online reputation management). The first element is Search Engine Reputation Management or SERM. SERM is focused on the search engine, mainly Yandex or Google, as well as on working with reviews by evaluating their tone and applying methods of their correction. The second component of ORM is SEO ORM, which is dedicated to the promotion of the company's website or other selected online resource in search engine results. The final element is SMM ORM, which forms the company's reputation in social networks and other media spaces.

REFERENCES

Gimadeev G., Abdukhalilova L. 2023. From like to sales: to the question of automation of lead generation process in social networks and lead quality assessment. Technoeconomics 2, 3 (6). 28–43. DOI: https://doi.org/10.57809/2023.2.3.6.3

Fombrun Ch. 1990. What's in a Name? Reputation Building and Corporate Strategy. Academy of Management Journal 33(2), 233-258. //doi: 10.2307/256324

Kozlova N.P. 2011. Formation of positive image and business reputation of the company. Vestnik AGTU. Ser. Ekonomika, 67-68.

Markov D.A. 2023. Automated management systems: problems of implementation and integration. Technoeconomics 2, 1 (4). 55–63. DOI: https://doi.org/10.57809/2023.2.1.4.5

Sharkov F.I. 2015. Constants of goodwill: style, publicity, reputation, image and brand of the firm, 67-73.

Shulgina R.B. 2017. The concept of honor, dignity and business reputation in Russian civil law. Young scientist, 266-269.

6 hotel marketing tools and KPIs for the hotel. URL: https://www.travelline.ru/blog/gostinichnyy-marketing-osnovy-zadachi-i-sovety-ot-eksperta/ (accessed: 15.04.2024).

Advertising that does not irritate - is it possible? URL: https://crystal-digital.ru/blog/reklama-kotoraya-privlekaet-a-ne-razdrazhaet/ (accessed: 11.04.2024).

Content plan: what it is and why it is necessary. URL: https://smmplanner.com/blog/kontent-plan-chto-eto-i-zachem-nujno/ (accessed: 15.04.2024).

Course "Creativity in Content Marketing" // URL: https://ikraikra.ru/content (accessed: 15.04.2024).

CPM: what it is. URL: https://roistat.com/rublog/cpm (accessed: 15.04.2024).

Definition of online reputation index. URL: https://adves.com/blog/onlajn-reputatsiya-opredelyaem-indeks/ (accessed: 11.04.2024).

Features of formation of business reputation. URL: https://cyberleninka.ru/article/n/osobennosti-formirovaniya-delovoy-reputatsii-organizatsiy (accessed: 05.04.2024).

IKRA. Official website URL: https://ikraikra.ru/content#programm (accessed: 15.04.2024).

Institute of Corporate Law and Governance. URL: http://www.iku-rao.ru/ (accessed: 03.03.2024).

Medialogy. URL: https://www.mlg.ru/ (accessed: 15.04.2024).

Negative reviews in the Web: how to eliminate the consequences. URL: https://www.if24.ru/negativnye-otzyvy-v-seti-kak-ustranyat-posledstviya/ (accessed: 02.04.2024).

Reputation management in the Internet: methods and tools. URL: https://school.kontur.ru/publications/2641 (accessed: 03.03.2024).

Spindoctoring: what is it? URL: https://www.unisender.com/ru/glossary/spindoktoring-chto-eto-takoe-priemy-igde-primenyaetsya (accessed: 03.03.2024).

TrustYou CXP. Tariff "Light". URL: https://www.bigt.ru/trustyou (accessed:15.04.2024).

СПИСОК ИСТОЧНИКОВ

Gimadeev G., Abdukhalilova L. 2023. From like to sales: to the question of automation of lead generation process in social networks and lead quality assessment. Technoeconomics 2, 3 (6). 28–43. DOI: https://doi.org/10.57809/2023.2.3.6.3

Fombrun Ch. 1990. What's in a Name? Reputation Building and Corporate Strategy. Academy of Management Journal 33(2), 233-258. //doi: 10.2307/256324

Козлова Н.П. 2011. Формирование положительного имиджа и деловой репутации компании. Вестник АГТУ. Сер. Экономика, 67–68.

Markov D.A. 2023. Automated management systems: problems of implementation and integration. Technoeconomics 2, 1 (4). 55–63. DOI: https://doi.org/10.57809/2023.2.1.4.5

Шарков Ф.И. 2015. Константы гудвилла: стиль, паблисити, репутация, имидж и бренд фирмы, 67-73.

Шульгина Р.В. 2017. Понятие чести, достоинства и деловой репутации в российском гражданском праве. Молодой ученый, 266-269.

6 инструментов гостиничного маркетинга и KPI для отеля. URL: https://www.travelline.ru/blog/gostinichnyy-marketing-osnovy-zadachi-i-sovety-ot-eksperta/ (дата обращения: 15.04.2024).

Реклама, которая не раздражает – возможно ли это? URL: https://crystal-digital.ru/blog/reklama-kotoraya-privlekaet-a-ne-razdrazhaet/ (дата обращения: 11.04.2024).

Контент-план: что это и зачем нужно. URL: https://smmplanner.com/blog/kontent-plan-chto-eto-i-zachem-nujno/ (дата обращения: 15.04.2024).

Курс «Креатив в контент-маркетинге» // URL: https://ikraikra.ru/content (дата обращения: 15.04.2024).

CPM: что это такое. URL: https://roistat.com/rublog/cpm (дата обращения: 15.04.2024).

Определение индекса онлайн-репутации. URL: https://adves.com/blog/onlajn-reputatsiya-opredelyaem-indeks/ (дата обращения: 11.04.2024).

Особенности формирования деловой репутации. URL: https://cyberleninka.ru/article/n/osobennosti-formirovaniya-delovoy-reputatsii-organizatsiy (дата обращения: 05.04.2024).

IKRA. Official website URL: https://ikraikra.ru/content#programm (accessed: 15.04.2024).
Институт корпоративного права и управления. URL: http://www.iku-rao.ru/ (дата обращения: 03.03.2024).
Медиалогия. URL: https://www.mlg.ru/ (дата обращения: 15.04.2024).
Негативные отзывы в Сети: как устранять последствия. URL: https://www.if24.ru/negativnye-otzyvy-v-seti-kak-ustranyat-posledstviya/ (дата обращения: 02.04.2024).
Управление репутацией в интернете: методы и инструменты. URL: https://school.kontur.ru/publications/2641 (дата обращения: 03.03.2024).
Спиндокторинг: что это? URL: https://www.unisender.com/ru/glossary/spindoktoring-chto-eto-takoe-priemy-igde-primenyaetsya (дата обращения: 03.03.2024).
TrustYou CXP. Тариф «Лайт». URL: https://www.bigt.ru/trustyou (дата обращения 15.04.2024).

INFORMATION ABOUT AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

SHELEYKO Victoria A. – assistant.
E-mail: hareva.v@mail.ru
ШЕЛЕЙКО Виктория Анатольевна – ассистент.
E-mail: hareva.v@mail.ru
ORCID: https://orcid.org/0000-0002-0266-1043

KRESTNIKOVA Anastasia – student.
E-mail: nkrestnikova@list.ru
КРЕСТНИКОВА Анастасия – студент.
E-mail: nkrestnikova@list.ru

Статья поступила в редакцию 25.05.2024; одобрена после рецензирования 03.06.2024; принята к публикации 07.06.2024.
The article was submitted 25.05.2024; approved after reviewing 03.06.2024; accepted for publication 07.06.2024.

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 72–84.
Техноэкономика. 2024, Том 3, № 2 (9). С. 72–84.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.6

IMPROVEMENT OF THE BUSINESS MODEL OF A MANAGEMENT COMPANY VIA OPTIMIZATION OF BUSINESS PROCESSES

Yulia Rudkovskaya ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ uliasha.ru@yandex.ru

Abstract. This study is devoted to the analysis and improvement of the business model of a management company based on the optimization of business processes. In the course of the research, we analyzed the features of the business modeling system in terms of management, main and supporting processes of management companies, as well as considered the business processes of the company's core activities and key resources of the company. As a result of the study the main shortcomings in the work of enterprises and a number of measures to improve the business processes of problem areas of the company's business model were identified.

Keywords: business model, management company, business process, business process model

Citation: Rudkovskaya Yu. Improvement of the business model of a management company via optimization of business processes. Technoeconomics. 2024. 3. 2 (9). 72−84. DOI: https://doi.org/10.57809/2024.3.2.9.6

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.6

СОВЕРШЕНСТВОВАНИЕ БИЗНЕС-МОДЕЛИ УПРАВЛЯЮЩЕЙ КОМПАНИИ НА ОСНОВЕ ОПТИМИЗАЦИИ БИЗНЕС-ПРОЦЕССОВ

Юлия Рудковская ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ uliasha.ru@yandex.ru

Аннотация. Данное исследование посвящено анализу и совершенствованию бизнес-модели управляющей компании на основе оптимизации бизнес-процессов. В ходе работы были проанализированы особенности системы бизнес-моделирования с точки зрения управляющих, основных и обеспечивающих процессов управляющей компании, а также рассмотрены бизнес-процессы основной деятельности компании, а также ключевых ресурсов. В результате исследования были выявлены основные недочеты в работе предприятий и ряд мероприятий по совершенствованию бизнес-процессов проблемных зон бизнес-модели компании.

Ключевые слова: бизнес-модель, управляющая компания, бизнес-процесс, модель бизнес-процесса

Для цитирования: Рудковская Ю. Совершенствование бизнес-модели управляющей компании на основе оптимизации бизнес-процессов // Техноэкономика. 2024. Т. 3, № 2 (9). С. 72–84. DOI: https://doi.org/10.57809/2024.3.2.9.6

Introduction

Nowadays, when cities are growing and countries are continuously developing, one of the key sectors of the economy of many countries is considered to be construction. It is this sphere that provides for the creation of new infrastructure, housing and commercial real estate. On the territory of modern Russia there are more than 20 thousand construction companies.

The successful functioning of any company, including construction companies, depends on many factors, among which an effective business model is of particular importance.

Nowadays, the construction industry has a large and serious competition in the market and in the absence of an established business model and business processes, the company loses its position relative to other construction colleagues. Today, a company that does not have a developed business model tends to inevitably lose profits due to the lack of an established system in operation.

In order to identify or smooth out "irregularities" in the company's work, it is necessary to have an idea of the business processes formed earlier and implemented in the company. It is at the level of business process that it is possible to identify the causes of problems faced by the company on its development path.

In a constantly changing market, improving the business model of the construction company is simply necessary. This is the relevance of the optimization of business processes of the company. Since the business model directly depends on the work of business processes, which in turn may have flaws in its structure, which directly affects the work of the company as a whole. And improving and analyzing the existing business processes in the company is a direct path to

success and achievement of the company's goals.

The purpose of this study is to improve the business model of the construction company by analyzing the main business processes of the company and developing measures to improve the performance of business processes, as well as improving performance in general. "Lenstroytrest" will be considered as a case study in this paper.

A business model is a visual format for the operation of a company's business processes with the definition of important areas for the company. For example, one of the most popular in use types of business model is recognized to be the business model of A. Osterwalder and I. Penier. This model is one of the most basic and understandable when setting the task of forming a business model of the company.

The business model of A. Osterwalder and I. Penier is not infrequently referred to as a strategic management tool. The model consists of nine key elements describing the company's business processes and is used to identify points of growth, analyze competitors and determine the best options for business development.

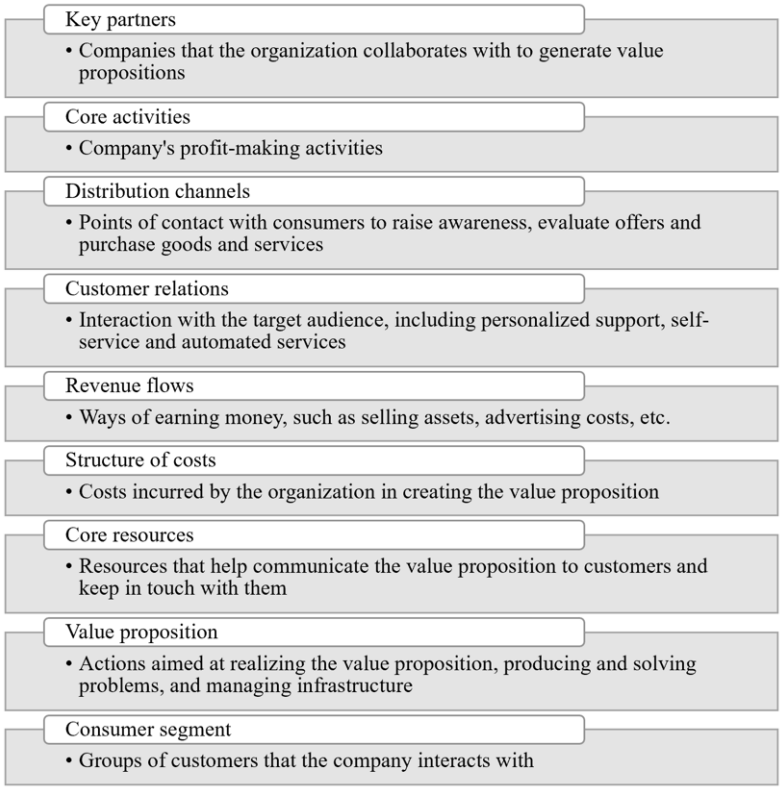


Fig. 1. Key elements of the business model of A. Osterwalder and I. Penier

In general, it is worth noting that business process modeling is an effective tool for identifying weaknesses in the work of an enterprise and eliminating them. It includes a detailed description of the company's activities, dividing it into separate operations and analyzing the interrelationships between them. The main purpose of business modeling is to improve the efficiency of the company's operations, increase profitability and profit accordingly

Materials and Methods

The key methods of this study include: collection and analysis of information, comparison, description, classification and generalization, as well as modeling.

In order to collect information regarding the peculiarities of the analyzed company and the

mechanism of its work, a detailed survey of employees involved in the performance of the processes under study was conducted.

The theoretical basis of the study was provided by scientific works on business model formation - A. Osterwalder and I. Peca, V. Repin, V. Eliferov. Also, educational literature, scientific articles, federal laws and other Internet resources were used as sources for the study.

Results and Discussion

In this study, Lenstroytrest, one of the oldest real estate developers in modern St. Petersburg, was selected as a case study. This company implements projects of various scales in residential real estate segments (Ilin, 2022). For the long period of its work the company has realized more than 20 objects and now continues the construction of 4 main objects.

To analyze the problematic processes of the company, let's consider the business model "as is".

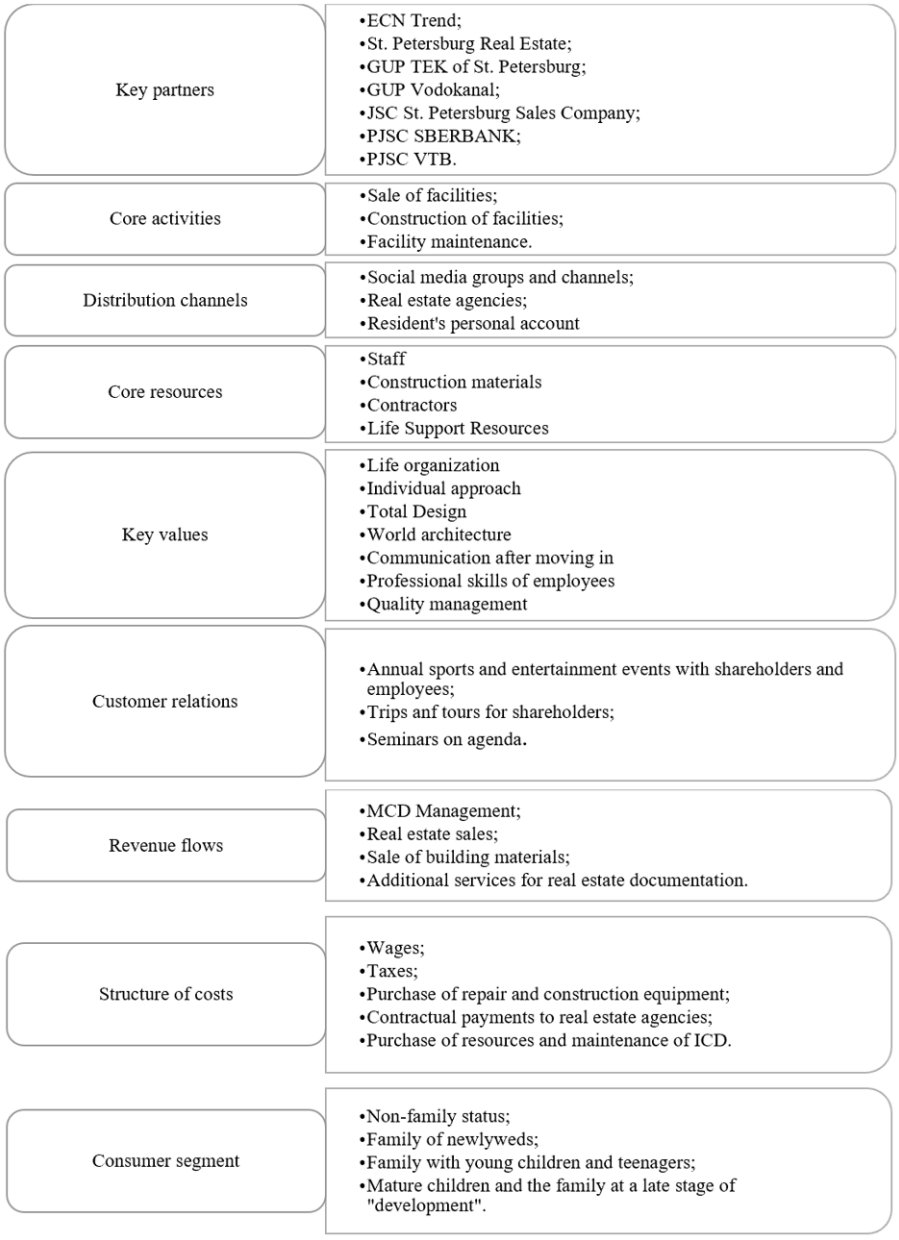


Fig. 2. Elements of the business model of Lenstroytrest (designed by the author)

According to the business model of A. Osterwalder and I. Pinier of the construction company "Lenstroytrest", we can see that in general the company has a developed understanding of its value proposition, as well as a good analysis of the target audience. To understand the work of the company one business model is not enough so let's turn to the reference model. In order to figure out the main directions of the company's work, let's consider the reference model of the company (Kopp, 2020).

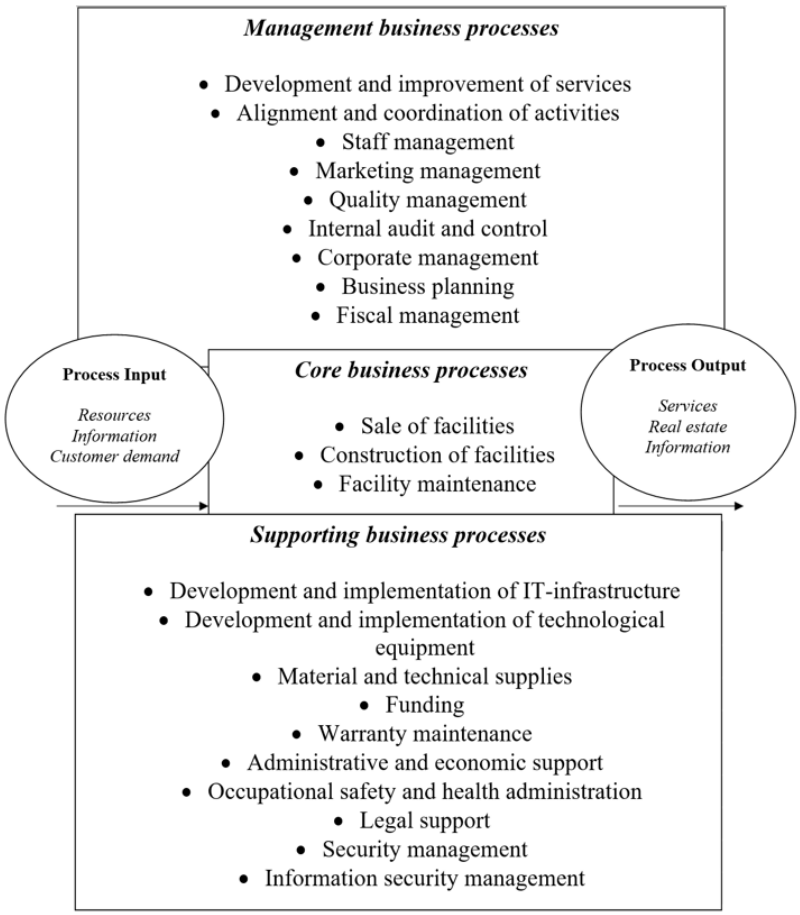


Fig. 3. Reference model of top-level business processes of "Lenstroytrest" (designed by the author)

Summarizing all the main processes of the top level, the following scheme can be created. Reference model can be called a type of model more understandable for perception and understanding of the company's development. In the case of the construction company JSC "Lenstroytrest".

This reference functional model contains a set of functions of the construction company, optimal for this type of enterprises. The mentioned functions allow to reduce the process of model building to a rather quick process of questioning and subsequent removal of unused functions from the reference model. All the mentioned business processes are debugged, but since the work of the company is connected with people who have nothing to do with these processes, sometimes various emergency situations can occur. Since this model is built taking into account the occurrence of such emergencies, you cannot worry about the stable functioning of the construction company (Barbera, 2012).

The business model refers to a comprehensive view of how a company selects its customers, how it defines and differentiates its value proposition, through which channels it communicates this proposition to its target customers, which business processes are key and which can be

outsourced, what resources the company uses, including partnerships and finally how it makes profits for the owners (Kulchytskiy, 2019).

Let's turn to the company's problem areas and look at the processes that may have flaws in their operation.

The following problem areas exist in the company's business model:

– Key resources;
– Sales channels;
– Key activities.

Let's consider ways to improve the business process of the construction company for each module.

Improving the business process of a construction company - Key Resources module.

The company regularly receives a lot of requests related to malfunctions or breakdowns of warranty nature. At the same time, the actual values of the number of requests to the warranty department are in the critical zone. This is too much work for the warranty department. It is because of such an influx of appeals that the time of their processing and elimination increases accordingly, which in turn causes resentment and bad impression of shareholders (Artamonov, 2019).

After reviewing the processing and problem-solving process, it was found that there are no irregularities in the process. In this case, it is worth paying attention to the reason for the occurrence of such a large number of appeals of warranty nature. More specifically, look directly at the quality of the building contractor's services, the quality of the materials, and possibly the quality of the home acceptance process by the company's construction subcontractors (Ilyin, Shirokova, Lyovina, Rostova, 2022).

In order to improve the quality of construction, it is necessary to review the specific areas where warranty issues occur. Most often, warranty failures occur with equipment or materials that were purchased from third-party manufacturers. Such as windows, elevators, mirrors, sanitary ware. These resources are purchased through tenders (Li, 2024).

In order to stabilize the work of the Warranty Department and reduce the number of warranty claims while preserving the company's cash flow, it is proposed to consider an alternative model of the process of acceptance of services rendered by a subcontractor.

Let's consider the planned performance of the Warranty Department due to the introduction and work according to the alternative model of the business process of acceptance of completed work from subcontractors.

Table 1. Planned performance indicators of the warranty department (designed by the author)

Indicator	Recommended value	Actual value
Number of processed telephone inquiries received	50-60	70
Number of processed applications received from management companies	85-100	150
Number of requests from the personal account of the shareholder	3-5	7
Number of warranty problems eliminated	55-75	56
Timeframe for elimination (days)	Not more than 60	40
Repeated request for problem elimination	Not more than 15	17
Color Specifications: – Below standard – Standard – A little more than standard – More than standard – Significantly more than standard		

According to the data in Table 1, we can see that some items are close to the recommended indicators, and some items are completely within the recommended range. Thus, the Warranty Department has an even flow of requests for troubleshooting. This flow allows processing and elimination of warranty requests within the regulated period of time, in compliance with all regulations, including a high level of work quality.

Improving the business process of a construction company - Sales Channels module

The process of selling an object is one of the fundamental processes of the company. Let's consider the process of attracting customers through sales channels, which is currently established in the company.

Initially, the marketing department receives a request from the sales department to build a customer base and attract customers to a new facility, or to a facility that has low sales. Then the marketing department is engaged in choosing the type of advertising, based on the previously conducted analysis of the target audience. After determining the type of advertising must understand what contractor will work with the company to get the best results (Abeynayake, 2021). Then there is an analysis of the availability of the contract with this or that contractor, which is responsible for providing services for the selected type of advertising. After determining the marketing department proceeds to the formation of a request for a contractor. If the contractor has not previously cooperated, then the legal, financial, sales and marketing departments are responsible for the formation of contracts and their signing, for further cooperation (Kifokeris, 2020).

The next step on the part of the marketing department is to receive the service to attract clients. Upon receipt of the service, the results are seriously analyzed together with the sales department. According to the results of the analysis, the marketing department can choose 2 ways to complete the process of customer acquisition: to continue cooperation with contractors, if the results of their work have improved the conversion rate of the sales funnel. And accordingly, on the contrary, to terminate cooperation or to revise the terms of cooperation, and in the future to request repeated provision of services based on the results of the earlier analysis (Treptow, Kneipp, 2022).

At the moment, the main types of advertising within the advertising campaign used by the company are:

- Website;
- Calling people who have left requests on the website and other services;
- Communication in the chat room;
- Radio advertising;
- Agency contracts with partners;
- Merch and printed materials.

It should be noted that in order to attract the target audience of younger age category it is worth paying attention to the development of contextual advertising, due to which interest will be formed even before the initial consultation (Rovinska, 2023).

Let's consider the proposed process of attracting customers through the sales channel. This process consists of two stages of implementation. The first stage begins with the Marketing Department receiving a request from the Sales Department for a certain type of target audience for a particular object that needs to be realized (Wanxin, 2023). The Marketing Department in turn selects a certain type of advertising that will be similar to the previously done analysis of the target audience of the object. After selecting one of the seven types of advertising department turns to the procedure for finding contractors, or rather analyze the availability of contractors with whom the contract for the selected type of advertising has already been concluded. If there is no such, then the contract is concluded and then on the basis of the terms of the contract and

the application from the sales department Marketing Department forms a request for services (Carpinetti, 2003).

The second stage is the evaluation and control of the work performed. After receiving the results, the Marketing Department together with the sales department analyze the results obtained and evaluate the indicators of the sales funnel. If the indicators have increased, the application from the sales department is closed, and it also means that cooperation with the contractor was fruitful and will continue in the future (Ibrahim, 2019).

If the sales funnel indicators have not changed or on the contrary have fallen, in this case, the question of resolving the situation is raised through the repeated provision of services with a change in the terms - the terms of reference and re-analysis of the target audience.

Let's consider the planned changes in the conversion rates of the sales funnel and KPI of the sales process, which directly depends on the work of the sales funnel, due to the work with a new type of advertising within the Advertising Campaign as a sales channel.

Table 2. Planned conversion rates of the sales funnel after the introduction of contextual advertising (designed by the author)

Indicator	Coverage	Input	Conversion
Make a statement	60 000	35 000	58.33%
Get familiar with the offer	25 000	20 000	80.00%
Create interest	17 000	10000	58.82%
Influence the choice	7000	5000	71.43%
Make a deal	4000	3000	75.00%
Second appeal	2500	1500	60.00%
Loyalty	900	700	77.78%

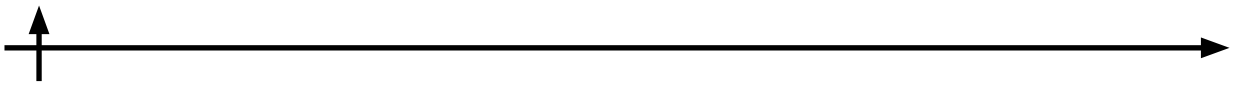
According to the data in Table 15, we can conclude that the planned indicators have positive changes. And these indicators will also positively affect the sales statistics. It should be noted that the conversion rate of "Make a statement" is still one of the lowest. In this case, it is worth re-analyzing the target audience, which is aimed at contextual advertising and possibly resort to alternative options for external advertising. That is, consider not only billboards, but also pay attention to advertising signs in public transportation. To raise the level of recognition thereby attracting more people willing to familiarize themselves with and subsequently purchase the provided "product".

Improvement of the business process of the construction company - modules Key activities

Let's consider another type of the company's core activity - management. According to the data received on a regular basis by the Customer Service Directorate. Residents of residential complexes have some dissatisfaction with the fact of rendering services by the management company.

Dissatisfaction of quite different nature from the lack of awareness of the general meeting of owners, to the failure to provide reports on the works carried out on the territory of the complex on the improvement of the adjacent territory. As stated earlier in the processes there are shortcomings and perhaps because of them come complaints of this nature.

In this case, it is proposed to establish a process between the management company and the construction company. In order to respond in a timely manner to the issue of utility arrears. This process will establish internal communication between the holding companies and reduce the number of calls to the call center, sales department and dissatisfaction of tenants in general.



The process works at level 1:

1. A request is received from the developer to generate documents for debt repayment.

2. The management company generates a document on the basis of the collected data for the riser of the recently handed over house or for the whole house.

3. After that, on the basis of the collected data, a document with debt calculations is formed.

4. There is a check, after which the calculations are repeated or sent to the developer.

5. The developer's documents are checked again and if there are any questions about the amounts in the documents, the process returns to the stage of debt calculation.

6. If the developer's accounting department has no questions, the debt is settled and the application is closed.

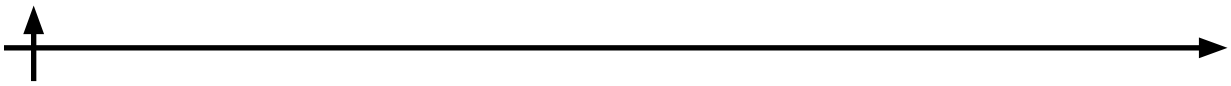
The process does not have complex schemes, as speed and accuracy are important in its implementation. By having simple and clear elements, this process will be much easier to adapt in companies, thus simplifying the work of several departments. And preserve the image of the company in front of customers who will no longer face such problems.

Through the six proposed processes it is possible to improve the work of management companies and reduce the level of criticism from tenants towards the quality of work of the holding companies. Thus, it is possible to establish positive relations with the residents of the neighborhoods and possibly increase the number of repeat sales calls.

Based on the analysis of the company's business processes, as well as practical observations, options for improving business processes have been proposed. In this regard, it is necessary to consider the planned dynamics of the main economic indicators of economic activity of the construction company.

Table 3. Planned dynamics of the main economic indicators of economic activity of the construction company "Lenstroytrest" (designed by the author)

Indicator	Report year	Plan year	Absolute deviation, th. rub.	Growth rate, %
Revenue, th. rub.	287536000	288973680	-1 437 680	100.50%
Cost of sales	291177000	297000540	-5 823 540	102.00%
Gross profit (loss)				
Th. Rub.	3641000	3626436	14 564	99.60%
- as % of revenue	1.266%	1.255%		
Selling and administrative costs				
- Th. Rub.	96 122 000	91556205	4 565 795	95.25%
- as % of revenue	33.430%	31.683%		
Profit from operating activities				
- Th. Rub.	99 763 000	101259445	-1 496 445	101.50%
- as % of revenue	34.696%	35.041%		
Other income, th. rub.	331 880 000	333539400	-1 659 400	100.50%
Other expenses, th. rub.	70 306 000	71360590	-1 054 590	101.50%
Profit from financial and economic activities				
- Th. Rub.	4788000	4859820	-71 820	101.50%
- as % of revenue	1.665%	1.682%		
Income tax, th. rub.	734000	722990	11 010	98.50%
Net profit				
- Th. Rub.	4 054 000	4136830	-82 830	102.04%
- as % of revenue	1.410%	1.432%		
- as a % of equity capital	0.110%	0.112%		



According to the table, with the introduction of new processes and improvement of existing ones, the planned indicators of profit and revenue will increase by about 1.5% relative to the reporting year. These indicators are not significant, but they confirm the correctness of the direction of the company's earlier analysis and the selected problem areas.

Conclusion

Real estate companies are a complex mechanism, the work of which is based on the relationship between the elements, as between the gears. And if the connection between the elements is broken or there are deficiencies in some element, the whole mechanism is in danger of stagnation and difficulties in work. For this reason, when problems arise in a company, it is necessary to refer to the concepts of business processes and business models.

In addition to looking at the business model, this study also modeled problematic business processes, the analysis of which revealed the perceived deficiencies that were causing the poor performance. In addition, process improvement options were considered, which subsequently became specific process improvement activities.

To improve the Key Resources module, it is proposed to make changes to the process of control and acceptance of completed work from subcontractors. By specifying the steps of the process, it was possible to simplify its system and minimize the occurrence of warranty failures, which had a positive impact on the performance of the Warranty Department.

As for the improvement of the Sales process, it was suggested to consider working with contextual advertising to attract customers. By making adjustments to the business process, according to the planned indicators, the conversion of the sales funnel will have data within the limits of acceptable for regular closing of the sales plan.

In order to optimize the management/service process, 4 process improvement activities are proposed:

- The process of holding the General Meeting of Owners;
- Process of processing applications and appeals;
- The process of control of work performance;
- Process of submitting a report on completed works.

It is necessary to note the importance of forming a business model of the company and analyzing business processes. The business model of the company has its own peculiarities of formation, which can point to specific deficiencies, and business processes in turn can help to understand the cause of deficiencies in the work.

This study is a clear example of the need to refer to the business model and business processes to identify bottlenecks in the company's work. As well as improving or identifying solutions when deficiencies occur in order to eliminate them.

All the developments and results presented in this article have practical value and can be used by the management of the construction company "Lenstroytrest", in particular, and real estate industry companies in general, to analyze the state of the company at the moment and possible improvement of processes.

REFERENCES

Abeynayake D. N. 2021. A roadmap for business model adaptation in the construction industry: a structured review of business model research. Construction Innovation. doi:10.1108/CI-05-2020-0077

Artamonov K. 2019. What has remained unchanged in your business process model? CBI 2019 1, 551-558. doi:10.1109/CBI.2019.00070

Barbera A. 2012. Advanced model for maintenance management in a continuous improvement cycle: integration into the business strategy. International Journal of System Assurance Engineering and Management 3 (1), 47-63. doi:10.1007/s13198-012-0092-y

Carpinetti L.C.R. 2003. Quality management and improvement. A framework and a business-process reference model. Business Process Management Journal 9 (4), 543-554. doi:10.1108/14637150310484553

Ibrahim M.S. 2019. Towards successful business process improvement – An extension of change acceleration process model. PLoS ONE 14 (11), e0225669. doi:10.1371/journal.pone.0225669

Ilin I.V. 2022. Integration of information and management technologies. Technoeconomics 1 (1), 24-32. doi:10.57809/2022.1.1.2

Ilyin I.V., Shirokova S.V., Lyovina A.I., Rostova O.V. et al. 2022. Information Technologies in Business Management. Politech-press, 215.

Kifokeris D. 2020. A conceptual digital business model for construction logistics consultants, featuring a sociomaterial blockchain solution for integrated economic, material and information flows. Journal of Information Technology in Construction 25, 500-521. doi:10.36680/J.ITCON.2020.029

Kopp A. 2020. Intelligent Support of the Business Process Model Analysis and Improvement Method. Communications in Computer and Information Science 1175, 111-135. doi:10.1007/978-3-030-39459-2_6

Kulchytskiy R. 2023. Creating an interference model of the cadastral value of real estate: advantages for business. Cadernos de Educaзго, Tecnologia e Sociedade 16 (3), 758-767. doi:10.14571/brajets.v16.n3

Li Y. 2024. Business Model Innovation in the Construction Industry: Emerging Business Model Archetypes from Bathpod Modularization. Journal of Management in Engineering 40 (2). doi: 10.1061/jmenea.meeng-5651

Rovinska N. Yu. 2015. Practical application of the method by Alexander Osterwalder. East European Scientific Journal 2 (2), 55-59.

Treptow I.C., Kneipp J.M. 2022. Business Model Innovation for Sustainable Value Creation in Construction Companies. Sustainability 14 (16), 10101. doi:10.3390/su141610101

Wanxin X. 2023. Modern concepts, principles and perspectives of business process management in real estate enterprises. Economy and Society 52. doi:10.32782/2524-0072/2023-52-22

Wanxin X. 2023. Research on business process reengineering of real estate enterprises. Market Infrastructure 75. doi:10.32782/infrastruct75-11

BPMN notation. Business Studio business modeling system. URL: https://www.businessstudio.ru/wiki/docs/current/doku.php/ru/csdesign/bpmodeling/bpmn_notation (accessed 27.04.2024).

ELAMA. Contextual advertising. Fundamentals. URL: https://elama.ru/blog/kontekstnaya-reklama-osnovy/ (accessed 15.04.2024).

Official site of the construction company JSC "Lentsroytrset". Shares and offers. URL: https://6543210.ru/aktsii-i-skidki/ (accessed 21.03.2024)

ENTERCHAIN. Business process modeling: objectives, methods and results. URL: https://www.enterchain.ru/experience/mbp/modelirovanie-biznes-protsessov-tseli-metody-i-rezultaty/ (accessed 14.05.2024)

Consultant Plus. Federal law "On mortgage (pledge of real estate)" from 16.07.1998 N 102-FZ. URL: https://www.consultant.ru/document/cons_doc_LAW_19396/ (accessed 20.04.2024)

СПИСОК ИСТОЧНИКОВ

Abeynayake D. N. 2021. A roadmap for business model adaptation in the construction industry: a structured review of business model research. Construction Innovation. doi:10.1108/CI-05-2020-0077

Artamonov K. 2019. What has remained unchanged in your business process model? CBI 2019 1, 551-558. doi:10.1109/CBI.2019.00070

Barbera A. 2012. Advanced model for maintenance management in a continuous improvement cycle: integration into the business strategy. International Journal of System Assurance

Engineering and Management 3 (1), 47-63. doi:10.1007/s13198-012-0092-y

Carpinetti L.C.R. 2003. Quality management and improvement. A framework and a business-process reference model. Business Process Management Journal 9 (4), 543-554. doi:10.1108/14637150310484553

Ibrahim M.S. 2019. Towards successful business process improvement – An extension of change acceleration process model. PLoS ONE 14 (11), e0225669. doi:10.1371/journal.pone.0225669

Ilin I.V. 2022. Integration of information and management technologies. Technoeconomics 1 (1), 24-32. doi:10.57809/2022.1.1.2

Ilyin I.V., Shirokova S.V., Lyovina A.I., Rostova O.V. et al. 2022. Information Technologies in Business Management. Politech-press, 215.

Kifokeris D. 2020. A conceptual digital business model for construction logistics consultants, featuring a sociomaterial blockchain solution for integrated economic, material and information flows. Journal of Information Technology in Construction 25, 500-521. doi:10.36680/J.ITCON.2020.029

Kopp A. 2020. Intelligent Support of the Business Process Model Analysis and Improvement Method. Communications in Computer and Information Science 1175, 111-135. doi:10.1007/978-3-030-39459-2_6

Kulchytskiy R. 2023. Creating an interference model of the cadastral value of real estate: advantages for business. Cadernos de Educазго, Tecnologia e Sociedade 16 (3), 758-767. doi:10.14571/brajets.v16.n3

Li Y. 2024. Business Model Innovation in the Construction Industry: Emerging Business Model Archetypes from Bathpod Modularization. Journal of Management in Engineering 40 (2). doi: 10.1061/jmenea.meeng-5651

Rovinska N. Yu. 2015. Practical application of the method by Alexander Osterwalder. East European Scientific Journal 2 (2), 55-59.

Treptow I.C., Kneipp J.M. 2022. Business Model Innovation for Sustainable Value Creation in Construction Companies. Sustainability 14 (16), 10101. doi:10.3390/su141610101

Wanxin X. 2023. Modern concepts, principles and perspectives of business process management in real estate enterprises. Economy and Society 52. doi:10.32782/2524-0072/2023-52-22

Wanxin X. 2023. Research on business process reengineering of real estate enterprises. Market Infrastructure 75. doi:10.32782/infrastruct75-11

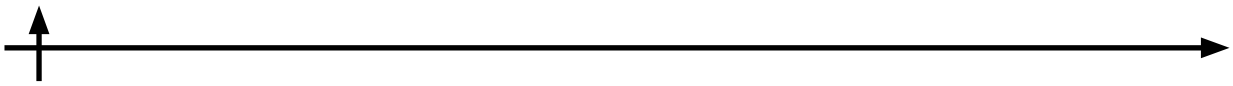
Нотация BPMN. Система бизнес-моделирования Business Studio. URL: https://www.businessstudio.ru/wiki/docs/current/doku.php/ru/csdesign/bpmodeling/bpmn_notation (дата обращения: 27.04.2024).

ELAMA. Контекстная реклама. Основы. URL: https://elama.ru/blog/kontekstnaya-reklama-osnovy/ (дата обращения: 15.04.2024).

Официальный сайт строительной компании АО «Лентсройтрсет». Акции и предложения. URL: https://6543210.ru/aktsii-i-skidki/ (дата обращения 21.03.2024)

ENTERCHAIN. Моделирование бизнес-процессов: цели, методы и результаты. URL: https://www.enterchain.ru/experience/mbp/modelirovanie-biznes-protsessov-tseli-metody-i-rezultaty/ (дата обращения: 14.05.2024)

Консультант Плюс. Федеральный закон "Об ипотеке (залоге недвижимости)" от 16.07.1998 N 102-ФЗ. URL: https://www.consultant.ru/document/cons_doc_LAW_19396/ (дата обращения: 20.04.2024)



INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

RUDKOVSKAYA Yulia – student.
E-mail: uliasha.ru@yandex.ru
РУДКОВСКАЯ Юлия Владиславовна – студент.
E-mail: uliasha.ru@yandex.ru

Статья поступила в редакцию 21.05.2024; одобрена после рецензирования 01.06.2024; принята к публикации 04.06.2024.
The article was submitted 21.05.2024; approved after reviewing 01.06.2024; accepted for publication 04.06.2024.

Technoeconomics. 2024, Vol. 3, No. 2 (9). Pp. 85–98.
Техноэкономика. 2024, Том 3, № 2 (9). С. 85–98.

Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.7

INFORMATION INVESTMENT PLATFORM AS AN IMPROVEMENT TOOL FOR INVESTMENT CLIMATE OF WAREHOUSE REAL ESTATE

Amina Babkina ✉

Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

✉ babkina_ak@spbstu.ru

Abstract. This article is devoted to the study of the information investment platform in the context of the market state of the investment climate and the existing system of its development in the warehouse real estate market. The study analyzes warehouse real estate as a sector of the economy and considers the key components of the investment climate. In addition, the authors outlined the weaknesses of the existing development mechanism. As a result of the study, an updated mechanism of functioning and development of the investment climate of warehouse real estate was formed through the development of an information platform as a tool to improve investment conditions and increase the attractiveness of the industry.

Keywords: investment climate, warehouse real estate, market analysis, development mechanism, information platform

Citation: Babkina A. Information investment platform as an improvement tool for investment climate of warehouse real estate. Technoeconomics. 2024. 3. 2 (9). 85–98. DOI: https://doi.org/10.57809/2024.3.2.9.7

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2024.3.2.9.7

ИНФОРМАЦИОННАЯ ИНВЕСТИЦИОННАЯ ПЛАТФОРМА КАК ИНСТРУМЕНТ СОВЕРШЕНСТВОВАНИЯ МЕХАНИЗМА РАЗВИТИЯ ИНВЕСТИЦИОННОГО КЛИМАТА СКЛАДСКОЙ НЕДВИЖИМОСТИ

Амина Бабкина ✉

Санкт-Петербургский политехнический университет Петра Великого,
Санкт-Петербург, Россия

✉ babkina_ak@spbstu.ru

Аннотация. Данная статья посвящена исследованию информационной инвестиционной платформы в контексте рыночного состояния инвестиционного климата и существующей системы его развития на рынке складской недвижимости. В ходе исследования был проведен анализ складской недвижимости как сектора экономики, а также рассмотрены ключевые составляющие инвестиционного климата. Кроме того, авторами были обозначены слабые стороны существующего механизма развития. В результате исследования был сформирован обновленный механизм функционирования и развития инвестиционного климата складской недвижимости за счет развития информационной платформы, как инструмента, позволяющего улучшить условия инвестирования и повысить привлекательность отрасли.

Ключевые слова: инвестиционный климат, складская недвижимость, анализ рынка, механизм развития, информационная платформа

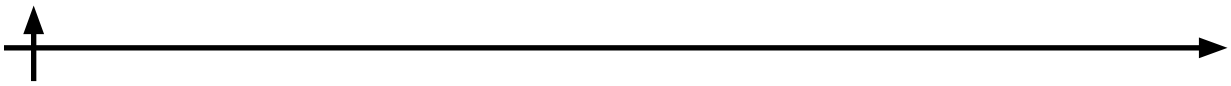
Для цитирования: Бабкина А. Информационная инвестиционная платформа как инструмент совершенствования механизма развития инвестиционного климата складской недвижимости // Техноэкономика. 2023. Т. 3, № 2 (9). С. 85–98. DOI: https://doi.org/10.57809/2024.3.2.9.7

Introduction

In the modern world, the investment industry continues to actively develop and increase its importance in the activities of individual enterprises and holdings, as well as entire markets and states. That is why today much more attention is paid to the study of this industry than decades ago. Nevertheless, the study of this issue in the field of individual areas is extremely low, which becomes a platform for analysts and researchers, because large investments are impossible without taking into account all the features, risks and attractiveness of the investment object.

In view of global world changes over the last 5 years, the leaders of the most developed and developing countries are especially concerned about the investment climate of their countries, because competitiveness in this issue directly affects the volume of foreign investment. In addition, the presence of investments inside and outside the country increases stability in the global arena. The investment climate of the state is formed by the attractiveness of all potentially possible areas of activity as an object of investment. Undoubtedly, one of these industries is real estate.

In real estate, investment is often the main source of financing, which in turn is the engine of progress. Due to the huge leap in development over the last decade and the high sustainability



of the industry, commercial real estate is becoming a competitive player in the investment market. Today, warehouse properties are popular among investors due to their ease of maintenance and incredibly high demand among various market players. In addition, the payback and speed of realization of the facilities is peaking year after year. However, it is important to realize that the development of investments in warehouse real estate also depends on a number of factors that form the basis for the improvement of all the previously mentioned indicators. If there are favorable conditions for progress, the analyzed market will continue its prosperity. Nevertheless, there are also weaknesses in the existing mechanism of investment climate development, which negatively affects the speed and quality of progress in the warehouse real estate investment market in Russia. Based on the above, the relevance of the work is related to the insufficient elaboration of the mechanism of investment climate development of the warehouse real estate market in the conditions of active development of the industry.

In this scientific research, correlation analysis tools are used to confirm the presence of the cause-and-effect relationships. Due to the originality of the nominal data, the study of their correlation differs significantly from the studies in other sections of the correlation analysis. At the same time, despite the numerous efforts of scientists to develop and improve this section of correlation analysis, it still does not provide a satisfactory solution to the problem of identifying and evaluating correlation. The difficulty in determining the correlation between data measured in nominal data is explained by the fact that no mathematical operations can be performed on these data. Occurrences of some numbers are already the data of the metric scale, and these data can be processed statistically. The number of occurrences of nominal numbers is used to judge whether or not there is a relationship between the nominal numbers.

Since the warehousing real estate segment in Russia has only recently started to develop actively, the regulatory and legal framework in this area does not yet fully meet the level of demand for regulation of issues at the legislative level. According to the existing regulatory legal acts, the concept of a warehouse is not fixed in a single form.

The main legal act regulating the activities of warehousing is the second part of the Civil Code of the Russian Federation, namely Chapter 47, which contains general provisions on storage, a detailed description of storage in a commodity warehouse, as well as special types of storage.

One of the most important documents in the field of warehouse real estate objects is the Federal Law dated 03.08.2018 N 289-FZ (ed. of 19.12.2022, amended on 28.04.2023) "On Customs Regulation in the Russian Federation and on Amendments to Certain Legislative Acts of the Russian Federation". Article 357 ("Requirements for the arrangement, equipment and location of temporary storage warehouses") of this regulatory legal document stipulates the following requirements for warehouses:

1) warehouses must be arranged and equipped with everything necessary to ensure the safety of products;

2) access to warehousing real estate objects must be restricted (persons or their representatives having authority over goods);

3) customs control of stored goods should be possible at the warehousing real estate objects;

4) access roads should be provided to the warehouses and so on.

For all other issues, relations in the warehouse real estate market are regulated by the legislation relating to real estate in general.

The concept of "investment climate" has been widely used and applied in real estate for the last decades. Investment climate is commonly understood as the conditions and circumstances of the analyzed object that demonstrate its investment attractiveness and investment activity.

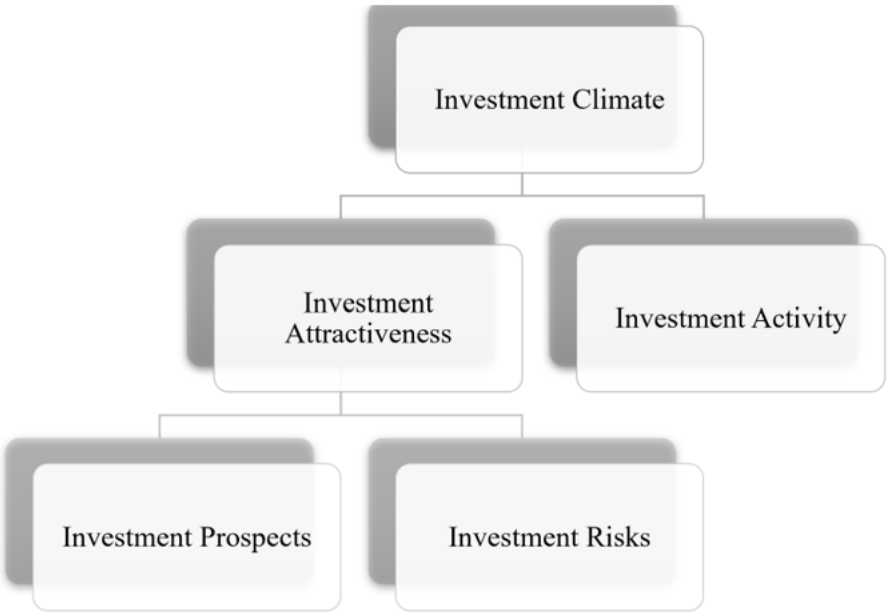


Fig. 1. Components of the investment climate (developed by the author)

Based on the presented scheme, we can conclude that the investment climate inherently consists of investment activity and investment attractiveness, which in turn includes investment potential and investment risk.

The main groups of prerequisites that subsequently lead to the formation of a certain level of investment climate are presented in Figure 2.

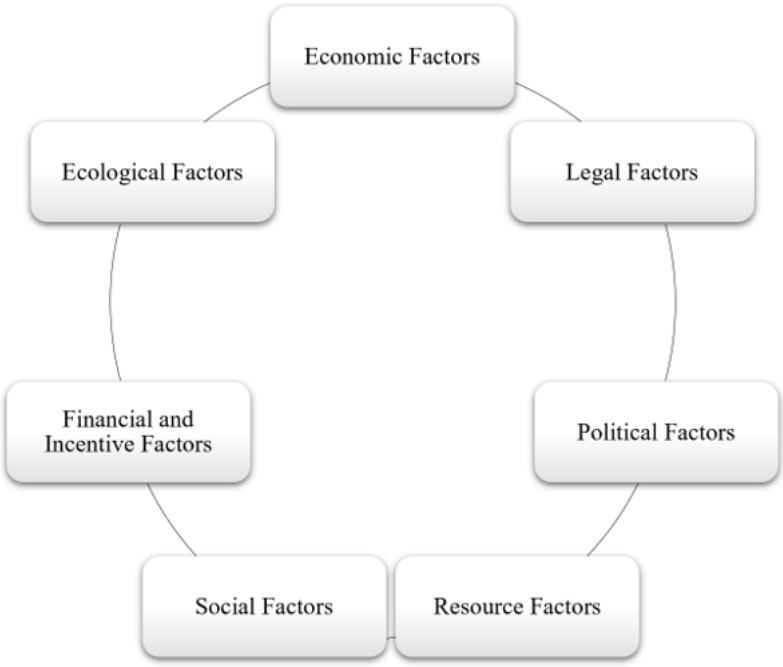
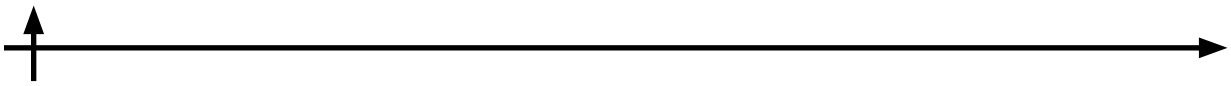


Fig. 2. Groups of factors shaping the investment climate (developed by the author)



As can be seen from Figure 2, the above groups affect virtually all aspects of any enterprise, segment or market, which makes this system multifunctional and applicable to absolutely different areas of activity.

Materials and Methods

In this article the authors invite a mixed-methods approach, blending qualitative and quantitative data to comprehensively analyze the warehouse real estate and its key features. The study pays specific attentions to extensive literature review, encompassing academic papers, government reports, and industry analysis in order to distinguish the current dynamics of the sector. Data collection focuses on results and prospects related to the implementation of the information investment platform in warehouse real estate. Improvement of the mechanism for the development of the investment climate of the warehouse real estate market in Russia consists in improving the existing tools and creating new ways to influence the development of the environment through the implemented changes. Thus, a descriptive analysis method is also invited in order to present a clear picture of current condition of the warehouse real estate, highlighting its potential reliance on information and communication technologies.

Results and Discussion

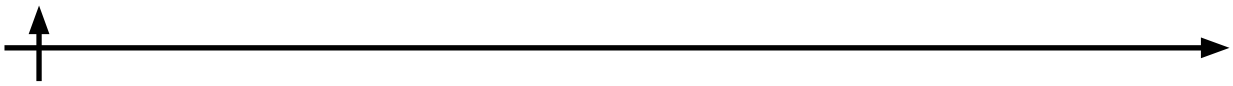
Improvement of the mechanism for the development of the investment climate of the warehouse real estate market in Russia consists in improving the existing tools and creating new ways to influence the development of the environment through the implemented changes. Thus, to improve the system it is necessary to assess the level of the environment and introduce tools for the development of problem areas.

The most problematic area according to the results of the analysis is the level of financial incentives, changing the tools of which will improve the mechanism of investment climate development. However, it is important to remember about the complexity of the implemented changes, so in view of the availability of financial incentives at the federal and regional level, the implemented measures should also include tools that can potentially be implemented at the state and municipal levels.

At the moment warehouse infrastructure objects are subject to taxation as property of legal entities and individuals. In this paper the tools for improving the mechanism of development of the investment climate of organizations and enterprises are developed, so the further proposal concerns this part of taxation. Within the framework of the property of legal entities at the federal level, the rates are set, reflected in Table 1.

Table 1. The size of the tax rate on the property of legal entities (compiled by the author)

Subject of taxation	Maximum rate, %
Immovable property objects in respect of which the tax base is determined as cadastral value.	2.0
Residential premises, garages, parking spaces which belong to the personal fund by right of ownership and the tax base in respect of which is determined as the cadastral value, except for taxable objects the cadastral value of each of which exceeds 300 million rubles.	0.3
Items of immovable property for which the tax base is determined as their average annual value.	2.2



The exact size of the rate is determined at the local level by regional authorities within the specified ranges, which allows for a general adjustment of the situation, but at the same time taking into account the specifics of each territory. In fact, when analyzing the level of financial stimulation of the investment climate, the following drawback was revealed: retail and office facilities belong to the category of objects taxed on the basis of their cadastral value and at a reduced rate of maximum 2.0%. While warehouse facilities, which are also part of commercial real estate, are subject to taxation based on the average annual value of the property in accordance with the maximum rate of 2.2%.

This division in the creation of such a system could have been caused by a strong lag in the development of the warehouse infrastructure market compared to retail and office facilities. However, according to the results of the analysis of the warehouse real estate market in Russia outlined earlier, the market has been actively progressing over the last 5 years, which led to the need to adjust the taxation of warehouse infrastructure facilities. Within the framework of this article it is proposed to add warehouse facilities to the real estate, the value of which is determined on the basis of cadastral value, which will entail at the federal level a change in the maximum property tax rate for such warehouse facilities from 2.2% to 2.0%. Thus, to a certain extent, the conditions for investing in warehouse, retail and office real estate in terms of property tax will be equalized, which will allow to increase investments in the industry (Podshivalenko, 2014).

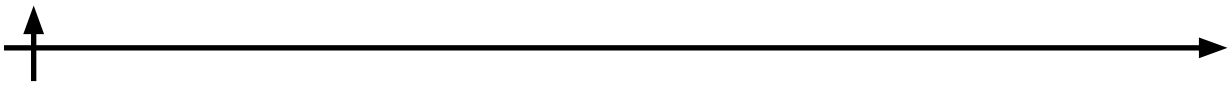
Nevertheless, it is important to clearly define the expediency and benefit of such changes for the state, because, certainly, superficially analyzing the proposed tool, it may seem that this solution is attractive only for market subjects. The interest of the state in the investment environment lies in the following scheme: an increase in the attractiveness of the industry leads to an increase in investment in the market, which subsequently causes an increase in the number of objects in the possession of companies, as well as the turnover of enterprises and their income subject to taxation, which ultimately has a positive impact on the level of the consolidated budget of the country by increasing tax deductions. Thus, by introducing this method of improving the mechanism of development of the investment climate of the country's warehouse real estate, the state on its part ensures in the long term an increase in its own profits.

In addition, such a change will avoid passing the Laffer point. According to the concept developed by the American economist Arthur Laffer, there is a dependence between tax rates and tax revenues, which is as follows: an increase in the tax rate initially leads to an increase in budget revenues, however, after passing the Laffer point leads to a decline in tax revenues.

Increasing tax rates should be treated with extreme caution and it should be understood that the tax burden affects the attractiveness of the industry and the existence of illegal tax evasion schemes, the reduction of which is also possible as a result of reducing the rate, since the new level will allow more taxpayers to pay tax in proportion to the property in their possession (Litvinova, 2014).

Changes in property taxation may become an opportunity for the state at the federal level to influence the investment climate by improving an instrument in the mechanism of environment development. In addition, such an instrument will allow further consideration of the possibility of progressive taxation in terms of warehouse infrastructure. The essence of progressive taxation is to change the tax rate in accordance with the level of income. Having a unified approach to the taxation of retail, office and warehouse real estate as a result of the proposed improvement, the process of transition to progressive taxation can happen faster due to the unification of the method.

The next possible tool of the mechanism of development of the warehouse investment market may be project financing, which has started to develop actively during the last 5 years.



However, commercial real estate in general understanding throughout this time is not the main participant of such programs.

Project finance means a method of attracting long-term debt financing for a project by providing a loan against the cash flow generated by the project. The loan is provided on a concessional basis, and the level of the rate is formed and approved based on the attractiveness and profitability of the project. The idea is that projects that do not have sufficient financing with their own or sponsor's funds get a chance to implement projects on condition of their high profitability, quick and guaranteed payback, as well as investment attractiveness for the state.

The participants of financing are the company initiating the project, which often does not have financial resources and collateral, the sponsor investing in the project with the prospect of making a profit, and the lending company providing most of the borrowed capital.

In the initial engagement, the company initiating the project obtains financing from the investor and commercial bank, and enters into a concession agreement with the municipality. In the framework of the concession agreement concluded in the project financing of the warehouse real estate investment market, the concessionaire, i.e. the initiating company, creates and uses in its operations a warehouse infrastructure facility, which is at the same time owned by the municipality.

An important feature of the relationship enshrined in the agreement is the clause stating that the income received by the concessionaire in the course of carrying out the activities envisaged by the agreement is the property of the concessionaire.

The most important step for the implementation of project financing is the creation of a business plan, which is the starting point after the creation of the project team, because it is on its basis that the investor studies the risks to assess the effectiveness of its own investments, the lending bank analyzes the possibility of granting a loan against the cash flow, and the state studies the feasibility and attractiveness of the proposed facility and its activities for the development of the industry as a whole, on the basis of which a general decision on financing and volumes is made.

The main tasks of the state at the stage of creating project financing in terms of warehouse infrastructure are to document all stages, determine the procedure for obtaining authorization for the implementation of projects, as well as possible ways to resolve situations arising in the process of creation and operation of the facility. It is also important to specify the requirements for potential participants of the program. Often the list of requirements consists of the minimum project cost, maximum payback period, duration of financing and designation of the share of own and borrowed funds (Tkachenko, 2019).

Analyzing the feasibility of implementing this improvement, it is necessary to assess, first of all, qualitative indicators. Thus, the advantage for the company lies in the financial opportunity to implement the project, which it did not have before, in the state support in terms of the amount of credit provided and support at all stages, as well as in gaining experience in the implementation of this project, which may subsequently have a positive impact on the investment involvement of private sponsors in new projects. As a result of this program, the investor will be able to share the risks, which in turn will ensure, to a certain extent, the safety of its funds, as well as dividends after the object is taken into the ownership of the company after the completion of the full cycle. The benefit of the state in the implementation of this program is obvious: as a result of the implementation of full cycles, municipalities will increase the share of tax deductions to the consolidated budget due to the creation of new facilities in the possession of companies. In addition, this system will increase investment in the industry, which in turn will help solve a number of other problems (Salova, 2013).

For example, these projects will allow small and medium-sized businesses to realize their

potential. One of the most accessible and understandable examples of project finance implementation could be the construction of warehouse complexes for food products in the Far East. Today, residents of the Far East regions face the problem of high prices and a global shortage of food products, which in turn is partly due to the monopoly of the largest players. High logistics costs per unit of goods are reduced by increasing the volume of purchases, but since small and medium-sized businesses have practically no storage facilities of their own due to risks and lack of capital, there is no opportunity to purchase products in large batches for temporary partial storage in the process of realization, thus reducing the final markup. Thus, medium and small businesses are forced to sell goods at inflated prices, which leads to a decrease in demand, since the same products can be purchased from the largest market players at lower prices, as well as to the deterioration of competitiveness of enterprises and their subsequent liquidation. As a result of such a trend, the state suffers losses in terms of tax revenues to the consolidated budget, as well as risks in terms of flourishing monopolism, which in turn jeopardizes the market economy (Gryaznova, 2016).

Thus, project financing is an effective tool for regional development of small and medium-sized enterprises in terms of warehouse infrastructure, which in addition to the general increase in the attractiveness of the industry leads to an increase in tax deductions to the country's treasury (Lisitsa, 2016).

According to the results of the analysis, in addition to low indicators in terms of financial stimulation of the warehouse real estate investment market, the economic component is also a problem area. However, it is very difficult to introduce changes in the mechanism of development of this part, because this area shows indicators that are the resultant impact of a large number of external factors. Nevertheless, by introducing small tools into the development mechanism, it is possible to start the process of gradual change.

Today there is a problem of low vacancy of infrastructure facilities in the warehouse real estate market, which is primarily due to the active growth of BTS transactions. In the framework of such transactions the construction of facilities is carried out in accordance with the customer's request and requirements, which makes it impossible for the warehouse to be sold or leased. Thus, a shortage of space is created in the market, which in turn leads to an increase in the imbalance between supply and demand, as well as to a disproportionate increase in the level of rates, which in the foreseeable future may lead to a decrease in the purchasing power of warehouse infrastructure market players.

Nevertheless, there is a difference in the vacancy rates of class A and B warehouses. The number of vacant class B facilities on the warehouse infrastructure market is significantly higher than the vacancy rate of higher-class warehouses. However, the demand for rent and purchase of class B premises is decreasing every year, as there is now a desire to create multifunctional facilities, which requires the introduction of more of the latest technologies and results in the assignment of class A to the facility. Thus, low vacancy of class B facilities is associated with reduced demand and as a consequence idle property of organizations.

This paper proposes a step-by-step inventory of Class B warehouse infrastructure facilities at the municipal level, followed by the development of recommendations for possible renovation and assignment of Class A. A step-by-step plan for using the proposed tool is presented in Figure 3.

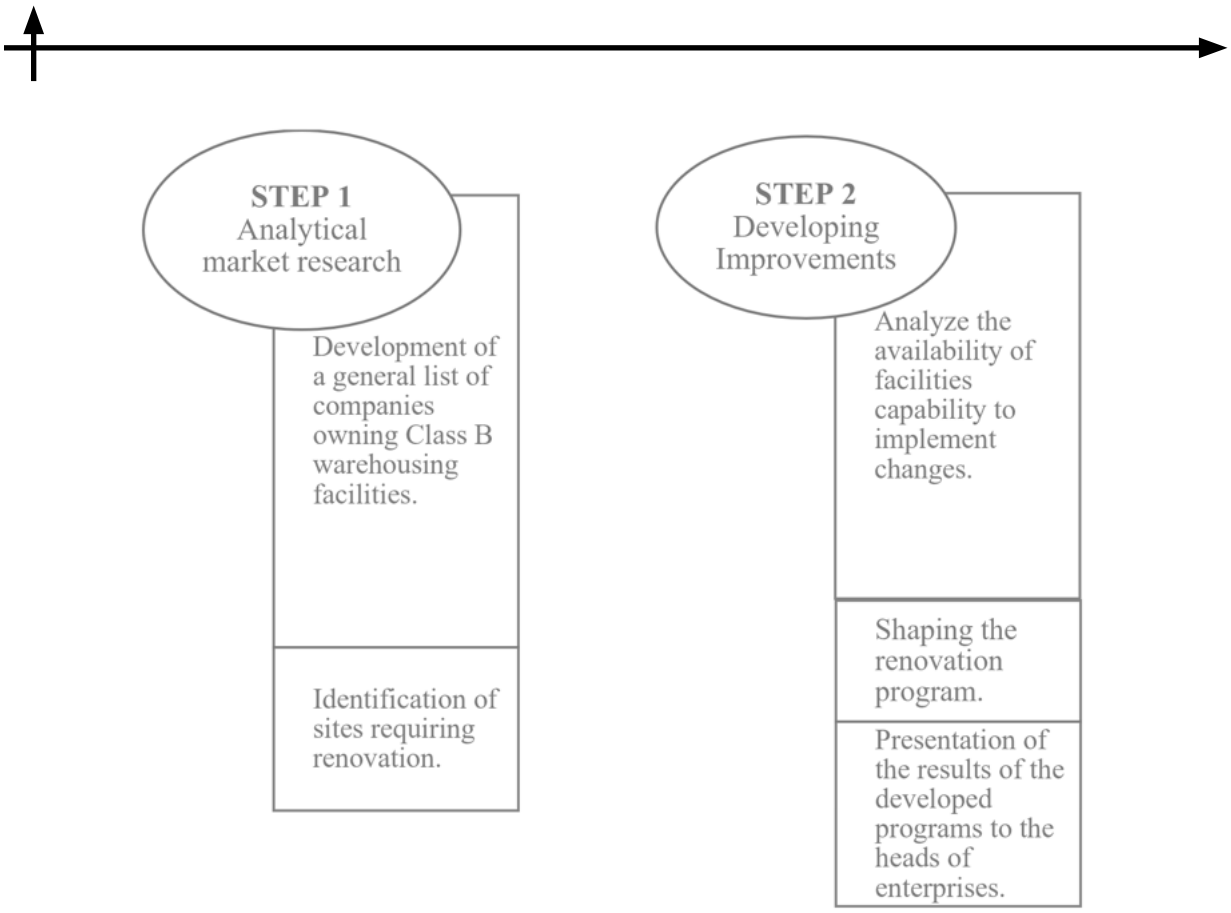


Fig. 3. Implementation plan for the tool "warehouse inventory program" (developed by the author)

In order to implement the previously outlined plan, it is necessary to create an interested focus group of experts at the municipal level, who will jointly develop renovation programs, and property committees or property relations committees will become curators of this program.

In order to participate in this program, all legal entities owning warehouses that are used for profit-making purposes in the core business of the enterprise will have to submit all the necessary documentation on the facility through an online form or through a personal visit to the supervising authority. Then, after the applications are collected, the supervising authority will form a general list of businesses interested in participating in this program. Within the timeframe established by the focus group, the characteristics and current condition of the facilities will be analyzed to identify potential renovation opportunities. Based on the results of the study, explanations will be provided to all submitters of applications with a general summary of acceptance or non-acceptance of the facility into the inventory project. In case of approval of the object by the focus group, the project of the object renovation will be further developed with a detailed calculation of financial costs and risk assessment in the implementation of changes. The final stage will be a face-to-face meeting of the focus group, supervising body and project participants to summarize and present the results of the work done, namely the developed programs for assigning the object to a higher class of warehouse real estate. Further decision on the renovation of the facility will be made by the owner himself (Volkov, 2004; Ikramov and Emelyanov, 2022).

When analyzing the feasibility of converting a Class B warehouse to Class A, it becomes clear that the facility must initially meet the characteristics of Class A in terms of building density, absence of columns, and ceiling height. This requirement is mostly due to the practical impossibility of implementing the relevant changes, as well as the irrationality of the investments spent with the available opportunities for renovation of the object. The costs of implementing such

changes depend on the input data and the state of the object at the moment, so the calculation of the economic effect should be made for each warehouse object individually.

Thus, creation of a parking area, increase in the number of automatic gates with loading and unloading areas and development of a professional management system will allow to improve warehouse facilities within the framework of renovation according to the results of the inventory program of warehouse facilities.

The advantage of such a tool for the government is, firstly, the inventory of warehouse infrastructure facilities, which, in addition to obtaining general real information about the state of real estate in the industry, will make it possible to identify existing deficiencies in the valuation of facilities and taxation accordingly. In addition, such a tool will enable managers to improve the performance of their organizations owning class B warehouses by increasing the demand for them as a result of assigning a higher class.

Thus, this instrument will reduce the imbalance between the vacancy and demand of the respective warehouse facilities. The result will be an increase in the vacancy rate of Class A warehouses, for which demand is much higher than the available supply, and a decrease in the vacancy rate of Class B warehouses, for which interest is progressively decreasing. In addition, the proportionality of demand and vacancy of the market will create the most favorable conditions for its development, as well as eliminate possible spontaneous growth of rental rates.

The changing geopolitical situation in the world has had a significant impact on the Russian warehouse real estate investment market and the existing mechanism of its development. At the first stage, a large number of foreign players left and as a consequence there was an outflow of investments, which in turn initially led to an increase in concerns on the part of leading analytical companies and financial enterprises about the deterioration of the market situation. However, this then led to increased interest among domestic investors in the warehousing market. As a result of intensification of the domestic warehouse real estate market, the main economic indicators returned to the previous level.

Despite the substitution, foreign investments continue to play a major role in financing the socio-economic development of the country, as well as in the formation of investment potential. In addition, foreign investments allow to create additional jobs, which leads to economic growth in the long term, as well as stimulate scientific development, which positively affects the level of scientific and technological progress of the country (Buzova, 2017).

To date, at the state level it is planned to create ways to stimulate the investment activity of foreign investors. Despite the difficult situation on the global stage, the Russian investment market continues to adhere to the principle of openness and accessibility of the industry to the extent that will not contradict the financial stability of the state and the preservation of national sovereignty. The Ministry of Finance has set a goal to increase the volume of foreign investment in fixed capital by 20 trillion rubles in the period from 2021 to 2030. Such indicators can be achieved with the improvement of conditions for investment of non-residents, as well as the general increase in the attractiveness of industries.

In the framework of this work, the improvement of the mechanism of development of the investment climate of the warehouse real estate market in terms of foreign investments is made on the basis of the formation of a tool that allows to improve the conditions of investment of non-residents, since the attractiveness of the industry can be increased through the introduction of other methods mentioned above.

As a result of Russia's ambiguous image on the world stage, a large part of potential foreign investments is questioned in terms of sales guarantees. Investors are increasingly reluctant to invest in foreign projects because the risks of failing to realize the goods or services are extremely high. It is very difficult to eliminate this disadvantage within the framework of investment

activities in the warehouse real estate industry. However, as the results of analytical activities of leading companies in the commercial real estate market show, foreign direct investments are most often realized in the territory of the leading subjects, which gives the regions an opportunity to become a new point of attraction with the highest indicators in terms of sales guarantees, since the supply in the regions lags behind the growth of demand for warehouse infrastructure facilities.

This program can be implemented by changing the regulatory and legal framework at the state level, namely in terms of creating contractual relations with foreign investors through the conclusion of a contract like an offset contract. This contract implies a document that provides for the delivery of goods and counter investment obligations of the supplier on the territory of the subject. The analog of this instrument in terms of the supply of goods has existed since 2016 after the introduction of amendments to Federal Law No. 44 "On Contract System in the Sphere of Procurement of Goods, Works and Services for State and Municipal Needs". However, for all this time, only a few entities in Russia have created the relevant local regulatory and legal documents that allow the system to be implemented at the city level. Nevertheless, the application of the already existing experience in regulating relations in terms of foreign investments in the supply of goods to the creation of warehouse infrastructure facilities will allow to introduce a new way of interaction with foreign investors in the analyzed industry with minimal costs.

The main features of the document concluded with a foreign investor under the new relationship include:

1) creation and construction of a complex or a single object of warehouse infrastructure on the territory of the subject strictly defined by the terms of the agreement;

2) the volume of investments should be not less than the amount determined at the state level;

3) the term of the contract is strictly limited;

4) the contract is concluded as a result of an open tender;

5) the customer is the executive authority of the subject, and the investor is a legal entity.

In addition, it is important to determine the responsible executors of the program at the entity level, since the level of elaboration of the regulatory framework and compliance of the system with the requests of investors will determine the success of the use of this tool.

Thus, the creation of relevant legal acts will allow foreign investment activities in Russia to be carried out to an even greater extent. However, it should be remembered that in using such an instrument it is important to strike a balance between attracting foreign direct investment and ensuring competition in the warehouse real estate market.

In addition to the low level of financial incentives, as well as ambiguous economic indicators, there is a problem with investor awareness of available programs and systems to facilitate and improve the process of investing in warehouse real estate. Certainly, due to ignorance about these tools used by the government to attract investment, market participants do not use them, which partly leads to low efficiency of the implemented programs at the state level.

To date, information on the implementation of programs in the warehouse real estate investment market is available on the websites of the relevant authorities or on third-party websites of analytical or financial companies. However, this approach does not meet the government's desire to create instruments that are in demand, as a potential investor has to spend a lot of time searching for detailed terms and conditions of the programs, which leads to a partial impossibility of obtaining this information and, as a consequence, low involvement of market participants. In the long term, this trend negatively affects the level of efficiency of the implemented changes in the mechanism of development of the investment climate of the warehouse

real estate market in Russia.

This paper proposes to improve the information policy of the state in terms of creating an online platform containing information about the programs implemented by the state in the warehouse real estate investment market. The created platform should have information about the content of state support instruments, their terms, program executors and detailed conditions, as well as the regulatory framework, sources of information received. And the procedure for participation.

This platform can be promoted and the target audience can be attracted through regular forums, conferences, meetings and open dialogs, as well as by placing a link or other information on the investment portals of regions and municipalities.

Thus, potential investors will have the opportunity to be fully informed about their own possible participation in programs implemented at the state or municipal level, which in the long term will increase the attractiveness of the market by increasing the number of players due to changing awareness.

For the state this tool is attractive because with relatively small financial investments for the creation and operation of the platform the efficiency of the implemented programs will increase. In addition, through the introduction of the information investment platform will simplify the process of identifying the most problematic regions in terms of availability of state support, which will allow to solve this problem more quickly. In addition, with further use of this system, it will be possible to modernize it and create within the platform a unified procedure for accepting applications from potential participants.

Conclusion

The existing mechanism of investment climate development, despite its ambiguous effectiveness, can be improved in accordance with the developed measures. However, it is important to realize that effective results from the implemented tools can be obtained only if the following conditions are met:

1) all parties should be interested in obtaining the result;

2) the proposed measures should be enshrined in relevant documents at the federal, regional or municipal level in full;

3) before implementing the tool, it is necessary to create a detailed implementation plan with the identification of executors, setting implementation deadlines, as well as the formation of a system of performance indicators.

The mechanism of development of the investment climate of the warehouse infrastructure market directly affects the dynamics of key indicators, as well as the success and potential of the industry as a whole, so this system should be given special attention and control changes at all levels, paying special attention to the development of information systems.

REFERENCES

Buzova I.A., Makhovikova G.A., Terekhova V.V. 2017. Commercial evaluation of investments, 128.

Gryaznova A.G. 2016. Financial and credit encyclopedic dictionary. Finance and Statistics, 356.

Ikramov M.A., Emelyanov A.D. 2022. "Lean Production" in Warehouse Real Estate Management: Russian and Foreign Experience of Implementing Digital Technologies at Warehouse Facilities. Technoeconomics 3 (3). 51–64. DOI: https://doi.org/10.57809/2022.3.3.5

Lisitsa V.N. 2016. Investment relations as a subject of legal regulation. Science and educa-

tion: economy and economy; entrepreneurship; law and management 8 (75), 76-78.

Lisitsa V.N. 2016. Legal nature of the agreement on public-private partnership. Juridicheskaya nauka i praktika 12 (2), 80-89.

Litvinova V.V. 2014. Investment attractiveness and investment climate of the region: to the issue of definitions and assessment. Vestnik Finansovogo universitet 1 (79), 139-152.

Podshivalenko G.P. 2010. Investitsionniyi climate and investment attractiveness. Finansovaya analitika: problemy i resheniya 15 (39), 7-10.

Salova L.V., Degterenko K.N. 2013. Management of factors of investment attractiveness of companies. Russian entrepreneurship 1 (223), 110-114.

Tkachenko I.Y., Malykh N.I. 2019. Investments: textbook for students of higher educational institutions, 92-94.

Volkov I.M., Gracheva M.V. 2004. Project Analysis: Advanced Course, 495.

Civil Code of the Russian Federation: Part Two. URL: https://www.consultant.ru/document/cons_doc_LAW_9027/ (accessed: 25.05.24).

Contracts with counter investment obligations. GMP News. URL: https://www.pgplaw.ru/analytics-and-brochures/articles-comments-interviews/contracts-with-counter-investment-obligations/ (accessed: 15.05.2024)

Federal Law of 03.08.2018 N 289-FZ (ed. of 19.12.2022, amended on 28.04.2023) "On Customs Regulation in the Russian Federation and on Amendments to Certain Legislative Acts of the Russian Federation". URL: https://www.consultant.ru/document/cons_doc_LAW_304093/ (accessed: 25.05.24).

Labor resources, employment and unemployment - Federal State Statistics Service. URL: https://rosstat.gov.ru/labour_force (accessed: 10.05.2024).

National Investment Rating - research of the Agency for Strategic Initiatives. URL: https://asi.ru/government_officials/rating/ (accessed: 21.05.2024).

New normative legal acts - St. Petersburg Investment Committee. URL: https://www.gov.spb.ru/gov/otrasl/invest/documents/new_npa/ (accessed: 22.05.2024).

Normative legal acts of the city of Moscow - Department of Investment and Industrial Policy of the city of Moscow. URL: https://www.mos.ru/dipp/documents/normativnye-pravovye-akty-goroda-moskvy/ (accessed: 24.05.2024).

On citizens' appeals received by the Government of the Russian Federation in December 2023 - Government of the Russian Federation. URL: http://services.government.ru/overviews/50619/# (accessed: 10.05.2024).

Regulatory and legal support of investment activity - Ministry of Economic Development of the Novosibirsk Region. URL: https://econom.nso.ru/page/172 (accessed: 29.05.2024).

Results 2023. Russia. Warehouse real estate - Nikoliers research. URL: https://nikoliers.ru/analytics/itogi-2023-rossiya-skladskaya-nedvizhimost/ (accessed: 22.05.2024).

Warehouse real estate market in Russian regions - NF Group research. URL: https://kf.expert/publish/rynok-skladskoj-nedvizhimosti-regiony-rossii-2023 (accessed: 21.05.2024).

СПИСОК ИСТОЧНИКОВ

Бузова И.А., Маховикова Г.А., Терехова В.В. 2017. Коммерческая оценка инвестиций, 128.

Грязнова А.Г. 2016. Финансово-кредитный энциклопедический словарь. Финансы и статистика, 356.

Ikramov M.A., Emelyanov A.D. 2022. “Lean Production” in Warehouse Real Estate Management: Russian and Foreign Experience of Implementing Digital Technologies at Warehouse Facilities. Technoeconomics 3 (3). 51–64. DOI: https://doi.org/10.57809/2022.3.3.5

Лисица В.Н. 2016. Инвестиционные отношения как предмет правового регулирования. Наука и образование: хозяйство и экономика; предпринимательство; право и управление 8 (75), 76—78.

Лисица В.Н. 2016. Правовая природа соглашения о государственно-частном партнерстве. Юридическая наука и практика 12 (2), 80—89.

Литвинова В.В. 2014. Инвестиционная привлекательность и инвестиционный климат региона: к вопросу о дефинициях и оценке. Вестник Финансового университета 1 (79), 139–152.

Подшиваленко Г.П. 2010. Инвестиционный климат и инвестиционная привлекательность. Финансовая аналитика: проблемы и решения 15 (39), 7–10.

Салова Л.В., Дегтеренко К.Н. 2013. Управление факторами инвестиционной привлекательности компаний. Российское предпринимательство 1 (223), 110–114.

Ткаченко И.Ю., Малых Н.И. 2019. Инвестиции: учебное пособие для студ. высшее учеб. заведений, 92–94.

Волков И.М., Грачева М.В. 2004. Проектный анализ: Продвинутый курс, 495.

Гражданский кодекс Российской Федерации: часть вторая. URL: https://www.consultant.ru/document/cons_doc_LAW_9027/ (дата обращения 25.05.24).

Контракты с встречными инвестиционными обязательствами. Новости GMP. URL: https://www.pgplaw.ru/analytics-and-brochures/articles-comments-interviews/contracts-with-counter-investment-obligations/ (дата обращения: 15.05.2024)

Федеральный закон от 03.08.2018 N 289-ФЗ (ред. от 19.12.2022, с изм. от 28.04.2023) "О таможенном регулировании в Российской Федерации и о внесении изменений в отдельные законодательные акты Российской Федерации". URL: https://www.consultant.ru/document/cons_doc_LAW_304093/ (дата обращения 25.05.24).

Трудовые ресурсы, занятость и безработица - Федеральная служба государственной статистики. URL: https://rosstat.gov.ru/labour_force (дата обращения: 10.05.2024).

Национальный инвестиционный рейтинг - исследование Агентства стратегических инициатив. URL: https://asi.ru/government_officials/rating/ (дата обращения: 21.05.2024).

Новые нормативные правовые акты - Комитет по инвестициям Санкт-Петербурга. URL: https://www.gov.spb.ru/gov/otrasl/invest/documents/new_npa/ (дата обращения: 22.05.2024).

Нормативные правовые акты города Москва - Департамент инвестиционной и промышленной политики города Москвы. URL: https://www.mos.ru/dipp/documents/normativnye-pravovye-akty-goroda-moskvy/ (дата обращения: 24.05.2024).

О поступивших в Правительство Российской Федерации в декабре 2023 года обращениях граждан - Правительство Российской Федерации. URL: http://services.government.ru/overviews/50619/# (дата обращения: 10.05.2024).

Нормативно-правовое обеспечение инвестиционной деятельности - Министерство экономического развития Новосибирской области. URL: https://econom.nso.ru/page/172 (дата обращения: 29.05.2024).

Итоги 2023. Россия. Складская недвижимость - исследование Nikoliers. URL: https://nikoliers.ru/analytics/itogi-2023-rossiya-skladskaya-nedvizhimost/ (дата обращения: 22.05.2024).

Рынок складской недвижимости регионов России — исследование NF Group. URL: https://kf.expert/publish/rynok-skladskoj-nedvizhimosti-regiony-rossii-2023 (дата обращения: 21.05.2024).

INFORMATION ABOUT AUTHOR / ИНФОРМАЦИЯ ОБ АВТОРЕ

BABKINA Amina K. – student.
E-mail: babkina_ak@spbstu.ru
БАБКИНА Амина Константиновна – студент.
E-mail: babkina_ak@spbstu.ru

Статья поступила в редакцию 27.05.2024; одобрена после рецензирования 10.06.2024; принята к публикации 17.06.2024.

The article was submitted 27.05.2024; approved after reviewing 10.06.2024; accepted for publication 17.06.2024.

Научное издание

Technoeconomics

Том 3, № 2, 2024

Учредитель, издатель – Федеральное государственное автономное образовательное учреждение высшего образования
«Санкт-Петербургский политехнический университет Петра Великого»

Телефон редакции 8 (812) 550-36-52

E-mail: technoeconomics@spbstu.ru

Компьютерная верстка *Д.М. Гугутишвили*
Редактирование английского языка *И.В. Ильина*
Ответственный секретарь *О.В. Воронова*
Выпускающий редактор *А.И. Лёвина*

Санкт-Петербургский политехнический университет Петра Великого.
195251, Санкт-Петербург, ул. Политехническая, д. 29.