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THE POSSIBILITY OF CONSTRUCTING UNIVERSAL NONLINEAR AUTOREGRESSIONS

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Abstract. Autoregression models are widely used in economic practice both in modelling stochastic processes and in forecasting them. However, all these models generating nonlinear dependencies are essentially linear models. The accuracy of these models can be increased by giving them a nonlinear form. However, at present, there are no universal methods and techniques for forming such models, and the problem of constructing nonlinear autoregressions does not have a satisfactory solution. Researchers add non-linear components to autoregressions, most often using intuition. In our study, we examine the possibility of using the model of the elementary image of the Kolmogorov-Gabor polynomial as a formalized and universal tool for solving such problems. Several examples show that imparting nonlinearity to autoregression models can lead not only to an increase in the accuracy of approximation but also to an increase in the accuracy of short-term forecasting.

Keywords: autoregressions, elementary image of Kolmogorov-Gabor polynomial, modeling of stochastic processes, short-term forecasting, nonlinearity

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ВОЗМОЖНОСТЬ ПОСТРОЕНИЯ УНИВЕРСАЛЬНОЙ НЕЛИНЕЙНОЙ АВТОРЕГРЕССИИ

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Аннотация. Модели авторегрессий широко используются в экономической практике как в моделировании стохастических процессов, так и в их прогнозировании. Однако, все эти модели, генерирующие нелинейные зависимости, по своей сути являются линейными моделями. Повышения точности этих моделей можно добиться, придав этим моделям нелинейную форму. Но в настоящее время отсутствуют универсальные методы и методики формирования подобных моделей, и задача построения нелинейных авторегрессий не имеет удовлетворительного решения. Исследователи добавляют нелинейные составляющие в авторегрессии, чаще всего, используя интуицию. В данном исследовании изучается возможность использования в качестве формализованного и универсального инструмента решения таких задач модели элементарного образа полинома Колмогорова-Габора. Показано на нескольких примерах, что придание нелинейности авторегрессионным моделям может привести не только к повышению точности аппроксимации, но и к повышению точности краткосрочного прогнозирования.

Ключевые слова: авторегрессии, элементарный образ полинома Колмогорова-Габора, моделирование стохастических процессов, краткосрочное прогнозирование, нелинейность

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Introduction

One of the most in-demand tools for short-term economic forecasting and modelling stochastic processes is the modelling of autoregressive dependencies using the corresponding models.

The essence of autoregressive models stems from the stochastic process they model, where the current values of the variable being modelled are not determined by external forces but by the previous values of the variable itself. Such stochastic processes are quite common in economics, as the economy has a cyclical nature of development.

There are cases where the modelled process has an obvious cyclical component; for example, the volume of goods consumed in retail is determined by the day of the week, and for such series, an autoregression with a lag of 7 observations would be suitable.

Much more frequently in economics, we encounter cases where the modelled process contains several cycles of varying lengths, which ultimately generate complex time series with nonlinear dynamics.

The task of modelling such series is tackled with varying degrees of success using different types of autoregressions, the main ones being simple autoregressions with a lag p AR(p); au-

toregressions with moving averages of residuals ARIMA(p, d, q), where residuals are included with a lag of q; autoregressions with a seasonal component SARIMA(p, d, q); autoregression and distributed lag model ADL(p, q), where external factors with a lag q are used instead of residuals; and vector autoregressions, where instead of one indicator, a vector of k indicators VARk (p) is used along with their modifications.

In this group, there are theoretically known, but rarely applied in practice, nonlinear autoregressions.

This feature can be explained by the fact that linear autoregressions generate nonlinear processes.

In these nonlinearities, it is impossible to distinguish between factors that affect the process linearly and those that affect it nonlinearly.

Therefore, non-linear autoregressions are not used as often as they could be, and their practical application has been fragmented, as identifying nonlinearity remains a subjective task.

Let's consider the possibility of formally constructing nonlinear autoregressions.

Materials and Methods

All the main types of autoregressions are linear with respect to the variables and parameters of the model. However, these models describe various types of nonlinear dynamics. The first and simplest first-order autoregression model, studied by A.A. Markov, has the following form (Markov, 1900):

$$y_t = ay_{t-1} + \varepsilon_t \quad (1)$$

Here, y_t is the current modeled value of the indicator, y_{t-1} is its previous value, a is the proportionality coefficient, and ε_t is the random component, which is normally distributed with a zero mean.

Depending on the values taken by the constant a, the process can be either divergent or convergent. However, in all cases, nonlinear dynamics are being modeled. Even when this coefficient equals one, due to the influence of the random component, the model represents a nonlinear stochastic process known as "random walk" (Bhattacharya, 2021).

It is evident that the more complex the autoregression model used, the more intricate nonlinear stochastic processes it can describe. This very factor has determined the widespread popularity of autoregression models in solving applied problems across various scientific fields, including the modeling and forecasting of stochastic processes in economics.

Clearly, model (1) can be further refined and represented, for example, in the following nonlinear form:

$$y_t = a(y_{t-1})^b + \varepsilon_t \quad (2)$$

It is clear that model (1) will be a special case of model (2). By assigning different values to the coefficients a and b, different types of dynamics can be generated. Even more complex trajectories are generated by such nonlinear autoregressions of order p:

$$y_t = a_1(y_{t-1})^{b_1} + a_2(y_{t-2})^{b_2} + ... + a_p(y_{t-p})^{b_p} + \varepsilon_t \quad (3)$$

However, solving the inverse problem, namely, determining the order of the autoregression (3) from the available data, turns out to be impossible. This problem does not yet have a satisfactory solution even for autoregressions in linear form, and it is even more unsolvable when applied to autoregressions of type (3).

Moreover, nonlinear autoregressions, which can perfectly describe complex nonlinear types of dynamics, do not reduce to power functions like (3). They can involve logarithmic, exponential, or trigonometric functions, as well as their combinations. It is impossible to identify the best ones from the available statistical data.

Therefore, autoregressions of any type are presented in a linear form, and the emergence of

nonlinear models in practice is very rare.

This problem can be solved by using the elementary Kolmogorov-Gabor polynomial model. The basic model, which we call the Kolmogorov-Gabor polynomial, was independently developed by V. Volterra (Volterra, 1930) with N. Wiener (Wiener, 1958) and Kolmogorov (Kolmogorov, 1956) with Gabor (Gabor, 1961). It has the following form:

$$y = a_0 + \sum_{i=1}^{m} a_i x_i + \sum_{i=1}^{m}\sum_{j=1}^{m} a_{ij} x_i x_j + \ldots + \sum_{i=1}^{m}\sum_{j=1}^{m}\ldots\sum_{z=1}^{m} a_{ij\ldots z} x_i x_j \ldots x_z \quad (4)$$

Here, y is the modeled nonlinear discrete process, x_i are the discrete variables influencing the process, a_i are the polynomial coefficients, and *m* is the number of discrete variables considered in the polynomial.

The Kolmogorov-Gabor polynomial (or the Volterra-Wiener series) can theoretically describe very complex nonlinear dependencies accurately. However, this polynomial sharply increases the number of its terms and, consequently, the number of unknown coefficients. Therefore, this model has not found practical application.

At the end of the last century, the Ukrainian scientist A.G. Ivakhnenko proposed a method for stepwise construction of polynomial (4) (Ivakhnenko, 1963; 1971; 1975). However, his method turned out to be cumbersome, resulting in a polynomial with a number of terms exceeding that of polynomial (4) (Svetunkov, 2024). It is evident that the properties of this new polynomial by A.G. Ivakhnenko differ from those of the original polynomial (4), and thus it will not always demonstrate the expected accuracy. Consequently, there are very few examples of successful applications of A.G. Ivakhnenko's method, and mainly such examples are presented in publications by scientists from former Soviet republics, although there are instances of its use by foreign researchers as well (Marateb, 2023).

In 2024, an elementary image of the Kolmogorov-Gabor polynomial (hereinafter referred to as the EI) was proposed, which serves as a simplified model of polynomial (4) (Svetunkov, 2024). In general form, the EI can be represented as follows:

$$\hat{y} = c_0 + \sum_{j=1}^{m} c_j (b_0 + \sum_{i=1}^{m} b_i x_i)^j \quad (5)$$

where c_i and b_i is coefficients.

The essence of the model and the method for estimating its parameters is revealed by another form of recording:

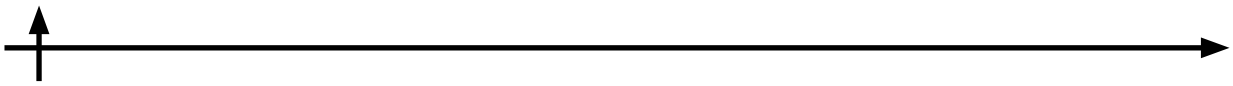
$$\hat{y}' = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_m x_m \quad (6)$$

$$\hat{y} = c_0 + c_1 \hat{y}' + c_2 (\hat{y}')^2 + \ldots + c_m (\hat{y}')^m \quad (7)$$

As can be seen, the first equation (6) represents a simple linear one-factor model, the coefficients b_i of which can be easily estimated from statistical data on the values of *y* and x_i corresponding to the characteristics of the stochastic process using a statistical method, such as the method of least squares (MLS).

The second equation contains only one influencing factor, namely, the calculated values of the linear multifactor model (6). These calculated values are used as a factor in the polynomial of degree m. The values of the coefficients of this polynomial c_i can also be easily determined from the data on *y* and x_i using a chosen statistical method.

If (6) is substituted into (7), and the brackets are expanded and grouped, a polynomial will be obtained that structurally, in form, and in the number of terms completely coincides with the Kolmogorov-Gabor polynomial. However, unlike it, constructing (5) requires estimating a significantly smaller number of unknown coefficients: for instance, with the number of factors m equal to 11, constructing the Kolmogorov-Gabor polynomial requires estimating 705,432 unknown coefficients, whereas for constructing the elementary image, only 24 coefficients need to



be estimated—12 unknown coefficients for model (6) and then 12 unknown coefficients for (7).

It is clear that model (5) is simpler than model (4), which means it is less accurate than polynomial (4), of which it is a simplified version. However, as research has shown, the EI has proven to be a surprisingly accurate model for describing various nonlinear economic processes. It effectively describes exponential, power, and trigonometric trajectories, as well as various superpositions of these nonlinear functions, sometimes yielding better results than those of artificial neural network models (Svetunkov, 2024). It can also be used to solve the problem posed in our study. Let us demonstrate how this can be done.

A simple autoregression of order $p = m$ can be represented as a linear multifactor model:

$$\hat{y}'_t = b_0 + b_1 y_{t-1} + b_2 y_{t-2} + ... + b_m y_{t-m} \quad (8)$$

and it can be considered as the first part of EI (6).

Then, substituting the calculated values of the autoregression (8) into (7), we obtain the second nonlinear part of the autoregression:

$$\hat{y}_t = c_0 + c_1 \hat{y}'_t + c_2 (\hat{y}'_t)^2 + ... + c_m (\hat{y}'_t)^m \quad (9)$$

Since the model is universal and describes various nonlinear forms, the question of selecting the type of nonlinear function for the autoregressive model is resolved — the nonlinearity is generated automatically by fitting the coefficients of polynomial (9).

For practical application of the nonlinear autoregression (8) — (9), it is necessary to find an answer to the question of how to choose the order of autoregression for each series. We proposed the following hypothesis to answer this question: the order of the best nonlinear autoregression (8) — (9) corresponds to the order of the best linear autoregression.

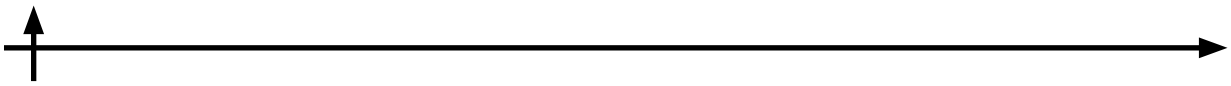
To test this hypothesis, an algorithm was developed in Python to compute the coefficients of linear autoregressions of various orders from the first order up to p, where the order p can be any number but should not exceed 1/3 N, with N being the number of observations. Since these autoregressions form the basis for constructing the nonlinear autoregression, an algorithm was also developed to construct the corresponding polynomials (9) for each autoregression (8).

Both linear and nonlinear autoregressions were tested for the accuracy of data approximation, where the measure of accuracy was the values of the approximation error variance. To understand how much worse or better the nonlinear autoregression describes the nonlinear processes of the data compared to the linear autoregression, the relative error of the EI was calculated in comparison with the autoregression.

The calculation algorithm was carried out as follows: first, a first-order autoregression was constructed, and its statistical characteristics (including variance) were calculated for all data. Then the data was reduced by one unit, and the statistical characteristics of the first-order autoregression were recalculated. This process was repeated by reducing the data by one unit each time. The variance values for the autoregression, depending on the number of used values in the series, were recorded. After that, a second-order autoregression was built on all the datasets, and its statistical characteristics were determined. The database was then reduced by one unit, and the calculations were repeated. As a result, a kind of "map" of the series was created, showing, on one hand, how the variance of the approximation error of the autoregressive model changed for fixed data as the order of autoregression increased, and on the other hand, how stable the best model in terms of minimum variance approximation was when the number of used data points decreased.

The recorded values of the coefficients from the linear autoregressions served as the basis (8) for constructing nonlinear autoregressions (9) using the EI. Nonlinear autoregressions were also computed based on the lag of the autoregression and the number of observations, similar to how it was done for linear autoregressions. "Maps" of the series were created for them as well.

To visualize the obtained results, "heat maps" of the error variances and relative errors were



constructed based on numerical values, allowing for a visual comparison of the areas of best and worst performance of the models at various lags and degrees.

Results and Discussion

A comparative analysis of linear and nonlinear autoregressive models was conducted using the M3C database from the International Institute of Forecasters (Makridakis, 2000). Monthly series numbered 2830, 2834, 2835, 2836, 2837, 2838, 2839, 2840, 2841, and 2842 were selected for this analysis.

The results showed that the optimal order of autoregression, which has the minimum approximation error variance, remains consistent as the sample size decreases. This indicates that the modeled process exhibits the characteristics of autoregression of this specific order. For example, for series number 2830, the optimal autoregression is of order p=29.

As indicated by the results of the statistical characteristics of the nonlinear autoregressions, the order of the optimal nonlinear autoregression generally coincides with that of the linear autoregression. This means that a researcher, having determined the order of the best linear autoregression and estimated its coefficients based on statistical data, can use (9) to compute its nonlinear form and can reasonably expect that this nonlinear autoregression will be the best in its class for the given series.

As expected, nonlinear autoregressions consistently provided better approximations of the data series than linear autoregressive models. For instance, for series number 2830, the optimal linear autoregression has a variance of about 6700, while the error variance of the nonlinear autoregressive model is equal to 5200.

It is well known that the best model for approximation is not necessarily the best for forecasting (Fildes, 1985; Makridakis, 1982). Although autoregressive models are tools for modeling stochastic processes (Chen, 2023; Kulkarni, 2009), they are primarily used for forecasting tasks (Athanasopoulos, 2023; Hyndman, 2008; Kwiatkowski, 1992). Therefore, it is essential to assess the feasibility of using nonlinear autoregressions for short-term forecasting tasks. This assessment was conducted on the same M3C database but for different data series. The existing series was divided into a training set and a testing set. Statistical characteristics of the autoregressions were evaluated on the training set, while the forecast error variance was computed on the testing set. For data series number 1402, the optimal model on the training set turned out to be a third-order autoregression. It predicted data on the testing set with a forecast error variance of 810.01. The nonlinear autoregression on the testing set yielded a forecast error variance of 711.39. For another data series number 1429, the optimal linear autoregression is of fourth order, providing a forecast error variance of 497.44. The nonlinear autoregression of the same order has a forecast error variance of 437.29.

Conclusion

We demonstrated that the elementary image of the Kolmogorov-Gabor polynomial, which has proven effective in modeling complex nonlinear economic dependencies, can be applied as a formal model of nonlinear autoregression. Our research indicated that the process of constructing this autoregression should begin with the search for the best linear autoregression, as the order of the optimal linear autoregression generally coincides with that of the optimal nonlinear autoregression.

In randomly selected data series, it was shown that nonlinear autoregressions provide more accurate forecasts in short-term forecasting of stochastic processes compared to linear autoregressions.

We examined the simplest of the autoregressive models, namely the AR (p) model, and

demonstrated how to form a nonlinear autoregression based on it using the Kolmogorov-Gabor polynomial. It seems that our approach can also be extended to more complex autoregressive models, such as the ARIMA (p, d, q) model:

$$\hat{y}_t = \sum_{i=1}^{p} a_i y_{t-i} + \sum_{j=1}^{q} b_j \varepsilon_{t-j} \tag{10}$$

we should first calculate the estimated values y'_{1t} and y'_{2t}:

$$y'_{1t} = \sum_{i=1}^{p} a_i y_{t-i}, \quad y'_{2t} = \sum_{j=1}^{q} b_j \varepsilon_{t-j} \tag{11}$$

Then form a nonlinear ARIMA(p,d,q):

$$\hat{y}_t = \sum_{i=1}^{p} c_i (y'_{t-i})^i + \sum_{j=1}^{q} d_j (y''_{t-j})^j \tag{12}$$

But these are tasks for future scientific research. Similarly, other types of autoregressive models can also be transformed into nonlinear forms.

Nonlinear models constructed using the elementary image of the Kolmogorov-Gabor polynomial will always provide better approximations of stochastic processes than the original autoregressions. This can be explained by the way they are constructed: if the linear autoregression perfectly describes the modeled process, then fitting it into the nonlinear form (9) using the least squares method will result in all coefficients (9) being equal to zero, except for the coefficient c_i. In this case, a linear autoregression will be used.

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APPLICATION OF MACHINE LEARNING ALGORITHMS IN IMPROVEMENT OF THE TEXTILE PRODUCTION EFFICIENCY

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Abstract. The light industry of Russia is a large national economic complex, which occupies an important place in the formation of the gross national product and has a significant impact on the economy. This research examines the possibilities of using a hardware-software complex based on machine learning algorithms to automate the process of detecting defects in fabrics at a textile enterprise. Throughout the study, the authors define the main reasons for the urgent need to automate the process of unpacking fabrics, draw up the system of requirements for the hardware-software complex using machine learning algorithms to detect and classify defects in fabrics, justify the effectiveness of the implementation of the developed hardware-software complex. As a result, it was proved that the implementation of this complex will contribute to improving the overall efficiency of textile production by automating the process of fabric quality control.

Keywords: textile industry, defects of textile products, quality control, software and hardware complex, convolutional neural networks, efficiency of implementation

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ИСПОЛЬЗОВАНИЕ АЛГОРИТМОВ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРОИЗВОДСТВА ТЕКСТИЛЬНЫХ ИЗДЕЛИЙ

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Аннотация. Легкая промышленность России – это крупный народнохозяйственный комплекс, который занимает важное место в формировании валового национального продукта и оказывает значительное влияние на экономику страны. В данном исследовании рассматриваются возможности применения программно-аппаратного комплекса на базе алгоритмов машинного обучения для автоматизации процесса обнаружения дефектов тканей на текстильном предприятии. В ходе работы были выявлены основные причины острой необходимости в автоматизации процесса разбраковки тканей, разработана система требований к программно-аппаратному комплексу с использованием алгоритмов машинного обучения для обнаружения и классификации дефектов на тканях, а также доказана эффективность внедрения разработанного программно-аппаратного комплекса. Было установлено, что внедрение данного комплекса будет способствовать повышению эффективности производства текстильных изделий посредством автоматизации процесса контроля качества тканей.

Ключевые слова: текстильная промышленность, дефекты текстильных изделий, контроль качества, программно-аппаратный комплекс, сверточные нейронные сети, эффективность внедрения

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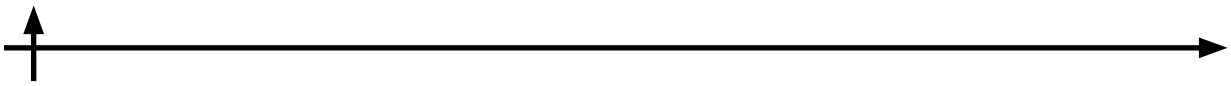
Introduction

Sustainable development of the light industry is crucial for the social aspect of citizens' lives. Light industry enterprises shape the basis for the existence of many small towns, determining their main activities and creating jobs for local residents. Currently, the textile industry ranks second in the domestic market of the country, following the food industry. An important feature of the modern development of the textile industry is that the production of fabrics is not limited to the needs of ordinary consumers. Now the textile industry also plays an important role by supplying inputs to many industries such as the aircraft industry, agriculture, the automobile industry, etc.

However, in the last few years, a much slower dynamics are observed in the development of the domestic textile industry. The reason lies in a number of problems, for instance, the current dominance of foreign textile companies and equipment in the Russian market.

At present, an important task is to strengthen the position of local textile mills and thus ensure the intensive development of the Russian textile industry. One of the main solutions to this issue is the digital transformation of the textile industry. It is a well-known fact that industrial



production plays a significant role in the growth of any country's economy. It is digital transformation that can help Russian firms to regain their competitiveness, ensure further retention of their positions in the textile market, and even enable individual factories to become leaders in their textile products.

The process of digital transformation may include the creation of smart factories, automation of a significant part of production processes, widespread use of information technology, and the introduction of enterprise platforms based on machine learning technologies.

Materials and Methods

The data for this study primarily rests on the materials from OOO "Textile" enterprise, scientific papers and Internet resources on the topic. The methods used throughout the research include: business process modeling, comparative analysis, literature review and analysis, multi-criteria decision analysis, classification, performance evaluation.

Results and Discussion

The organizational structure of OOO "Textile" can be characterized as linear-functional. This form of management organization is based on the principle of separation of cost centres and responsibility centres.

In the current organization of the quality control process, a number of shortcomings can be identified:

1. Due to the presence of the human factor in the process of fabric inspection, there may be unjustified overestimation or underestimation of the quality of rejected material. Both will result in additional production costs.

2. Many defects may go unnoticed, resulting in customer complaints. This will not only lead to a loss of money spent on production and delivery but may also have a negative impact on the reputation of the textile company as a whole.

3. The process of disassembling fabric by a person can take quite a large amount of time due to its laboriousness, which leads to a direct increase in the costs of this process, as well as a later detection of defects.

It is known that the losses of a textile company due to the presence of defects on its sold products can be quite significant. In small and medium-sized enterprises, the detection process can be carried out manually by the quality department staff. For such enterprises, it may not be economically feasible to use information technology to automate this process. For large enterprises, however, it is recommended to replace manual labour with machine labour.

For this purpose, the use of machine vision-based systems together with the corresponding software and equipment has been gaining popularity recently. Such a system can significantly facilitate the process of defect detection and make the results of fabric quality testing more reliable and accurate.

Before designing the necessary machine learning-based software and hardware complex for optimizing the process of tissue defect detection, it is necessary to identify a number of requirements for the implemented solution.

The requirements for the implemented solution will be divided into three groups: business requirements, user requirements, and functional requirements.

During the requirements definition phase, it was possible to establish the following business requirements:

1. Increasing the efficiency of the textile quality control process by minimizing the role of the human factor.

2. Reduction of the company's costs due to the reduction of expenses for the quality control

process.

3. Improved reputation of the company due to the reduced number of defects in the textile materials supplied to customers and, consequently, the reduced number of customer complaints.

User requirements include:

1. Move from visual inspection of fabrics by quality department personnel to an automated system for rapid defect detection.
2. Perform automated rejection in real time.
3. Collect complete statistics on the quality of products.
4. Prevent defective products from reaching the consumer or the next stages of production.
5. Ensure impartial quality assessment and grading of fabrics.
6. Control the process through a program.
7. Reduce the impact of human error by reducing manual labour.
8. Increase the accuracy of defect detection.
9. Increase the speed of the quality control process.
10. Increase the quality of finished products.

The functional requirements should include:

1. Obtaining images from typical or specialized linear and matrix video cameras.
2. Pre-processing of the received images: elimination of geometric distortions, normalization, and protection from interference.
3. Scanning of the product surface and detection of the smallest defects.
4. Segmentation and filtering of defects according to their size, geometric properties, location, and statistical characteristics.
5. Reflection of the fact of defect occurrence and information about it in the program.
6. Providing viewing of defect history, providing information about its characteristics, defect class, size, location, and visualization of defects in the form of photos.
7. Saving reports, images (both with and without detected defects), and detailed visualization of processing results.

To create a database of defects of textile products, fabrics received from OOO "Textile" were used. The process of database formation is as follows. First, all supplied fabrics are placed on the stand for photographing the existing defects. Then all received information about defects with photos is entered into the database.

An important point before starting the development is to design the architecture of the created solution, maximally corresponding to all the requirements of the customer. The created complex should provide an opportunity to read all incoming information, process it, store it, and output it in a user-friendly form (Abdukhalilova, Ilyashenko, Alchinova, 2023; Terekhina, 2020).

For reading information in the architecture of the complex, there are cameras that record all the defects of tissues and transmit images further to the computer. The cameras transmit the information to the calculator through a switchboard. In the role of the calculator is a computer, which must be equipped with a network card for reliable reception of data from the cameras, as well as a video card that supports the calculations of the neural network (Ilyin, 2015).

Further, all incoming data are stored and processed in the software part of the complex, which consists of a number of modules that will be discussed in more detail in the next section (Saidi, 2020).

The task of detecting defective areas on tissues is reduced to the search for anomalies that should differ from the normal pattern of tissues (Sheromova, 2016). To detect anomalies, methods based on prediction are used: statistical methods, classical machine learning methods, and methods using deep neural networks.

The software part of the architecture shall include the following parts:

1. The kernel of the software part serves for preparation for work and launching of all program modules and also provides interaction between them. Development of the kernel and all modules is performed in C++ language and using Boost libraries (Popova, 2019).

2. The configurator is responsible for saving parameters of operating modes of all available program modules.

3. Camera management module includes the camera operation module and the state manager. The camera module helps to exchange data with cameras.

4. The image-saving module. All images can be saved in different formats.

5. The image processing module is responsible for image preprocessing as well as subsequent defect search in streaming mode.

6. Report generation module.

7. File storage. SSD drives are capable of providing faster data access.

The hardware part of the complex also includes two parts: an image capture module and a processing module. In general, the architecture of the hardware part consists of the following elements:

1. Image capture camera and lens.
2. A board with LEDs, lenses for LEDs, and a power supply.
3. Computer and power supply.
4. Ventilation system.
5. Construction elements.

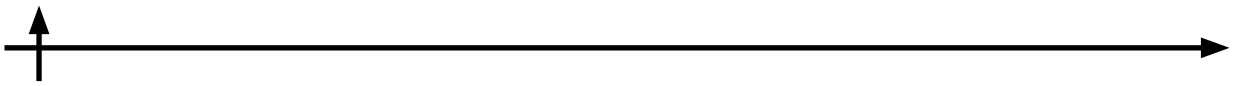
The second module of the architectural part is the module of processing and storage of the received images. It is responsible for processing the images received from the cameras, performing procedures to detect and classify the defects found, and storing all the necessary information about the defects and samples. The key element of this module is an industrial computer. At this stage, it is recommended to use a GPU graphics processor, as it has a higher processing power than the CPU. The Nvidia 1060-1080 series is taken as the main graphics gas pedal. These graphics cards have high performance and efficiency when working with graphics applications and calculations that utilize CUDA technology. In addition, Nvidia 1060-1080 series graphics cards have a large enough memory capacity, which allows you to work with large amounts of data. USB 3.0 controllers are built into the motherboard for interaction with the external environment.

Conclusion

The authors evaluated the compliance of the developed complex with the relevant requirements. The evaluation results are presented in Table 1.

Table 1. Analysis of the solution compliance with the requirements (designed by the author)

№	Requirements	Features		Result
		Planned	Obtained	Compliant
1	Business requirements	Improving the efficiency of the quality control process of textile materials	By minimizing the role of the human factor, the process was optimized, and efficiency increased	Compliant
		Reduction of operating costs	Reduction of costs for quality assurance process by 60%	Compliant
		Enhancing the reputation of the company	Reduced number of complaints and fewer defects resulted in a stronger company reputation	Compliant



№	Requirements	Features		Result
		Planned	Obtained	Compliant
2	User requirements	Transition from visual inspection by the operator to an automated system of operational defect detection	The platform has been implemented, with testing showing that the system detects 5.63 times more defects than humans do	Compliant
		Automatic rejection in real time	The system successfully detects and classifies defects for a moving fabric web	Compliant
		Collection of complete statistics on the quality of output products	All characteristics of the found defects are stored in a separate module of the program part of the complex	Compliant
		Preventing defective products from reaching the consumer or subsequent stages of production	The number of undetected defects is minimized	Partly compliant
		Ensuring impartial quality assessment and grading of fabrics	Fabric grades are determined automatically by the program based on fabric parameters and defects	Compliant
		Reduce the impact of the human factor by reducing the amount of manual labor	Automation of defect detection has virtually eliminated human intervention in the process	Compliant
		Increase defect detection accuracy	Testing has shown high accuracy of defect detection	Compliant
		Increase the speed of the quality control process	The system's defect detection rate is far superior to that of the quality department staff	Compliant
		Improve the quality of finished products	Product quality improved due to reduction of undetected defects	Compliant
3	Functional requirements	Acquisition of images from standard or specialized linear and matrix video cameras	Images are produced with high sharpness, brightness and contrast	Compliant
		Image preprocessing: geometric distortion removal, normalization and noise protection	The preprocessing of the acquired images is successful	Compliant
		Scanning the surface of the product and detecting the smallest defects	Defect detection is correct	Compliant
		Segmentation and filtering of defects according to their size, geometric properties, location and statistical characteristics	Classification of defects is provided in accordance with the specified classes	Compliant
		Reflection in the program for the operator of a defect and information about it	Defects are signaled, defect data is recorded and available for review by quality personnel	Compliant
		Providing viewing of defect history, providing information about its characteristics, defect class, size, location, visualization of defects in the form of photos	All information about the defects, including pictures of them, is provided by the	Compliant
		Saving reports, images (both with and without detected defects), detailed visualization of processing results	All defect reports are generated and saved	Compliant

№	Requirements	Features		Result
		Planned	Obtained	Compliant
4	Technical requirements	Accuracy of localization of defect boundaries – 1mm	95% of detected defects have precise boundary localization	Compliant
		Recall – at least 80%	Recall accuracy 99.7%	Compliant
		False positive rate – at least 0.1%	False alarms detected 0.02%	Compliant
		Maximum material handling speed - 1 m/s	The maximum material handling speed during testing was 66 m/min	Compliant
		Number of detectable defects – not less than 10 types of defects	Seventeen types of defects occurring at various stages of textile production were detected	Compliant
		The system response time is no more than 1 s.	The system response time was less than 0.9 s	Compliant
		Resolution – at least 1 megapixel	Resolution greater than 5 megapixels	Compliant

Based on the developed table, it can be concluded that the hardware-software complex meets the stated requirements. Eight defects of four different types were not detected due to the fact that the defect database lacks a sufficient number of examples. It can be remedied in the future by supplementing the defect database with images of defects of the corresponding types.

The application of machine vision-based systems in the textile industry is an effective solution for improving the quality and productivity of production. Such solutions allow detecting defects and problem areas quickly and accurately, classify defects, and establish the grade of fabric. The development of software and hardware complexes based on machine vision requires high qualifications of specialists, but when implemented properly, it can significantly improve the enterprise efficiency.

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ENERGY TRANSITION: DEVELOPING A CONCEPT OF A DIGITAL TRANSFORMATION MODEL FOR A RENEWABLE ENERGY ENTERPRISE

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Abstract. The energy transition has a significant impact on global energy consumption, changing the structure of the global electricity market. The research is aimed at assessing the opportunities of digitalization of the energy sector. The authors analyze the current state of the global energy sector; consider the development trends in renewable energy sources around the world; examine the technical aspects of the transition to renewable energy sources; study the possibility of introducing the IoT into the infrastructure of renewable energy sources using the existing cases; develop implementation models and digital transition using the example of a wind farm; describe the successive stages that ensure the effective implementation of new technologies and minimize risks when implementing the digital transformation model of a wind farm.

Keywords: energy transition, digital transformation, digitalization, renewable energy sources, smart sensors

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ЭНЕРГЕТИЧЕСКИЙ ПЕРЕХОД: РАЗРАБОТКА КОНЦЕПЦИИ МОДЕЛИ ЦИФРОВОЙ ТРАНСФОРМАЦИИ ЭНЕРГЕТИЧЕСКОГО ПРЕДПРИЯТИЯ, РАБОТАЮЩЕГО НА ВИЭ

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Аннотация. Энергетический переход оказывает значительное влияние на глобальное энергопотребление, меняя структуру мирового рынка электроэнергии. Данная работа посвящена оценке возможности цифровизации энергетического сектора. В статье проводится анализ текущего состояния мирового энергетического сектора, рассматриваются тенденции развития возобновляемых источников энергии в ближайшие года в странах по всему миру, проводится анализ технических аспектов перехода на возобновляемые источники энергии, а также возможностей внедрения Интернета вещей в инфраструктуру возобновляемых источников энергии на примере успешно внедренного кейса. В результате, авторами были разработаны модели внедрения и цифрового перехода на примере ветряной станции, а также описаны последовательные этапы, которые обеспечивают эффективное внедрение новых технологий и минимизацию рисков, при реализации модели цифровой трансформации ветряной станции.

Ключевые слова: энергетический переход, цифровая трансформация, цифровизация, возобновляемые источники энергии, умные датчики

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Introduction

Today, digital technologies in renewable energy are developing at an extremely high pace, thus becoming more affordable and competitive with traditional energy sources.

This research aims to conceptualize a digital transformation model for a renewable energy enterprise (REE) that will improve production management efficiency, minimize costs, and integrate digital technologies such as the Internet of Things (IoT) into the REE infrastructure. In order to perform this goal, the authors analyze the current state of the global energy sector; identify key trends in the development of RES; study the opportunities of introducing the IoT into the RES infrastructure; develop a digital transformation model; and assess its implementation prospects.

Materials and Methods

The research methods of this research rest on literature review and analysis of existing solutions, modelling, and evaluation of the implementation prospects. Various scientific articles, journals, and reports on energy transition, digitalization, and renewable energy were analyzed. Thus, more than 20 editions (2020-2024), both Russian and foreign, for were reviewed. The

most significant sources of scientific data include the following:

– 2023 reports of the World Economic Forum, International Energy Agency;

– The World Economic Forum (WEF);

– The International Energy Agency (IEA);

– Internet of Energy Architecture (IDEA). Version 2.0 – refined description of the architectural approach to building next-generation energy systems. Conceptual model, architectural framework, demonstration complex, pilot projects, and variants of architecture realization.

Results and Discussion

The energy transition is a shift in energy production from traditional carbon-based resources such as coal and oil to renewable energy sources including wind, solar and geothermal sources, as well as hydropower (Anser, 2020 ; Imangali, Bekturganova, 2024). The goal of the energy transition is to ensure the responsible use of the natural resources to improve the quality of life in a greener way, without harming the environment. The use of renewable energy sources can significantly reduce greenhouse gas emissions and meet most of the primary energy demands. The transition to renewable energy will undoubtedly determine the future of global energy supply.

The Energy Transition Index (ETI), developed by the World Economic Forum, assesses the readiness of countries to apply sustainable and renewable energy sources. The ETI takes into account many factors that determine the ability and readiness of countries to introduce the energy transition. The key factors include:

1. Economic and institutional aspects:

– support of energy transition from public and private institutions;

– economic stability of the country;

– overall level of investment in the energy sector.

2. Energy system:

– stability and reliability of energy supply in the country;

– level of infrastructure development for RES;

– energy efficiency and innovation in the energy sector.

3. Environmental sustainability:

- level of environmental pollution, greenhouse gas emissions;

- measures to protect the environment and reduce carbon footprint.

According to the ETI form 2023, the first position with a total 65.2 score for all factors is taken by countries with developed economies, in particular the USA, Canada, Australia, Japan, and Western Europe. The countries of Eastern Europe, with a total score of 57.7, rank second, followed by the countries of Latin America, with a total score of 54.8.

The high energy transition index in different countries shows that successful implementation of renewable energy sources is possible because it not only evaluates countries by current features but also reflects the forecast of the development and readiness of countries for energy transition.

Germany is the fourth largest economy in the world and ranks eleventh out 120 countries in the ETI-2023 ranking. Since 2014, Germany's ETI score has increased by 6%, reflecting both the robustness of its energy transition efforts and the challenges faced by large economies in the pursuit of rapid improvement. Within systemic efficiency, Germany's security and sustainability scores improved, mainly due to supply security, an increased share of renewable energy in the electricity mix, and a significant reduction in the energy intensity of the economy. Although the carbon intensity of the overall energy mix has decreased by 9% in recent years, it remains relatively high due to decarbonization challenges in difficult-to-decarbonize sectors such as

heating, transport, and heavy industry. Germany is the fifth most transition-ready country in the world (Dehtiarova, 2020).

The United States rank 12th, with the ETI increase by 10% over the last ten years, driven by improvements in system performance, especially in safety and sustainability. The sustainability category has seen significant improvements, with energy intensity and per capita CO_2 emissions decrease by 20% and 22%, respectively, since 2014.

In recent years, the U.S. federal government has set ambitious greenhouse gas emission reduction targets, incentivized the deployment of renewable energy technologies through tax credits and grants, and established mandatory renewable energy standards at the state level. In addition, the private sector has made significant investments in clean energy R & D, as well as renewable energy projects. The results of these efforts are reflected in ETI's high scores on regulation, political commitment, and energy decarbonization, making the U.S. a leader in the global transition to a low-carbon, sustainable energy.

These examples demonstrate that energy transition to renewable energy is possible and quite successful. They also prove that renewable energy development can have a positive environmental impact by reducing greenhouse gas emissions and overall negative environmental impacts.

The International Energy Agency is an intergovernmental organization established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) in response to the 1973 oil crisis. The main goal of the IEA is to promote energy security and sustainable development through cooperation between countries, analyzing energy policies and supporting technological development.

In 2023, the IEA compiled an energy report, which focused on renewable energy, among other significant factors (Figure 1).

Breakdown of electricity sector supply and emissions, 2020-2025

TWh	2020	2021	2022	2025	Growth rate 2020-2021	Growth rate 2021-2022	CAAGR 2023-2025
Nuclear	2 676	2 803	2 684	2 986	4.8%	-4.3%	3.6%
Coal	9 414	10 171	10 325	10 217	8.0%	1.5%	-0.3%
Gas	6 330	6 489	6 500	6 522	2.5%	0.2%	0.1%
Other non-renewables	776	764	785	611	-1.5%	2.7%	-8.0%
Total renewables	7 475	7 902	8 349	10 799	5.7%	5.7%	9.0%
Total generation	26 671	28 129	28 642	31 135	5.5%	1.8%	2.8%
Mt CO_2	2020	2021	2022	2025	Growth rate 2020-2021	Growth rate 2021-2022	CAAGR 2023-2025
Total emissions	12 302	13 039	13 207	13 043	6.0%	1.3%	-0.4%

Notes: CAAGR = compound average annual growth rate. For the CAAGR 2023-2025 reported, end of 2022 data is taken as base year for the calculation. Data for 2021 are preliminary; 2022 data are estimated; 2023-2025 are forecasts. Differences in totals are due to rounding. Unless otherwise specified, generation numbers refer to gross generation.

Fig. 1. Production and Emissions, IEA Energy Report Section.

In this table, we can see the trend of decreasing energy production from coal, gas, and other non-renewable sources, while increasing the share of RES, which contributes to the reduction of greenhouse gases. The IEA forecasts that nearly 3.700 GW of renewable energy capacity will come online between 2023 and 2028, thanks to the support of public institutions in more than 130 countries.

Several important renewable energy milestones are expected to be achieved in the next five years:

1. In 2025, renewable energy will surpass coal as the largest source of electricity generation;

2. Wind and solar PV will surpass nuclear power generation in 2025 and 2026, respectively.

3. Renewable energy is expected to account for more than 42% of global electricity generation in 2028, with wind and solar photovoltaic systems increasing to 25%.

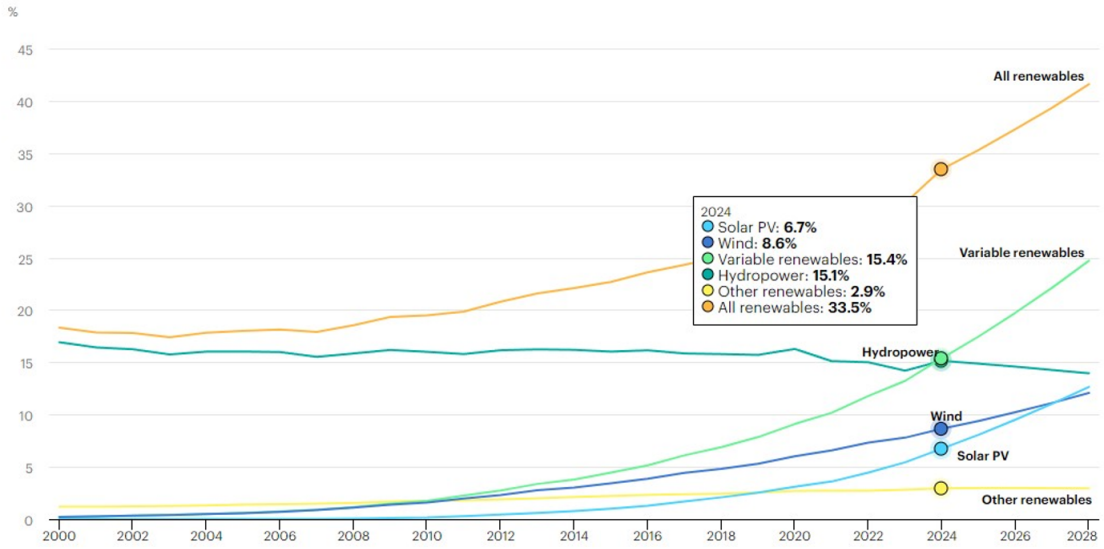


Fig. 2. Renewable energy development trend.

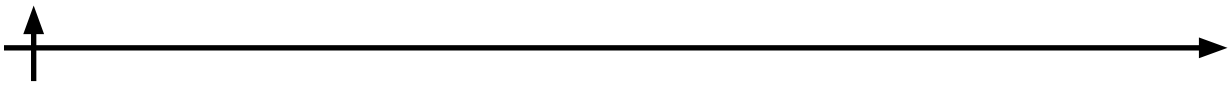
The graph in Figure 2 shows a growing trend in variable energy sources such as wind and solar. Hydropower, on the other hand, is declining due to changing hydrological conditions.

Having analyzed the world's readiness for energy transition, it should be clarified that the transition to renewable energy sources is accompanied by a number of difficulties, both technical and infrastructural. One of the main challenges is the integration of renewable energy sources into existing energy networks. Conventional grids are not always adapted to work with RES, which creates a mismatch in the typical electricity consumption schedule. To solve this problem, significant investments are required in the modernization and development of smart grids, which will allow efficient management of changes in energy production and consumption (Drobyazko, 2021; Zhukov, 2023).

Another challenge is to ensure the stability and reliability of energy supply when using renewable energy sources. The variable nature of such sources, such as solar and wind energy, can lead to instability of energy supply. In order to address this problem, energy storage systems such as batteries, hydro storage plants, and other storage technologies need to be developed. According to the “Water” journal from February 2022, droughts – which are becoming more frequent and severe due to climate change) could potentially create problems for US hydropower in Montana, Nevada, Texas, Arizona, California, Arkansas, and Oklahoma.

With the advent of Internet of Things technologies, the renewable energy sector is undergoing revolutionary changes to make it more efficient and manageable. IoT provides tools for real-time data collection and analysis, which enables wind and solar power plant operators to optimize their operations and increase overall productivity (Gaisina, 2022).

Smart sensors are installed on solar panels, wind turbines, and other renewable energy facilities to continuously monitor their performance. These devices collect data on weather conditions, light levels, wind speed, temperature, and other factors that affect energy production. The collected data is used to create models and algorithms that help predict the future performance of energy systems. For example, machine learning models can analyze historical data and predict changes in solar radiation levels or wind speeds, allowing operators to prepare for changes in advance and maximize the use of available resources (Ye, 2023; Zhang, 2024).



Smart grids equipped with IoT devices can balance loads and manage energy flows, ensuring a stable and efficient supply of electricity. This promotes better utilization of renewable resources and reduces the burden on traditional energy sources.

Internet of Things technologies play a key role in increasing green energy generation by providing tools to predict, optimize, and manage renewable energy sources. These technologies contribute to more efficient resource utilization, increased productivity and reliability of energy systems.

One of the successful cases of digitalization in the energy sector is Tencent* – the leading technology companies in China, which has commissioned a solar power plant (SPP) installed on the roof of a data centre in Tianjin. This project is part of the company's strategic plan to increase the use of renewable energy and reduce its carbon footprint.

IoT devices installed at the power plant provide continuous monitoring of the solar panels and related equipment. Sensors and controllers collect data on:

– solar panel performance;
– solar radiation levels;
– temperature and humidity;
– status of inverters and batteries.

The collected data is transferred to a centralized platform for further analysis. The use of machine learning and artificial intelligence algorithms enables the specialists to:

– optimize panel angles and maximize solar energy capture;
– adjust system operation based on weather conditions and time;
– predict future performance based on historical data and current trends.

The IoT platform provides operators and management with detailed reports and data visualization of SES performance. It facilitates informed decision-making and supports strategies to increase the share of renewable energy.

Thus, the integration of IoT technologies into roof-mounted SES is an example of how modern technology can significantly improve the efficiency and manageability of renewable energy.

Digital transformation model can also be developed and applied in wind farms.

For such digitalization to be effective, an integrated approach is absolutely necessary. It is important not just to implement modern technologies but to make them part of a unified system that optimizes all processes—from design to management, operation, and maintenance.

For this goal to be hit, a digital transformation model should include several key components:

– IoT sensors and devices to collect information on wind speed, temperature, vibration, and energy generation;
– centralized control system (SCADA), a platform to control and monitor the real-time operation of all turbines;
– cloud-based data warehouses that store large amounts of data from IoT devices, with the ability to provide quick access.
– AI analytics platform based on machine learning algorithms. These technologies provide an opportunity to predict energy production based on weather conditions, historical data, and current performance. What is more, they optimize turbine operation, adjust equipment operation to achieve maximum efficiency in changing conditions, and implement predictive maintenance, based on the data on vibration and possible failures;
– integration with the smart grid;
– development of a digital twin of a wind farm.

The introduction of digital technologies radically changes the process of wind farm control,

making it more efficient, predictable, and automated. Whereas in the past the operation of the plant depended on the decisions of a dispatcher based on instrument readings, now real-time data analysis plays a key role. The information collection system integrated with the data centre and ASCUE allows not only to react to changes quicker but also forecast them and optimize equipment operation.

In addition, it becomes possible to store surplus energy, making the plant more stable and independent of fluctuations in generation. As a result, digital technologies do not just facilitate management but also open up new horizons for the development of renewable energy, making it more reliable, sustainable, and economically viable.

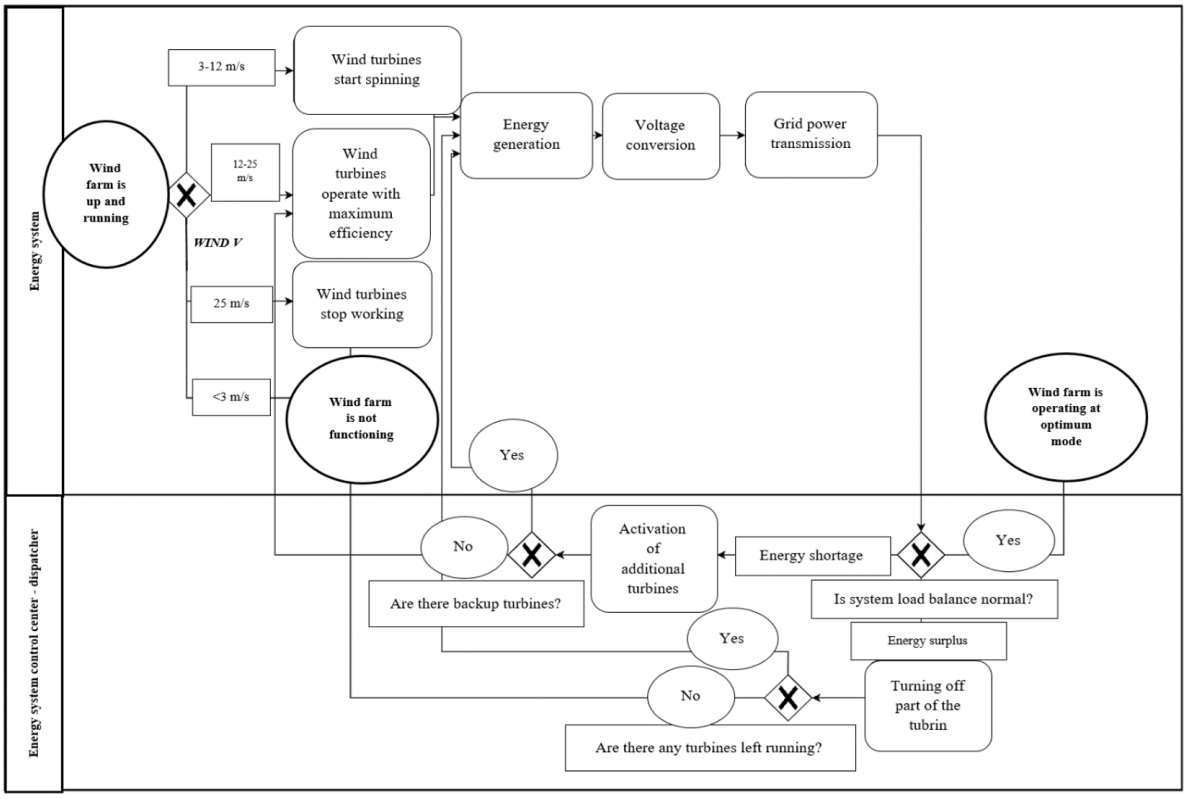


Fig. 3. Wind farm process before digitalization in BPMN notation (designed by the author).

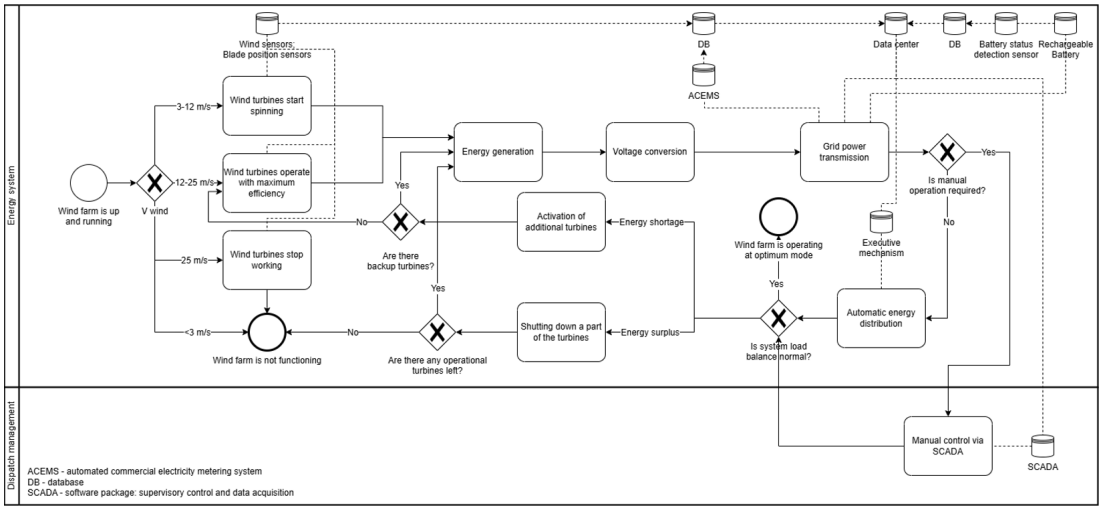


Fig. 4. Wind farm operation process after digitalization in BPMN notation (designed by the author).

The implementation of the wind farm digital transformation model requires a systematic approach and consistent implementation of all stages that ensure the effective implementation of new technologies and minimize risks (Gitelman, 2023; Grishin, 2017). Each stage is aimed at solving specific tasks related to the preparation, testing, and optimization of digital infrastructure.

The first stage of the model implementation includes a comprehensive assessment of the wind farm infrastructure and analysis of current business processes. Here, an inventory of equipment is conducted to determine its readiness for digitalization. An important element of the diagnostic is the identification of problems that could be a barrier to technology adoption. Additionally, key performance metrics that will be used to evaluate the results of the transformation, such as capacity utilization, downtime frequency, and cost of operation, are identified. This step sets the foundation for building the architecture of the future model.

The nest step is devoted to shaping the structure of the digitalization system, including selection of the necessary hardware, software, and analytics methods. The essence of this stage is to design a centralized management platform that integrates IoT sensors, data collection and processing systems, as well as forecasting and predictive analytics tools.

In the pilot implementation stage, digital solutions are tested on a limited area of the wind farm, such as individual turbines or small groups of equipment. This stage plays a key role due to the fact that it allows the interaction of all model components to be assessed under realistic operating conditions. The pilot project provides an opportunity to analyze the collected data, identify possible integration problems, and test the automation of processes such as turbine blade control or power generation forecasting. The success of the pilot project serves as a starting point for further scaling.

When the pilot project is tested successfully, the digital transformation model is implemented throughout the entire wind farm. This stage involves adapting the digital system to the specifics of each wind farm site, taking into account its technical and geographical features. The scaling process requires significant resources but allows for comprehensive coverage of all aspects of plant management. During this stage, internal processes are optimized to achieve stable and efficient operation of the entire farm.

The final stage involves regular evaluation of effectiveness. Based on the collected performance data, individual components are analyzed and adjusted. For example, machine learning algorithms are updated to improve the accuracy of predictions, and new technological solutions are integrated into the overall infrastructure. Consistent optimization allows not only maintaining high efficiency but also adapting to changes in external conditions, including technological innovations and market trends.

Conclusion

Consistent execution of all implementation stages minimizes risks and enables the benefits of digital technology to be leveraged effectively in energy management. By implementing predictive maintenance and process automation, equipment maintenance becomes more accurate and timely. Predictive algorithms allow specialists to identify potential faults and make repairs before major failures occur. It helps to reduce unscheduled maintenance and downtime costs. In addition, automating routine tasks such as turbine blade control or power regulation reduces the need for manual labour, thus lowering operating costs.

The integration of the digital model with smart grids ensures stable power supply even when weather conditions change. Smart grids enable efficient energy distribution and optimize energy supply based on demand. Is is especially relevant for wind farms, where power generation can be unstable due to the variability of wind resources. Digital solutions minimize the impact of

such factors, ensuring stable operation and reliable connection to the general power grid.

Effective use of digital technologies also helps to reduce the carbon footprint of the farm. Optimization of energy generation processes reduces losses, which allows for maximum use of natural resources without the need to build additional capacity. What is more, digitalization helps reduce emissions associated with equipment maintenance and operation, making the wind farm a greener solution to energy transition.

The wind farm digital transformation model is becoming an important tool to improve the competitiveness of renewable energy companies. Its implementation provides not only economic but also environmental benefits, contributing to the overall energy transition around the world.

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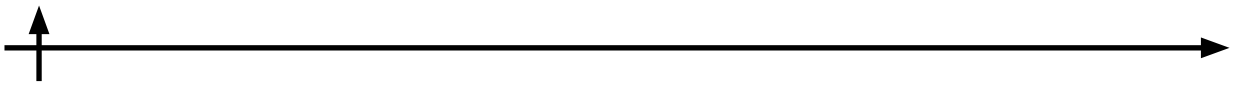

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OPTIMIZATION PROJECT FOR THE MANAGEMENT SYSTEM OF A LOYALTY PROGRAM BASED ON THE PROCESS APPROACH

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Abstract. This study is devoted to the development of the project optimization of the club loyalty program at a small hotel on the basis of the "Loyalty program discount accrual" business process. Throughout the research the authors examine a typical model of this business process and describe the main theoretical and methodological aspects of the formation and improvement of the loyalty program. As a result, the authors articulate the main elements and features of the automated loyalty program management system and develop the model of the "Optimization of the club loyalty program" business process.

Keywords: process management, service sector, relationship marketing, loyalty program, hospitality industry

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ПРОЕКТ ОПТИМИЗАЦИИ СИСТЕМЫ УПРАВЛЕНИЯ ПРОГРАММОЙ ЛОЯЛЬНОСТИ НА ОСНОВЕ ПРИМЕНЕНИЯ ПРОЦЕССНОГО ПОДХОДА

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Аннотация. Данное исследование посвящено разработке концепции проекта оптимизации клубной программы лояльности малого отеля на основе анализа бизнес-процесса «Начисление скидки по программе лояльности». В ходе исследования авторами представлена типовая модель анализируемого бизнес-процесса, описаны основные теоретико-методические аспекты формирования и совершенствования программы лояльности. Результатом работы является разработка основных элементов и характеристик автоматизированной системы управления программой лояльности и модель бизнес-процесса «Оптимизация клубной программы лояльности».

Ключевые слова: процессное управление, сфера услуг, маркетинг взаимоотношений, программа лояльности, индустрия гостеприимства

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Introduction

The loyalty program of a service enterprise is a set of marketing activities aimed at establishing long-term relationships (Trofimova, 2015; Chuvatkin, 2023; Corbishley, 2020) with customers (guests), expressed in an increase in the number of repeated purchases and bookings, as well as the optimization of marketing costs, which contributes to increasing the level of economic sustainability (Vlasova, 2012) and profits. Building, maintaining, and developing such a system is a complex multi-level process within the marketing strategy of an enterprise. The presence of an effectively functioning guest loyalty program becomes one of the main arguments in the competitive struggle in the service market (Trofimova, 2015). In the conditions of active digitalization, the application of innovative technologies (Voronova, 2019) and the development of a comfortable consumer environment, as well as the formation of competitive advantages on the basis of the loyalty program application becomes insufficient and requires improvement. Without advances in this direction it would be impossible to ensure the development of personnel competencies of innovative design of service management technologies (Ilyina, 2016; Steinhoff, 2016).

Materials and Methods

The research is based on the system and process approach to enterprise management. The authors employ materials and data devoted to loyalty management by a number of domestic

authors (Savenkova, 2015; Kozlova, 2016; Grigoryeva, 2023), studies on service activity development and service management by O.V. Ilyina, as well as research in the field of digitalization of the hotel industry by O.V. Voronova and V.A. Khareva. The methods of literature analysis and functional modelling of business processes were also applied in this paper.

Results and Discussion

According to Babenko P., General Director of CJSC Hotel Technologies and developer of the management system for hotel business "1C:Hotel," participants of loyalty programs bring 45% more stays and 50% more revenue compared to other guests. At the same time, within one of the most famous loyalty programs, Marriott Rewards program participants account for about 20% of the company's income; their average expenses are 2.5 times higher than those of an ordinary client. At the same time, due to the activation of the transfer of guests to direct sales within the framework of participation in the loyalty program, there is also a saving on commissions, which also affects the growth of profits. In this connection, the following regularity was put forward: "The growth of direct sales by 1% leads to the growth of annual profit per room for the amount from 2 thousand rubles."

Traditionally, the following generalized types of loyalty programs are distinguished: bonus programs, discount programs, programs for offering additional services, and premium service. In practice, independent small accommodation facilities use non-automated closed (club) discount loyalty programs for returning guests (Basrowi, 2022; Dominguez Perez, 2020).

The principle of operation of such programs is quite complicated, as each time it is necessary to agree on the amount of discount with the hotel director. At the same time, such programs can divide guests by categories. Thus, the most important categories of guests (VIP) in addition to accommodation at the price of the closed tariff are given compliments and gifts upon arrival. The gift itself and the budget for it are agreed upon first of all with the hotel director, and then the purchasing manager works with this information. As a compliment, there is a welcome letter, which will be placed in the room, and it can be a small set with tea or sweets. For regular guests, there is a specific system of discounts from 5 to 20%. The operation of the program itself is quite complex, as the employees need to constantly agree on the amount of the discount; this takes a lot of time, as the director cannot always be in touch (Bade, 2024). In order to visually assess the functioning of the loyalty program in the hotel, let us present the first-level decomposition diagram in Figure 1.

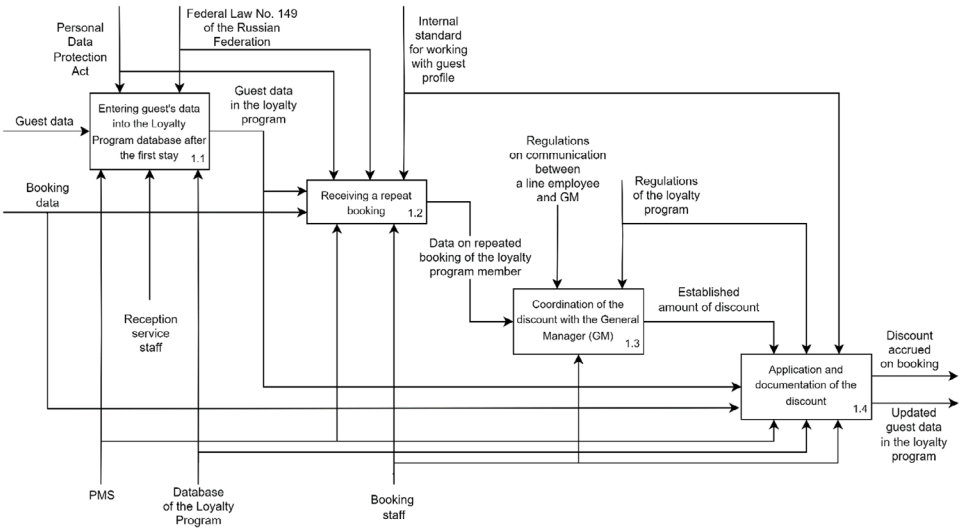


Fig. 1. Level-1 decomposition diagram of the "Accretion of discount on the club Loyalty Program" business process (designed by the authors).

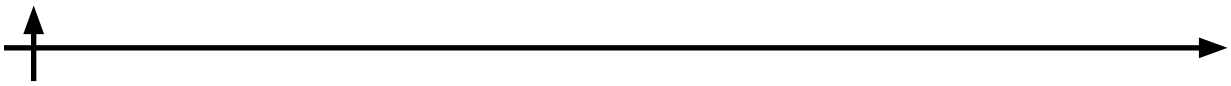
The business process of charging a discount under such a club loyalty program, is very complex and time-consuming. Before giving a discount to a guest, an employee has to prepare a request with the necessary information for the director, coordinate the decision, record the decision on paper and electronic media, recalculate the price in the booking window, issue a new invoice, coordinate the invoice with the guest, make payments, update the guest's profile and make a comment in the system why the price in the booking window is different from the open rate in the sales channel so that no mistake is made at check-out (Kimura, 2022). This process takes a large amount of time, on average, the guest waits about 30 minutes for a discount decision, not including the time to generate the bill and send a new booking confirmation.

In order to see how the system is functioning in visual figures, it is necessary to develop a system of KPIs of process execution (Table 1). The development of the KPI system is necessary to see clearly who is responsible for the process execution, what system for measurement should be used, what result is considered as a norm, what is considered as a planned result and what result will be considered as a norm when deviating from the actual value.

Table 1. KPI system of the business process "Accretion of discount on the club loyalty program" (designed by the authors)

Business process operation	KPI title	Executor	Value	
			Real	Planned
Approval of discount with the director	Average time to negotiate a discount	Shift Supervisor	30-35 minutes	3-5 minutes
Guest identification in the system	Average time for an employee to search for a guest's profile in the system	Shift Supervisor	5 minutes	2 minutes
Entering a return guest in the system	Number of data entry errors	Guest Relations Manager	1-3 errors	0 error
Discount application	Average negotiated discount	Hotel Manager	10%	15%
Recalculation of the new booking price	Time to change the cost and draw up a new invoice	Shift Supervisor	7 minutes	2 minutes
Preparation of a package of documents to the sales manager, guest relations manager	Number of packages sent to managers	Shift Supervisor	10 packages	20 packages
Informing the guest about the new account	Time taken to inform the guest of the new discounted price after receiving a booking request	Shift Supervisor	5-7 minutes	2-3 minutes

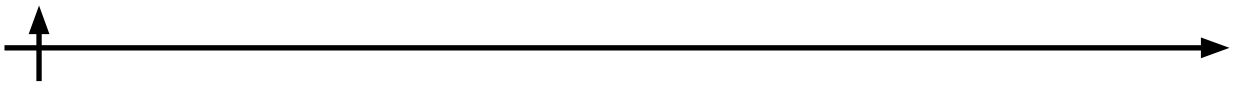
Table 1 shows that there are various metrics when dealing with the analyzed hotel company loyalty program. One of the main KPI metrics is the average time spent on a particular process. The table of values shows that the actual time is very different from the planned time because employees spend too much time making reservations, talking to the director about the discount, fixing the discount, recalculating the guest's room rate and creating a new invoice, reconciling the new room rate with the guest, and generating reporting documents for the sales and guest relations managers. In addition to the average time spent on an individual process, there are quantitative metrics, such as the number of errors in entering up-to-date information into a regular guest's profile (Haverila, 2022).



The best-case scenario is to enter data without errors so that the system runs without interruption, but in fact employees may make one to three errors, which may result in a smaller discount when negotiated with the director. Also, there is such an indicator as the size of the average agreed discount, because of the fact that the hotel does not have any accounting of the list of returning guests and information is searched and collected only by guest profiles in the ACS, employees can make mistakes and the agreed discount from the director may be less. In order to draw conclusions on the analysis of loyalty program technologies, it is necessary to refer to the data presented in Table 2.

Table 2. Conclusions on the existing problems of technologies of the hotel enterprise loyalty program organization (designed by the authors)

Business process	Identified problems in the technology of business process execution	Identified problems in business process KPIs
Guest identification in the ACS	1. no systematized and up-to-date list of guests from profiles; 2. long time interval for identification	1. the average planned time spent on identification of a guest in the system deviates from the actual time by three minutes, which increases the time of work with PL
Approval of discount with the director	1. heavy workload on the director and increase of his additional tasks; 2. long time taken to decide on a discount; 3. possible errors when forming a request with information to agree on a discount	1. measuring the average time to negotiate a discount is almost 10 times out of the norm; 2. the average discount measurement percentage is subject to errors, may vary from the director's opinion, there is no established accrual system
Entering a return guest in the system	1. there may be errors because administrators do not reconcile information with a separate file of returning guests; 2. not all return guests are color-coded in the checkerboard so that staff can quickly identify them and be attentive to them	1. the average time to make a reservation is not measured; 2. the level of automation of the process is not measured
Informing the guest about the new account	1. too much time spent on making a new bill and adjusting the old one, as well as communicating with the guest, as they may get confused by the numbers and pay the old bill; 2. a guest may change his/her mind about booking a room if he/she needs to pay for the room at a moment's notice	1. the number of errors made in making a new count is not measured; 2. the number of guests who were not sent a new invoice for payment is not measured
Preparation of a package of documents to the sales manager, guest relations manager	1. no automation of the process so that reports could come to managers automatically through the system and are captured with the ability to self-update	1. the number of packages is measured, which shows the efficiency of the administrator's work and the awareness of guests, as well as the number of returning guests, but does not take into account the average time to prepare and forward a complete information package to managers; 2. there is no indicator showing the correctness of forming the package of documents and the number of errors in filling out the information
Discount application	1. there is no systematized system of applying discount, different guests can be given different discount; 2. the system of discount application is not built, VIP-code systems in the ACS are not set up, there is no color solution for returning guests	1. the level of automation and average time taken to apply the discount in general is not measured



Overall, it is possible to conclude that the main problem of the existing loyalty program is its lack of systematization and the absence of the ability to independently calculate the discount in the system. What is more, it can be seen that when filling out the questionnaire of the returning guest in the window of editing the reservation, administrators can make mistakes, because of which the guest can incorrectly calculate the discount. Different guests may be charged different discounts, provided that the number of stays and the amount of profit brought by them are the same. This happens because there is no established uniform system for calculating discounts.

Let's turn to the theoretical and methodological bases of the formation and improvement of loyalty programs. Each of the programs is formed in the course of the implementation of a certain algorithm. For example, the proposals presented in the works (Trofimiva, 2015) and (Tsunevskaya, 2008) focus most of their attention on the ways of assessing the level of customer loyalty, while the work (Kozlova, 2016) proposes the formation of a loyalty program on the complexity of the process of formation of technologies and mechanisms of the program. In turn, in business literature, as a rule, the loyalty program is described in terms of the application of IT solutions and ways to encourage customers, which is facilitated by the active implementation of digital solutions (Voronova, 2019; 2024).

Thus, within the framework of loyalty program optimization projects, each of the enterprises studies the experience of its industry in this area and determines which technologies of each model are presented on the market and are in demand and effective. As a rule, there is a question of choice between them, as each of them offers consumers its own advantages. The task of the enterprise from the point of view is to justify the introduction of one or another model.

According to the research results of F. Reichheld from Bain & Company, customer retention by 5% (i.e., an increase of CRR by 5%) carries a profit increase from 25 to 95%. At the same time, the probability of sale—i.e., frequency of sales—to an existing customer is from 60 to 70% and to a new customer—from 5 to 20%, while loyal customers spend 33% more than new customers (Tsunevskaya, 2008).

To determine the key directions of loyalty program implementation, it is necessary to properly assess the key customer segment to which it will be directed. For this purpose, traditional quality management methods can be used (Pal Bariha, 2021).

According to the Pareto rule, 20% of loyal customers give the company 80% of profit. Moreover, 20% of customers are loyal customers and business partner customers. The Pareto rule is concretized if all customers are then categorized into "ABC" importance categories ("ABC analysis"). Using the letters "A," "B," and "C," customers are categorized according to their importance, in terms of profitability for the company, into three classes: most important, important, and less important. ABC analysis is based on the following patterns (Arakelova, 2013):

— The most important customers (category "A") make up approximately 15% of the total number of customers. Their share in the total profit of the company is 65 %;

— Important customers (category "B") are on average 20 % of the total number, and their share in the total profit of the company is also 20 %;

— Less important clients (category "C") make up 65 % of the total number of clients, and their share in the total profit of the company is about 15 %.

Thus, to form a loyalty program, it is necessary to determine which clients (guests) make up 15-20% of the client (guest) base and bring 65-80% of the profit, to study their typology, nature, and structure of expenses (from the point of view of the company—the revenue brought) and, on the basis of the obtained data, to conduct further analysis and make decisions on the choice of technologies and tools of the program itself. An example of the development of a discount loyalty program based on such analysis is presented in Table 2.

Table 3. Discount size and colour code of the guest status depending on money turnover, number of stays, and stay-in days (designed by the authors)

Guest's cash turnover in the last two years	Number of visits in the last two years	Number of stay-in days in the last two years	Discount size	Color code
from 50 to 70 th. rub.	At least 3 times	At least 10 days in total	7 %	Blue
from 70 to 90 th. rub.	At least 3 times	At least 15 days in total	10 %	Purple
from 90 to 120 th. rub..	At least 3 times	At least 20 days in total	15 %	Red

The following system is proposed during the development of the loyalty program optimization project. On the basis of this list, it is possible to determine which guests came to the hotel for more than 3 times in the last two years, what amount of money turnover they brought, and for how many days they stayed. Next, it is necessary to make a new list with returning guests who are entitled to a discount. The maximum amount of discount that the hotel can give the guest is 15%. It gets those customers who, in the aggregate, for the last 2 years, came to the hotel at least 8 times, given that the total number of days spent in the hotel was not less than 20, and the total turnover of funds that they brought is from 90 thousand rubles. At the same time, guests with a minimum discount will burn blue colour when making a repeat booking, guests with an average discount—purple, and guests with a maximum discount—red. Depending on the change in the number of stays, the system will automatically recalculate the brought amount, cash turnover, and the number of stays, as well as automatically enter the size of possible discounts and set up algorithms to automatically switch the size of the discount with the increase in the number of reservations from the returning guest.

For the process of optimizing the club loyalty program in the hotel, it is necessary to first upload profiles of all guests who have stayed in the hotel since its foundation. Then, with the help of various tools and independent segmentation on the basis of available calculation formulas and the established possible range of discounts, it is necessary to upgrade the functioning of the system so that in the end it gets an automated program with an accessible understanding of use for both guests and staff. Let's present in figure 2 the model of the business process of loyalty program optimization.

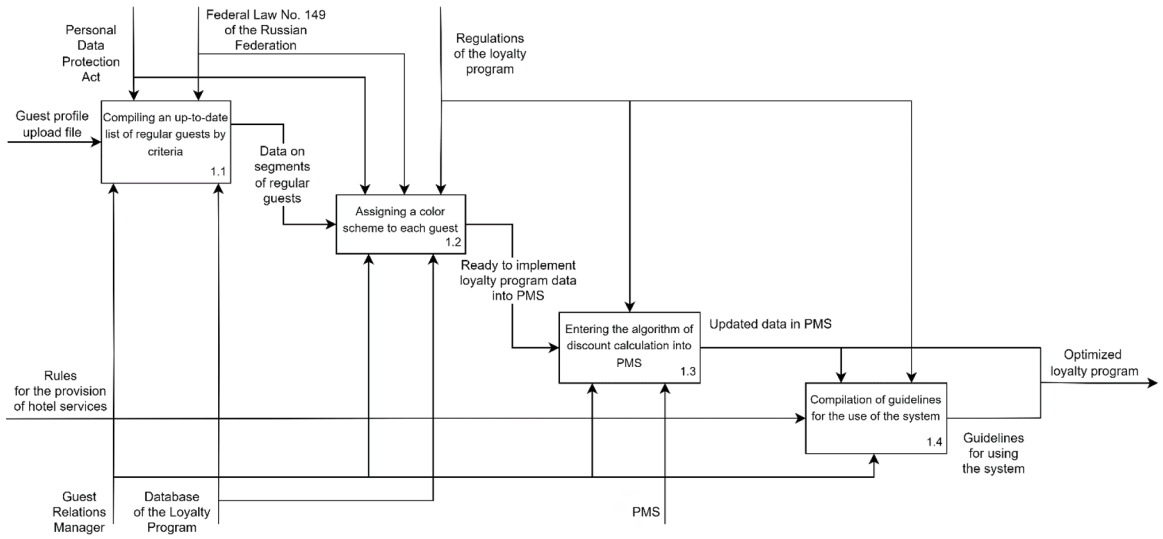


Fig. 2. Model of the "Optimization of club loyalty program" business process (designed by the authors).

Conclusion

From the diagrams above, it is possible to observe how the process of optimizing a club loyalty program in a small hotel will be structured. According to this project, the output should be an automated system that does not require constant coordination of the discount with the director. Based on the criteria of discount calculation and its size depending on the cash turnover, number of visits, and stay-in days, an algorithm is developed, checked by the ACS technician. Then the discount algorithm is manually entered for each guest. At the next visit, the discount will be automatically displayed in the guest's profile, and the amount and the bill for accommodation will be displayed with the already calculated discount. Another plus of such a system is that when the number of bookings from a regular guest increases, his discount will automatically increase within the parameters independently, thanks to the system's capabilities and algorithm customization. The difficulty of implementing such a program is the independent introduction of colour solutions for guests, as the employee must do it manually, based on a complete list of returning guests, as well as a file where the parameters of the guest, the size of the discount, and colour solutions are specified.

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IMPLEMENTATION OF A PLATFORM SOLUTION FOR PROJECT MANAGEMENT AUTOMATION IN THE ENTREPRENEURIAL ECOSYSTEM OF RUSSIAN UNIVERSITIES

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Abstract. One of the most promising areas for ensuring the technological sovereignty of the Russian Federation is involvement of university students and young researchers in technological entrepreneurship. A startup studio – a startup factory that focuses on the mass production of new high-tech companies – seems to be an effective direction for increasing the "convertibility" of business ideas based on HEI developments into an operating business. This research examines an "AS-IS" architecture model of a university startup studio for the first post-launch year as a part of the Russian federal project. In the "TO-BE" model, the authors show that the implementation of a project management platform across the net of Russian university startup studios may increase the potential of transferring technologies form universities to a much vaster application in business.

Keywords: technological entrepreneurship, startup studio, university entrepreneurship, enterprise architecture

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ВНЕДРЕНИЕ ПЛАТФОРМЕННОГО РЕШЕНИЯ ПО АВТОМАТИЗАЦИИ УПРАВЛЕНИЯ ПРОЕКТАМИ В ПРЕДПРИНИМАТЕЛЬСКОЙ ЭКОСИСТЕМЕ РОССИЙСКИХ ВУЗОВ

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Аннотация. Вовлечение студентов и молодых сотрудников высших учебных и научных центов в технологическое предпринимательство является одним из многообещающих направлений обеспечения технологического суверенитета РФ. Стартап-студия, как фабрика стартапов, ориентированная на массовое производство новых высокотехнологических компаний представляется перспективным направлением повышения «конвертируемости» бизнес-идей в работающий бизнес. В данной статье анализируется текущая архитектурная модель университетской стартап-студии первого года реализации ФП ПУТП. В целевой архитектурной модели демонстрируется, что внедрение платформы управления проектами во всей сети университетских стартап-студий федерального проекта сможет повысить эффективность трансфера университетских наработок и технологий в коммерчески успешные компании.

Ключевые слова: технологическое предпринимательство, стартап-студия, университетское предпринимательство, архитектура предприятия

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Introduction

Universities, their campuses, and associated facilities represent the main source of innovation in the world transforming organized science and venture capital into business. The Russian Federation has a long way to go in this direction. Leading university centres are increasingly focused on training a new class of actors for modern technological markets—technological entrepreneurs. Ideologists of the Russian National Technological Initiative expect that university ecosystems are well capable of removing the barrier that prevents Russian scientists from entering the unfamiliar and for now incomprehensible arena of entrepreneurship (Ivanov, 2015).

Startup studios, or venture studios/startup factories, make one of the globally well-known tools for entrepreneurship development. A startup studio contributes to the development of technological entrepreneurship, via focusing on rapid testing of business ideas and mass "production" of new companies. Despite the fact that the first startup studio was created back in 1984, even before the first accelerator program, their rapid growth has occurred over the last 15-17 years. In Russian practice, this format has been widespread among universities since 2022: within the framework of the federal project "Platform of University Technological Entrepreneurship." In 2022 the Government of the Russian Federation launched a federal project "University platform of technological entrepreneurship. According to the Deputy Prime Minister Dmitry Chernyshenko, "The project was designed to encourage students to create their own

businesses and attract investors."

A startup is a company with an ultra-short operating history, founded by one person or a group of entrepreneurs who go on to develop a new high-demand product or service. In other words, a startup is an innovative business plan that aspires to scale very quickly. This research focuses on the features of a startup studio business model and its architecture.

Materials and Methods

Methodologically, the research centers around the analysis of open sources. The main methods include a literature review of "university entrepreneurship" and scientific studies published in Web of Science and ResearchGate, as well as Russian government documents and technology initiatives. The majority of the examined papers were published from 2007 to 2024 by foreign experts from USA and Europe. Domestic studies on the technology transfer were also considered. A case study approach was invited to observe the processes of a Russian medical startup studio.

In order to visualize the existing processes, model the enterprise architecture, and identify gaps between the current state and target architectural model, the authors used ArchiMate and TOGAF. As a result, it became possible to assess the current processes and highlight excessive steps and bottlenecks that impede the optimization of project management.

The majority of studies focus on aspects of identifying the position of the university in the infrastructure supporting technological entrepreneurship (Zayakina, 2023; Mutalimov, 2021; Bolchek, 2023), the definition of technological entrepreneurship tasks (Belskikh, 2022; Zobnina, 2019), and evaluation methods for technological entrepreneurship (Polozkov, 2022).

The Strategy for Scientific and Technological Development of the Russian Federation defines directions that will allow solving large-scale tasks to modernize the Russian economy and its transfer to innovations, based on new knowledge and technologies. This task proves to be highly important due to the fact that their application sets new requirements for the qualification of specialists and the system of personnel training in general (Konstantinov, 2022; Polbitsyn, 2021).

According to the "National Technological Initiative" federal project, it is planned to implement a package of measures to improve the quality of education and training. What is more, the project specifies the application of a package of measures aimed at providing highly qualified personnel for high-performance export-oriented sectors of the Russian economy (Repina, 2022; Osiobe, 2020). Another important task is to unlock the entrepreneurial potential of young people and train professionals specifically for technological entrepreneurship (Sibirskaya, 2022; Yashin, 2019).

The "Platform of University Technological Entrepreneurship" federal project (PUTE) is aimed at solving these problems. Its goal is to shape a cadre of serial entrepreneurs, people who massively launch new businesses. The key objective of the project is to bring 30.000 technological entrepreneurs from universities into the economy by 2030. The main directions of the project include: mass entrepreneurial training of university students and employees; launch of university technological startups and startup projects; development of mechanisms to attract investment in university startups and projects.

By the end of 2025, the PUTE initiatives are expected to ensure the following increase:

– the number of university students and employees involved in technological entrepreneurship – 435.000 people;

– the number of university startups – 8.8000 companies;

– the volume of investment – 9.9 billion rubles.

Undoubtedly, the PUTE indicators seem to be extremely ambitious. However, in order to

achieve them, it is necessary to overcome certain problems in the relationship between the corporate sector and startups (Kovalevich, 2021; Guo, 2023).

The initiative focuses specifically on technological entrepreneurship. Unlike trade and service entrepreneurship, technological one reduces production costs. It benefits both companies, which reduce their costs, and consumers, who can obtain the goods and services they need at a lower price, subsequently leading to inflation control. With the help of new technologies, entrepreneurs are able to create new types of products that will replace old ones. The project is aimed at supporting a range of activities: creating co-working space based on universities, launching accelerator programs at universities, providing grants to students with business ideas, creating university startup studios, and paying cashback to business angels who invest in student projects.

The startup studio is a "startup factory" where students and university employees are working on projects with effective support from the startup studio staff and in a safe environment partially protected from financial risks. Students and employees are offered an approach to working with technology startups that minimizes risks and maximizes human capital.

A startup studio is basically a funder that takes care of routine operations at all stages of the product and company life cycle, from idea to product scaling. The startup studio makes the decision to support (or not) a particular startup. The startup funding tactic involves the use of a tranche-based funding mechanism within a stage of the startup's lifecycle. Based on the results of each stage, a decision on further financing is made.

The startup studio's staff and its partners implement the following set of services:

– Generation of startup ideas startups

– Testing business models with the involvement of technological entrepreneurs' competencies;

– Expertise in startup projects;

– Investing in startups, creating legal entities, and solving operational issues;

– Marketing and analytical research;

– Development and preparation of technological and organizational processes to ensure production and sales;

– Product branding;

– Attracting investors;

– Public relations and product promotion;

– Accounting services for established legal entities;

– Legal services, etc.

Supporting projects at different stages allows startup studios to balance the portfolios, diversify risks, and ensure financial stability. Thus, startup studios created within PUTE ensure the involvement of students and young people in technological entrepreneurship and stimulate an increase in the number of technological startups, identify, support, and develop promising university projects and scientific breakthroughs.

The architecture of the PUTE startup studio for the post-launch year invites many standard programs (Figure 1).

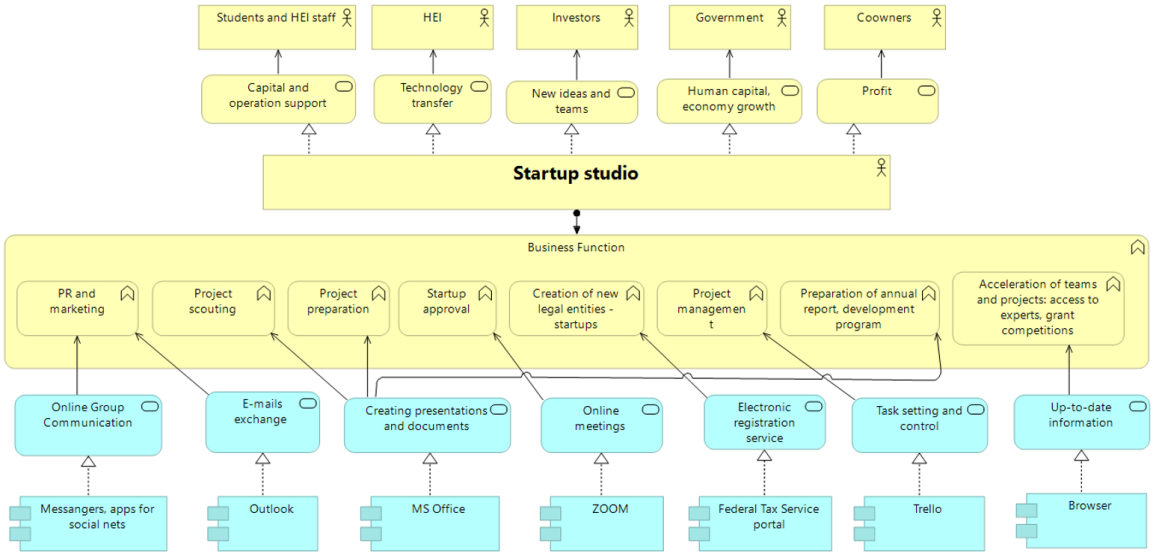

Fig. 1. “AS IS” architectural model of a startup studio.

Results and Discussion

The target enterprise architecture model involves replacing a multitude of disparate automation tools with a single platform that provides project management, online meetings, and supports unified information among a network of university startup studios (Figure 2) (Buckl, Krell, Schweda, 2020).

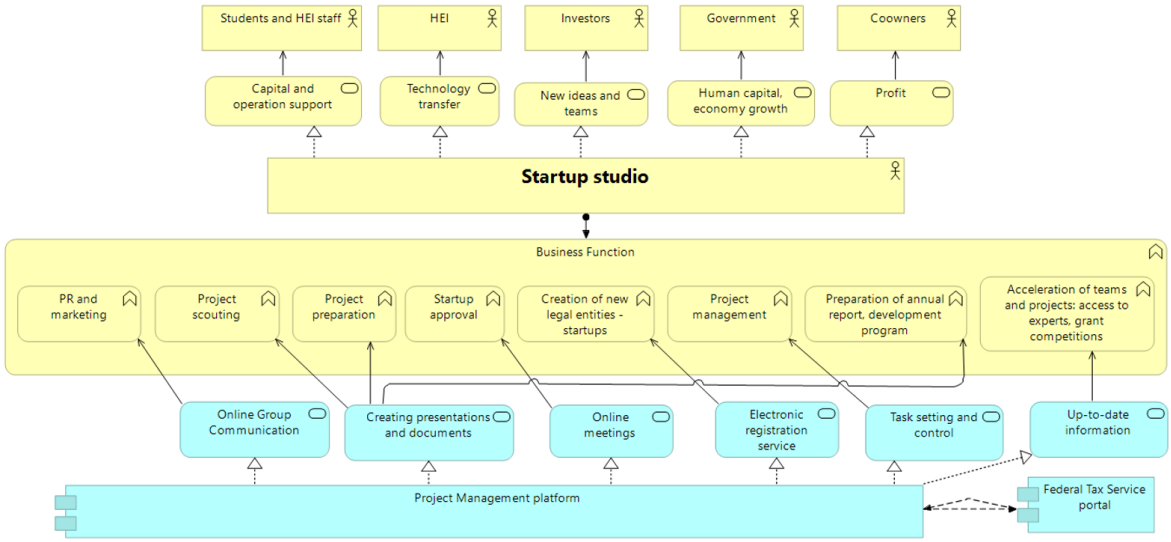

Fig. 1. “TO BE” architectural model of a startup studio.

With the advancement of information technology, project management activities are increasingly undergoing automation. Automated project management systems allow project managers to promptly obtain the necessary information about the project stages, control processes and performers. Automation of project management is the introduction of information systems into project activities that optimize the management tasks for project managers.

According to (Kostalova, Tetrevova, Svedik, 2015), “project management information system is a set of organizational and technological, methodological, technical, software, and information tools that support and improve the effectiveness of project management.” Such systems

are used at each stage of project realization and allow making management more effective.

Modern project management information systems perform a number of highly important functions, primarily they:

– draw up the project work plan;
– plan the critical path method;
– plan resources;
– control the project implementation (Safonova, 2020).

There is also a number of necessary requirements for the functionality of information systems:

– automation of processes;
– document management capability;
– reporting tools;
– project time management;
– project cost management;
– unified information space (Safonova, 2020).

Accordimg to the authors of "Support of Project Management Methods by Project Management Information System", the probability of successful project implementation increases when project management methods are invited. In its turn, project management is greatly simplified through the use of information systems thus reducing time costs (Kostalova, 2015; Filippov, 2023).

Conclusion

The significance of this research rests on the fact that entrepreneurship is a key factor in economic growth and development, where universities play a crucial role in fostering entrepreneurial activities. The startup studio business model is a new and effective management model for creating and developing commercial innovative projects. There is a variety of startup studios that are created at large "global" corporations to ensure effective implementation of new product solutions in their divisions or allocation of innovative ideas to spin-offs, giving the later the opportunity to be flexible and independent from the red tape. Independent investors that look for promising suggestions and teams, who are ready to provide expert business support, can also create startup studios. Startup studios combine the format of funds, as they have an investment budget, develop programs for "growing up" teams and back-office functions, taking over the routine operations of a startup team. Unlike venture capitalists, startup studios invest not only money but also managerial and human resources.

The target architecture of the startup studio proposed in the current research is based on a project management platform primarily focused on efficient and rapid implementation and dissemination of innovations. The platform should also be open to external project teams—startups. At the same time, it is a heterogeneous solution, i.e., they can include several platforms, though, integrated through a unified web platform.

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MVP WEB SERVICE FOR A COSMETOLOGY COMPANY WITH ARTIFICIAL INTELLIGENCE ELEMENTS

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Abstract. This article focuses on the development of an MVP web service for a cosmetic company utilizing internet search technologies, web scraping, and generative artificial intelligence models. The increasing demand for personalized cosmetic products highlights the relevance of this study, which aims to optimize product selection and analysis processes. The research introduces a web service designed to analyze cosmetic products and provide personalized recommendations. The IT architecture, comprising two microservices, was developed and tested on real data. The results demonstrated a recognition accuracy of 99.45% for the company's products and 92.45% for products from other brands. The overall success rate for data processing reached 92.97%. The proposed solution proves to be effective for creating digital products with minimal development costs and offers potential for further functionality expansion.

Keywords: MVP web service, cosmetic industry, artificial intelligence, OCR, personalized recommendations, generative AI, LLM, microservices architecture, parsing

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MVP ВЕБ-СЕРВИС ДЛЯ КОСМЕТОЛОГИЧЕСКОЙ КОМПАНИИ С ЭЛЕМЕНТАМИ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

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Аннотация. Данная статья посвящена разработке MVP веб-сервиса для косметологической компании с использованием технологий поиска в Интернете, парсинга и генеративного искусственного интеллекта. Актуальность исследования обусловлена растущим спросом на персонализированные косметические продукты и необходимостью оптимизации процессов выбора и анализа. В данной работе исследуется веб-сервис для анализа косметических продуктов и предоставления персонализированных рекомендаций. В ходе исследования разработана IT-архитектура, включающая два микросервиса, и проведено тестирование на реальных данных. Результаты показали точность распознавания продуктов компании на уровне 99,45% и других брендов — 92,45%. Общая успешность обработки данных составила 92,97%. В заключение, предложенное решение показало свою эффективность для создания цифровых продуктов с минимальными затратами и возможностью дальнейшего расширения функционала.

Ключевые слова: MVP веб-сервис, косметическая индустрия, искусственный интеллект, OCR, персонализированные рекомендации, генеративный ИИ, LLM, микросервисная архитектура, парсинг

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Introduction

The cosmetics industry is currently showing steady growth. According to Fortune Business Insights, the cosmetics market was valued at $374.18 billion in 2023, and it is projected to increase up to $758.05 billion by 2032. The rapid development of the industry is driving the demand for personalized products, which presents new challenges related to safety and consumer awareness. Modern customers are increasingly facing difficulties in selecting cosmetic products due to a lack of information about ingredient composition and compatibility, which can lead to adverse reactions and a decrease in trust in brands.

To address these issues, companies in the cosmetics sector are increasingly using digital technologies to optimize processes related to analysis, personalization, and recommendation delivery. However, the high cost of developing and integrating such solutions remains a significant barrier for startups and small businesses. In a competitive market, cosmetic companies must quickly adapt to the changing environment and implement pilot projects to strengthen their positions and maintain market share in the digital landscape.

In this context, the creation of minimally viable products (MVPs) using ready-made tools and technologies that can be tailored to the company's specific needs is particularly relevant.

Such solutions allow for quick testing of key metrics and the collection of user feedback, which is essential for further product improvement and reducing risks during implementation. The aim of this research is to develop an MVP product for a cosmetic company that enables the analysis of cosmetic products, provides personalized recommendations to users, and allows the company to make its presence known in the digital cosmetics market with minimal development costs. The following tasks are set to achieve this goal:

1. Analyze existing digital technologies applicable in the field of cosmetology;
2. Develop an IT architecture tailored for the MVP product;
3. Formulate recommendations for improving user experience and further product development.

Materials and Methods

To achieve the goal and objectives of the research, a methodology was developed, which includes the analysis of digital technologies used in cosmetology, the design, and testing of the IT architecture of the MVP product. The overall sequence of actions within the methodology is presented in the following stages:

1. Technology Analysis.

The study examined advanced digital technologies such as artificial intelligence (AI), machine learning (ML), optical character recognition (OCR), augmented reality (AR), biometrics, and intelligent assistants and their application in the cosmetics industry.

Artificial Intelligence: AI is a branch of computer science focused on creating systems capable of learning and adapting to perform tasks typically associated with human intelligence, such as pattern recognition, natural language processing, and decision-making (Russell, Norvig, 2016; Skatova, 2024). In cosmetology, AI is used to analyze customer preferences and automate product selection, enabling personalized recommendations.

Machine Learning: ML is a subset of AI in which algorithms are trained on large datasets to improve accuracy and task performance (Goodfellow, Bengio, Courville, 2016). In the cosmetics industry, ML is used for skin condition diagnosis and to create models that analyze user data, allowing for precise cosmetic product recommendations.

Optical Character Recognition (OCR): OCR is a technology that converts text from images into a digital format for subsequent analysis and processing (Smith, 2007; Wu, 2023). In cosmetics, OCR helps scan product ingredient lists on packaging, ensuring transparency of information for consumers.

Augmented Reality (AR): AR is a technology that overlays digital elements onto real-world objects on a device's screen, enabling users to interact with virtual objects in real-time (Azuma, 1997). In cosmetics, AR is used for virtual makeup try-ons, enhancing the customer experience and reducing the likelihood of returns.

Biometrics: This technology involves the automatic recognition and analysis of physical characteristics, such as skin structure and fingerprints, for identification and service personalization (Jain, 2004; Raj, 2021; Kazakevich, 2023). In cosmetics, biometric technologies assist in selecting products tailored to a client's skin condition and characteristics, improving the accuracy and effectiveness of recommendations.

Intelligent Agents: AI-powered systems, such as large language models (LLMs), interact with users through text or voice interfaces, providing personalized information and recommendations. In cosmetics, intelligent agents offer consultations, cosmetic product recommendations, and 24/7 support, improving service quality and customer satisfaction.

2. IT Architecture Development.

Based on the analysis, an IT framework was proposed, including two microservices. Key

technologies include SerpAPI, Google Search, OCR for text recognition and source retrieval, parsing for content extraction from websites, and GPT-4 for analysis and conclusions.

3. Modeling and Testing.

To validate the functionality of the proposed IT architecture, a prototype of the MVP product was created and tested using automated tests, which evaluated the accuracy of product recognition and the quality of the recommendations provided.

4. Literature Review.

A review of scientific literature was conducted, focusing on the application of modern technologies and highlighting their significance. For example, the use of machine learning for diagnosing skin diseases has shown impressive results. Research demonstrates that ML-based algorithms, such as Convolutional Neural Networks (CNN), can classify skin diseases with accuracy comparable to dermatologists and identify hidden correlations in data, enabling more accurate and personalized diagnoses (Chan, 2020; Yoo, 2024).

Another significant achievement is the integration of artificial intelligence and extended reality (XR) for creating interactive skincare recommendations. One study describes a system that analyzes skin images and provides personalized recommendations based on identified features, such as acne and pigmentation. Using XR, users can not only see the analysis results but also visualize the potential effects of using the products, making the selection process more informed and engaging (Rajegowda, 2024).

These achievements represent only a small portion of the research highlighting the potential and relevance of modern technologies in the field of cosmetology.

Results and Discussion

As a result of the analysis of modern technologies and IT solutions, a proposal was made for a cosmetic company considering its resources and limitations. The company's IT framework, presented in the diagram (Figure 1), provides the basic infrastructure sufficient for integration with external systems and the deployment of the new product.

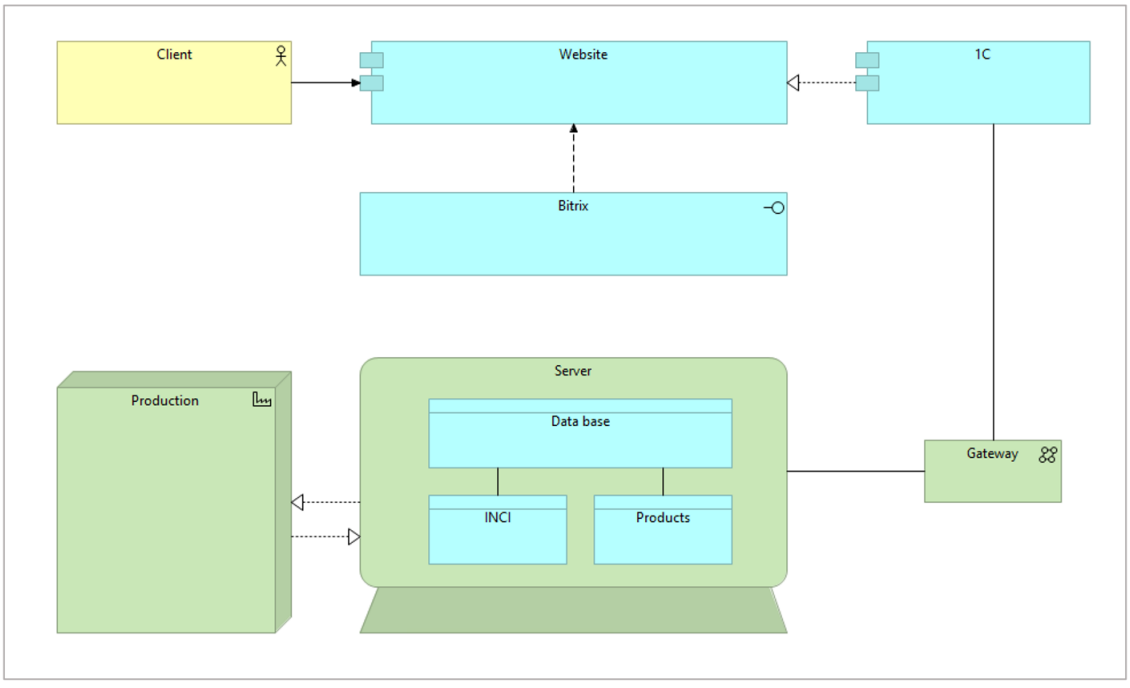


Fig. 1. IT Architecture of the Company.

Based on the experience of large companies, a web service has been developed that allows users to upload an image of a cosmetic product, specify its intended use, and receive an analysis of its composition. The service also provides usage recommendations, selects alternatives, and suggests complementary products from the company's range. User scenarios are illustrated in the Use Case diagram (Figure 2).

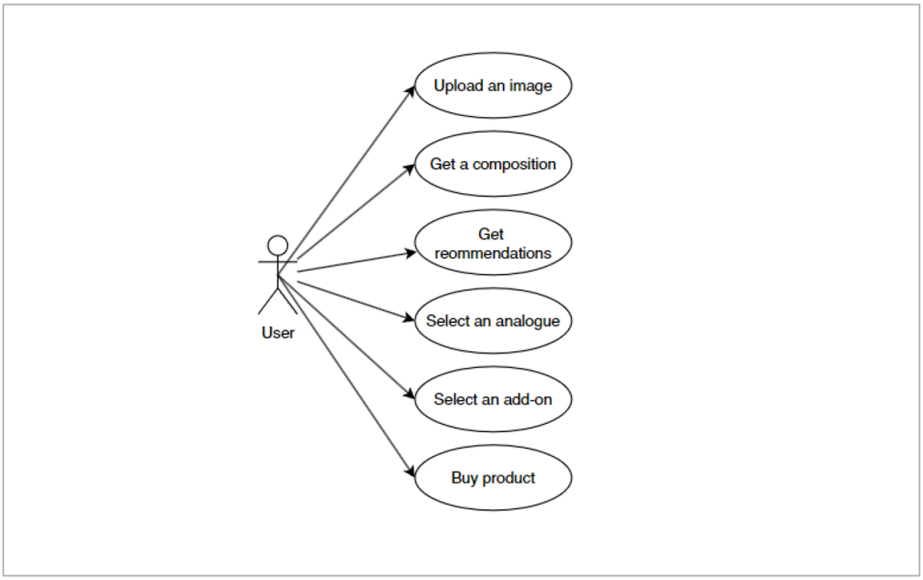


Fig. 2. Use Case Diagram.

The core of the web service consists of internet search technologies, parsing, and generative artificial intelligence models. Since the company has a database of its own products and ingredients (INCI), integration with new technologies allows the use of verified data to provide accurate recommendations.

On the backend, it is proposed to develop two microservices: the first handles the company's data, including algorithms for analyzing product compositions and providing recommendations, while the second is responsible for recognizing products from images, collecting data from external websites via parsing, and using a generative model to transform unstructured data into a formatted output for the user. This interaction between components allows for efficient processing of user queries, ensuring a response time of 5 to 15 seconds (Figure 3).

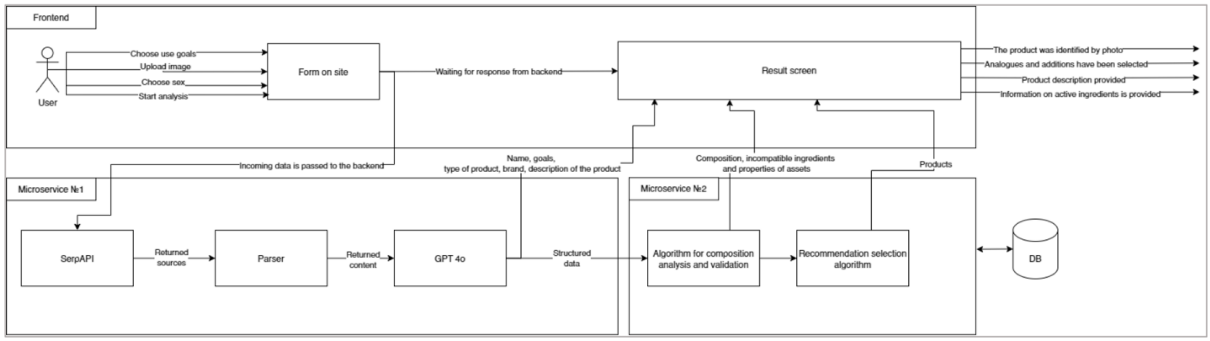
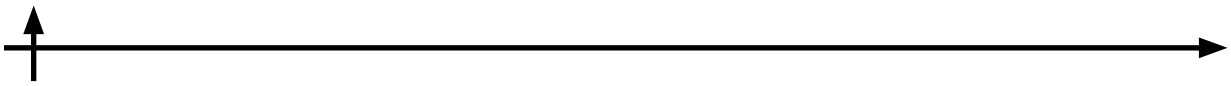


Fig. 3. Solution Architecture.



The internet search is performed using SerpAPI (Google Search API), which, when a photo is uploaded, queries the global network and returns relevant sources. Additionally, OCR technology is used to recognize text on the image, improving the accuracy of the search. Parsing technology is applied to extract content from the most relevant websites, which is then analyzed by the GPT-4 model. The output data includes the cosmetic product name, brand, product type, composition, true purpose of the product, and its description. Prompt testing helped improve the accuracy of the output.

The testing results showed that the solution architecture is flexible and easily adaptable to changes, minimizing development and deployment costs. The testing was conducted on two datasets. The first dataset consisted of images from websites: 73 products from the company and 95 products from other cosmetic brands. The second dataset consisted of 84 real photos from company users and 96 real photos from other brands. Additionally, a link to the original image on Google Drive was provided.

Table 1. Example of products from dataset

91	Protein Silk Scrub Ayurvedic	La Sultane de Saba
92	Midnight Blue Calming Cream	Dear, klairs
95	Sensibio Gel moussant cleansing gel	Bioderma
96	Mugwort Calming Soothing Gel	Round Lab
98	Нуяйас Tonique Purifiant cleansing toner	URIAGE
99	Enzyme powder enzyme powder	Skin Helpers
102	Niacinamide 10% Zinc 1%	The Ordinary
103	HYDRO GEL Reviving	PROFKA
105	Ultra-moisturizing tonic	Sendo
109	Future Solution Lx Extra Rich Cleansing Foam E	Shiseido

As a result of testing and iterative improvements, the following outcome was achieved on real product photos, which serves as a litmus test in this case. The results are divided into two parts: the quality of recognizing the full product name (recognize service) and the quality of obtaining the other required data – composition, product description, and intended use (describe service). The results are based on 5-10 runs across the entire dataset. For the company's real photos, an accuracy of 99.45% was achieved. The results are presented in Table 2.

The accuracy on photos of cosmetic products from other brands was 92.45%. The results are presented in Table 3.

Table 2. Results report of recognize service. Products of company

Iteration	Accuracy, %	Number correct/total	Average accuracy over 10 iterations, %	Total number of unique errors
1	98.63	72/73	99.45	4
2	100.00	73/73		
3	98.63	72/73		
4	98.63	72/73		
5	98.63	72/73		
6	100.00	73/73		
7	100.00	73/73		
8	100.00	73/73		
9	100.00	73/73		
10	100.00	73/73		

Table 3. Results report of recognize service. Products of other brands

Iteration	Accuracy,%	Number correct/total	Average accuracy over 5 runs, %
1	93.68	89/95	92,46
2	92.63	88/95	
3	90.62	87/96	
4	92.63	88/95	
5	92.71	89/95	

The histogram below shows the incorrect product name detections, distributed by brand.

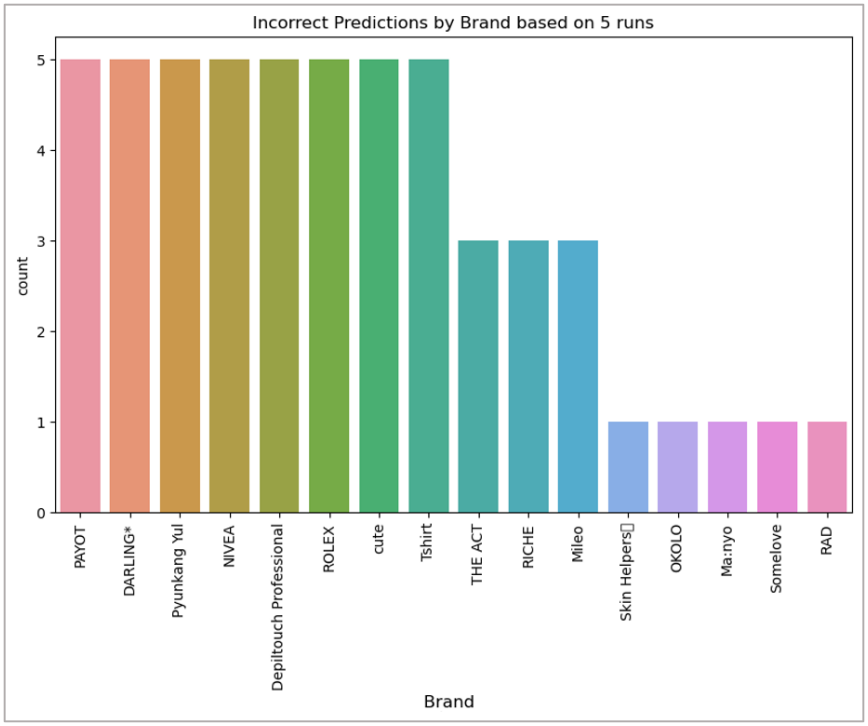


Fig. 4. Incorrect predictions by Brand.

For the identification of other product attributes from other brands, the following results were obtained. On average, for 95.63% of the products, all data were successfully retrieved, except for the composition. The average percentage of failure to retrieve the composition was 8.12%. Therefore, the overall average accuracy of obtaining product data was 87.51%. The results are presented in Table 4.

Table 4. Results report of describe service. Products of other brands

Iteration	Success Describe API, %	No composition, %	Elements total	Average Describe API Success Rate, %	Average percentage no composition, %
1	94.79	7.29	96	95.63	8.12
2	96.88	8.33			
3	95.83	6.25			
4	93.75	10.42			
5	96.88%	8.33%			

The overall success rate (End-to-end) was 92.97%. This value reflects the total success in identifying and obtaining all product data. The results are presented in Tables 5 and 6.

Table 5. Results report of end-to-end tests

Iteration	Success Recognition (describe) API, %	Success Describe API, %	Success rate (end-to-end), %
1	98.96	90.53	89.58
2	98.96	95.79	94.79
3	98.96	94.74	93.75
4	98.96	94.74	93.75

Table 6. Results report of all main parameters

№	Parameter	Average value, %
1	Success Recognition (describe) API, %	98.96
2	Success Describe API, %	93.95
3	Success rate (end-to-end), %	92.97

The launch of the solution allowed the company to enter the digital product market, providing users with a personalized experience without the need to create custom solutions and with minimal development costs. The achieved recognition accuracy and data retrieval results from the internet about the product are sufficiently high for the proposed solution architecture and within the MVP framework.

In the future, it is suggested to expand the service's functionality by adding the ability to upload and analyze multiple products simultaneously for comparison and improved diagnostics. It is also recommended to integrate an intelligent agent that could provide consultations, manage objections, and answer user queries. After testing all metrics and receiving positive feedback from users, further product upgrades using more advanced technologies to improve analysis quality and accuracy may be considered.

Conclusion

During the research, an IT architecture for a minimally viable product (MVP) web service in a cosmetic company was proposed and tested. The application of internet search technologies, parsing, and generative artificial intelligence models enabled the creation of functionality for analyzing cosmetic products with minimal costs and resources, providing high accuracy and fast processing of user queries. The developed solution demonstrated its effectiveness. The accuracy results and data retrieval for the products showed high performance, confirming the viability of the chosen technologies for the MVP.

The goal of the research, which was to develop an MVP product for personalized cosmetic product analysis, was achieved. The completion of the research tasks led to the following results:

1. The analysis of existing technologies in the cosmetics industry justified the choice of suitable tools for solving MVP tasks. Technologies such as AI, ML, OCR, and AR were studied and adapted, showing high potential for integration into cosmetic services.

2. The development and testing of the IT architecture concluded with the successful creation of a prototype, which included the interaction of microservices and the integration of external APIs for processing and analyzing cosmetic product data. Testing results confirmed the stability of the architecture and the processing speed of user queries, averaging between 5 and 15 seconds, which met the MVP requirements.

3. Recommendations for improving the user experience and further product development were formed. Based on the collected data and testing results, recommendations were developed to improve the service, aimed at enhancing usability and personalizing recommendations.

Despite the achieved results, several aspects were beyond the scope of the current research. The MVP product did not yet support simultaneous analysis of multiple products, which could limit the functionality of the service. Additionally, an intelligent agent has not been implemented yet, which could interact with users, provide consultations, and handle objections. These areas open up opportunities for future developments and improvements.

Potential directions for further research include:

1. Adding the ability to analyze multiple cosmetic products simultaneously for more accurate compatibility diagnostics.

2. Developing and integrating an intelligent agent to improve user interaction and enhance service automation.

3. Expanding the database to include more ingredients and products, which would improve the accuracy of recommendations and broaden the service's application.

These improvements and development directions will help create a comprehensive platform for automating services and enhancing customer satisfaction in the cosmetics industry.

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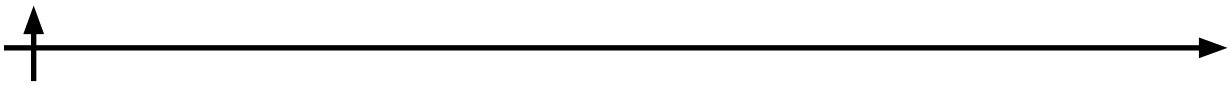

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IMPROVEMENT OF PERFORMANCE INCENTIVES IN HOSPITALITY EMPLOYEES ON THE BASIS OF BUSINESS PROCESS OPTIMIZATION

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Abstract. This research is devoted to the optimization of business processes in human resource management (HR) in order to improve performance incentives. Theoretical and methodological aspects of the formation of an HR management system are presented. The authors specify and describe the formation of an HR strategy and labour incentive policy in the hospitality industry. As a result, the conducted study makes it possible to develop typical models of business process – "stimulation of personnel" at different detailing levels. The key disadvantages of the presented models are described, together with the main directions of their optimization and "TO BE" models.

Keywords: process approach, business process, human resource management, personnel policy, performance incentives, hospitality industry

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СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИЙ СТИМУЛИРОВАНИЯ ТРУДА ПЕРСОНАЛА ПРЕДПРИЯТИЯ ИНДУСТРИИ ГОСТЕПРИИМСТВА НА ОСНОВЕ ОПТИМИЗАЦИИ БИЗНЕС-ПРОЦЕССОВ

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Аннотация. Данное исследование посвящено оптимизации бизнес-процессов в области управления персоналом в целях совершенствования стимулирования труда. Авторами представлены теоретико-методические аспекты формирования системы управления персоналом на предприятии, описана отраслевая специфика формирования кадровой политики в индустрии гостеприимства. Разработаны типовые модели бизнес-процессов «Стимулирования персонала» разного уровня детализации. В результате, описаны ключевые недостатки представленных моделей, предложены основные направления их оптимизации, а также разработаны модели формата «to be».

Ключевые слова: процессный подход, бизнес-процесс, управление персоналом, кадровая политика, стимулирование труда, индустрия гостеприимства

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Introduction

Personnel management is a functional area of enterprise activity, which is a set of measures aimed at maintaining the quantitative and qualitative state of personnel, acting in its own interests and for the benefit of the organization as a whole (Rudenko, 2022; Chuvatkin, 2023).

The strategic approach to personnel management allows the enterprise to form the most effective model of the relationship between the organization and its personnel, which, in turn, contributes to the development of the competitiveness of the organization due to the specific characteristics of the service as a product of the economic activity (Ilyina, 2016; Evgrafov, 2017).

In this regard, in order to achieve a high level of hotel service provision and a competitive position in the market, it is important for the hotel to develop such labour incentive mechanisms that would develop their personal qualities and interest in their business, maintain their level of qualification, and motivate them to work (Klimova, 2022; Sarfraz, 2023). At the same time, it is important to understand that employee motivation is a key tool for organizing such a business, where the employee is self-directed to achieve the goals of the enterprise.

Materials and Methods

The study is based on fundamental research in the field of organization of personnel policy and formation of personnel management technologies (Rudenko, 2022), research in the field of organization of service activities and service implementation (Evgrafov, 2017; Ilyina, 2016), as well as works devoted to the role of data systematization and the role of the process approach to enterprise management (Smirnov, 2017).

The key research methods rest on the analysis of literature sources, as well as modelling of business processes using IDEF0 and BPMN notations.

Results and Discussion

The technologies of the personnel management system can be grouped in accordance with the stages of its formation into three blocks: formation and presentation of personnel composition, personnel development, and technologies aimed at ensuring the rational use of human resources (Kalinina, 2021).

In turn, within the block of technologies aimed at ensuring the rational use of human resources, there are methods of assessment, motivation, and dismissal of employees. Due to the fact that employee motivation technologies are revealed through the implementation of a number of functions, it becomes possible to present the following fragment of the functional model of the hotel enterprise in the context of the generalized function "Stimulation and motivation of labour" (Table 1).

Table 1. Fragment of the functional model of the hotel enterprise in the context of the generalized function "Stimulation and motivation of labour" (designed by the authors)

Functional area	Generalized function	Specific functions
Human Resources Management	Labor incentives and motivation	– standardization (tariffication) of the labor process; – development of material incentive system; – development of labor remuneration system; – development of the system of moral incentives; – development of forms of personnel participation in profits and capital; – management of labor motivation.

The activity of a hotel enterprise consists in the formation and provision of services, which are characterized by such features as inseparability from the service provider, intangibility, and impermanence (Chuvatkin, 2023). The inseparability of the hotel service from its performer is reflected in the fact that the staff plays a key part in its provision so that the guest evaluates and pays for the work and attitude of the employee (Kitsios, 2020; Kloutsiniotis, 2020; Walsh, 2001). Thus, employees of hotel companies, who have responsibility for the quality of services provided, should have a broad base of knowledge and skills in the design and implementation of service activities, which include standards and regulations of service delivery and customer-centeredness, as well as possessing digital competencies (Ilyina, 2016). In this regard, the issue of providing effective labour incentives is relevant for modern hotels.

From the point of view of the process approach to enterprise management, the technology generalized function "Stimulation and motivation of labour" is implemented within the framework of the supporting business process "Provision of personnel." As a rule, the following sub-processes, in particular, belong to the provision of personnel: staffing, determination of personnel needs, planning and recruitment, personnel adaptation, training and development of personnel, accounting, motivation, and evaluation (Havrylova, 2023; Stoyanova-Bozhkova, 2022).

Let us present the decomposition model of the business process “Personnel Incentivization” in IDEF0 notation using Figure 1.

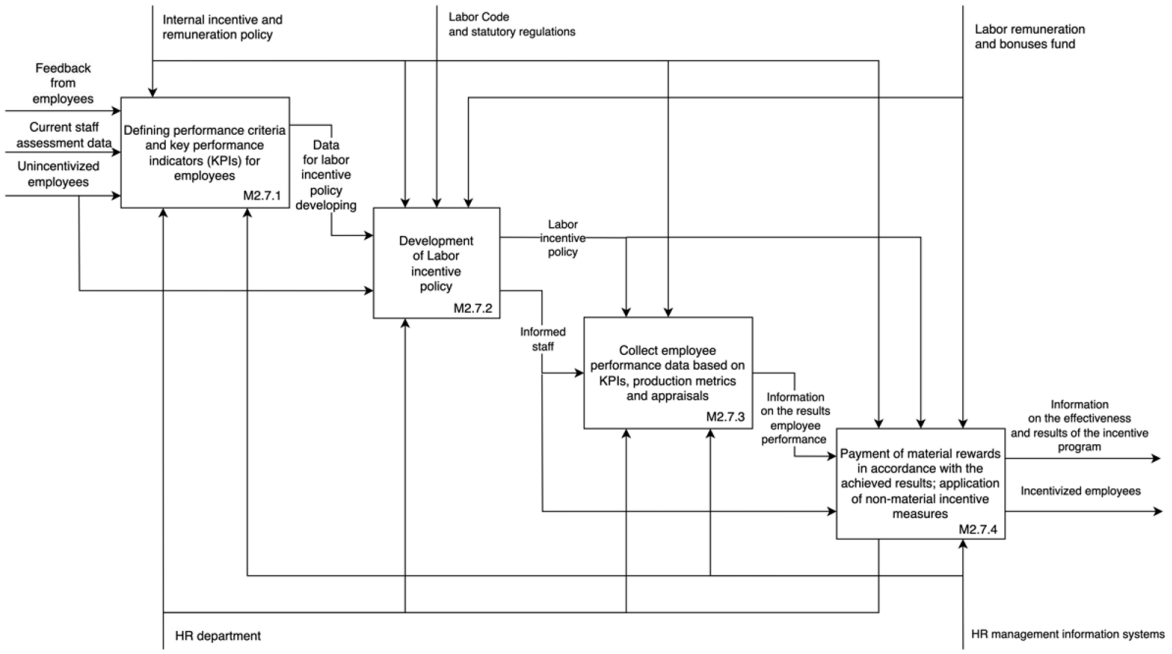

Fig. 1. Level 2 decomposition diagram of the subprocess “Personnel Incentivization” (M2.7) of the process “Personnel Provisioning” (M2) in the “AS IS” format (designed by the authors).

In this case, the process of personnel incentives can be represented as a sequence of the following logically interrelated sub-processes of the third level:

– M2.7.1. Defining performance criteria and key performance indicators for employees;

– M2.7.2 Develop a labour incentive policy;

– M2.7.3. Collect employee performance data based on KPIs, production metrics, and appraisals;

– M2.7.4. Paying material rewards according to the results achieved;

– M2.7.5. Application of non-material incentives.

Let's take a closer look at some of them. Figure 2 below shows the decomposition diagram of the 3rd level of subprocess M2.7.2 “Development of incentive policy” in IDEF0 notation in “AS IS” format.

According to the figure, the development of incentive policy at the enterprise is built up of consecutive steps, such as selection of incentive criteria (in particular, determination of KPI), selection of incentive types (determination of specific incentive tools), determination of frequency and conditions of incentives, coordination and approval of the system with the general director, organization of program coordination at all levels, and informing the employees about the system. By analyzing the diagram in Figure 2, it becomes clear that the process is rather labor- and energy-intensive, but it shows a sufficient share of efficiency.

Nevertheless, it is necessary to take a closer look at subprocess M2.7.2.4 “Organization of multi-stage process of agreement of the developed incentive system.” The process consists of inherently repetitive activities. The HR manager involved in the development of the incentive system has to coordinate this system first with the head of the HR department, then with external consultants, an accountant, a deputy director, and finally with the director himself. Each of the actors can send the system for revision and correction of inaccuracies, and therefore it may not reach the CEO. Thus, it can be understood that the limited resources of the enterprise,

which it could have allocated to the implementation of other processes and solutions, are not used efficiently.

The next sub-process that needs to be considered is M2.7.3 "Collecting employee performance data based on KPIs." Figure 3 shows the Level 3 decomposition diagram of this subprocess in BPMN notation in "AS IS" format.

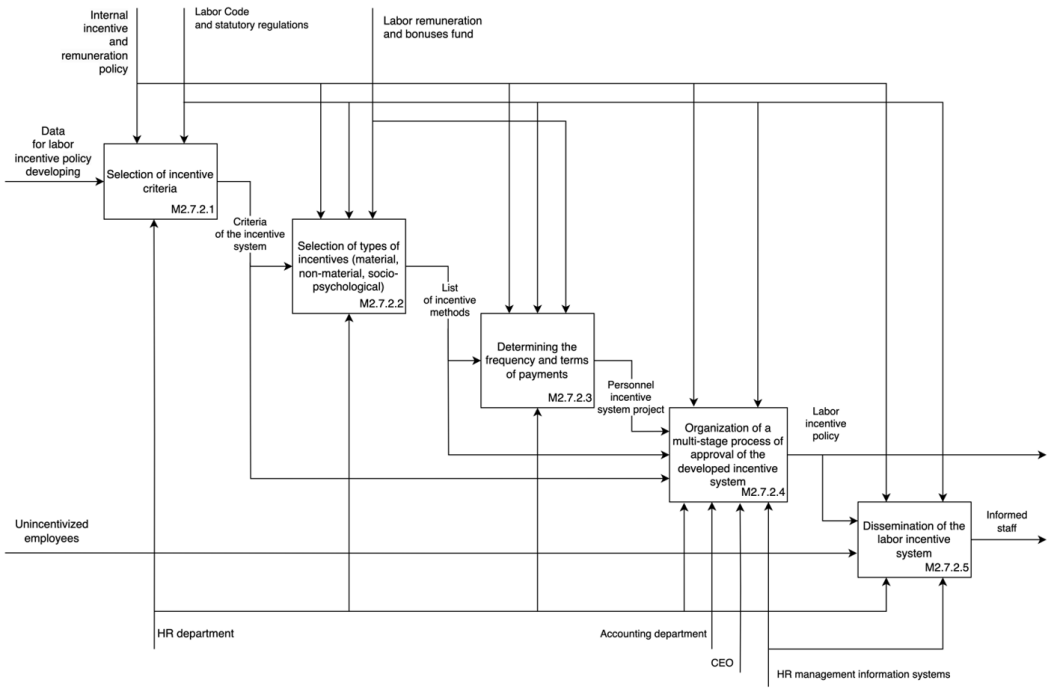

Fig. 2. Level 3 decomposition diagram of the subprocess "Incentive policy development" in "AS IS" format (designed by the authors).

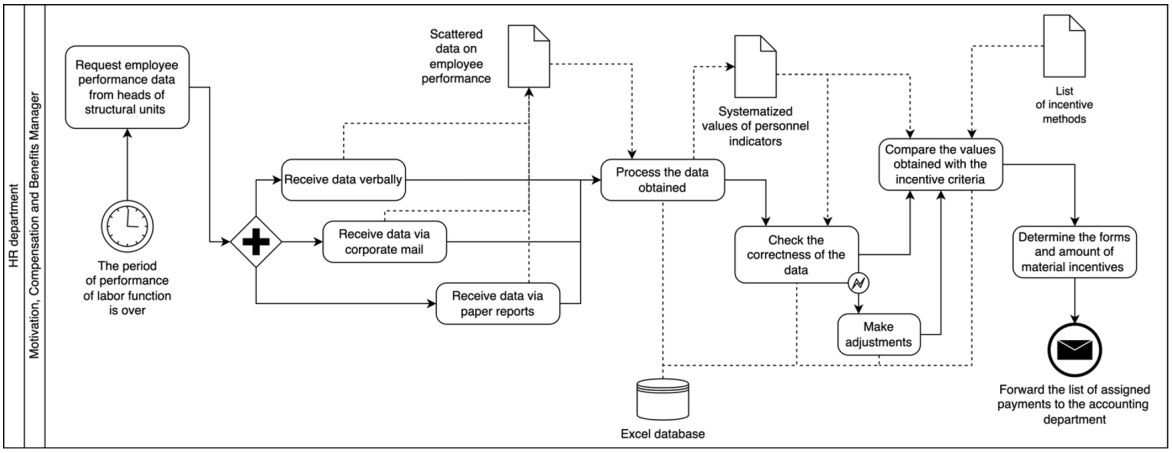

Fig. 3. Business process model "Collecting data on employee performance by KPI" in "AS IS" format (designed by the authors).

By analyzing the diagram in Figure 3, it can be concluded that the collection of employee performance data is done manually: the receptionists either verbally report the achieved performance indicators or send this information by e-mail to the HR department. The processing and assignment of entitlements is also done manually: the HR officer assigns the entitlement to each employee and transmits the information to the accounting department. Other than Excel, HR does not use any other software to record and store information on performance measures.

To solve the problems of personnel incentive technologies identified earlier, it is necessary to modernize business processes and update their information support technologies, which play a key role in ensuring operational efficiency (Smirnov, 2017 A. B., Ilyina O. V., 2017; Voronova O. V., Ilyin I. V., 2019).

Due to the fact that the enterprise does not conduct an initial analysis of the needs and motivation factors of employees, there is a significant risk of creating an incentive system that will not fully meet the needs of personnel. Therefore, it is necessary to introduce an additional stage, M2.7.2.1, "Conducting an analysis of personnel needs," which will be carried out with the help of questionnaires from McClelland, Sh. Ritchie, and P. Martin, and the Gerchikov test. It is also necessary to simplify the process of coordination of the incentive system because, for successful creation of the incentive system, it is sufficient to agree with the General Director on the final version of the regulations. Also, the CEO's involvement in the process should be minimized, as the entire HR department is involved in the development of the incentive system, bringing only the final version for approval (Pantha, 2024; Hsin-Ning Kuo, 2024; Klimovets, 2014).

The business process "Incentive policy development" (decomposition of the 3rd level process in IDEF0 notation) in the "TO BE" format, i.e., with corrected proposed changes, is presented in Figure 4 (changes and corrections are marked green in the diagram).

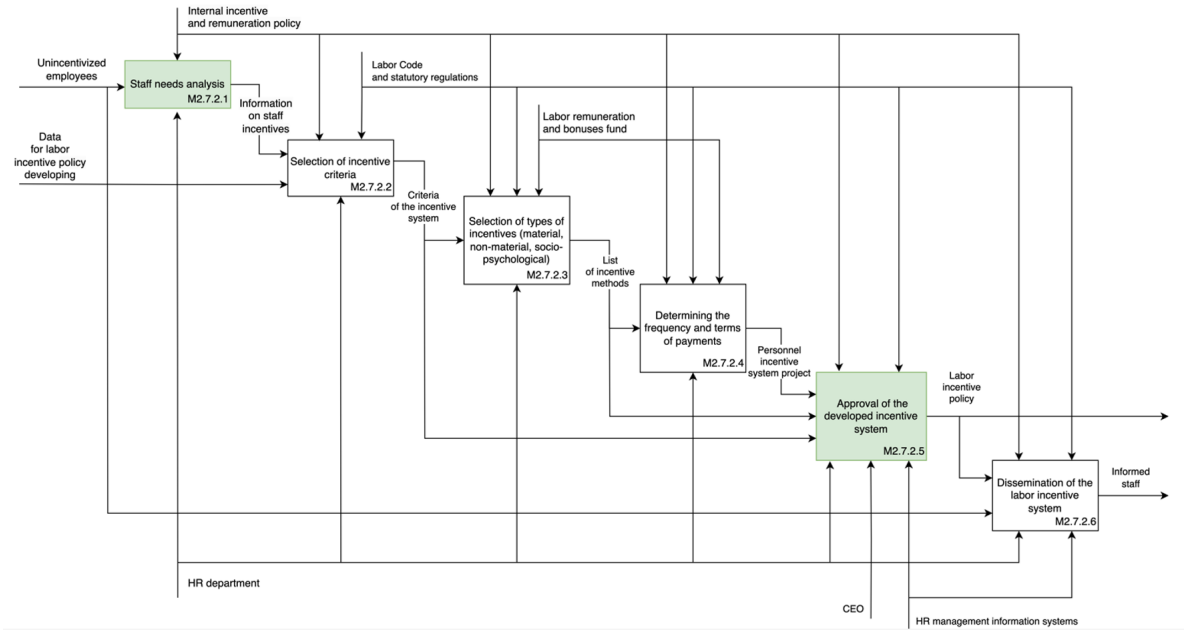

Fig. 4. Decomposition diagram of the subprocess "Incentive policy development" in "TO BE" format (designed by the authors).

Thus, improvement of the process of creation and development of an effective incentive system will lead to an increase in the efficiency of this system and the elimination of the risk of irrational waste of limited resources of the company.

In turn, due to the fact that the process of "Collecting data on employee performance on the basis of KPI" is complicated by the lack of automation in the field of obtaining data on employee performance, it seems appropriate to introduce special checklists, which are collected and transferred to the HR department by the head of operational services of the hotel (Gupta, 2023; Youssef, 2021). In this way, the process of information collection will be simplified, the risks of information loss will be eliminated, and the process of verifying the truthfulness of the

provided data will be simplified. It is also advisable to introduce new data storage software that will make it easier and clearer to enter information on compliance and performance indicators. For example, you can use the software "1C: Management by Objectives and KPIs." The last suggestion to improve the business process is to transfer the authority to determine the amount of payments to the accounting department, as this is the functional area of responsibility in the area of financial management and has sufficient qualifications. The HR department only needs to transfer information on the ratio between the fulfillment of performance indicators and the amount of payments.

The business process "Collecting data on employee performance based on KPIs" (decomposition of the 3rd level process in BPMN notation) in the "TO BE" format, i.e., with the proposed changes made, is shown in Figure 5 (the changes and corrections made are marked green).

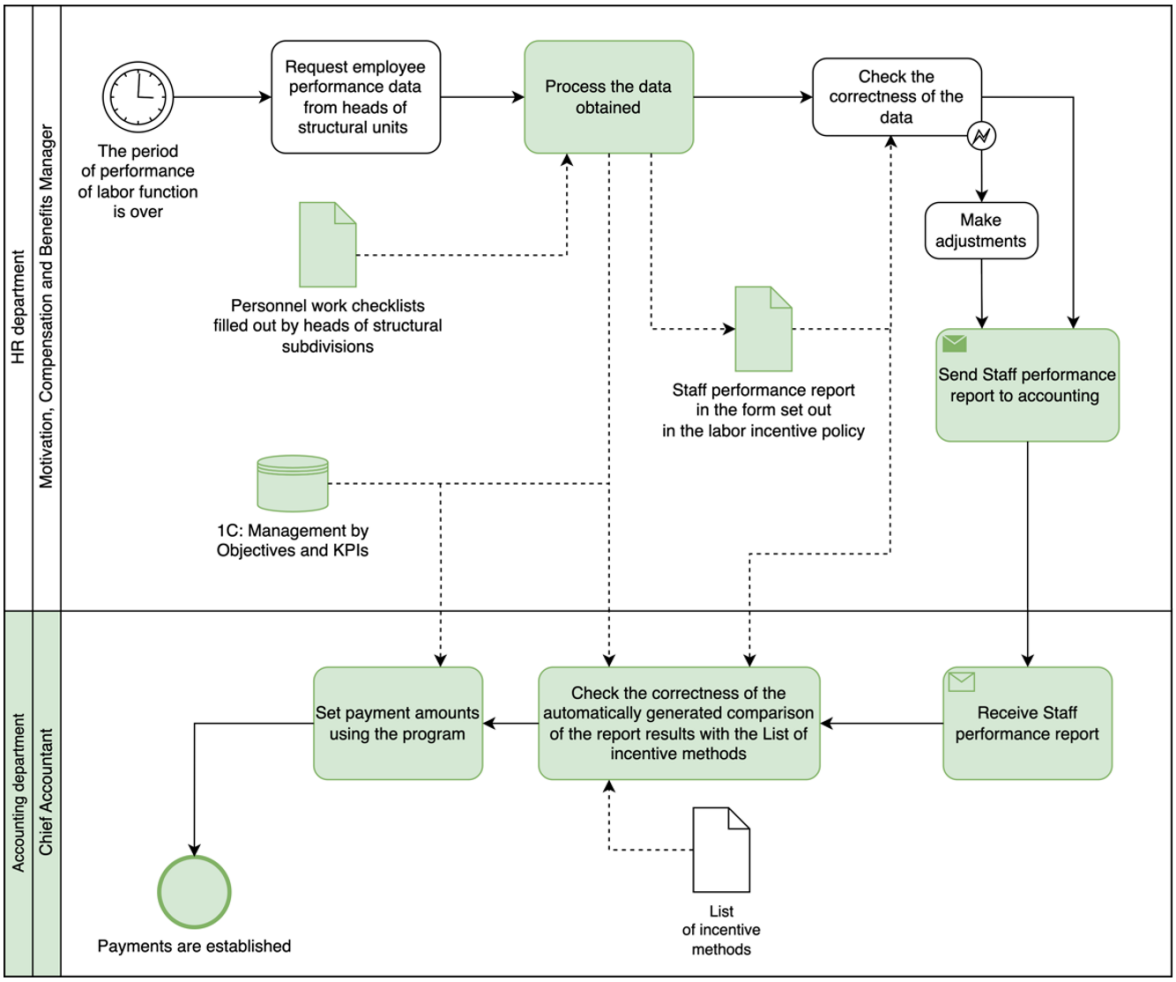

Fig. 5. Diagram of the subprocess "Collecting data on employee performance results based on KPIs" in "TO BE" format (designed by the authors).

Thus, improving the process of collecting employee performance data based on the KPI system will result in faster and easier access to information about employees and their performance, eliminating the risk of data loss or destruction. Separation of powers and distribution of tasks between departments will ensure high accuracy in determining payments and relieve the HR department, as well as contribute to the improvement of KPI indicators.

Conclusion

In the course of the research, such measures for optimization of personnel incentive technologies on the basis of business process re-engineering were proposed: simplification of the incentive system approval process; exclusion of external consultants' participation; reduction of the level of control over the process by the general manager to a minimum; automation of the process of obtaining data on employee performance; change of software for data storage; transfer of authority to determine the amount of payments to the accounting department; automation of the data collection process. It is assumed that implementation of the measures proposed above will lead to an increase in KPIs, revenue, and labour productivity and to greater cohesion of the hotel team, increased self-awareness of each individual employee, and the hotel as a whole.

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DIGITAL TOURISM ECOSYSTEMS AND PLATFORMS: THEORETICAL AND METHODOLOGICAL ASPECTS

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Abstract. This research considers the issues of digitalization of tourism. The need to create a universal digital platform in Russia as a result of the ecosystem approach is discussed at various levels, including state, education, and commerce. This study proves to be highly relevant because different strategies and investment initiatives are actively being undertaken in the industry. The attractiveness of the Russian regions is also increasing, thus contributing to the development of domestic tourism. The authors present a top-level comparative analysis of existing digital platforms and their limitations in meeting the needs of key stakeholders, and develop an algorithm of requirements gathering for the creation of a universal digital platform. As a result, a structured model for the development of a digital tourism platform is proposed, including the interests of stakeholders, functional roles of tourism market participants, as well as the necessary digital infrastructure. The obtained results can serve as a methodological basis for the development of a tourism ecosystem that promotes the interaction of market participants and increases the availability of industry tourism services.

Keywords: digitalization, ecosystem approach, digital platforms, tourism, tourism digital platform, integrative model

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ЦИФРОВЫЕ ТУРИСТИЧЕСКИЕ ЭКОСИСТЕМЫ И ПЛАТФОРМЫ: ТЕОРЕТИКО-МЕТОДОЛОГИЧЕСКИЕ АСПЕКТЫ

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Аннотация. Данное исследование посвящено вопросам цифровизации сферы туризма. Необходимость создания в России универсальной цифровой платформы в результате применения экосистемного подхода, обсуждается на государственных, образовательных и коммерческих уровнях. Актуальность исследования подтверждается стратегиями развития и инвестиционными инициативами отрасли, а также политикой повышения привлекательности регионов России и развития внутреннего туризма. В рамках исследования представлен верхнеуровневый сравнительный анализ существующих цифровых платформ, их ограничения в удовлетворении потребностей ключевых стейкхолдеров. Сформулирован алгоритм сбора требований для создания универсальной цифровой платформы. В результате предложена структурированная модель разработки цифровой туристической платформы, включающая интересы стейкхолдеров, функциональные роли участников туристского рынка, а также необходимую цифровую инфраструктуру. Полученные результаты могут послужить методологической основой для разработки туристической экосистемы, способствующей взаимодействию участников рынка и повышению доступности услуг отраслевого туризма.

Ключевые слова: цифровизация, экосистемный подход, цифровые платформы, туризм, туристская цифровая платформа, интегративная модель

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Introduction

The potential for the development of domestic tourism in Russia has been widely discussed in recent years. Since tourism products with service forms are significantly sensitive to the economic environment (Evgrafov, 2017; Artamonova, 2019), the development of the tourism market is positively influenced by the decentralization of economic routes to the regions, government support, changes in consumer preferences, increased interest in domestic travel, and the creation of new tourism infrastructure. In addition to creating and maintaining infrastructure for tourists, an important task is the digitalization of tourism, which is also actively encouraged by the state. Formation of a single economic space as a result of the integration of tourism market participants and processes within the digital ecosystem will provide domestic tourism with new opportunities and development prospects (Ilina, 2013; Golovina, 2019; Prasanth, 2024).

Recently, new tourism trends have been developing, arising at the junctions of industries (e.g., industrial tourism, ecotourism). This complicates the task of creating a single integrative model of tourism, making it cumbersome and difficult to grasp. Existing examples of tourism-related digital platforms, although successful, are limited in both tools and data volume. At

the same time, the mentioned issues of tourism, which are at the nascent stage, cannot be fully covered by existing solutions and require the application of innovative design tools in service activities (Ilyina, 2016).

In this regard, this research aims to develop an algorithm for creating a digital tourism platform as a tool for industry development, which will take into account international experience in the field, theoretical and methodological foundations of the ecosystem approach, and the latest tourism trends. This model could be adapted to different segments of the tourism market.

Materials and Methods

As a methodological basis of this research paper the authors relied on the ecosystem approach to the design of digital solutions in tourism (Serdukov, 2023; Voronova, 2024). In order to collect information on the experience of the development and functioning of tourism platforms, the tourism platforms of different segments of the tourism market were analyzed, including "Industrial Ring of Moscow Region," "Online Guide to Industrial Tourism in Russia," "Digital Ecosystem of Zheleznovodsk," "Svoye Farmstvo," "RUSSPASS," and "Turizm.rf". The methodology of this paper also employs the following research methods: analysis, deduction, induction, and description.

Results and Discussion

A tourism ecosystem is defined as "an innovative entrepreneurial ecosystem, where a group of interconnected stakeholders share tourism resources and infrastructure of a territory in the process of creating, promoting, and realizing competitive tourism products, goods, and services for tourists to achieve mutually beneficial goals, including joint creation and use of digital platforms" (Serdukova, 2023; Kalabukhova, 2020; Матиљнковб, 2024).

Existing research on digitalization of tourism by designing digital ecosystems focuses on the analysis of individual platforms and their functionality but does not provide a unified approach to their development (Gu, 2024). Examples of platforms such as RUSSPASS, VisitBritain, and other national tourism services demonstrate successful practices but remain restrained in their ability to adapt to new types of tourism. Table 1 summarizes the major features of Russian digital platforms for further analysis.

Table 1. Comparative analysis of online travel platforms

Platform	Description	Main functions	Target audience	Benefits	Drawbacks
"Industrial Ring of the Moscow Region" online service	Portal for booking trips to the enterprises of the Moscow region	Aggregation of routes to industrial sites, booking of trips	Tourists, industry, government	-highly specialized platform; -promotes industrial tourism in the region; - supported by the government	- territorially limited; - no integrated booking system, only external links
Online guide to industrial tourism in Russia	All-Russian database of excursions to enterprises	Information on excursions, routes and businesses	Tourists, guides, businesses	- wide database; - convenient interface; - promotes the development of industrial tourism in the regions	- lack of personal accounts for tourists; - complicated mechanisms of business interaction with the platform

Platform	Description	Main functions	Target audience	Benefits	Drawbacks
Zheleznovodsk digital ecosystem	Travel platform focused on regional vacations, bookings and itineraries	Tourist navigation, reservations, events	Tourists, businesses, local authorities	- full-fledged smart city ecosystem with various services	- territorially limited; - focused on one city; - aimed mainly at urban tourism and trade
RUSSPASS	Digital service for travel planning in Russia	Personalized itineraries, hotel and trip bookings	Tourists	- high integration with other services; - convenient route planning	- limited opportunities for non-standard tours (e.g. industrial or agritourism); - focus on large cities
“Own Farming” (Svoye Fermerstvo)	A platform to promote agricultural tourism and farms	Agritourism platform, booking farm tours	Tourists, farmers	- local business support; - user-friendly interface	- insufficiently developed booking and itinerary functionality
Tourism.rf	Government platform on tourism in Russia, includes routes, attractions, events	Information portal about tourism, routes and attractions	Tourists, investors, businesses	- large database; - government support; -easy information search	- does not include booking; - weak content personalization

Overall, existing digital solutions successfully fulfill the following functions:

– aggregation of data on attractions, events, businesses, and excursions;

– booking of excursions through external sources or deferred booking;

– access to interactive maps with possibilities to create complex tourist itineraries;

– commercial and partnership relations with representatives of local businesses;

– popularization of domestic tourism (history, video content, virtual tours).

At this stage, the digital environment of tourism in Russia is in the phase of active development. It successfully fulfills the tasks of popularizing domestic tourism, simplifying navigation of tourist resources, and increasing the economic attractiveness of regions. The existing digital solutions are mainly focused on cultural and recreational tourism and, despite the limitations, meet the needs of users to a large extent.

At the same time, the existing systems require modernization and expansion in order to catch up with the requirements and needs of sectoral areas of tourism, such as industrial, agricultural, educational, and others. Despite the narrow specialization of sectoral areas of tourism, its contour includes a greater number of participants, stakeholders, and the system of their interactions. In this regard, the conditions for the effective functioning of the platform expand. In order to realize the algorithm for the development of a universal digital platform, it is advisable to consider the interests of all stakeholders in different systems of their interactions to form the most complete map of interests. Table 2 summarizes the limitations of existing platforms from the perspective of each stakeholder.

Table 2. Limitations of existing systems

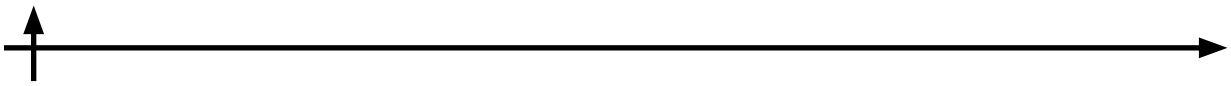
Stakeholder	State	Businesses - enterprises of the tourism industry (tour operators, travel agencies, hotel sector, tour guides, transportation companies, restaurant business)	Enterprises of other industries (plants, factories, farms, scientific centers, etc.)	Tourists (individual, groups, corporate, etc.)
Limitations of existing systems	- lack of sectoral tourism analytics, complexity of collecting a lot of information; - low level of integration with GIS; - low level of involvement of enterprises and businesses in sectoral tourism	- lack of understanding of the needs of industry travelers; - lack of tools and data to analyze consumer behavior; - limited opportunities for promotion and advertising integrations	- lack of effective communication channels with target audiences and partners; - lack of a single transparent mechanism of the process of organizing excursions and interaction with tourists; - difficulties in elaboration of routes at the enterprise and excursion material	- limited information about excursions, disparate information on different platforms; - lack of convenient tools for creating individual itineraries; - insufficient integration with digital services, which complicates the process of booking, buying tickets and other services.

Despite the active development of digital platforms in tourism, their functionality remains fragmented and does not comprehensively take into account the needs of different stakeholders, especially in the field of industry tourism. To address this issue, this study proposes to create a structured algorithm for gathering requirements in a future platform as a preparatory stage for the development of a universal digital platform. The requirements for the platform should take into account not only the interests of stakeholders but also the complex interaction between interested structures.

Defining the goals of the future platform and the target audience is the first step of requirements gathering. The format of interaction on digital platforms can vary: B2B, B2C, and hybrid format.

The B2B format consists of interaction between businesses—travel companies, enterprises, educational institutions, etc. Such a format will be convenient for corporate groups of tourists who, for example, work in different industrial enterprises of the same industry and want to regularly share best practices and technologies with each other (Linton, 2020; Raxmanova, 2024; Nurulla, 2021; Baggio, 2014). However, it does not take into account the interests of a large proportion of independent travellers, who do make up the bulk of consumers. The B2C format is focused on the interaction of business with the end consumer—tourists. These are the platforms that were analyzed in the framework of this study earlier, and their limitations were identified. The mixed model implies the presence of different mechanisms of interaction both between businesses and businesses directly with tourists. This format is most appropriate for the realization of a platform with the possibility of complex interaction of stakeholders.

Identification of the main and possible stakeholders with a description of their interests and



pains can be considered one of the most important stages of the elaboration of the image of the future platform. The key stakeholders of the tourism ecosystem have been described in Table 2:

– tourists—end users of tourist services (individual tourists, groups of tourists, corporate tourists);

– businesses—tour operators, hotels, excursion bureaus, transportation companies, restaurateurs, and other business representatives providing comfortable conditions and additional services for tourists;

– government—bodies responsible for tourism development, regulation of standards, and business support (Ministry of Economic Development of the Russian Federation, Ministry of Industry and Trade of the Russian Federation, Government of the Russian Federation, President's Office);

– enterprises: factories, production complexes, scientific and industrial centres, agro-industrial complexes, and other enterprises interested in conducting excursions.

In the future, the platform's toolkit can be expanded due to the increasing needs of stakeholders. Thus, the following participants can be added to the system:

– educational institutions—universities, colleges, centres of additional education, and other educational institutions interested in organizing educational tours;

– cultural and scientific organizations—museums, research centres, innovation clusters;

– online project offices—interested in supporting and scaling innovative solutions.

The business model of the platform will determine the availability of functions and roles, as well as regulate the relationship between the platform holder and other stakeholders. If there is public participation in financing, the use may be free of charge for participants, as it is implemented according to state strategies for regional and domestic tourism development. Commercial models can be built on subscription (users or businesses pay a subscription for access to additional features) or on transaction fees (monetization through a percentage of bookings, ticket sales, and excursions). Of course, in addition, a hybrid model is also possible—which will combine several sources of income; for example, for tourists and businesses, access to the platform is free, businesses that place their services need to subscribe, and monetization of transactions will be carried out according to the terms of digital services.

Defining and describing the functionality of the platform is impossible without first drawing up a list of active roles on the platform. They can be: tourist—an end user booking services; guide, tour guide—a person or a company offering excursion programs or who can respond and make a personalized itinerary; business companies—organizations promoting their own services that improve the experience of tourists (hotels, restaurants, transport companies, cultural centres); enterprise—a factory, farm, or other organization ready to host tourists; platform administrator—content moderation, data management.

The design of the digital infrastructure of the platform should be done in terms of platform usability, roles, and the most necessary actions. The main function is the aggregation of data on tourism destinations, businesses and attractions to visit, collective accommodation facilities, restaurants and cafes, guides and tour guides, available dates, etc. The platform's main function is the aggregation of data on tourism destinations, businesses, and attractions to visit; collective accommodation facilities; restaurants and cafes; guides and tour guides; available dates; etc. The personal account is one of the key features, thanks to which will be implemented not only the separation of roles but also personalized recommendations depending on the behaviour on the platform, as well as access to additional functionality necessary only for this ecosystem member. Search filters have now become an integral part of any online service (Popova, 2023; Cassia, 2020; Pencarelli, 2020; Khairetdinova, 2022; Baggio, 2020). Interactive maps with customized itinerary options, as well as virtual visuals such as AR/VR tours, will attract users to

the platform. In addition, it makes sense to think about optimizing the platform for different devices (computer, smartphone, tablet), as well as to determine the need for a mobile app.

In addition to the basic functionality of the platform, the ecosystem should minimize transitions to external services by integrating them into a single platform. It is advisable to consider connecting state information systems such as Gosuservices, Rosakkreditation, etc. for convenient identification and obtaining data on permits and licenses; payment systems to support online payment; online booking systems to make the process transparent and minimize manual processing of applications; and services for purchasing tickets for transport, events, and excursions.

Thus, the formation of a digital ecosystem of tourism requires an integrated approach that takes into account the interests of all stakeholders and provides convenient interaction between them. Defining the format of the platform, its business model, and active roles, as well as key and additional functionality, allows us to lay the foundation for the further development of a universal digital solution. The architecture of such a solution is presented in more detail in Voronova O. V. Vasiliev V.N. (2024).

The next stage is the formation of an algorithm for creating the platform, which will ensure the step-by-step implementation and integration of all necessary components. This algorithm covers the key stages of design, starting from conceptual planning and ending with the implementation of digital tools that ensure the usability and efficiency of the platform.

The algorithm for developing a digital platform for industry tourism is as follows:

1. Defining the objectives of the platform and key stakeholders. What problem does the platform solve? For whom is it being created? What is the format of interaction between the participants of the ecosystem? Which stakeholders are key, and which can be included in the ecosystem in the future?

2. Defining the business model. Will the platform include paid services, for whom, and in what format? What sources of revenue and monetization will be used? What will help ensure the cost-effectiveness and sustainability of the platform?

3. Defining the functional requirements of the platform and digital infrastructure. What main services should be implemented and integrated? What additional services could be useful in the long term? What roles for users should be prescribed?

4. Integration of external services. What services should be integrated: GIS, license registries, payment systems, online booking systems, etc.?

5. Platform testing, error correction, and launch. What methods will be used to test the platform after launch—feedback forms, surveys, tracking consumer behaviour?

6. Scaling the model, potential areas for development. What are the key areas of platform scaling, and what is their priority? What services are expected to be integrated in the future?

The algorithm of the digital ecosystem of tourism is presented in Figure 1.

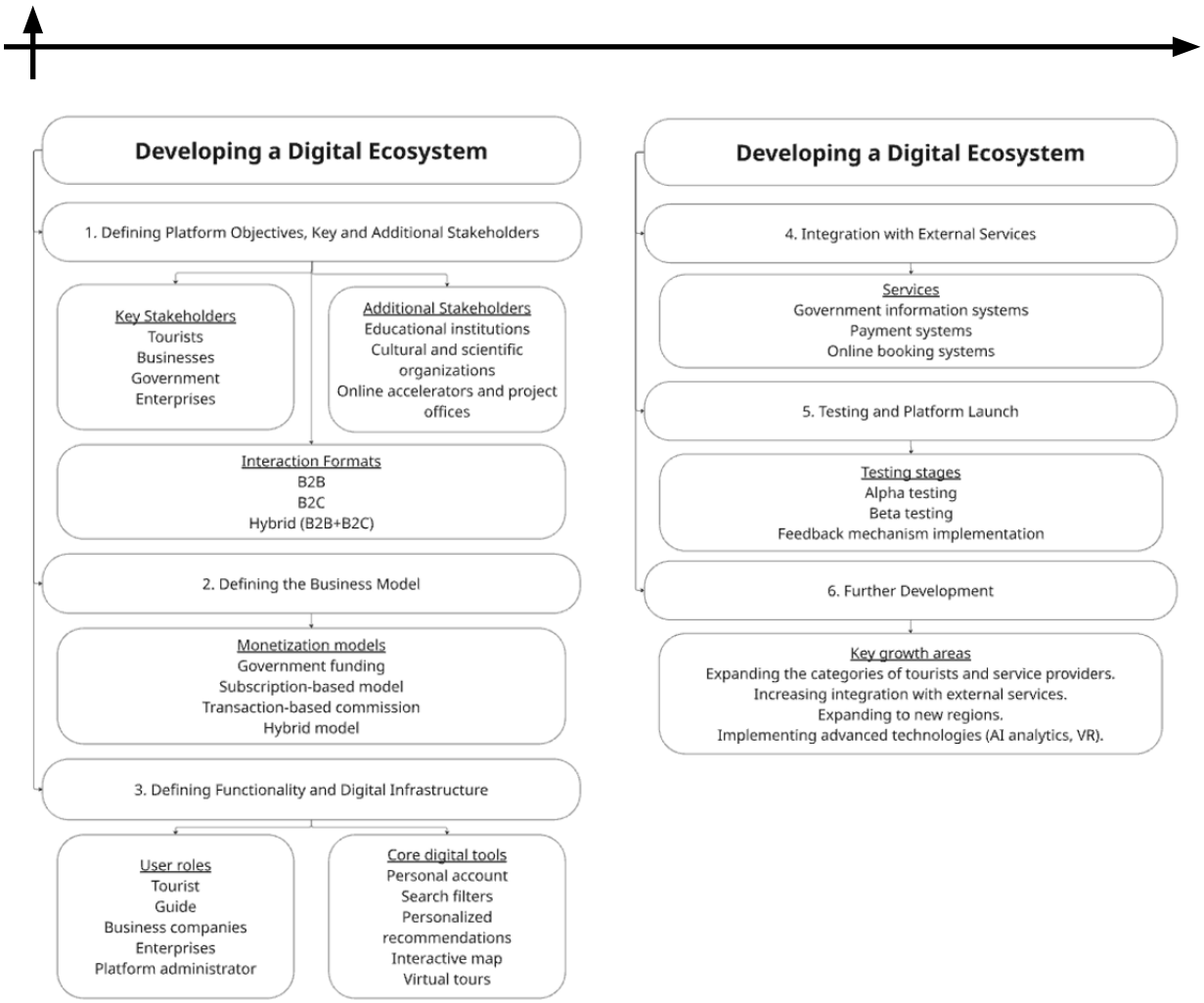


Fig. 1. Model of digital tourism ecosystem.

The developed algorithm for creating a universal digital platform for industry tourism is a structured model aimed at systematizing the processes of interaction between key stakeholders and providing an effective digital environment for the development of specialized tourist destinations. The application of this algorithm will allow:

– creating a digital ecosystem that ensures the integration of various industries into tourism;

– increasing the accessibility of sectoral tourism through personalized navigation and booking tools;

– stimulating the development of small and medium-sized tourism-related businesses by providing convenient mechanisms for promotion and interaction with customers;

– providing government agencies with analytical data for effective planning and support of sectoral tourism;

– promoting deeper integration of educational, industrial, and agricultural facilities into tourism activities.

Conclusion

The proposed algorithm can be applied as a methodological basis for the development of national and regional digital platforms aimed at the development of domestic tourism. Its application is especially relevant in the conditions of the digital transformation of the economy and the need to diversify tourism products.

Thus, the presented model of developing a digital platform for sectoral tourism not only meets the needs of key market participants but also contributes to the formation of a sustainable

and a win-win ecosystem capable of adapting to the changing conditions and requirements of the modern tourism sector.

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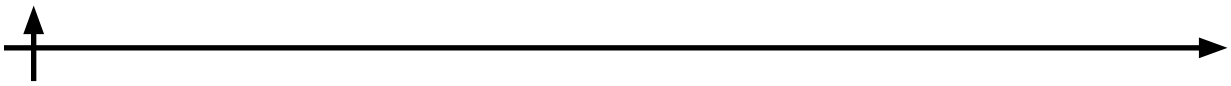

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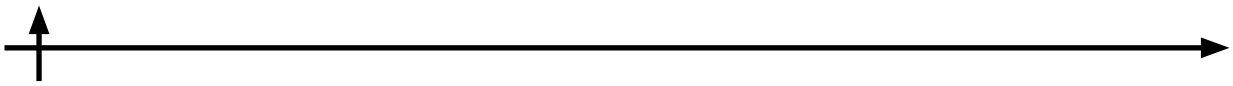

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