DECISION SUPPORT SYSTEMS
IN PROJECT AND PROGRAM MANAGEMENT

Collective monograph
edited by I. Linde

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LĒMUMU ATBALSTA SISTĒMAS PROJEKTU UN PROGRAMU VADĪBĀ

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The monograph presents the achievements of Ukrainian scientists in the field of business management, use of economic and mathematical modeling, information technologies, management technologies and technical means in the field of functioning, development, and project management at enterprises.

The publication is recommended for professionals in the fields of economics, information technology, project and program management – for undergraduate and graduate students, as well as academics and teachers of higher education.

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CONTENT

INTRODUCTION

The key to the successful operation of complex socio-economic and technical systems is their constant updating, adaptation to changing environmental conditions and appropriate self-regulation of the internal structure, processes and technologies.

The scientific and methodological developments proposed in the monograph relate to various areas of strategic development, the use of modeling and information technologies, project and program management technologies. They will help to improve existing processes and develop new ones in various sectors of the economy and production.

The issues of applying information technology in the management of dynamic objects in various industries are considered, each of which is characterized by the allocation of objects, management methods and their impact on the project as a way of organizing work to achieve a goal or solve a problem. Typical tasks that can be identified in project management are considered. Much attention is paid to the use of artificial intelligence methods.

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MODIFIED INSTRUMENTAL VARIABLES METHOD WITH SLIDING WINDOW

Anishchenko A., Timofeyev V. Yakushyk I.

The task of constructing a mathematical model of the object under study is not only of interest in itself, but is also part of the optimization problem, the quality of the solution of which depends significantly on the complexity of the model used. Therefore, in practice, it is often justified to simplify the mathematical model of an object and present it in the form of regression equations. In this case, the problem of estimating model parameters of the form

$$Y_n = X_n C_n^* + \Xi_n \tag{1}$$

where $Y_n = (y_1, y_2, ..., y_n)^T$ is the vector of output signals $n \times 1$; $X_n = \left(x_1^T, x_2^T, ..., x_n^T\right)$ – matrices of input variables $n \times N$; $C_n^* = \left(c_{1n}^*, c_{2n}^*, ..., c_{Nn}^*\right)^T$ – vector of estimated parameters $N \times 1$; $\Xi_n = (\xi_1, \xi_2, ..., \xi_n)^T$ – interference vector; n is discrete time and, subject to the usual assumptions of classical regression analysis, can be successfully solved using the least squares method (LSM). In this case, the essential assumptions are the absence of correlation between useful signals and interference, the absence of interference in the observed visible signals and the constancy of the estimated parameters c^*.

If, in the presence of correlated noise, the use of a generalized OLS is quite effective, then violation of other assumptions sharply reduces the effectiveness of the OLS.

Thus, if variables are measured with noise and there is a correlation between them, OLS estimates will be biased. In this case, it is advisable to use methods based on the use of specifically selected instrumental variables [1]. The instrumental variable method (IVM) estimate has the form

$$C_n = \left(W_n^T X_n\right)^{-T} W_n^T Y_n \ , \tag{2}$$

where W_n is the $n \times N$ matrix of instrumental variables.

In [2], a modification of the MIP was proposed, constructed by analogy with the generalized LSM and effective with corrected interference Ξ_n.

If the assumption of stationarity of parameters is violated, then the assessment, firstly, must be recurrent and, secondly, contain some mechanism for assessing the value of the information used. Such a mechanism can be either exponential weighting of information, which gives greater weight to newly received information, or some kind of sliding window, which also gives equal weight to a certain (usually fixed) amount of information taken into account [3].

An exponentially weighted recurrent MIP can be obtained by analogy with [2]. The goal of this work is to obtain a rcurrent form of MIP (RMIP) with a sliding window.

Let us denote the estimate obtained at the n-step over L previous steps, by analogy with [4] as follows:

$$C_{n/L} = \left(W_{n/L}^T X_{n/L}\right)^{-T} W_{n/L}^T Y_{n/L} \ , \tag{3}$$

where $X_{n/L} = \left(x_{n-L}^T, x_{n-L+1}^T, ..., x_n^T\right)^{-1}$, $W_{n/L} = \left(W_{n-L}^T, W_{n-L+1}^T, ..., W_n^T\right)^{-1}$ are $N \times (n-L)$ matrices; $Y_{n/L} = \left(y_{n-L}^T, y_{n-L+1}^T, ..., y_n^T\right)^{-1}$ – vector $n-L$; $L > n$ is the size of the sliding window (memory of the algorithm).

For the purpose of recurring forms, the modification of MMP is necessary obtained $jn(n+1)$ – step by L measuring,

$$C_{(n+1)/L} = \left(W_{(n+1)/L}^T X_{(n+1)/L}\right)^{-T} W_{(n+1)/L}^T Y_{(n+1)/L} \tag{4}$$

If you move to (4) the matrix and the vector are the same size as those in (3). If the ocean is half-way $(n+1)$-thous, it will take a larger number of measurements No, you can read the following statement:

$$C_{(n+1)/L} = \left(W_{n/L}^T X_{n/L} + w_{n+1} x_{n+1}^T - w_{n-L} x_{n-L}^T\right)^{-1} \left(W_{n/L}^T Y_{n/L} + w_{n+1} x_{n+1} - w_{n-L} y_{n-L}^T\right). \tag{5}$$

As can be seen from (5) and as noted in [4], a feature of algorithms with a fixed window is that the observation matrix $X_{n/L}$ (and, therefore, the IP $W_{n/L}$ matrix) and the vector $Y_{n/L}$ at each step are formed either by including newly received information $x_{n+1}(w_{n+1})$ and y_{n+1} or by initially eliminating outdated information and then introducing new information.

The corresponding algorithms implement the "accumulation-reset" and "reset-accumulation" rules.

In this case, the arrival of a new observation at the $(n+1)$th step allows us to obtain a new estimate for the $(L+1)$th observation

$$C_{(n+1)/(L+1)} = \left(W^T_{(n+1)/(L+1)} X_{(n+1)/(L+1)} \right)^{-1} W^T_{(n+1)/(L+1)} Y_{(n+1)/(L+1)} \tag{6}$$

where $X_{(n+1)/(L+1)} = \left(X_{n/L} \vdots x^T_{n+1} \right)$, $W_{(n+1)/(L+1)} = \left(X_{n/L} \vdots w^T_{n+L} \right)$ are $N \times (L+1)$ matrices.

Let's denote

$$P_{n/L} = \left(W^T_{n/L} X_{n/L} \right)^{-1}. \tag{7}$$

Then (6) will take the form

$$C_{(n+1)/(L+1)} = P_{(n+1)/(L+1)} W_{(n+1)/(L+1)} Y_{(n+1)/(L+1)} \tag{8}$$

Where

$$P_{(n+1)/(L+1)} = P_{n/L} + w_{n+1} x^T_{n+1} . \tag{9}$$

$$c_{(n+1)/L} = c_{(n+1)/(L+1)} - \frac{P_{(n+1)/(L+1)} w_{n-L}}{1 - x^T_{n-L} P_{(n+1)/(L+1)} w_{n-L}} \left(y_{n-L} - c^T_{(n+1)/(L+1)} x_{n-L} \right).$$

Applying the matrix inversion lemma to (9), we obtain

$$P_{(n+1)/(L+1)} = P_{n/L} - \frac{P_{n/L} w_{n+1} x^T_{n+1} P_{n/L}}{1 + x^T_{n+1} P_{n/L} w_{n+1}},$$

and substituting (10) into (8) and taking into account the block representation and, after simple transformations we have the following expression for the estimate corresponding to the accumulation of information

$$c_{(n+1)/(L+1)} = c_{n/L} + \frac{P_{n/L} w_{n+1}}{1 + x^T_{n+1} P_{n/L} w_{n+1}} \left(y_{n+1} - c^T_{n/L} x_{n+1} \right).$$

If outdated information is reset, the dimension of the matrices and vectors used in constructing the assessment decreases. Wherein

$$P_{(n+1)/L} = P_{(n+1)/(L+1)} - w_{n-L} x^T_{n-L}$$

or after applying the matrix inversion lemma

$$P_{(n+1)/L} = P_{(n+1)/(L+1)} + \frac{P_{(n+1)/(L+1)} w_{n-L} x^T_{n-L} P_{(n+1)/(L+1)}}{1 - x^T_{n-L} P_{(n+1)/(L+1)} w_{n-L}}.$$

The corresponding expression for the estimate after simple transformations will have the form

$$c_{(n+1)/L} = c_{(n+1)/(L+1)} - \frac{P_{(n+1)/(L+1)} w_{n-L}}{1 - x_{n-L}^T P_{(n+1)/(L+1)} w_{n-L}} \left(y_{n-L} - c_{(n+1)/(L+1)}^T x_{n-L} \right).$$

Thus, the recurrent MIP algorithm with a sliding window includes two procedures, the first of which, described by expressions (10) and (11), corresponds to the accumulation of new information (calculation of an auxiliary estimate when new information arrives), and the second, represented by relations (12) and (13), – resetting the outdated one.

The following must be said about the choice of initial values of the matrix (namely, for this algorithm it is involved in the calculations of matrices and). Since this algorithm starts working only after the number of observations becomes equal to the number of unknown parameters, i.e. at the initial stage coincides with the usual RMIP, then the choice occurs as in the usual RMIP.

By analogy with the above, it is not difficult to obtain relations for the RMIP algorithm with a sliding window, operating according to the "dump-accumulate" rule.

References

1. Eickhoff P. Fundamentals of identification of control systems. – L.: Mir, 1975. – 683 p.
2. Timofeyev V.A. Recurrent estimation by the method of instrumental variables in the presence of correlative noise // Proc. scientific proceedings based on the materials of the 5th International Conference "Theory and Technology of Transmission, Reception and Processing of Information". – Kharkov, 1999. – P. 467–478.
3. Perelman I.I. Operational identification of control objects. M.: Energoizdat. – 1982. – 272 p.
4. Liberol B.D., Rudenko O.G. Selecting the window width in the current regression analysis algorithm // Addendum of the National Academy of Sciences of Ukraine. – 1996 – No. 3. P. 69–73.
5. Rudenko O.G., Stefan A., Hubenal F. Recurrent least squares algorithm with a sliding window under correlated interference // Radioelectronics and Informatics. – 1998. – No. 1(02). – P. 79–81.

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INTEGRATION MODELLING IN SUSTAINABLE DEVELOPMENT PROJECTS OF ENTERPRISES

Bulavin D., Petrenko V.

The widespread use of project management methodologies shows a fundamental shift in how organizations struggle to cope with the complexity and volatility of the external environment. Decision making plays an important role throughout the entire project life cycle. The article examines the well-known methods of decision-making in project and program management and their analysis, in terms of procedures for systemic completeness and integration methodologies for managing projects, programs and project portfolios. This research focuses on the relationship between project management and decision-making processes, as well as potential opportunities for the integration of these scientific areas.

Introduction

To successfully solve the problems that Ukraine faces on the way to European integration, highly qualified project managers are needed. The widespread use of project management methodologies shows a fundamental shift in how organizations cope with the complexity and volatility of the external environment. The article examines promising strategies for managing integration in projects in order to describe different approaches to the formation of sustainable development strategies. It is expected that improved decision-making processes will increase the chances of successful project implementation. The implementation of the proposed scientific provisions will also help to ensure the growth of the efficiency of organization development.

Review of scientific literature on the topic

Methodological foundations for the management of qualitative decision-making procedures in the company was reflected in the emergence at the end of the last century by the ideology of continuous improvement management. As defined by Prosci [1], there are four main dimensions of the integration of scientific disciplines, namely: human resources, processes, tools, and results. It is expected that improved decision-making processes will increase the chances of successful project implementation.

Since the formation of the scientific discipline of Project Management, there are many standards or models developed for project management. The main institutions formed were the PMI Project Management Institute, IPMA (International Association of Management Systems) and some others based in Europe, which were formed around the same time period [2]. The Project Management Institute (PMI) was founded in 1969 and developed the PMBOK (Project Management Body of Knowledge), which is a set of standards established by consensus and approved by a recognized body. Basically, it was founded of how to succeed in project management. The main driving force behind its creation was the development of some form of certification for the profession. The adoption of the PMBOK is primarily based on the use of five groups of processes that integrate with ten areas of expertise, which ultimately aims to contribute to the successful implementation of the project [3].

These areas are recognized as fundamental aspects of integration and can form the structure of any study. The purpose of this study is to understand the experience of practitioners in implementing integration processes using various disciplinary approaches. The results have been analyzed following current scientific research, leading to some key recommendations for potential practitioners. According to many researchers, integrating project management methodology into management processes gives companies a real chance to provide organizational and resource support for the implementation of the enterprise strategy.

The article aims to analyze managerial design solutions and integrate them with the strategy of enterprise sustainable development.

Statement of the main material

At present, the activities of enterprises and organizations are carried out in the conditions of the knowledge economy and are based on the use of modern information technologies. Given the current state of information technology, each enterprise can accompany its products at all life cycle stages. An important aspect of the activities of enterprises is the correspondence of the level of knowledge, and skills of managers to apply the acquired knowledge to solve specific problems. Considering the above, It is expedient to carry out activities to create an integral information environment of the enterprise based on the project management methodology.

The study of the main interrelated factors that affect the level of development of enterprises, as well as the desire to ensure sustainable development [4], gave grounds to assert that one of the components of the strategy of an innovation-leading enterprise should be the widespread use of project management, based on successful international experience and combining the best practices of administrative management, technical management and others auxiliary disciplines of General Management.

Project Integration Management is a branch of project management that includes the processes necessary to ensure the coordination of various project management processes. Project integration management consists of the following components [5]:

1. Development of a project plan – creation of a final structured document based on the data obtained at the previous stages of planning.
2. Definition of success criteria – development of criteria for evaluating project implementation.
3. Implementation of the project plan – implementation of the project plan by performing the works included in it.
4. Overall Change Management – Coordination of changes across all project parameters.

One of the documents that should be used first is a description of the work on the project that is to be performed during its implementation. Such a description is usually made by the customer when formulating the project, determining its name, purpose and purpose. For external projects, where the employer is another legal entity in relation to the project executors, such a description may be made in the project financing memorandum (loan agreement, grant agreement). The second integration document can be drawn up in the form of a business plan [6]. Where the following sections of the project are contained:

1. Analysis of the market situation, made on the basis of marketing research of the enterprise implementing the project, which provide a market perspective for the implementation of the project product on the market and the return of money invested in the project.
2. Analysis of the needs and internal capabilities of the enterprise that is the customer of the project.
3. Description of the project customer's requirements for time constraints and project financing, as well as quality requirements for the project product.
4. Analysis of modern technical and technological achievements for the possibility of better implementation of the project and obtaining a greater guaranteed effect.
5. Legal and environmental requirements for the implementation of the project and the project outcome.
6. The organizational structure of the project, which should be based on the organizational structure of the enterprise.
7. A list of economic indicators and their expected parameters at the project end.
8. Investment and financial plans, production plan, etc.

As a third required document for the formation of the project charter, we can use the terms of the contract (agreement) for project management. Such an agreement provides a description of the composition and processes of a project management team forming, defines the working week, working conditions and reporting. Part of this contract can also be considered the terms of the contract for the financing of the project, which define the specific features of the project, in particular the requirements for procurement processes or sales of products [7]. The essence of the integration approach in the project documents is shown in Fig. 1.

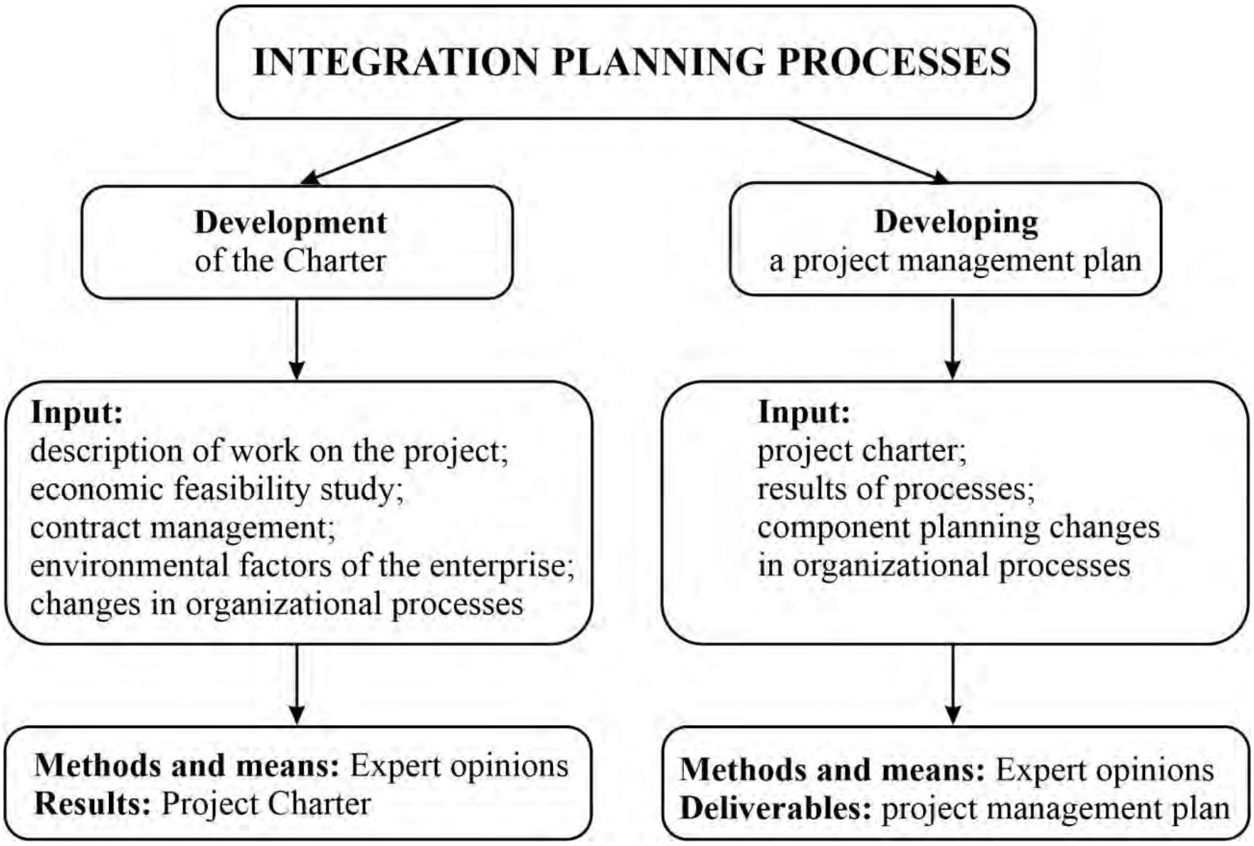

Fig. 1. The essence of the integration approach in the project

The main document on integration management is the project charter. The project charter is a brief description of the main data about the project: the main goals, objectives and main provisions of the project, the resources and conditions necessary for successful implementation, the timing and plan of the project. It is an official document that confirms the existence of the project, authorizes the project. The project charter is drawn up after conducting a project analysis, the purpose of which is to determine the value of the project. Project analysis includes such components as technical, financial, economic, commercial, social, environmental, and organizational analysis. The project charter performs various functions:

1. For the project manager, it is the basis for organizing work to achieve project goals and forming a project management system.
2. For the company's divisions, this is a regulatory document;
3. For contractors it is recommended actions that are defined in the contractual documentation for the project.

In general, the simplified structure of the charter has the following components: characteristics of the project; information about the project; the purpose of the project; project structure; participants of the project; project results, and restrictions of the project. The Charter may also contain: a description of the sources of the project funding; general description of the organizational structure of project management; distribution of responsibilities, functions and powers for project management.

As we know, the main objects of project-oriented management are several system concepts [8].

The concept of 3Ps (Project – Process – Product) is the basis of the model for creating a unique product or service within the framework of the implementation of innovations through projects.

The concept of 4Ps (Program – Project – Process – Product) forms the basis of the development model of any large-scale system (city, region, etc.) focused on the production of products or the provision of services.

The concept of the 5Ps (Portfolio – Program – Project – Process – Product) forms the basis of the model for creating a platform for the harmonious development of an organization or region.

Integration planning for project management is the process of developing a single internal project management methodology that combines the management of all objects (portfolio, program, project) and will ensure the implementation of the developed strategy and the achievement of its long-term goals. According to the definition of the project management standard:

A portfolio of projects is a set of projects that are implemented by an organization under resource constraints and ensure the achievement of strategic goals.

A program is a set of interconnected projects, the management of which is coordinated to achieve benefits and degrees of manageability that are not available when managed separately. The projects included in the program are united by a common goal, resources, deadlines, technology, etc.

Development project management is the continuous process of making management decisions by the project manager, regarding effective coordination of actions, in the project as a holistic system with unique indicators of value, quality, time, cost and stakeholder satisfaction. Classification of managerial decisions is necessary to determine general and specific approaches to their development, implementation and evaluation, which allows to improve their efficiency and quality. An example of a possible classification of management decisions is shown in Fig. 2.

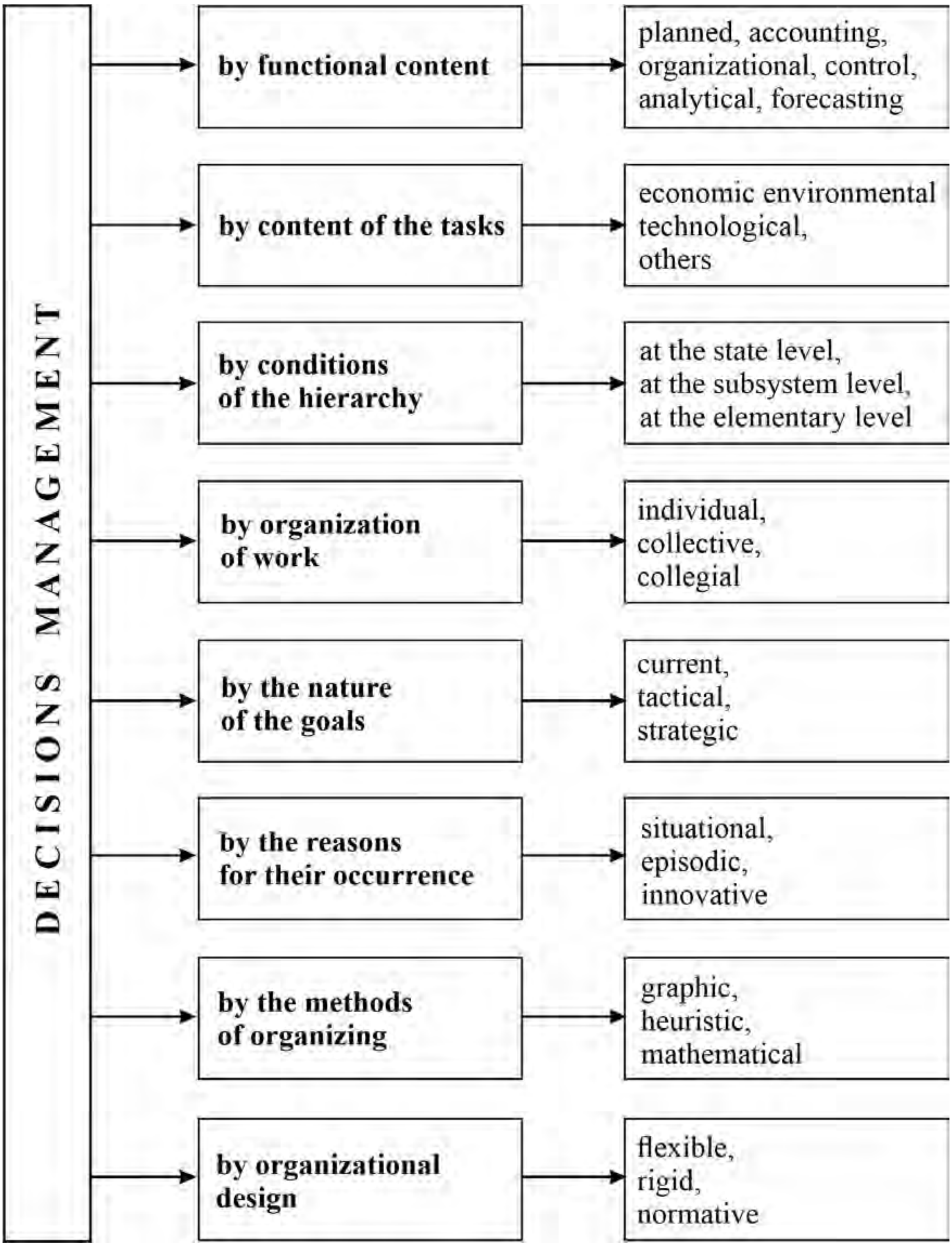

Fig. 2. Classification of management decisions

Rational technology of making and implementing a managerial decision involves the following stages: preparation, adoption and implementation of the decision.

1. Preparation stage – conducting a systematic analysis of the situation at the micro and macro levels; It covers the search, accumulation, processing of information, identification and formulation of problems that need to be solved and a thorough study of influencing factors.

2. The adoption stage includes the development and evaluation of alternative solutions, the determination of criteria for choosing the optimal solution, the selection and decision-making. Within the existing constraints, those solutions that meet the agreed criteria for solving the problem are selected from the developed solutions. The number of options proposed to solve the problem depends on the available resources, time, information needed to justify the decision, etc.

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3. Implementation stage – development of measures to specify the solution and bring it to the executors; monitoring its implementation; making the necessary adjustments; evaluation of the obtained result after decision implementation.

Successful management of the implementation of decisions requires not only a rational distribution of work among subordinates, but also the ability to set them up to perform tasks, to promote initiative. Motivation in the field of implementation of specific management decisions is stronger, the more significant is the participation in decision-making of direct participants in the performance of tasks [10].

Persons in leadership positions constantly have to make managerial decisions of a strategic and tactical nature. Improving the quality of organizational management can be achieved by improving the quality of management decisions, coordination, control, as well as by creating more advanced management systems.

An organization can achieve much more success if it identify and articulate its vision, mission, and values. They should be defined in such a way that both the staff and the manager feel them on an intuitive level and keep them in mind on a daily basis.

Indicators of project activity are devoid of their significance as long as they remain untied to the key indicators of the organization, which constitute a balanced system of indicators in relation to the organization strategic goal (Fig. 3).

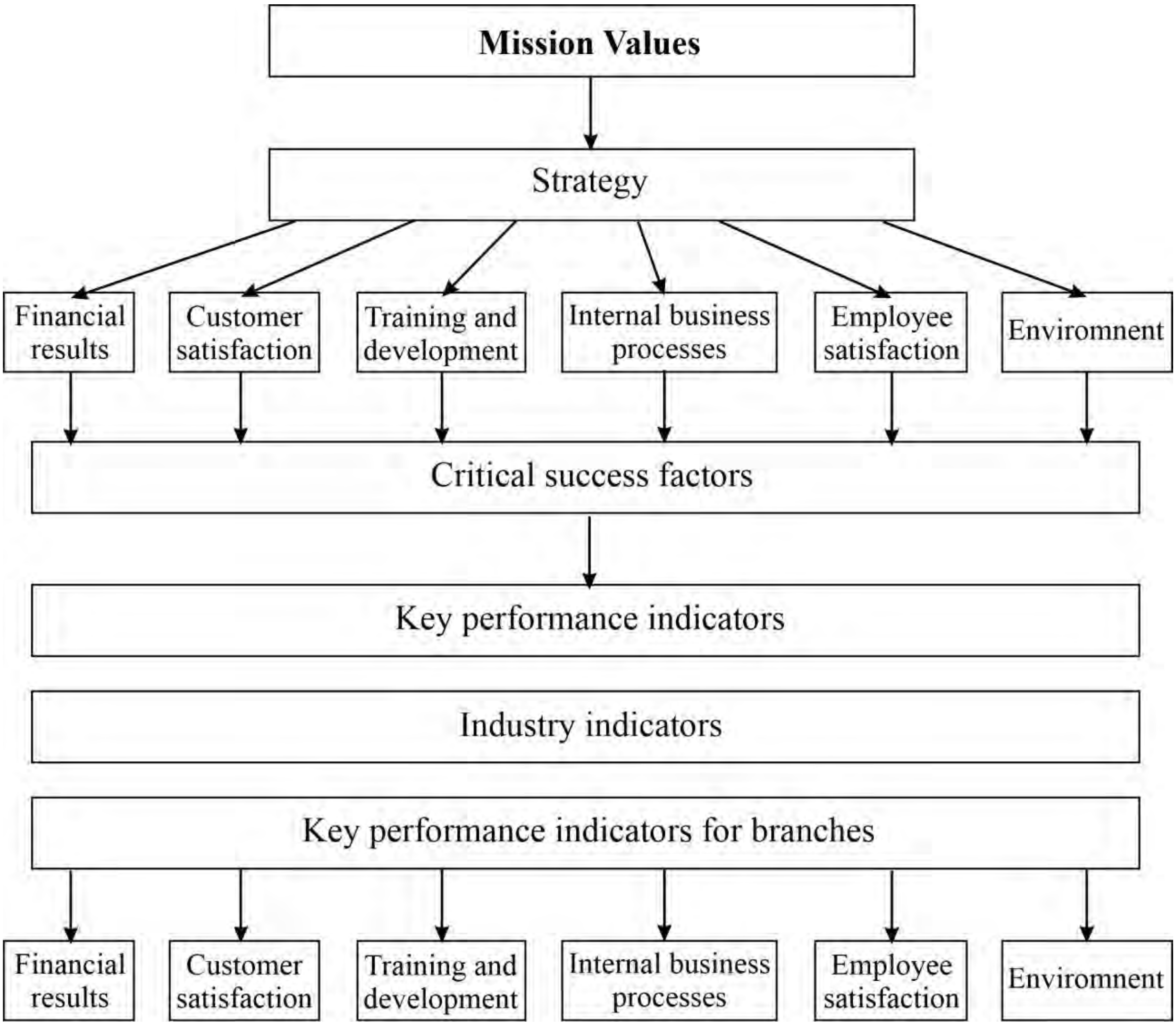

Fig. 3. A strategic goal depending on the mission and vision

The implementation of the key performance indicators system in an organization can take place in several stages.

Stage 1. Strategy formation

A well-articulated strategy describes the main steps to be taken to achieve the goal and desired results. The strategy should be broken down into specific strategic initiatives, within the framework of which tasks for individual structural units are allocated. The most important element of this stage is the prioritization of strategic initiatives and coordination between departments.

Stage 2. Identification of the most important success factors

At the second stage, the most important success factors are determined, that is, the parameters of the economic aspects of the organization's activities, which are vital for the implementation of its strategy.

Stage 3. Definition of key performance indicators

At this stage, indicators for the implementation of the strategy are being selected. The number of KPIs should be limited (for the feasibility of their implementation and the quality of monitoring). A tool for determining the most important success factors is KPIs, which, as quantitative indicators, are expressed digitally. In addition, the selected KPIs should incentivize employees to take appropriate actions.

Stage 4. Development and evaluation of the Balanced Scorecard

At this stage, a generalized system of financial and non-financial indicators is being developed, which will then be presented to management. Thus, the importance of this level is determined, since the combination of indicators, their informativeness and sufficiency will affect managerial decision-making.

The key indicators of successful integration of the KPI system are:

1. Pre-development of a strategy, which is a determining factor of success. The system of key performance indicators is only a tool for information support of the management decision-making process.
2. Determination of the goal of the enterprise, taking into account how much the achievement of the set goal increases financial costs.
3. Availability of an information system that is a source of data and a base for determining key performance indicators.
4. Management support, change in the style of corporate management and the system of staff incentives, since the system for evaluating key performance indicators is based on the assessment of the activities of a particular employee.
5. Constant use of the system, its introduction as a necessary permanent tool in the activities of management.

The positive effect of the implementation of the KPI system is a clear understanding of the purpose of this methodology and its limitations, which is really a very effective tool for information support of the decision-making process. It is important not only to have a KPI system, but also to constantly use it in practice, monitoring the implementation of strategic tasks. However, it should keep in mind that KPIs are unique for each industry; They can change in accordance with the progress of the organization towards the intended goal.

When implementing KPI technology, it is very important that the indicators used are clear to all civil servants involved in the process.

As projects become increasingly complex and require a more flexible, adaptable approach. Project management is moving away from a one-size-fits-all methodology, instead encouraging the adaptation of practices to meet the unique requirements of each project. Therefore, PMBOK 7 represents a paradigm shift from a process-based approach to a principles-based approach. While in PMBOK 6 integration management was about aligning and coordinating specific processes, PMBOK 7 emphasizes productivity areas. The focus is on integrating people, data, processes, and business systems to create, maintain, and develop a product or service throughout its lifecycle.

Conclusions

The article discusses the concept and essence of managerial decisions; which uses the project management methodology for sustainable development projects of organizations. The most important reserve for improving the efficiency of project management is to improve the quality of decisions made, which are achieved by improving the process of managerial decision-making.

The carried-out analysis makes it possible to visually assess the strategies of integration management in organizations that carry out project activities. A strategy for the development of the organization has been proposed, which is used to solve the strategic tasks of the system as a whole, with the help of the most significant key performance indicators combined into a system of balanced indicators. Key indicators of success and criteria for knowledge transfer, which are laid down in the universal model of strategic methodology, can and should be transformed into tools of different subject areas and can be transferred, ensuring the development of a methodology for managing projects, programs and project portfolios based on the balance of decisions made.

References

1. Prosci, 2018. Dimensions of Integrating Change Management and Project Management. [Online] Available at: https://www.prosci.com/change-management/thought-leadershiplibrary/dimensions-of-integrating-change-management-and-project-management [Accessed 17.07.2018].

2. Morris, P. W. G., Pinto, J. K. & Söderlund, J., 2012. The Oxford Handbook of Project Management, Oxford, UK: Oxford University Press.
3. Project Management Institute, 2013a. A Guide to the Project Management Body of Knowledge. Newtown Square, PA: Project Management Institute. Project Management Institute, 2018. What is Project Management. [Online] Available at: https://www.pmi.org/about/learn-about-pmi/what-is-project-management
4. Indicators for monitoring the state of achievement of the Sustainable Development Goals: methodology of data collection and calculation: analytical report / N. Vlasenko; with the support of the Global Environment Facility (GEF) and in cooperation with the United Nations Development Program in Ukraine, within the framework of the UNDP/GEF project "Integration of the provisions of the Rio Conventions into the national policy of Ukraine". 2017. 232 c. URL: https://www.undp.org/sites/g/files/zskgke326/files/migration/ua/UNDP_StatReport_v06.pdf
5. Project Management Guide (PMBOK Guide). ® American National Standard ANSI/PMI 99-001-2013. – 3rd ed. – Project Management Institute USA, 2013. – 388 p.
6. Project Management Guide (PMBOK Guide). ® American National Standard ANSI/PMI 99-001-2020. – 7th ed. – Project Management Institute USA, 2020. – 278 p.
7. Ahn, Y. H., Y. H. Kwak, and S. J. Suk. 2015. "Contractors' transformation strategies for adopting building information modeling". J. Manage. Eng. 32 (1): 05015005. DOI: https://doi.org/10.1061/(ASCE)ME.1943-5479.0000390
8. Eadie, R., H. Odeyinka, M. Browne, C. McKeown, and M. Yohanis. 2013. "An analysis of the drivers for adopting building information modelling". J. Inf. Technol. Constr. 1 (17):338–352.
9. Eastman, C.M., C. Eastman, P. Teicholz, and R. Sacks. 2011. BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. Hoboken, NJ: John Wiley & Sons.
10. Padar, K., Pataki, B. & Sebestyn, Z., 2011. A Comparative Analysis of Stakeholder and Role Theories in Project Management and Change Management. Special Issue: Circle Conference, International Journal of Management Cases.
11. Parker, D., Charlton, J., Ribeiro, A. & Pathak, R. D., 2013. Integration of Project Based Managment and Change Management. International Journal of Productivity and Performance Management, 62(5), pp. 534–544.

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FORMATION OF INVESTMENT ATTRACTIVENESS OF INTELLECTUAL CAPITAL OF ENGINEERING COMPANIES IN THE CONTEXT OF IMPROVEMENT OF INNOVATION ACTIVITIES MANAGEMENT

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The study examines the formation of investment attractiveness of intellectual capital of engineering companies in the context of improving their innovative activities. Market conditions and problems of the engineering services segment are studied, the need for domestic engineering enterprises to comply with the international regulatory framework is emphasized. The need to build modern marketing information systems as an element of increasing the intellectual capital of the company and the marketing activity of engineering companies in increasing the commercial potential of innovative technologies is substantiated. It is proposed to use modern technologies for managing innovation activities, such as design thinking, organizational laws adapted to the specifics of engineering using the capabilities of project management, and the latest methods of personnel training. The directions of forming the intellectual capital of engineering companies are studied. Directions for investing in the intellectual capital of an enterprise providing engineering services are developed. The organizational capital of engineering companies, conditions and factors for its increase are studied.

Introduction

Improving the innovative activities of engineering companies creates a solid foundation for innovative renewal and development of industrial enterprises and intellectual entrepreneurship in general. Consequently, the problems of engineering companies in Ukraine require research and development of directions for increasing their intellectual capital by forming and modeling the investment attractiveness of intellectual capital as the main source of profit in the context of its capitalization and commercialization of technologies in the digital knowledge economy.

Unfortunately, today there is a significant gap between the scientific achievements of leading scientists and the practical working conditions of engineering companies in their innovative activities. Therefore, it is necessary to increase efforts to combine science and practice, reduce the time of implementation of modern approaches to improving the management of innovative activities based on modern management methods and the exchange of practical experience of successful enterprises in the services and innovation market.

On this path, special attention and research are needed in the aspects of increasing the efficiency and success of innovative projects, which, in combination with attracted investments, form the innovative and investment basis for the innovative development of both the country as a whole and individual enterprises.

Ukraine's direction to the EU opens up opportunities to attract European investors and funds. The first step in this direction is understanding the importance of investing in the development of intellectual capital of companies, both enterprises-consumers of such technologies, and the engineering companies themselves, acting as intermediaries of the first two players, are able to more effectively implement technologies as a result of the development and implementation of innovation and investment projects. Taking into account the search for and attraction of investors, the second important step is to study the problems of increasing intellectual capital in the directions of its structural components and approaches to assessing the commercial potential of innovative projects, which are implemented by an engineering enterprise and directions for improving the management of its innovative activities.

Thus, the object of the study is the process of improving the management of innovative activities. The subject of the study is theoretical and practical approaches to the formation of investment attractiveness of intellectual capital in the directions of its structural elements to increase the commercial potential of innovative projects of engineering companies.

The purpose of the study is modern approaches to the development of investment attractiveness of intellectual capital and increasing the commercial potential of innovative investment projects (IIP) in the practical conditions of engineering companies. To do this, it is necessary to solve the following problems:

– study the market of engineering services and identify the problems faced by enterprises;

– formulate modern aspects of informatization at enterprises providing engineering services to increase their competitiveness;

– determine the importance of active marketing activities of engineering companies in increasing the commercial potential of innovative technologies;

– propose a design thinking methodology as increasing the efficiency of innovative activities of engineering enterprises;

– adapt the system of organization laws to improve the management of innovative activities of enterprises providing engineering services;

– provide recommendations on the use of modern management technologies for innovative development of the enterprise;

– study the directions of formation and capitalization of intellectual capital of engineering companies;

– develop directions of investment in the intellectual capital of the enterprise for the provision of engineering services;

– study the organizational capital of engineering companies, conditions and factors of its increase.

The issues of assessing the investment attractiveness of project portfolios, enterprises, industries, regions, and the state were the focus of such scientists as L. Gitman, J. Soros, W. Sharpe, A. Sheremet, I. Blank, A. Peresada, V. Shevchuk, P. Rogozhin, A. Goiko, M. Kreynina, and others. The concept of commercial potential of innovations was studied by leading scientists such as P. Pererva, T. Kobeleva, A. Butnik-Seversky, S. Ilyashenko, D. Korobkov, V. Pozdyakov, I. Posokhov, S. Sudarkina, B. Chernyshev, V. Sharpe, V. Charne, J. Schumpeter, A.I. Yakovlev, and others. Aspects of improving the management of innovation activities and increasing intellectual capital are devoted to the work of S. Ilyashenko, P. Pererva, V. Pozdyakov, I. Posokhova, V. Prudnikova, I. Repina, etc. But further research is required on the issues of forming the investment attractiveness of intellectual capital, increasing the commercial potential of innovative projects and improving the management of innovative activities in the field of providing engineering services.

Role of marketing activities in the process of forming investment attractiveness of intellectual capital

The structure of the study is based on understanding the essence and structure of intellectual capital and its role in managing the innovative activities of an enterprise providing engineering services (in Fig. 1), which, in turn, allows combining the areas of intellectual capital development through increasing investment attractiveness with increasing the commercial potential of technologies in the development and implementation of projects.

As can be seen from Fig. 1, engineering companies play an important role in the market of innovative technologies, they unite the enterprise-developer of the technology and consumers of the technology, in addition, they develop and implement projects for the implementation of technologies, and, therefore, to a certain extent, form the investment attractiveness of innovative investment projects for investors who evaluate not only the technology itself, but also the engineering company that will implement the project, primarily from the point of view of the intellectual capital owned by the engineering enterprise and the potential for the implementation of this capital, that is, how effectively the capitalization of intellectual potential occurs in a specific project. Thus, the definition of the directions for increasing intellectual capital forms the basis for improving innovative activities in general, which, in turn, leads to an increase in the commercial potential of innovative investment projects developed and implemented by the engineering company. The study is devoted to solving these issues. As stated above (see Fig. 1), the main factor of success of an engineering company is cooperation in the technology market with technology developer enterprises on the terms of system integration and the search for technology consumers-clients both in the domestic and international markets.

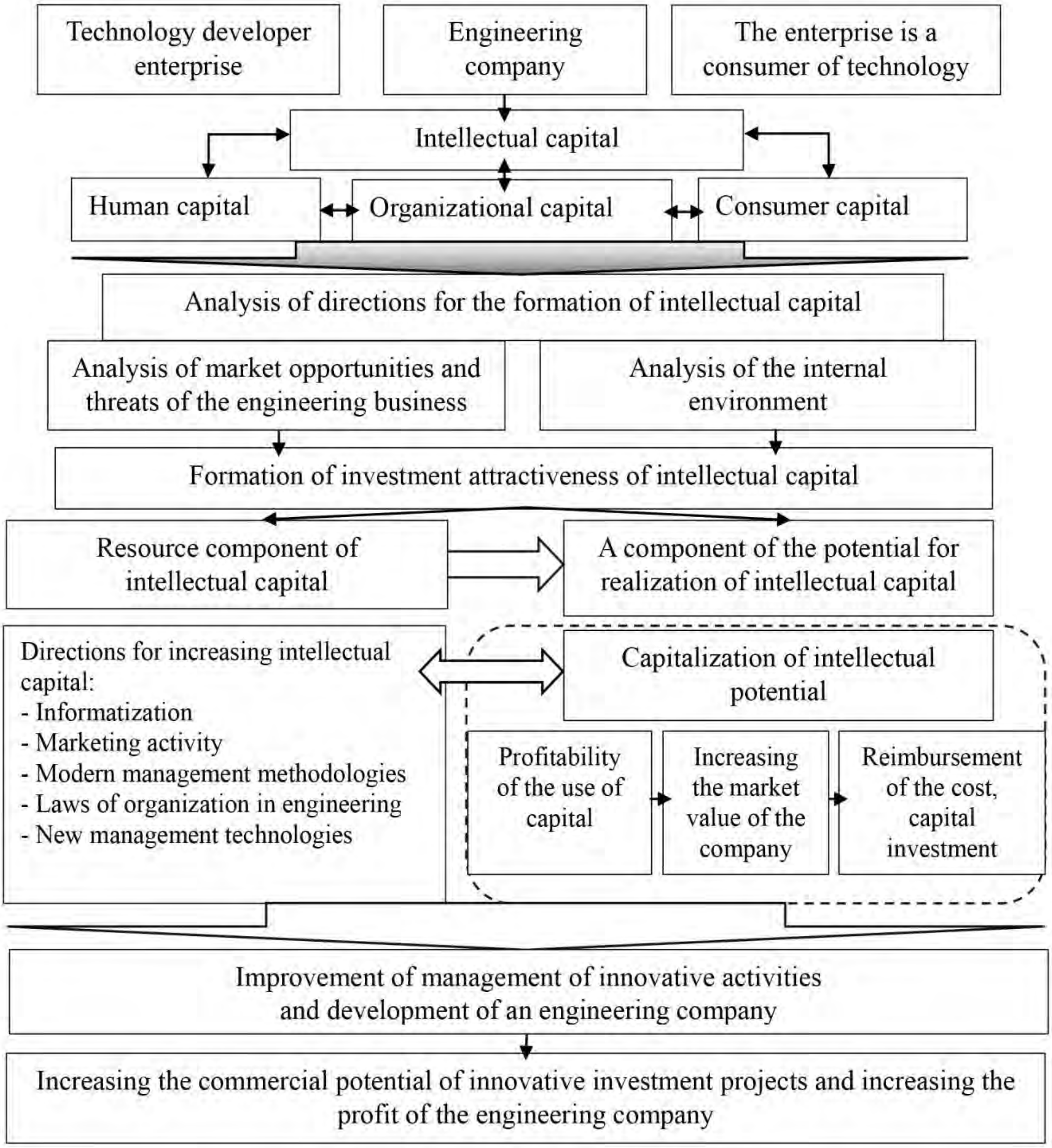

Fig. 1. Structure of the study of the formation of the investment attractiveness of the intellectual capital of engineering companies in the context of improving the management of innovative activities (*authors' development*)

Such clients are motivated in innovative renewal and development and are ready to implement the relevant projects, i.e. they either have their own funds and/or are willing and able to obtain funds from other sources. The problem of finding investors arises. Consequently, the formation of investment attractiveness helps to carry out the selection of both innovative investment projects and engineering companies-executors of the project. The study of trends in the development of the innovative technology market is associated with the analysis of the engineering services market and reflects the possibilities and intensity of the introduction of scientific and technological progress achievements into production, in particular, innovative technologies.

The supply on the market is mainly formed by engineering companies from economically and technologically developed countries, and demand is formed by developing countries. The result of increased demand is high prices for engineering services in consumer countries. There is a stable tendency for the costs of purchasing machinery, equipment and software to dominate. Pure and technological engineering, which is of the utmost importance for the Ukrainian economy and is associated with research, new developments and the acquisition of external knowledge, occupies a small share in the total volume of innovation costs. The engineering market in Ukraine has long been in the development stage [1]. Possessing high intellectual potential and experience of successful activity in this area, Ukrainian engineering companies are increasingly in demand on the domestic market, which is explained by the country's focus on the EU and the need to accelerate the innovative revival of the country in the post-war period.

Market analysis involves studying regulatory documentation on engineering services in various fields, for example, the "Guide to the Provision of Services to Engineers", which was developed by the American Society of Civil Engineers (ASCE). In addition, the United Nations Economic Commission for Europe, later, also developed the "Guide to the Establishment of International Contracts with Consulting Engineering", which identified various types of engineering. A large amount of work on the unification of engineering was carried out under the auspices of the European Bank for Reconstruction and Development, which made it possible to form a unified approach to attracting investment in new engineering developments, the development of economic and social factors.[1]

In addition, given the European integration, special attention should be paid to the aspects of informatization and obtaining creative information by managers of engineering enterprises.

Marketing information systems (MIS) for service enterprises in modern conditions are a mechanism for implementing the function of long-term forecasting and determine the orientation towards customer behavior for communication between the seller of the service and the buyer [2].

The main tasks of MIS:

1) assessment of the information needs of marketing managers (monitoring, accounting, analysis of plan implementation, verification of achieved results);

2) obtaining data (study of market characteristics; measurements of potential market opportunities; search for new clients (potential, existing), study of reactions to new and existing services);

3) analysis of information and forecasting of results (study of business activity trends, study of competitors, short-term and long-term forecasting to prevent threats to the marketing environment);

4) obtaining prepared information for decision-making [3].

According to the authors, digitalization and informatization of engineering companies should include decision support systems (DSS) that are integrated into the enterprise's MIS and use the capabilities of artificial intelligence.

An MIS with a neural network can solve such complex problems as: calculating the project forecast cost, calculating the cost of engineering services, which is agreed upon between the customer and the contractor (consultant) at the stage of concluding the contract. This is due to both the variety of services provided and their non-standard nature, the impossibility of pre-establishing the final volume of necessary work and the total amount of costs associated with their implementation. Therefore, the cost of services determined at the stage of concluding a contract can be adjusted in accordance with the actual costs upon completion of the work. Consequently, an engineering enterprise needs to submit a project with an already determined forecast cost that ensures the competitiveness of the enterprise in obtaining a tender for the performance of work. For this purpose, it is advisable to use the method of calculating remuneration for the provided engineering and consulting services based on actual costs plus a fixed remuneration. The input data for entering and training the neural network represent the first stage of training the neural network on the training sample. In this case, the user can choose different algorithms and an activation function for training the neural network. After entering new data, the user receives a projected value of the project cost, the projected cost of equipment, the cost of installation work, equipment setup, the number of workers who will perform installation and setup, the expected amount of wages for workers, and all this taking into account the projected hryvnia exchange rate [4].

But any digitalization and informatization cannot be implemented without the development of the company's intellectual capital.

As is known, intellectual capital consists of both tangible and intangible resources. All aspects are very important for an investor, since both the resource component and the component of the potential for the implementation of intellectual capital affect the improvement of innovative activities and the development of an engineering company, and, accordingly, the implementation of projects.

In general, three components are distinguished in the structure of intellectual capital (see Fig. 1): human capital, organizational capital; consumer capital (in a broader sense, as interface capital or relationship capital). The intellectual capital of an enterprise is a set of intellectual resources (tangible and intangible) and the ability to implement them, determining the ability of an enterprise to develop on the basis of information and knowledge in relation to specific market conditions [5].

Indeed, intellectual capital should be considered as the result of the implementation of intellectual potential. The result is manifested in the cost estimate or profitability of capital use in the process of its capitalization, as can be seen from Fig. 1, an increase in profitability increases the market value of the company, which, in turn, increases investment attractiveness and ensures investment in the further development of the enterprise's innovative activities.

It is in the market conditions that the efficiency of the implementation of intellectual potential is determined. The company's marketing activity ensures a more efficient implementation of intellectual capital and is one of the areas of growth of the resource component of intellectual capital. Research of demand for innovations is a very complex process, it must take into account the stage of the life cycle of the innovative technology. It is the engineering company that cooperates with the manufacturer of the technology that knows at what stage of life a certain technology is and can plan and forecast its commercialization, develop effective tactics and strategy for marketing entry into and exit from the market, helps to predict changes in consumer needs; identify changes in the competitive environment, promptly adjust the technology marketing plan; ensure a balanced proportion of new, growing and mature technologies; significantly reduce the market cycle of technology due to the acceleration of scientific and technological progress and investment growth [7]. Engineering companies create demand for a certain innovative technology by actively participating in international conferences, seminars, exhibitions, and within the framework of such events, they manage to influence the opinions of top managers of leading industrial enterprises of Ukraine, with whom close ties and cooperation have been established. On the one hand, an engineering company closely cooperates with technology developer corporations as their system integrator and carries out research and determines the demand and requirements of potential consumers regarding novelty, technological features, possibilities of gradual implementation, availability of software, etc. On the other hand, an engineering company informs the technology developer enterprise about its clients, usually medium and large enterprises that were provided with engineering services. At the price formation stage, the role of engineering companies is also difficult to overestimate, because they are able to help adjust the pricing policy of the owner and manufacturer of the technology in such a way as to ensure its competitiveness; for the customer enterprise, it is necessary to justify the price by proving the scientific, technical, economic and social potential of the technology, i.e. to conduct a presentation of technology as a system integrator. As for the channels for promoting technologies, engineering directly acts as a form of technology transfer, and they also engage in advertising as system integrators for individual manufacturers of innovative technologies [8].

Modern management technologies in improving innovation activities

In addition to marketing activities, aspects of improving innovation activities based on the introduction of modern management methodology that allows developing and implementing successful projects are of great importance. To create innovative products that meet consumer requirements, it is necessary to apply the modern concept of design thinking. Design thinking is understood today as a modern methodology that includes the following elements: principles, methods and research practice. Fig. 2 shows a logical diagram of the design thinking process.

A feature of the diagram in Fig. 2 is that it includes the stages of selecting the best ideas, creating a prototype and testing it, and is supplemented by mandatory feedback at the testing stage with the consumer/client, and only after that innovative goods/services are created that meet the needs and desires of market segments, ensure the commercialization of innovations, increased profits, a stable position in the market and sustainable development of the enterprise. [9] Design thinking requires the presence of appropriate design management. Design management links design, innovation, technology, management and clients, marketing of innovations to ensure a competitive advantage in three main areas: economic, socio-cultural and environmental factors. In addition, design management allows resolving the main contradiction of the "fuzzy external interface", that is, the process of developing an innovation with its subsequent commercialization and operations in the market. Design management creates an appropriate design contour of the company’s environment and the design of its corporate culture. It is this approach that determines the company to develop and maintain its intellectual potential.

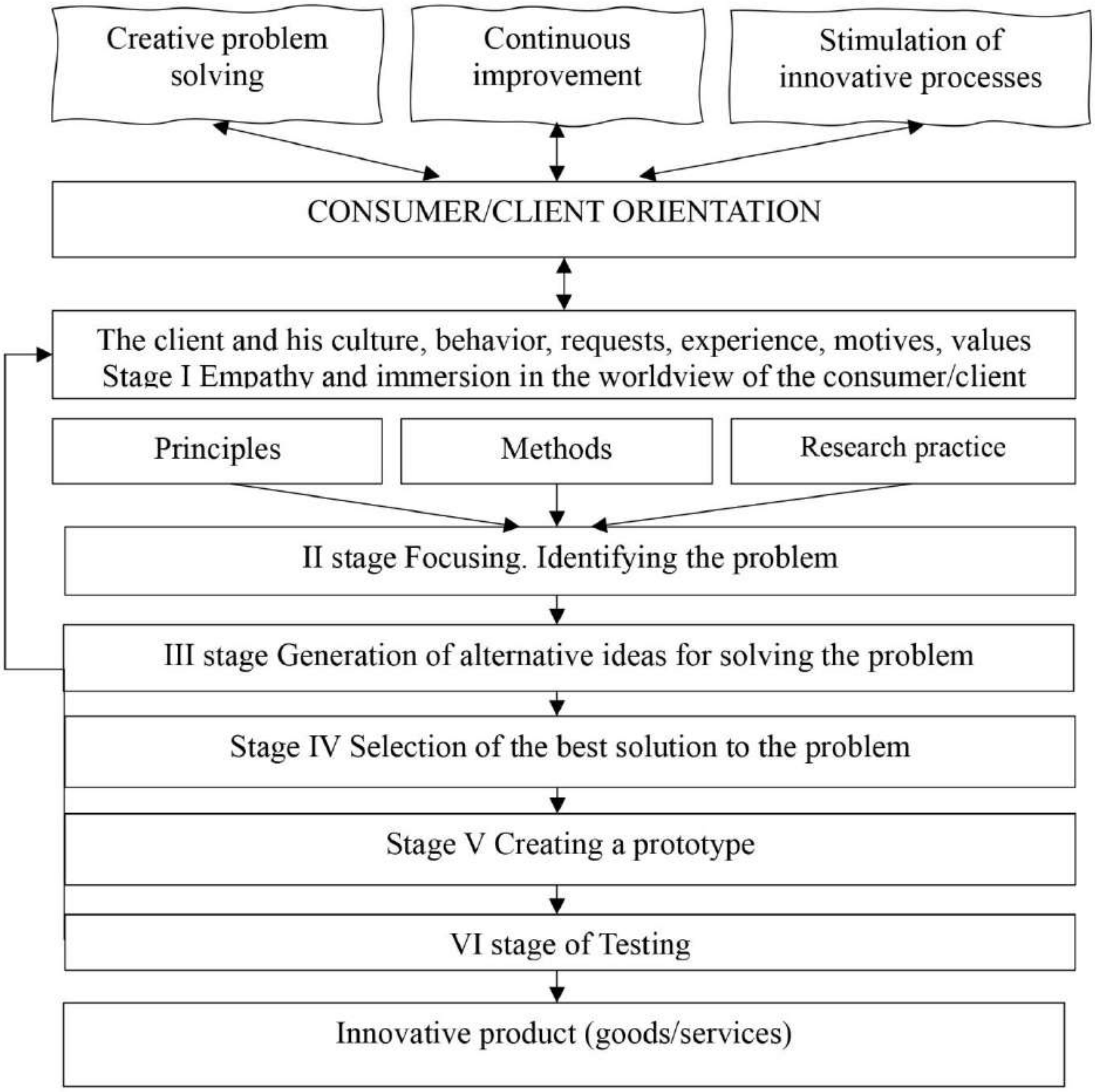

Fig. 2. Logical diagram of the design thinking process [9]

The design management process includes defining the mission, goals, principles and methods; design processes for solving business problems of innovative projects [10].

For successful development of the organizational capital of the company, it is necessary to use the system of laws of the organization. Engineering companies have their own characteristics and specifics of the organization. Table 1 indicates the main laws of the organization and indicates the features of the manifestation of these laws in the conditions of companies when implementing engineering projects. Managers who have knowledge of the laws of the organization, understand how to use this knowledge in practice, form the so-called organizational capital, which is part of the intellectual capital of the company [11].

The combination of modern management concepts based on the laws of organization is implemented through management technologies.

Table 1

The Laws of organization in the minds of engineering companies [11]

The laws of organization	Features of manifestation
1	2
1 The Foreign laws apply to all organizations	
The law of synergy	Monitoring and evaluation of synergy indicators in order to ensure the achievement of its positive effect
The law of self-preservation	Formation and increase of the enterprise creation potential based on internal and external market potential
The law of development	Virtualization of business systems based on the intellectualization of specialists for innovative development at all stages of the life cycle.
The law of correspondence between the subject of management and the object of management	Building cooperation between the project company, the project customer and stakeholders based on taking into account the interests of all interested parties, because the readiness to make changes and improve the project is more important than following the approved preliminary plan within the framework of the Agile philosophy.
The law of the relationship between the whole and the parts	Hierarchical structure of works, selection of effective decomposition of project execution works
The law of needs	Modern motivation systems are built on defined corrective pay coefficients depending on the assessment of the contribution to the implementation of the project.
2 The Private law valid in specific conditions	
The law of continuity and rhythm of production	Implementation of production automation projects based on innovative technologies and software, taking into account the specifics of the customer's production in order to eliminate non-rhythmic work and increase production efficiency.
The law of competitiveness of management personnel	Evaluation and appointment of project managers by competitive selection, ensuring horizontal rotation of managers for their professional growth.
3 The Specific law, acting in a specific type of activity	
The law of awareness	Creation of a project office and virtual infrastructure for the effective implementation of programs and projects based on the use of information and communication technologies to ensure the receipt and exchange of information.
The law of unity of analysis and synthesis	Application of the Waterfall method – project analysis, design, project development, testing, support.
The law proportion and composition	The distribution of resources in proportions that ensure convenience, efficiency and cyclical execution of work is based on the Agile philosophy.

Continuation of the Table 1

1	2
The law of differentiation and universalization of functions	Application of the iterative methodology, when the result of each sprint is a finished product, and each subsequent iteration increases the functionality of the previous one, for example, in the Scrum framework.
The law of originality	Features of creating an effective organizational structure of the project organization, its culture and technological philosophy.
The law of social harmony	Social development and social responsibility.
The law of optimal loading and effective perception	Taking into account creativity, the ability to be creative, an individual approach to each participant in the implementation of the project.

The present is characterized by the search for new management technologies that take into account changes in the environment. Unfortunately, existing management methods and technologies are ineffective in conditions of uncertainty, rapid intellectualization and digitalization of the economy. It is especially difficult to manage enterprises providing services, such as engineering companies. The main aspect in the innovative development of an enterprise is the desire of its employees to learn. The so-called Kolb model is gaining popularity, taking into account the psychological aspects of learning in the form of a spiral, which is based on the already acquired personal experience with subsequent reflection, and then action. In addition, the management technology based on the inspirational management of innovative projects deserves special attention, thanks to which it is possible to minimize the negative consequences of rapid changes. This is especially evident in the management of innovative projects and programs. In this case, the trust assessment technique becomes useful, which will allow: to assess the possible resistance of personnel and the motives for this resistance; to identify the weak links of the organization; to determine possible measures to minimize the risks of the behavioral factor of managers [12].

Nvestment directions and aspects of intellectual capital development

Investment attractiveness is a set of factors, the analysis of which indicates the possibility of investing in a particular object and obtaining a certain effect from the completed transaction, that is, it is a set of features that allow a potential investor to assess how much an investment object is more attractive than others for investing available funds [13].

A condition for investing in the development of intellectual capital is the interpretation of its essence as capital, i.e., based on the cost approach. Thus, as an economic and legal category, intellectual capital should be considered from the position of advanced intellectual value, which in the process of its movement brings greater value due to surplus value. Such an interpretation of intellectual capital can be defined as socio-economic. [14] Innovative activity of an enterprise in providing engineering services based on the socio-economic interpretation of intellectual capital is schematically shown in Fig. 3.

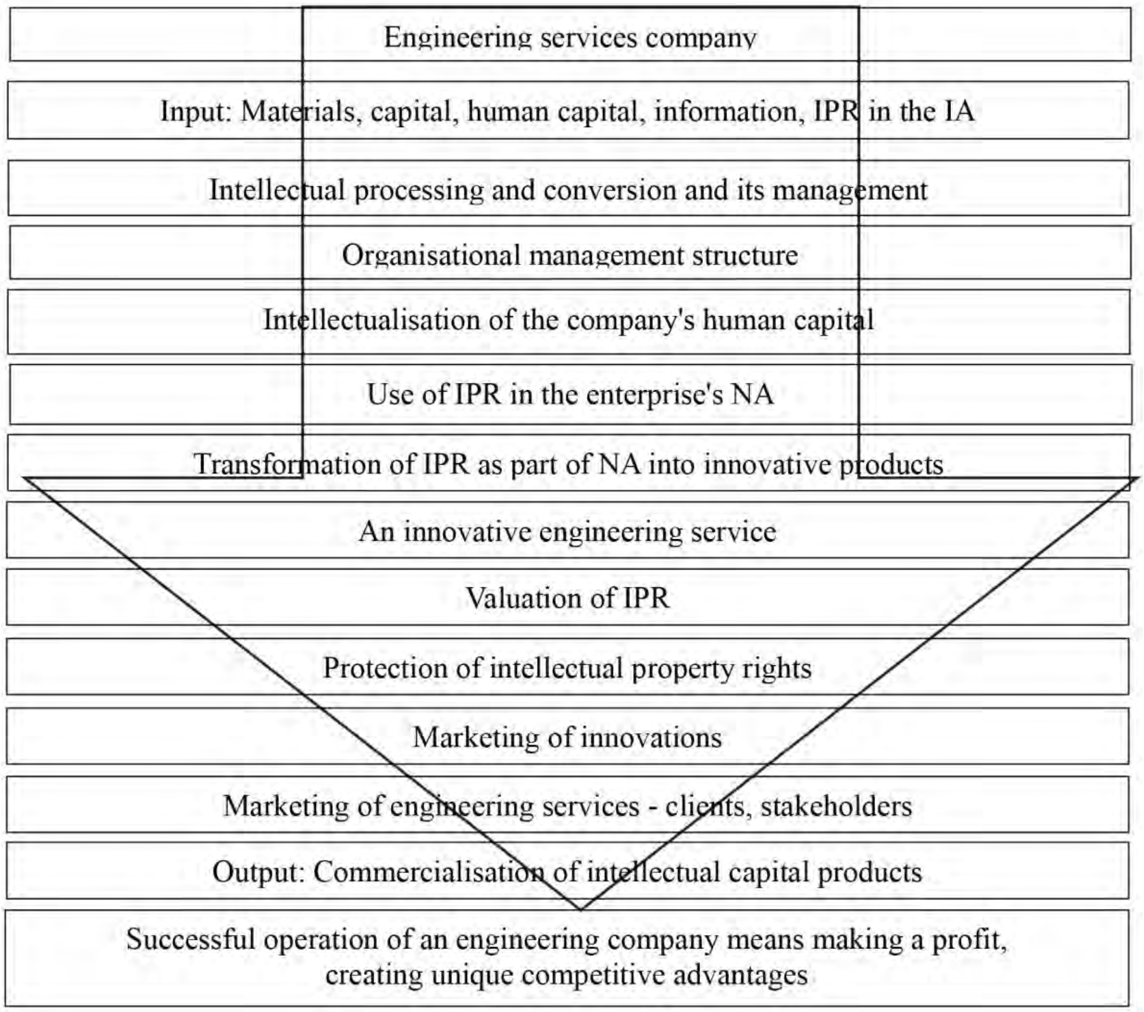

Fig. 3. Innovative activity of an engineering company based on the socio-economic interpretation of its intellectual capital [15]

Fig. 3 shows the stages of transformation of intellectual capital and its components into added value – making a profit and creating unique competitive advantages of an engineering company, ensuring continuous improvement of innovative activity in the innovation market.

The socio-economic interpretation of intellectual capital allows us to formulate investment directions in its development.

Financial capital acts as a function of intellectual capital; the dominants of intellectual capital are human capital and structural capital; human capital acts as the main factor of structural capital; the dominants of structural capital are client and organizational capital; organizational capital forms innovative and process capital; innovative capital is based on intangible assets (IA) of the enterprise, presented in the form of intellectual property rights (IPR) and other intangible assets [16].

The directions of investment in the development of intellectual capital are schematically shown in Fig. 4.

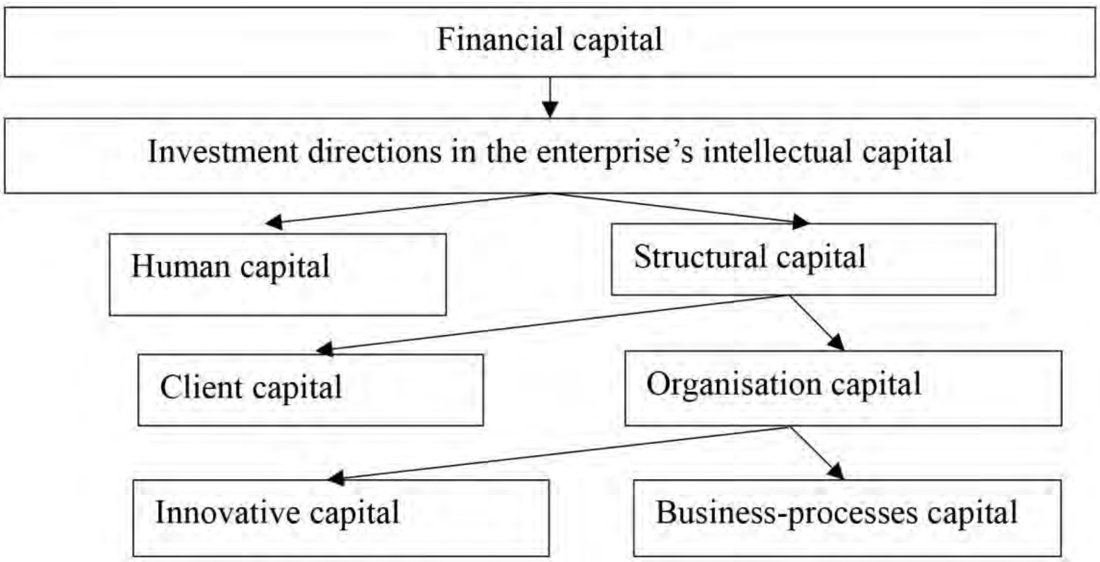

Fig. 4. Directions of investment in the intellectual capital of the enterprise [17]

As can be seen from Fig. 4, investments in intellectual capital are associated with the financial capital of the enterprise, in addition, the main directions of investment in intellectual capital are human and structural capital. The latter is formed from client and organizational capital. Organizational capital is based on innovation and business process capital, that is, on the basis of the business process model selected by the management of the enterprise. Thus, investment in intellectual capital has a complex multi-factor structure. In addition, one type of capital flows into another, which leads to a certain duplication. In order to ensure the effective development of the intellectual capital of the enterprise, in particular in the provision of engineering services, it is necessary to develop an appropriate investment strategy.

One of the directions for improving the innovative activity of the enterprise is the formation of organizational capital, which directly affects the final result not only in terms of economic efficiency, but also in terms of the social effect. Conditions and factors for increasing the organizational capital of the enterprise:

1) collective interaction;

2) priority of functions over structure;

3) elimination of dysfunctions in the work of the enterprise;

4) regulation and optimization of production processes in space and time;

5) compatibility of professional and collective norms, values of corporate culture through training, exchange of knowledge, skills and abilities;

6) organizational management structures based on standardization as the main method of coordinating actions and focused on transparent control of compliance;

7) the possibility of transforming human intellectual potential into objects of intellectual property rights;

8) conditions for flexibility of functions by structure;

9) formalization and regulation of procedures for the use of modern information IT technologies and software [6].

Organizational capital is of particular importance for engineering companies, because as a value it combines the interests of all stakeholders with whom the enterprise works through communications, information exchange, coordination and harmonization of actions, regulation of service provision and collective decision-making on engineering projects [19].

Since the study is specifically about the provision of engineering services, in addition to tangible assets, intangible assets also act as investment objects: intellectual property (IP) (patents, licenses, know-how, software), rights to use land and other resources, property rights, investments in staff development, etc. There are two types of investments in the intellectual capital of a company: financial and scientific and technical (intellectual). Intellectual investments are made in the form of:

1) acquisition of exclusive rights of use – purchase of patents, licenses for inventions, industrial designs, trademarks;

2) acquisition of information services through the hiring of various kinds of specialists – scientists and practitioners under a contract or through a one-time purchase of information services;

3) acquisition of scientific and technical products, i.e. intellectual goods in material form;

4) investments in human capital, i.e. expenses on education, training and retraining of personnel, training, etc. [19].

Thus, by investing in the intellectual capital of engineering companies, the efficiency of commercialization of technologies is increased through the development of engineering as one form of technology transfer.

Engineering aims to obtain the best results from investments in the implementation of projects through the achievements of science. Through engineering, it is possible to achieve a reduction in the terms of project implementation, reduce the volume of investments, reduce production costs per unit of output, and also increase the efficiency of capital investments. Engineering has a close connection with science, consisting in a single process of creation, testing and implementation of technical and technological achievements, advanced solutions and developments. Science learns, generates new ideas and solutions, and engineering brings them to practical use [20]

Conclusions

The conducted study made it possible to accomplish the tasks set to achieve the goal, namely:

1) the analysis of the market conditions in which engineering companies operate shows the need to activate engineering companies in the direction of improving innovation activities due to a significant gap between the achievements of science, the development of innovative technologies and their commercialization and implementation in the activities of domestic enterprises. Improving innovation activities is inextricably linked with the formation and development of the intellectual capital of such companies;

2) the study of information support for engineering companies confirms the need to improve marketing information systems using artificial intelligence by supplementing them with decision support systems and modern software, which will allow engineering enterprises to significantly increase not only their own intellectual potential, but also the commercial potential of the technologies that they implement at enterprises in innovative investment projects, increase competitive advantages and win in the competitive struggle;

3) the introduction of modern management technologies into the activities of companies increases intellectual capital by improving such components as human capital, organizational capital, and relationship capital. One of such technologies is the concept of design thinking, which focuses the attention of the company's management on the consumer-client. For engineering companies, it is extremely important to understand the desires of, on the one hand, the enterprises-customers of engineering services for the implementation of innovative technologies and technological renewal of production, on the other hand, the enterprises-developers of innovations, and on the third hand, investors, which increases the satisfaction and loyalty of the end client, creates conditions for investment attractiveness of both the company itself and the investment projects that it implements;

4) on the way to activating and continuously improving innovative activities, it is necessary to use a scientific approach based on the laws of the organization. The talent and experience of managers lies in the ability to adapt these laws to the activities of the enterprise in a specific area and industry. The study proposes

an interpretation of these laws (see Table 1) from the point of view of practical aspects of the activities of engineering companies, which, if implemented, will provide a significant increase in the intellectual capital of the company;

5) the result of the conducted research was the development of approaches and understanding of the formation of intellectual capital in accordance with its structural elements, the process of capitalization is shown, which is understood as the result of the implementation of intellectual potential;

6) the obtained results made it possible to show the investment attractiveness and develop directions for investing in the intellectual capital of an engineering company, which is beneficial both to the company itself and to all stakeholders of innovation and investment projects;

7) the conditions and factors of the formation of the organizational capital of the engineering business, one of the important components of intellectual capital, were studied, directions for its increase were proposed, which will allow, in combination with modern management technologies, to significantly increase intellectual capital, increase the intellectual potential and investment attractiveness of an engineering company in its innovations. .

Thus, it can be noted that the goal of the study has been achieved, modern approaches to the formation of investment attractiveness of intellectual capital in the context of engineering companies have been studied, the components of intellectual capital and the process of capitalization of intellectual potential have been considered, investment directions for improving the management of innovative activities have been shown, which will ultimately significantly increase the commercial potential of both innovative technologies and innovative investment projects that are developed and implemented by the enterprise providing engineering services, and this, in turn, will increase the innovative development of the domestic economy as a whole. The direction of further research is to study individual components of intellectual capital, such as human capital and relationship capital, in addition, aspects of the formation of organizational capital of engineering companies deserve a more detailed study, as the basis and main driver for the implementation of best practices and innovative changes.

References

1. Bushuiev M. Research of the market of engineering services. Young Academy – 2023. Collection of abstracts of reports of the All-Ukrainian scientific and technical conference of students and young scientists. Dnipro, Ukrainian State University of Science and Technologies, 2023. 216 p. P. 110.

2. Kompanets K.A. Implementation of the marketing information system in the activities of enterprises in the service sector. Economic analysis: collection of scientific papers. Ternopil: Publishing and printing center of the Ternopil National Economic University "Economic Thought", 2018. Vol. 28. No. 1. P. 231–235.
3. Fonarova T.A., Petrenko V.A., Bushuiev K.M., Bushuiev M.B. Modern aspects of informatization at enterprises providing engineering services. Project management. Prospects for the development of project and neuromanagement, information management technologies, technologies for the creation and use of intellectual property objects, technology transfer: Coll. of works for the materials of the V Int. science and practice. Internet conf. (March 23–24, 2023). UDUNT, UKRNET, NII NAPR of Ukraine, Dnipro: Yurservice, 2023. 730 p. Pp. 638 – 647. URL: https://nmetau.edu.ua/file/zbirnik__materialiv__konf_udunt_2023.pdf
4. Petrenko V.A., Bushuiev K.M., Savchuk L.M., Fonarova T.A. Application of neural networks in decision support systems of the company's marketing information system. Project management and development: Coll. of scientific papers. No. 3 (67). Kyiv: Publishing House of VNU im. V.Dalya, 2018. P. 43–52.
5. Ilyashenko S.M., Ilyashenko N.S., Shipulina Yu.S. Intellectual capital as the basis for innovative development of an enterprise in the knowledge economy. Creation, protection, defense and commercialization of intellectual property rights: Proc. of the 5th All-Ukrainian Scientific and Practical Conf. with international participation, April 26, 2022: el. collection of works. Nat. tech. univ. of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Kyiv, 2022. P. 252–256. URL: http://repository.kpi.kharkov.ua/handle/KhPI-Press/57103
6. Bushuiev M. Formation of organizational capital of a metallurgical enterprise. 17th International Symposium of Croatian Metallurgical Society Materials and Metallurgy, SHMD '2024 Croatian METALURGIJA 63 (2024) 2, p. 303–305.
7. Petrenko V.O., Fonarova T.A., Ustinov A.A. Technology marketing management as the main direction of increasing the competitiveness of Ukrainian innovative entrepreneurship. Issues of intellectual property in the field of technology transfer: collection. of science works IV All-Ukrainian science and practice conf. 2021, Kyiv: Research Institute of Intellectual Property of the National Academy of Sciences of Ukraine, 2021. 279 p. P. 196–210.
8. Fonarova T., Bushuiev M., Petrenko V., Bushuiev K. Marketing activities of engineering companies in increasing the commercial potential of innovative technologies. International Scientist-Pract. conference "Intelligent information systems in project and program management", Koblevo, September 12–15, 2023. Proceedings. Kharkiv: Khnure, 2023. 224 p. P. 22–26. DOI: https://doi.org/10.30837/IISRRM.2023.09
9. Bushuev M.B., Petrenko V.O., Fonaryova T.A. Design thinking as a modern methodology for solving innovation problems. Project management. Prospects for the development of project and neuromanagement, management information technologies, technologies for the creation and use of objects of intellectual property rights, technology transfer: a collection of scientific articles by subject. VI International science and practice internet conf. (March 23–24, 2024). UDUNT, UKRNET, NDIIV NAPRN of Ukraine, Dnipro: Yurservice, 2024. 730 p. URL: https://nmetau.edu.ua/file/zbirnik_naukovih_prats_udunt_2024.pdf
10. Fonarova T.A., Petrenko V.O., Bushuiev K.M. Design management in the context of innovation marketing. Marketing of innovations. Innovations in marketing. Materials of the International Scientific Internet Conference (December, 2022). Bielsko-Biala: WSEH, 2022. C. 20–23.

11. Fonaryova T.A., Petrenko V.O., Bushuev K.M., Bushuev M.B. The system of organization laws in the activities of enterprises providing engineering services. Management of projects in the development of society. Topic: "Management of projects of the post-war development of Ukraine": theses of reports. Ans. for issue S. D. Bushuev. Kyiv: KNUBA, 2023. 273 p. P. 196–198.
12. Bushuev S. D., Sukach S. M., Bushueva V. B. Inspiring management of innovative projects. Management of the development of complex systems. Kyiv, 2022. No. 51. P. 12 – 19, DOI: dx.doi.org\10.32347/2412-9933.2022.51.12-19
13. Usov M.A., Havrys O.O., Suslikov S.V. Investment attractiveness of innovative projects. Priazov Economic Herald. Issue 2(13), 2019. URL: http://pev.kpu.zp.ua/journals/2019/2_13_uk/32.pdf
14. Butnik-Siverskyi O.B. Development of intellectual capital and its components in the aspect of processes of intellectualization, capitalization and transformation. Materials II All-Ukrainian. science and practice conference "All-Ukrainian seminar on the problems of the economy of intellectual property (Kyiv, May 24, 2019)" NDC of forensic expertise on intellectual property of the Ministry of Justice Kyiv: FOP Kravchenko Ya.O., 2019 146 p. P. 9 – 46.
15. Bushuiev M.B., Petrenko V.O., Fonarova T.A. Directions of formation and capitalization of intellectual capital of engineering companies. Project and logistics management: new knowledge based on two methodologies. Volume 7: collection of scientific works. Odesa: KUPRIENKO SV, 2023 198 p.: illustrations, tables. (Series "Project and logistics management: new knowledge based on two methodologies", Volume 7). P. 66–69. DOI: https://doi.org/10.30888/2616-8936.2023-07
16. Sobko O. M. Intellectual capital of the enterprise: conceptualization – functioning – development [text]: monograph. Ternopil: Krok, 2014. 360 p.
17. Bushuiev M.B., Petrenko V.O., Fonarova T.A. Directions of investment in the intellectual capital of the enterprise providing engineering services. Economic cybernetics: tools and methods of research and organization of economic processes: collection. of science work for mother All-Ukrainian Internet Conference, Dnipro, March 1–2, 2024. Dnipro: UDUNT, 2024. 219 p. P. 95–100. URL: https://nmetau.edu.ua/file/zbirnik_naukovih_prats-2024.pdf
18. Bushuiev M.B. Conditions and factors for increasing the organizational capital of the enterprise. Young Academy – 24. Volume II: coll. theses add. International science and technology conf. students and young scientists (Dnipro, May 23–24, 2024). Dnipro: UDUNT, 2024, 208 p. P. 191.
19. Fonarova T., Bushuiev M., Petrenko V., Bushuiev K. Forming the investment attractiveness of innovative investment projects on the basis of increasing their commercial potential in the field of engineering services. Information system and innovative technologies in project and program management [Text]: Collective monograph edited by I. Linde. European University Press. Riga: ISMA, 2023. 317 p. R. 150–160. DOI: https://doi.org/10.30837/MMP.2023
20. Tugai O.A., Vlasenko T.V. General basics of engineering activity and its current state in Ukraine. New technologies in construction. No. 34, 2018. URL: https://journals.indexcopernicus.com/api/file/viewByFileId/636180.pdf

DOI: https://doi.org/10.30837/MMP.2024.041

SPATIAL ASSESSMENT OF INFRASTRUCTURE PROJECTS

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The aim of the study is to improve the soundness of decisions on the choice of infrastructure development areas by taking into account spatial factors when evaluating infrastructure projects (IPs). The article analyzes the properties and features of such projects and the known methods of their evaluation. It is noted that existing methods are laborious, complex, and based on large amounts of data. This limits the benefits of their use, leads to a decrease in project efficiency and sustainability. The uniqueness of IP complicates design work, although most of them are regulated by current building codes. Astudy of the content of some of them confirms the need to take into account the spatial features of the area where IPis implemented. The examples show that the involvement of spatial analysis methods in the assessment already in the initial phases of the IP life cycle increases the thoroughness and accuracy of the initial project estimates (parameters, budget, timing), and further simplifies and accelerates the implementation of some project works, contributes to the achievement of sustainable development goals, and helps the public better understand the concept of IP and its features.

Introduction

In the context of prolonged martial law, the importance of the country's regions to ensure its sustainable and secure development increases significantly, and there is a need to build their potential and create infrastructure prerequisites for their growth. In these circumstances, infrastructure becomes a driver of socio-economic growth, affects the quality of life of the population and the satisfaction of their needs in accordance with the concept of sustainable development, develops existing infrastructure, stimulates certain sectors of the economy, and creates new jobs. The proper functioning of infrastructure, as well as the creation of new infrastructure facilities and the modernization of existing ones, are achieved through infrastructure projects (IP) [1, 2].

Infrastructure projects (e.g., construction of water supply, sewerage, transport and energy facilities, residential and social development, etc.) that implement strategic efforts to achieve social, economic, and environmental sustainability goals are aimed at solving long-term problems; they become a means of defining, creating, and realizing values with long-term consequences for the environment and society [1, 3].

The concept of sustainable development defines sustainability as the practice of meeting the needs of the current generation without affecting the ability of future generations to meet their needs. Thus, it is intended to maximize social and economic benefits while minimizing environmental damage [4]. Therefore, for such infrastructure to be considered sustainable, it must be planned, designed, constructed, operated, and decommissioned in a way that promotes economic, social, and environmental development at every stage of its life cycle [5]. Traditionally, however, IP performance is assessed mainly by economic indicators, while ignoring environmental and social arguments, despite their significant impact on sustainable environmental development. The well-known "iron triangle" of cost, time, and quality in project management, which traditionally determines project success, refers to the formation of a technologically efficient product within budgetary and time constraints, providing for the creation of certain technical specifications at a lower price without much attention to the environmental and social value of projects [3]. However, IP implementation takes a long time, these projects are capital-intensive, require significant investment and labor, which is significantly complicated in the context of the financial crisis and budget shortages and requires, first of all, careful justification. Such projects are expensive, controversial, and difficult to manage, requiring mandatory assessment of their impact on natural resources, ecosystem services, and access to social services to prevent social conflicts, cost overruns, and reputational losses of the administration, ensuring project sustainability [2]. Therefore, an integrated approach to the formation of project performance indicators that combines methods for assessing its various environmental impacts with traditional cost, time, and quality assessments is becoming necessary.

Features of comprehensive assessment of infrastructure projects

Unlike other projects, IP (Table 1) is a long-term strategic initiative that determines the competitiveness of the territory, its sustainable and balanced development, aimed at building, reconstructing or modernizing infrastructure facilities, improving the quality of services provided to consumers, and improving the socio-economic situation in the territory [6]. The analysis of the properties and features of these projects (Table 1) once again emphasizes that even the formation of their feasibility studies within the framework of a contradictory process to achieve different interests and goals of numerous influencing bodies (local governments, businesses, the state, local residents, etc.) requires careful preliminary justification, analysis, and consideration of a set of not only economic factors. Although infrastructure improvements are necessary, the possible negative environmental impact of the project should be carefully investigated, which requires focusing on (Fig. 1) [5–7]:

– technical aspects of the project, the components of which lead not only to economic changes, but also to environmental and social disruptions in the environment;

– dynamic development of the project with the introduction of new technologies and construction methods, in compliance with health and safety rules, building codes, legal aspects and legal features related to the industry, etc.

Table 1

Properties and features of IP

IP Properties		IP Features
Objective:	improving the competitiveness of the territory and its sustainable development;	Uniqueness and innovation
Targets:	infrastructure objects that have a significant impact on the industry, or on the quality of services provided to consumers, or on improving the socio-economic and/or environmental situation in the territory;	Technical complexity
Life cycle:	long economic planning horizon; prolongation of the design phase due to the need to develop innovations; possible overlap between the design and implementation phases of the project;	Long-termism
Scale:	a large project with a significant amount of work;	Multi-channel supply
Participants:	state authorities and governments, a significant number of companies, including foreign ones;	Organizational complexity
Organizational structure:	takes into account the specifics of a particular infrastructure sector and provides a mechanism for interaction between the parties;	Availability of a unified information space
Resources:	attracting unique resources (highly qualified specialists, materials, devices, etc.); the possibility of financing the project from various sources; availability of schemes for replacing some financial obligations under the project with others;	Long period of investment return
Risks:	possible changes in scale, investment attractiveness, and goals during design and implementation, which reduces the reliability of the initial technical and economic information;	Adaptability in management High risks
Relationships:	various organizational, legal and financial interactions between numerous participants.	Complex interaction system

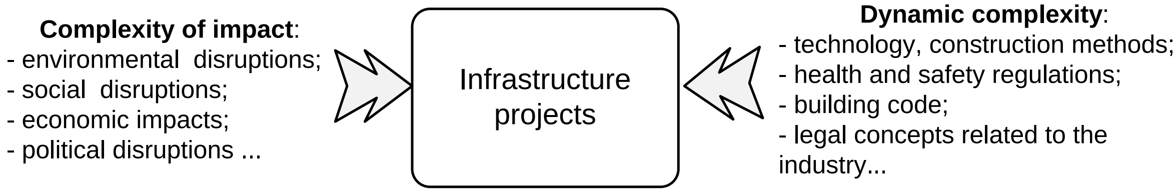


Fig. 1. IP features in the context of forming a comprehensive assessment

Under these circumstances, the importance of economic assessments is shifting in favor of sustainability, which is becoming a key factor in IP decision-making throughout their life cycle; environmental impact assessments are becoming increasingly important at both the state and local levels (given the long-term environmental impact of project decisions) [7, 8].

The environmental impact assessment of a project is often carried out using the Life-Cycle Assessment (LCA) method, one of the well-known EU environmental management tools designed to assess the environmental, economic, social and environmental impacts of projects. The versatility of this method contributes to its use in almost all industries where IP is appropriate, including transportation, healthcare, construction, traditional and alternative energy, waste management, etc.

In the LCA method, life cycle assessment is defined as "...a systematic set of procedures for collecting and analyzing all material and energy flows of a project, taking into account their environmental impacts throughout the life cycle of a project product and/or process... [9]". The method is unified in a series of international standards ISO 14040 – 14043 (Fig. 2), which define an iterative procedure for continuously analyzing the results of each phase of the project and adjusting the results obtained, when the experience gained at the next stage is considered as feedback that can change the previous stages of the assessment process. The purpose of such an assessment is to obtain a thorough assessment of the project's environmental impacts to make economic, technical, and social decisions without solving direct environmental problems [9].

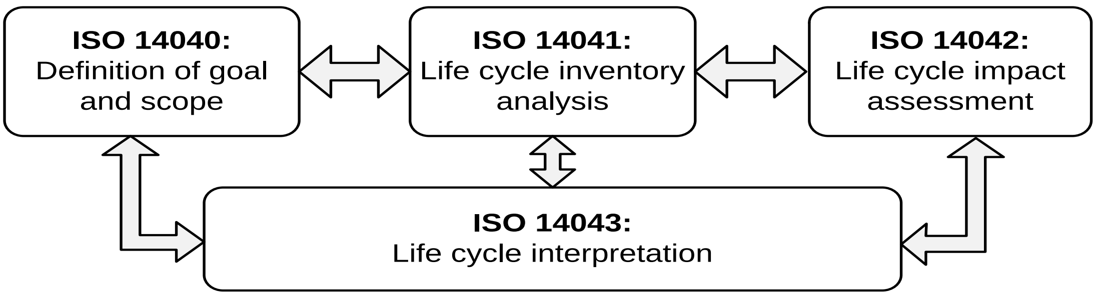


Fig. 2. The structure of the LCA method
in the context of forming a comprehensive IP assessment

According to ISO 14041, life cycle inventory analysis is the longest and most costly stage, where data on input and output flows are analyzed and appropriate project environmental impact assessments are generated. However, this procedure is time-consuming and complex, and experts face the problems of lack of data of the required volume and quality, subjectivity in characterizing and determining its consequences, inadequate definition of the project's environmental impact and assumptions about its duration [10]. Therefore, LCA is usually performed at the end of the design stage, when, on the one hand, all the necessary information is available, and on the other hand, the design decisions with the most negative environmental impact have already been made, and therefore it is almost impossible to take into account its environmental impact when making IP decisions [8, 10]. In these circumstances, there is a gap between environmental impact assessment and other aspects of the project, which complicates the process of ensuring the environmental sustainability of IP and makes it impossible to improve it.

Such a fragmented assessment process is one of the reasons for the formation of ambiguous public opinion on IP [10, 11]. On the one hand, local residents understand the benefits of IP, as it is aimed at creating new jobs and public services. On the other hand, in the event of an emergency or an accident with environmental pollution, local residents may become potential victims. Therefore, the local population often organizes active opposition to the implementation of IP, given that their interests may be harmed.

It should be noted that the general public is not subject to the influence of IP stakeholders, but it is very interested in its economic and environmental performance, and public discussion is becoming an important element of the political life of society. That is why these opinions and comments are increasingly considered more objective and unbiased, forming a holistic assessment of the entire project [11, 12], and are increasingly taken into account when determining environmental assessments of IP, developing an individual environmental trajectory for its implementation, and encouraging the public to protect the environment.

Thus, the scale and complexity of IPs, the ambiguity of their environmental impact, and the significant social resonance require new approaches to project evaluation at the initialization and planning stages, ensuring the sustainable development of society as a whole. Increasing the number of infrastructure facilities, improving their quality, and balancing quantity and quality in terms of achieving sustainable development goals is possible only if a systematic approach to infrastructure development is implemented, taking into account a combination of factors [11, 13].

Remote sensing is a modern source of data for IP valuation

The justification, design, and evaluation of IP at the national, regional, or local level is carried out in accordance with applicable law. Depending on the area of implementation, this procedure is prescribed in the relevant State Building Codes, which are legal acts approved by the authorities on construction, urban planning, and architecture. According to the portal https://dbn.co.ua/, the Building Code covers all sectors of the national economy, regulates activities in various spheres of human life, and therefore becomes the legal basis for the valuation of any IP.

As a rule, the requirements of completeness of assessment and comprehensive consideration of the environmental impact of an object are the main requirements of the Building Code, which implement a systematic approach regardless of the scope of application. At the same time, the uniqueness of IP leads to the complexity of design work, requires original design solutions, and creates special requests during design, which are usually taken into account by Building Codes focused on certain types of construction projects. However, the content of the Building Code also includes general categories aligned with the goals of sustainable development that are inherent in any type of facility (Table 2).

Analyzing the data in Table 2, we note that the combination of these factors focuses on the geographical aspects of the IP location and, when making a decision, requires taking into account its spatial features and even the spatial configuration of the existing transport and communication network, settlement structure, etc. Usually, this data is obtained based on the results of comprehensive engineering surveys. Their volume directly depends on the available instrumentation and technical base, the complexity of the survey conditions, and the culture of assessment and decision-making. Usually, they are obtained on a "come and see" basis using traditional geodetic instruments, which is quite labor-intensive, time-consuming, and the measurements obtained during these surveys are point measurements obtained in pre-selected locations. In some cases, compliance with the principle of data completeness is limited by the impossibility of conducting comprehensive engineering surveys on the ground due to their high cost, which further reduces the accuracy of calculations of project parameters, estimates of its budget, timing, etc. Moreover, due to the peculiarities of IP (Table 1), they are often started without clearly defined goals and without detailed knowledge of how the project will develop or what results will be achieved [15].

Therefore, to increase the effectiveness of survey results and ensure the objectivity of the initial data for IP planning, it is possible to combine well-known project evaluation methods, such as the LCA method, with new advanced methods, such as remote Earth sensing (RES) and geographic information technologies (GIS) [13, 15, 16].

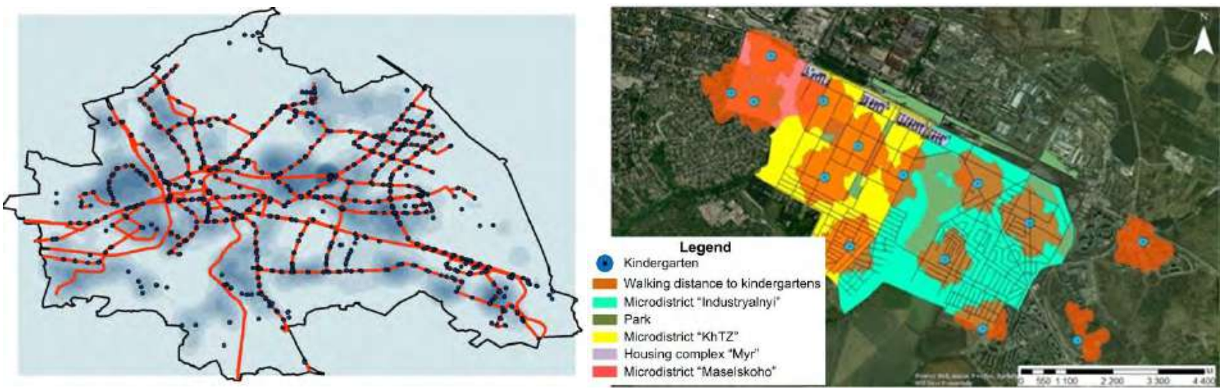
Table 2

Building Code requirements for the most common IP applications

General requirements	Building Code from the field of:		
	Transportation infrastructure design (B.2.3-4-2015)	Waste management (B.2.4-4:2010)	Construction of social objects (Б 2.2.-12:2019)
Regulates the distance:	– to the elements of the power grid; – does not allow crossing with pipelines; – takes into account animal passage routes, etc.	– to airports; – to the boundaries of settlements; – to resort facilities and nature reserves; – to fish farms; – to water bodies, etc.	for objects: – daily maintenance – within 15 minutes of pedestrian accessibility, at a distance of up to 500 m – periodic maintenance – within 30 minutes of transport accessibility, etc.
Geodesic and geologic parameters (acceptable value):	– slope of the territory – no more than 10% (for simple conditions); – special design solutions in the presence of slopes, swamps, weak soil foundations, etc.	– slope of the territory – no more than 1%; – groundwater depth is more than 20 meters, etc.	– the slope of the territory reduces the standard distance, ensuring the necessary accessibility; – special design solutions for settlements with difficult terrain, etc.
Location:	special design solutions are required within valuable lands, nature reserves, etc.	– land not suitable for agricultural use; – non-agricultural land, etc.	depends on the location of transport, social and engineering infrastructure elements.

In our opinion, engineering surveys are the main element of the conceptual phase of IP; they are usually carried out in two stages: the first one is to justify the choice of a site for the implementation of IP by options, and the second one is to obtain initial data for the development of the necessary project documentation. Of course, the uniqueness of IP requires an individual approach to organizing and implementing surveys, but even in less complex projects, one can see the benefits of using RES and GIS [13, 16]. For example, at the first stage, when justifying the directions of development of social or transport infrastructure, it is necessary to study its existing elements, thoroughly analyze existing problems, and identify possible improvement steps [13, 17]. Unfortunately, more applicable practices in this case are expert methods [15], which are becoming less and less effective in the context of urbanization and the distribution of such structures. RES and GIS make it possible to assess the feasibility of modernization, reconstruction or expansion of existing infrastructure, for example, taking into account changes in the settlement structure and existing trends in the development of settlements.

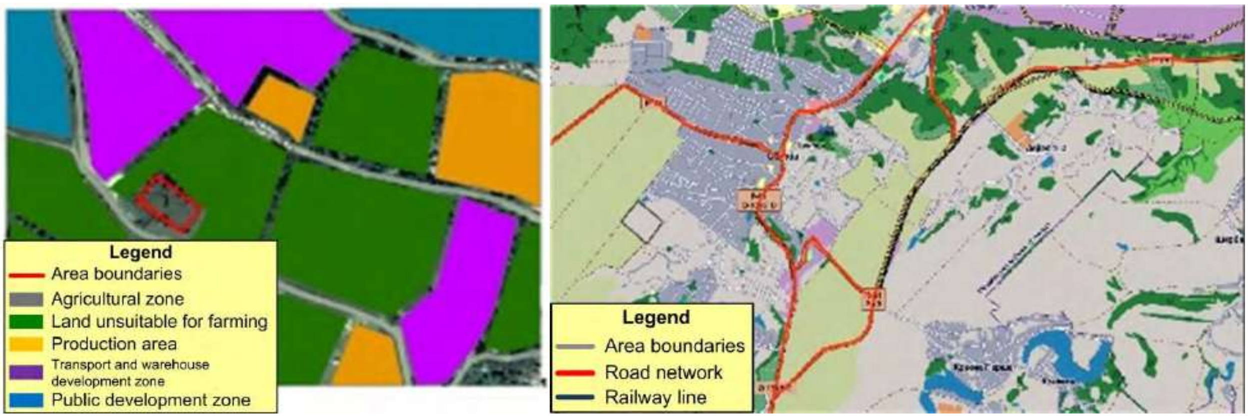
Fig. 3 shows examples of spatial analysis of the city's public transportation infrastructure (Fig. 3, a) and the infrastructure of kindergartens in the city's neighborhoods (Fig. 3, b). The flexibility inherent in GIS makes it possible to combine several layers and obtain different results, helping to draw important practical conclusions. For example, in Fig. 3, a combination of layers of the city's settlement structure, public transport routes, and available stops makes it possible to find hard-to-reach areas of the city, optimize transport routes, and equip stops in accordance with the requirements of current legislation [3].



a) b)

Fig. 3. Spatial analysis of transport and social infrastructure elements of the city:
a) to improve the network of public transport stops;
b) to improve the network of kindergartens in the neighborhood

Based on the definition of IP, we note that the project product should "fit" into the existing zoning structure of the territories, become an element of the existing electrical, communication network, and engineering infrastructure [6]. Given the specificity and fragmentation of these data, as well as possible problems with their updating, there is a significant difficulty in forming a "single picture" and assessing the effectiveness of IP and the consequences of its implementation. RES and GIS are becoming an effective tool for solving such problems: satellite data provide information on remote and hard-to-reach areas, GIS and spatial analysis methods ensure its fast processing, visualizing the results.Fig. 4 illustrates a study of the spatial planning organization of the territory where IP is supposed to be implemented in order to explore possible options for expanding the waste management system. Using GIS, cartographic models of the zoning of the analysis area (Fig. 4, a) and the existing transport network (Fig. 4, b) were built to support decision-making on the justification of possible IP implementation sites [16].



a) b)

Fig. 4. Study of the spatial and planning organization of the territory where IP is supposed to be implemented:
a) spatial analysis of the functional zones of the study area;
b) analysis of the existing transport network near the place of possible IP implementation

Of course, the study of the relief features of the territory where the IP will be implemented is a central element of any construction-related projects. This is the most costly part of engineering surveys, the results of which directly affect the cost of the project, its efficiency, and sometimes its feasibility [7, 13]. The use of RES data obtained using photogrammetric methods of earth surface surveying, for example, models obtained from the results of a radar topographic mission – SRTM, becomes promising here.

The effectiveness of SRTM data is confirmed by their wide application in the scientific environment [18]: they cover about 80% of the earth's surface from 560 south latitude to 600 north latitude, and can be used to study objects that are large in area, with a significant elevation difference, with complex terrain (hollows, valleys, gullies, erosion, etc.), different vegetation, water bodies, etc. Processing this data in GIS, overlaying several layers allows to obtain a composition (overlay) of spatial objects, the topology of this composition, and its attributes (Fig. 5).

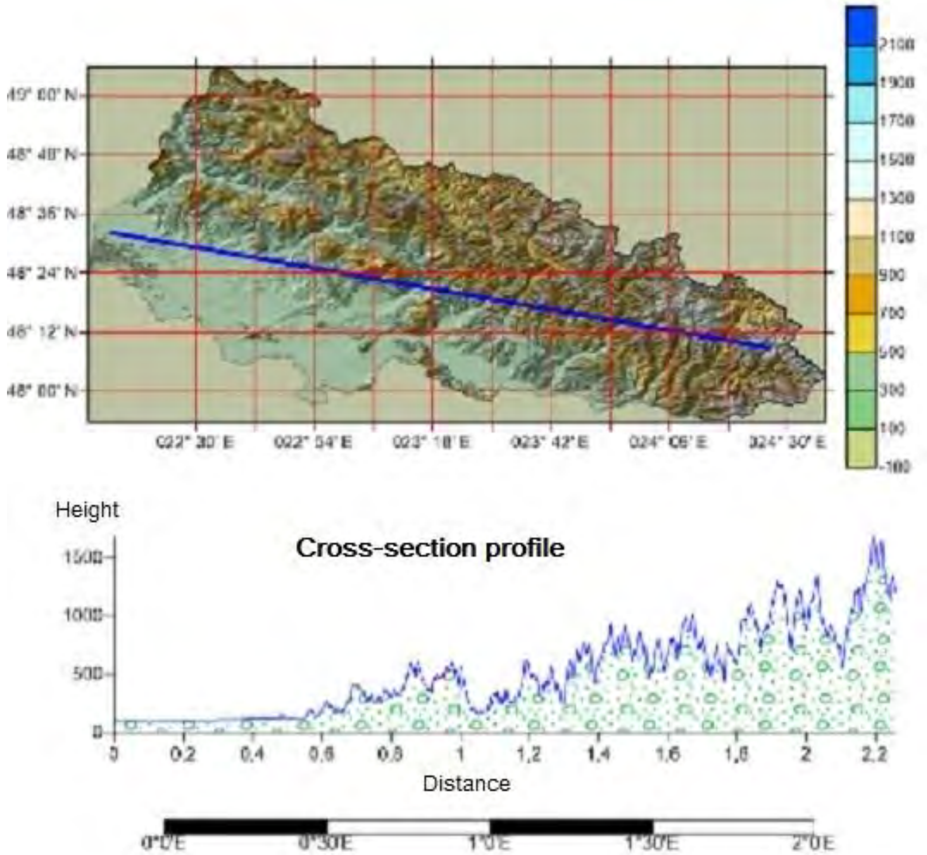


Fig. 5. Study of the relief features of the territory where IP is supposed to be implemented using RES and GIS tools

The obtained digital data become the basis for many topographic and geodetic IP materials, in particular, taking into account the peculiarities of the relief and geometry, they determine the sectors for topographic and geodetic survey of the site and plan the sequence of its implementation. In conditions where project implementation takes place in areas with complex terrain, these data become the only source of accurate information, because without them, work related to the calculation of excavation and/or soil fill, the required amount of construction materials, etc. is based on generalized recommendations with little accuracy [8, 13, 16]. This increases the accuracy of obtaining the geometric parameters of the site, reduces the direct time spent on surveying, creates the basis for design and survey work, development of land management documentation necessary for the implementation of IP, for calculating the amount of work on the construction site, reducing the total project costs, etc.

Thus, the involvement of spatial analysis methods in IP assessment at the initial stages of the life cycle increases the thoroughness and accuracy of initial project assessments, and further simplifies and accelerates the implementation of some project activities, contributing to the achievement of sustainable development goals.

Conclusions

The complexity and uniqueness of IPs and their focus on achieving sustainable development goals require new approaches to project performance evaluation and planning. Focusing on the LCA method and combining it with modern RES and GIS tools in solving these problems provides good results that have been experimentally confirmed. Digital data, combined with RES materials, facilitates effective communication between stakeholders, helps to store all project data, making it accessible to all participants, ensuring interaction at all stages of work without delays and data loss. At the same time, the accuracy of the project results increases: mapping and digital models make it possible to identify errors and inaccuracies during design and later during construction, providing protection against additional costs due to errors and inconsistencies. The resulting digital models of the IP product clearly illustrate and explain what the project results will look like, helping the public to better understand its concept or design. As a result, professionals from various fields involved in IP can design, plan, evaluate, and build infrastructure facilities more effectively.

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Reference

1. Political ecology perspective for a new way of understanding stakeholders and value in infrastructure projects [Text] / M. S. Cidik [at etc.] // International Journal of Project Management. – 2024. – Vol. 42, issue 2. – Article 102565. DOI: 10.1016/j.ijproman.2024.102565
2. Spatial disparities of social and ecological infrastructures and their coupled relationships in cities [Text] / R. Pakharel, Ch. Jing, W. Zhou, Yu. Qian // Sustainable Cities and Society. – 2022. – Vol. 86. – Article 104117. DOI: 10.1016/j.scs.2022.104117
3. Danshyna, S. Formalization of development processes at changes in business-model of the company [Text] / S. Danshyna // Information systems and innovative technologies in project and program management: collective monograph / edited by I. Linde, I. Chumachenko, V. Timofeyev. – Riga (Latvia): ISMA University of Applied Science, 2019. – Chapter 12. – P. 151 – 160.
4. Srivastava, Sh. Integrated approach for sustainability assessment and reporting for civil infrastructures projects: Delivering the UN SDGs [Text] / Sh. Srivastava, U. Iyer-Raniga, S. Misra // Journal of Cleaner Production. – 2024. – Vol. 459. – Article 142400. DOI: 10.1016/j.jclepro.2024.142400
5. Ninan, J. Educating engineers of the future: T-shaped professionals for managing infrastructure projects [Text] / J. Ninan, M. Hertogh, Y. Liu // Project Leadership and Society. – 2022. – Vol. 3. – Article 100071. DOI: 10.1016/j.plas.2022.100071

6. Hertogh, M. Playing with Complexity. Management and Organization of Large Infrastructure Projects [Text] / M. Hertogh, E. Westerveld. – Netherlands: Erasmus University, 2010. – 377 p.
7. Minor loss or huge threat? Assessment of potential infrastructure projects reveals drastic landscape degradation in the Atlantic forest [Text] / J. S. Alves Cunha [at etc.] // Journal for Nature Conservation. – 2024. – Vol. 81. – Article 126662. DOI: 10.1016/j.jnc.2024.126662
8. BIM-based environmental impact assessment for infrastructure design projects [Text] / M. A. van Eldik [at etc.] // Automation in Construction. – 2020. – Vol. 120. – Article 103379. DOI: 10.1016/j.autcon.2020.103379
9. Bribian, I. Z. Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification [Text] / I. Z. Bribian, A. A. Uson, S. Scarpellini // Building and Environment. – 2022. – Vol. 44, issue 12. – P. 2510 – 2520. DOI: 10.1016/j.buildenv.2009.05.001
10. Nwodo, M. N. A review of life cycle assessment of buildings using a systematic approach [Text] / M. N .Nwodo, J. A. Chimay // Building and Environment. – 2019. – Vol. 162. – Article 106290. DOI: 10.1016/j.buildenv.2019.106290
11. Jiang, H. Assessment of online public opinions on large infrastructure projects: A case study of the Three Gorges Project in China [Text] / H. Jiang, M. Qiang, P. Lin // Environmental Impact Assessment Review. – 2016. – Vol. 61. – P. 38 – 51. DOI: 10.1016/j.eiar.2016.06.004
12. Feng, W. Factors influencing private and public environmental protection behaviors: Results from a survey of residents in Shaanxi, China [Text] / W. Feng, A. Reisner // Journal of Environmental Management. – 2011. – Vol. 92, issue 3. – P. 429 – 436. DOI: 10.1016/j.jenvman.2010.08.002
13. Danshyna, S. Information technology of transport infrastructure monitoring based on remote sensing data [Text] / S. Danshyna, A. Nechausov, S. Andrieiev // Radio Electronics, Computer Science, Control. – 2022. – no. 4 (63).– P. 86 – 97. DOI: 10.15588/1607-3274-2022-4-7
14. A methodology for road cutting design guidelines based on field observations [Text] / E. Robson, A. Agosti, S. Utili, D. Milledge // Engineering Geology. – 2022. – Vol. 307. – Article 106771. DOI: 10.1016/j.enggeo.2022.106771
15. Bourne, M. Synthesizing social and environmental sensing to monitor the impact of large-scale infrastructure development [Text] / M. Bourne, M. Bosch-Rekveldt, O. Pesämaa // International Journal of Project Management. – 2023. – Vol. 41, issue 5. – Article 102486. DOI: 10.1016/j.ijproman.2023.102486
16. Information technology of analysis of waste management objects infrastructure [Text] / S. Danshyna, A. Nechausov, S. Andrieiev, V. Cheranovskiy // Radioelectronic and computer systems. – 2022. – no. 2. – P. 97 – 107. DOI: 10.32620/reks.2022.2.08
17. Synthesizing social and environmental sensing to monitor the impact of large-scale infrastructure development [Text] / Y. Li [at etc.] // Environmental Science & Policy. – 2022. – Vol. 124. – P. 527 – 540. DOI: 10.1016/j.envsci.2021.07.020
18. Shuttle Radar Topography Mission (SRTM) [Online]. – Available at: https://www.earthdata.nasa.gov/sensors/srtm – 1.11.2023.

DOI: https://doi.org/10.30837/MMP.2024.053

EFFICIENCY OF PROJECT IMPLEMENTATION FOR THE RESTORATION OF UKRAINIAN OBJECTS

Druzhinin Eu., Davydenko O., Obukhova N.

Under the conditions of a market economy, a crucial indicator of the implementation of projects to restore damaged objects in Ukraine is the assessment of the economic efficiency of investments, which is a comparison of the profitability of investment options. In a market economy, investment efficiency will depend on the investment in restoration and the market value of the restored facility. The problem of assessing the efficiency of investments depends on the formation of an investment strategy for choosing the most efficient use of the restored facility. The risks of an investment project should be taken into account when determining the effectiveness of investments in facility restoration. Implementation of the BIM technology system will reduce risks and ensure the efficiency of a construction project at different design stages.

Introduction

The post-war recovery of Ukraine is primarily about rebuilding the country and intensive economic growth. The question arises as to how to quickly and cost-effectively restore the destroyed economic objects, as their number is growing.

The main areas of restoration of damaged objects should be the restoration of the facility in its original form, reconstruction and diversification.

A facility restoration project goes through all stages of the life cycle, and each of them is an important part of the systemic work on its implementation.

When implementing projects to restore damaged objects, special attention should be paid to the pre-project and project stages.

The pre-project stage involves conducting a technical inspection of structures and determining their further suitability; determining the amount of damage caused to the objects as a result of destruction and damage; assessing technical options for restoring the facility; assessing the economic efficiency of investments in the restoration project with an estimate of the market value of the restored facility.

The implementation of the design stage involves the development of project documentation using BIM technology, and determining the cost of restoring the damaged facility in market conditions, as well as project approval.

The features of the selected stages are disclosed in this paper.

Economic efficiency of investments in the restoration of damaged objects

Under the conditions of a market economy, the decisive indicator is the assessment of the economic efficiency of investments in reconstruction, which is reduced to a comparison of options for the profitability of investment based on the determination of the expected net income by various methods.

The assessment of the economic efficiency of investments is reduced to comparing the profitability of a particular placement of funds (capital) based on the determination of net income by various methods. The assessment of the economic efficiency of real investments – capital investments is based on a number of fundamental principles:

1. Estimation of the return on capital based on the cash flow (W_k) generated by profit (P) after tax and depreciation (M), which are received during the operation of the object and remain at the disposal of the investor:

$$W_k = P + M. \quad (1)$$

2. Mandatory adjustment to the current value of both the invested capital (K) and the amount of cash flow (W).

This is due to the fact that cash, instead of being invested, being invested in a bank guarantees an income at the level of the interest rate. In addition, future cash flows must be discounted to the present due to the loss of the value of money.

3. Selecting a differential interest rate (discount rate) in the process of discounting the cash flow for different options for investing in the restoration of the facility.

4. Variation in the forms of using the interest rate for discounting depends on the purpose of the valuation and can be assumed to be equal to

– average deposit or lending rate;

– an individual rate of return adjusted for inflation;

– an alternative rate of return;

– the rate of return on current business activities.

These circumstances require that when assessing the economic efficiency of investments in each specific case, the interest rate norms and multivariate calculation should be justified, taking into account the forecast of its change in the future.

The implementation of the principles of assessing the economic efficiency of capital investments has led to the emergence of various assessment methods that are recommended to be applied comprehensively: the method of net present value, profitability index, payback period, internal rate of return.

The net present value method (W/NPV) involves calculating the difference between the present value of cash flows for the life cycle period – operation of the facility $\left(W_k\right)$ and the amount of investment – capital investment $\left(K\right)$ in the restoration, reconstruction, diversification, brought to the current moment:

$$W = -K + W_k \tag{2}$$

The investment life cycle is the period of time from the start of investing in a real investment project to the next significant investment in an existing facility.

There are 2 stages of the investment life cycle:

1) the investment period – before the start of operation of the facility;

2) the period of operation of the facility – until the start of subsequent investments in technical re-equipment. The invested capital $\left(K\right)$ is calculated for the 1st period, and for the 2nd period, if the duration of the 2nd period is uncertain, most researchers recommend taking it equal to five years, which corresponds to the average depreciation period of equipment, after which it is subject to replacement (in countries with established market economies).

When comparing comparable investment options, the option with the highest positive W/NPV is preferred.

The rate of return method largely coincides with the previous method, but involves determining the average index of return on options $\left(E'\right)$ as the ratio of the present value of cash flow $\left(W_k\right)$ to the present value of investment $\left(K\right)$:

$$E' = \frac{W_k}{K}. \tag{3}$$

The payback period method involves the calculation of the turnover period for which the present value of the investment $\left(K\right)$ at the average amount of cash flows brought to the current moment $\left(\overline{W_k}\right)$, for long-term investments, will return to the investor:

$$T_{ok} = \frac{K}{\overline{W_k}}. \tag{4}$$

The internal rate of return method involves calculating the internal interest rate that ensures the return of the invested amount $\left(K\right)$, i.e. $W = 0$.

The analysis of four methods for assessing the economic efficiency of capital investments shows that the net present value method $\left(W\right)$ meets the objectives of studying the efficiency of investments in the reconstruction of damaged facilities [1, 2].

Assessment of the economic efficiency of one-time investments in a one-time purchase of fixed assets involves determining the maximum positive value of the net present value of income $\left(W^{ok}\right)$ for the period n:

$$W^{ok} = \sum_{t=1}^{n} \frac{W_{kt}}{\left(1+I\right)^{t}} - K' . \tag{5}$$

When rebuilding, reconstructing or diversifying facilities, there are multiple investments that are made over several months or years (τ) in instalments with a net present value return in subsequent years (n). In this case, the investor incurs losses associated with freezing funds K^{pk} for τ years at a certain interest rate (I):

$$K^{pk} = \sum_{j=1}^{\tau} K_j \left(1+I\right)^{\tau-j} . \tag{6}$$

The maximum present value of net income (W'') for a period of n years of multiple investments under the options is:

$$W'' = \sum_{t=1}^{n} \frac{W_{kt}}{\left(1+I\right)^{t}} - K^{pk} . \tag{7}$$

These provisions are adopted as the basis for modelling the market value of destroyed objects in the course of their multivariate reconstruction to assess the economic effect of the buyer's investment.

In a market economy, the regulator of capital market development is the interest rate (I), which causes the loss of equivalence between investments and current costs over time (t).

To estimate the real term of return on investment – the payback period – it is necessary to take into account this temporal unevenness of cash flows, bringing their value to the initial year.

In the case of a one-time investment within a year $\left(K^{ok}\right)$:

$$K^{ok} = \sum_{t=0}^{T_{ok}} \frac{W_{k_t}}{\left(1+I\right)^{t}} , \tag{8}$$

where W_{k_t} net income in the t-th year after investment, UAH;

I – interest rate, in fractions of a unit;

T_{ok} – payback period, years.

In this case, we are talking about current costs, which implies a uniform income flow within each year and allows us to use the expression:

$$K^{ok} = \sum_{t=0}^{T_{ok}} W_{kt} \cdot e^{-I_t}. \tag{9}$$

After converting using the geometric progression and logarithmic formula, we find the payback period:

$$T_{ok} = \frac{1}{I \cdot \left(\ln W_k - \ln\left(W_k \cdot e^{l} - l \cdot K^{ok} \right) \right)} + 1. \tag{10}$$

For the purposes of analysis, it is advisable to express the net income of each year after investment in terms of the rate of return (E) on investment:

$$W_{k_t} = K^{ok} \cdot E_t \cdot \tag{11}$$

Then the output formula will take the form:

$$E_t = \frac{l \cdot e^{l \cdot (T_{ok-1}))}}{e^{l \cdot n} - 1}. \tag{12}$$

If we assume $I = 0 - 0{,}5$ with an interval of 0,05, $T_{ok} = 0 - 10$ with an interval of 1, we can build a nomogram to justify the rate of return on the average over the payback period, taking into account the fall in the equivalence of cash at a certain interest rate (I).

In a market environment, the effectiveness of the investment will depend on the investment in the rehabilitation and the market value of the rehabilitated property.

Market value is the most likely price that a property would fetch in a competitive and open market, provided that all conditions of a fair sale are met.

To determine the market value of real estate, three methodological approaches are used: cost, comparative, and income.

An analysis of the methodological approaches to determining the market value of real estate showed that they are focused on the valuation of completed construction projects, while destroyed properties require additional investment and time to rebuild, reconstruct or diversify. The leading method for assessing economic efficiency is the method of calculating the net cash flow over the life cycle of an investment based on the equality of the cash flows of the seller and the buyer.

The problem of assessing the efficiency of investments depends on the formation of an investment strategy for choosing the most efficient use of the restored object.

The initial stage of developing an investment strategy is to determine the overall period of its formation, which depends on the predictability of the development of the economy as a whole and the investment market. The effectiveness of the investment strategy depends on the reliability of the forecast and the justification of trends in the factors that shape the investment climate, which affects the state of the investment market in the future. Forecasting the investment market conditions is a probabilistic process of strategy formation [3].

All forecasting methods are grouped into three groups: expert estimates, logical modelling, and mathematical. The analysis of methods shows that in order to solve long-term problems of forecasting the investment market and the real estate market, which is part of it, requires the integrated use of various forecasting methods and justification of forecast calculations depending on the information support of decision-making conditions for the restoration of facilities, based on the factor approach.

When determining the effectiveness of investments in facility restoration, the risks of an investment project should be taken into account – a set of possible circumstances that may cause a decrease in project efficiency or the impossibility of its implementation [4, 13].

Particular attention should be paid to the following risks:

– pre-project phase risks (errors in the technical inspection of structures and determination of their further suitability; determination of the amount of damage, assessment of technical options for the restoration of the facility)

– risks of the project phase (errors in design and budgeting, incorrect calculations of probability and expected financial receipts, imperfect forecasting and determination of project implementation time).

The introduction of BIM technologies will allow:

– during the technical inspection of facilities – to reduce the time of the inspection, build a 3D model of the damaged object and compare it with the original appearance of the building, determine the level of structural damage;

– during design – to significantly increase the objectivity and reliability of design decisions, reduce the likelihood of design errors, reduce the cost of project development and reduce the time for developing project documentation.

– at the project implementation stage – to increase the efficiency of resource use, minimise the availability of warehouse stocks directly at the construction site, promptly adjust construction costs, and reduce construction time;

– support at the stage of facility operation – determination of operating costs, efficiency of work on the restoration, reconstruction and diversification of facilities.

Problems of designing construction projects using BIM technology in Ukraine

The implementation of a BIM technology system should ensure the efficiency of a construction project at various stages of design, implementation and operation.

The use of BIM technology in the design and construction process allows you to quickly access any information about the facility, control the quality of work at all stages, avoid conflicts in the project, and significantly reduce construction costs. However, the main advantage of implementing BIM technology in construction is the ability to achieve almost complete compliance of the characteristics of the future facility with the customer's requirements [6].

The introduction of BIM technologies in Ukraine has many challenges that need to be addressed through software improvements.

Today, the formation of a 3D design model is associated with software tools: the architectural part of the project (Autodesk (Revit), AllPlan Deutschland GmbH, Graphisoft (Archi CAD), Tekla Corporation, AutoCAD, and others); the structural part (LIRA – CAD, Monomakh, SAPFIR); plumbing and electrical parts (Magi CAD for AutoCAD). These software systems are autonomous products that are not connected to each other and have different owners, which makes it difficult for independent developers to implement them. A number of measures are proposed to export data and establish feedback between these programmes.

A significant number of software products operating in Ukraine remain disconnected from the 3D project model, including 4D construction organisation and management (Microsoft Project, Primavera P6, Spider Project, etc.); 5D estimate and contract pricing (Construction Technologies – Estimate 8.1 (Computer Logic Group), ABK−15, AC−4, TK Investor)[12].

In designing the organisation of construction production, it is important to choose a method of construction organisation and models to substantiate the technical and economic indicators of the relevant organisational projects, among which the following models should be distinguished: analytical (calculations of initial data, tables, matrices), graphical (tape chronograms, network, cyclograms), computer (programs such asProject, Allplan).

Software products such as Microsoft Project provide satisfactory construction schedules for an object under certain deterministic or probabilistic indicators of the duration of work, the combination of work and time, and the cost of investment by construction period. However, the reliability of the resulting models depends on the state of the regulatory and reference base and the dynamics of its change over time. This is how the transparency of the regulatory framework for labour and machine resources in determining the duration of work has been lost [7, 8].

The BIM 6D system allows for the calculation of energy efficiency and energy consumption of a building, as well as comprehensive calculations of the economic efficiency of the entire building (taking into account the location) and all its elements simultaneously. When using BIM 6D and 7D, 8D, it is possible to additionally collect and use various information about the object in one central system, which allows for efficient use of the building and its operating time. Due to this, the functional BIM 6D, 7D, 8D system is used in facility management, but there are no software products of this level in Ukraine [9, 10].

The use of BIM technology increases the objectivity and reliability of design decisions, the likelihood of obtaining real indicators in the restoration of affected facilities and the construction of new facilities. The development of software in accordance with BIM technology will allow for the design, organisation and management of construction projects at a modern level.

Conclusions

The above provisions indicate that the basis for assessing the economic efficiency of the restoration of damaged objects should be a model of discounted equilibrium net income for the investment cycle with forecasting the market value of the restored object and additional investments at a certain rate of return.

The introduction of BIM technology in the process of restoring damaged facilities has undeniable advantages, as it allows instant access to any information about the facility, control over the quality of work at all stages, and avoidance of project conflicts. The development of new software products and improvement of existing BIM-based programmes is relevant for Ukraine.

References

1. Peresada, A.A.(2017), "Management of the investment process". – Kyiv: Libra, 472 p.
2. Mayorova, T.V.(2019), "Investment activity: support".– Kyiv: Center for Educational Literature, 472 p. URL: https://www.yakaboo.ua/ua/investicijna-dijal-nist-pidruchnik-zatverdzhenij-mon-ukraini.html
3. Lutsiv B.L., Kravchuk I.S., Sas B.B.(2014), "Investing: Textbook". – Ternopil: Economic Opinion, 544 p. URL: http://dspace.wunu.edu.ua/bitstream/316497/26337/1/4-Lutsiv_Investyvanna.pdf
4. Druzhinin A., Druzhinin E., Davydenko O., Obukhova N.(2023), "Risk-oriented approach to optimising management in the context of using BIM technology", Information systems in project and program management: Collective monograph edited by I. Linde. European University Press. Riga: ISMA, 317p. URL: https://mmp-conf.org/documents/archive/monography2023.pdf

5. Richard Newton. (2015), "Project management from A to Z". – M.: Alpina Publisher / business, 178 p. ISBN 978-5-9614-3047-9
6. Samad, M. E., Sepasgozar, M. L., Steven, R. Davis.(2016), "Conceptualising information and equipment technology adoption in construction". Engineering Construction & Architectural Management, Vol. 23(2), P.158-176. URL: http://doi.org/10.1108/ECAM-05-2015-0083
7. "BIM technologies in construction: experience and innovations" [Text] / by general ed. Dr. Tech. Sciences, Prof. D. F. Goncharenko, H., (2021), Materials of reports of the First All-Ukrainian scientific and practical conference: FOP Brovin O. V., 292 p. URL: http://en.bim.kstuca.kharkov.ua/
8. A., Druzhinin, O., Davidenko, S., Bratishko, O., Kuchma, O., Zhyliakova. (2023), "Problems of optimization of innovative solutions and improvement of the current building information system". AIP Conf. Proc. 2490, 040006, 7desember, 2023. URL: https://doi.org/10.1063/5.0143924
9. Monograph "Project Management Based on VIM Technology", Druzhinin A.V., Druzhinin E.A., Davidenko O.A. (2023), Kharkiv: FOP Brovin O.V., 130 p. ISBN 978-617-8238-03-2. URL: https://odnb.odessa.ua/vnn/book/15469
10. "Value proposition on interoperability of BIM and collaborative working environments"(2010), Automation in Construction, August, No 19(5), p. 522–530. URL: http://doi.org/10.1016/j.autcon.2009.11.003
11. Smetanková J., Mésároš P., Krajníková K.(2022), "Use of Building Information Modelling (BIM) in planning and managing the life cycle of buildings". September IOP Conference Series Materials Science and Engineering 1252(1):012053. URL: http://doi.org/10.1088/1757-899X/1252/1/012053
12. Obukhova N.V., Davydenko O.A.(2024). "Adaptive management technologies as a mechanism for ensuring the stability of the functioning of the development of companies". Financial and credit systems: development prospects. Vol.1(12) , P. 60–69. (online) URL: https://periodicals.karazin.ua/fcs/article/view/23409/21410
13. T. Golterova, O. Savchenko, N. Obukhova, D. Nimkov, A. Babintsev. (2023) "Organizational and technological desing of construction objects in the conditions of innovative development of design and construction firms"/ 5th International scientific and practical conference “Innovative technology in architecture and design” (ITAD-2021), 20–21 May 2021, Kharkiv, Ukraine, AIP Conf. Proc. 2490, 040014,7desember, Vol.2490 Is. 1. https://www.scopus.com/authid/detail.uri?authorId=58293550200

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ALGORITHMS FOR DECISION SUPPORT IN RISK MANAGEMENT IN THE DEVELOPMENT OF INFORMATION-SENSITIVE SOCIALLY ORIENTED SYSTEMS

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The increase in the amount of data and the overall change in social and market processes are driving the transformation of basic management principles. This is especially true for risk management. Under non-deterministic conditions, when developing solutions for socially oriented systems, forecasting possible problems requires the use of modern data mining tools. Existing concepts cannot fully guarantee high efficiency in the face of social shifts exacerbated by a falsified information environment, for example, during discrediting campaigns against ideas proposed by businesses. At the same time, there is a problem with the speed of simple solutions and the high cost and security of using more complex cloud technologies. The current work is focused on considering modifications to simple decision support models and building a data processing algorithm to improve the accuracy and reliability of project forecasting. The proposed sequence of steps allows us to take into account the essence of instability and its impact on society, while taking into account the peculiarities of the information environment. Experimental comparison of various classical models with the proposed solution allows us to state the higher efficiency of the created algorithm, both in terms of accuracy and speed due to parallelization. This, in turn, opens the way to solving the problem of risk prediction for information-sensitive socially oriented systems

1 Introduction

One of the most important preparatory steps in project management in any field is to identify key risks and ways to mitigate them. In today's environment, this task is becoming complex and requires processing a large amount of historical data. This state of affairs has given rise to the development and popularization of decision support systems (DSS), which can both aggregate information or make forecasts and, in some cases, provide recommendations on how to solve problems. Nevertheless, most DSSs, based on available reviews on specialized resources, are not effective enough in the face of uncertainty, especially when targeted projects relate to the activities of social groups, such as urban systems [1]. The intensification of social shifts over the past few years, which was reflected in the pandemic, and later in the Russian-Ukrainian war and several local armed conflicts, raises the issue of improving the algorithms that may underlie the described systems. At the same time, this problem is even more acute when building a highly intelligent infrastructure for various sectors of human life. Not least because of the impact of falsified information on human behavior. As an example, we can mention the campaign against the installation of a more modern Internet based on 5G technology, which is certainly necessary for the more reliable functioning of all the latest infrastructure solutions [2]. Another similar example is the discrediting of the "smart city" concept by linking it to the forest fires on the island of Maui [3].

Another important problem is that existing solutions either require significant cloud resources or are not fast enough, which can play a critical role under certain conditions. Although there are several large companies that provide their own facilities for deploying complex software products, the issue of their reliability and security remains unresolved [4].

Given this, it was decided to modify the existing algorithms of the SPPR in order to increase their effectiveness in managing risks for socially oriented systems. Such a modification should not only take into account the nature of social shifts or audience behavior, but also the likelihood of falsified information aimed at discrediting the solutions being developed, in particular those related to urban infrastructure. At the same time, the speed of these algorithms should be sufficient for their practical application To achieve this goal, the following tasks were identified

- review of existing solutions that underlie modern SPDS and identification of their key shortcomings;
- development of a data pre-processing algorithm that would allow to take into account changes in the behavior of the target audience and the impact of news on it;
- determination of the basic algorithm for forecasting the company's performance within the target project and opportunities for its further improvement;
- researching the possibilities and implementing the parallelization of the algorithm;
- determining the effectiveness of the proposed solution by conducting an experiment and solving a linear optimization problem.

We will gradually review the results of the above steps.

2 Theoretical basis

This section presents the results of the analysis of the key algorithms used in decision support systems and the identification of the features of target indicators of audience behavior, information environment, social shift and business environment.

2.1 Choosing the basic algorithm

In general, DSSs are usually divided according to two criteria [5]:

- the way of decision support: focused on data, knowledge, documents, communication, and models;
- method of interaction with the user: active, passive, combined.

Given that it was decided to focus on simple solutions that do not require significant hardware capacity and on the development of an algorithm for information processing, only data-oriented passive DSS will be considered in the following. The choice of the “passive” form is explained by the fact that the recommendation subsystem is a separate model and goes beyond the defined tasks.

In 2023, some of the most popular systems implemented in the risk management process are: Hyperproof, Soterion, Whistic [1].

After analyzing the feedback over the past 3 years and the official websites of the identified projects, the following features were identified

- the predictive algorithms are based on neural networks and/or autoregressive models. It is worth noting that some other DSSs are also capable of using a probabilistic approach, but it is slower and requires the use of cloud computing;
- there is a limited consideration of risks associated with the activities of the target audience of the systems being developed, in particular, problems with forecasting business activity during the COVID-19 pandemic were noticed;
- lack of consideration of the information environment in which the target project is being created.

The defined classes of basic predictive algorithms are relatively broad and require additional filtering. In particular, in the case of neural networks, we can consider:

- convolutional neural networks (CNNs) that use a convolutional function to reduce the dimensionality of input data;
- recurrent neural networks (RNN), which are based on reusing the results of the previous layer. More complex networks with long-term memory support can also be considered here;
- combined hybrid networks (generalized RCNN) that combine several simple models, providing higher accuracy.

At the same time, among autoregressive models, it is worth mentioning

- distributed lag autoregression and seasonal autoregression based on the use of basic features of time series;
- moving average autoregression and integrated moving average autoregression, which allow for the aggregation of related data.

An additional study of the problem of forecasting economic indicators by using international scientific papers allows us to limit the set of basic forecasting algorithms to a combined hybrid neural network and autoregressive integrated moving average. These models, although the slowest, have the highest accuracy of the proposed ones, they are also capable of parallelization and do not require significant hardware capacity [6].

2.2 Defining target indicators

In order to mitigate the risks that may accompany the development and implementation of a socially oriented program project, a set of key aggregate indicators should be identified. Based on the discussion in Section 1, the following general indicators can serve as

- social shift profile, a parameter that allows converting the uncertainty of conditions into a numerical form;
- target audience profile, which summarizes the behavior of the most influential targeted actors;
- business environment profile, which defines the specifics of implementing a particular project in the market context;
- information environment, an indicator that reflects the intensity of the impact of fabricated information on the target concept.

In order to form a mathematical representation, it is necessary to understand the specifics of each of the identified factors. The following indicators were formed based on the analysis of modern scientific publications and expert evaluation among 100 sociologists, engineers, managers and executives of Kharkiv, Lviv, Dnipro, Kyiv, Lisbon and Krakow.

When studying the concept of a social shift, also called a "social catastrophe", it was found that the most influential sub-indicators are the prevalence of the source of the shift, its duration (including the moment of the first information appearance), specifics for a particular area of activity, and the level of severity. The first two indicators are inherently objective numerical variables, while the other two reflect the subjective perception of the shift and require additional algorithms to be used in forecasting.

The profile of the target audience can be determined by taking into account the size of this audience, the market paradoxicality of the target decision (if it is subject to well-known neoclassical economic paradoxes), the degree of trust, and the general description of society. As in the first case, there is a mix of numerical objective indicators with textual indicators subjective to the target project.

The profile of the business environment focuses on the reaction of business entities to both the implementation of the proposed project solution in general and the social catastrophe in particular. To take this into account, it was decided to focus on indicators of financial stability of the economy (both global and local) and business readiness for emergencies. Although the latter indicator in most cases does not directly affect systems focused on the smart city concept, it allows for an adjustment of the objective assessment of a city's financial stability with the subjective perception of its internal counterparties.

The information environment, in the framework of the current work, refers to the intensity of the spread of fake news about the project topic, technological reforms, and other similar domains of knowledge. To be able to calculate this, it is necessary to understand the specifics of defining fabricated information. Since it was decided to focus on textual data, the following characteristics can be identified [7, 8]:

- the use of an unnatural number of rhetorical questions (contextual distortion of socially significant topics). Linguistic studies show that this type of speech construction is not often used in official business and journalistic styles for use by the media;
- lack of negative constructions to reduce the cognitive load in combination with pessimistic colors of the selected words. As an example, the replacement of the word "bad" with "catastrophe". It is worth noting here that profanity will be deliberately removed from further texts, as it complicates the process of analyzing emotional coloration;
- the use of appeals and encouragement in the wrong context and the use of an unreasonable number of pronouns. In this case, there is an imitation of a journalistic style of presentation;
- high frequency of using short sentences and words with grammatical errors.

These characteristics are not exhaustive, but it should be emphasized that the target texts for review, in addition to obscene vocabulary, will not include the mixing of several languages and the use of regional dialects. Such add-ons are beyond the scope of the tasks described.

In general, the field of determining the falsity of information is not new, as mentioned above. Several groups of European scientists have shown that machine learning algorithms based on both neural networks and more modern transformers or autoencoders require significant amounts of data to achieve an accuracy of more than 90% [9, 10]. However, this problem can be solved by using a balanced data set, as demonstrated by Ukrainian researchers.

Another well-known way to determine whether data has been falsified is to use graph models [11]. In their work, Harvard scientists have demonstrated their high efficiency in solving the problem of detecting fake accounts. However, this method will not allow to fully process textual information from news, or will require more significant capacity for pre-processing. A similar problem applies to algorithms that help detect spam. A research team of Chinese-American scientists has proved the possibility of effective use of Markov networks [12]. However, given the specifics of the field and the goal, their use is quite cumbersome and will require the use of cloud technologies. A similar problem has already been considered for the basic predictive algorithm [6].

3 Mathematical basis

This section will outline the key features of the proposed basic algorithms and target indicators of pre-processing.

3.1 Target algorithms

As noted above, the current paper considers two basic algorithms - RCNN and vector moving average autoregression. The vector nature of the latter is necessary for the possibility of simultaneous processing of several indicators.

In a simple CNN model, passing a filter allows to take into account the neighborhood of each element, but the specificity of the proposed indicators requires understanding a longer time period without a significant shift to the future. Thus, a significant context may be outside the filter of the CNN model. To avoid this problem, it was decided to combine RNN and CNN.

Although there are several ways to do this, this study will only consider an architecture that uses two neural networks in sequence. In other words, after convolution is performed, the result is not only concatenated, but sent to the layer with the recurrent neural network.

To be able to take into account the context to the fullest extent, it was decided to use a bidirectional recurrent neural network with support for both long-term and short-term memory rather than a simple RNN architecture. It is based on the use of hyperbolic tangents and sigmoidal lines, which avoid the problem of exploding and disappearing gradients by limiting the area of the resultant values. At the same time, the defined model allows to take into account the entire historical context. Thus, the RCNN architecture can be represented as shown in Figure 1.

As a result of the cross-validation testing, it was determined that the best key hyperparameters are the following values:

- the kernel size is 4;
- the step size is set at 1;
- based on the set step size, the parameter for adding insignificant zeros will not be applied;

- based on the specifics of the subject area, it was decided not to apply the offset parameter;
- the filter dimension is set to 5´5´3 (the last value of the dimension is determined by the number of target indicators).

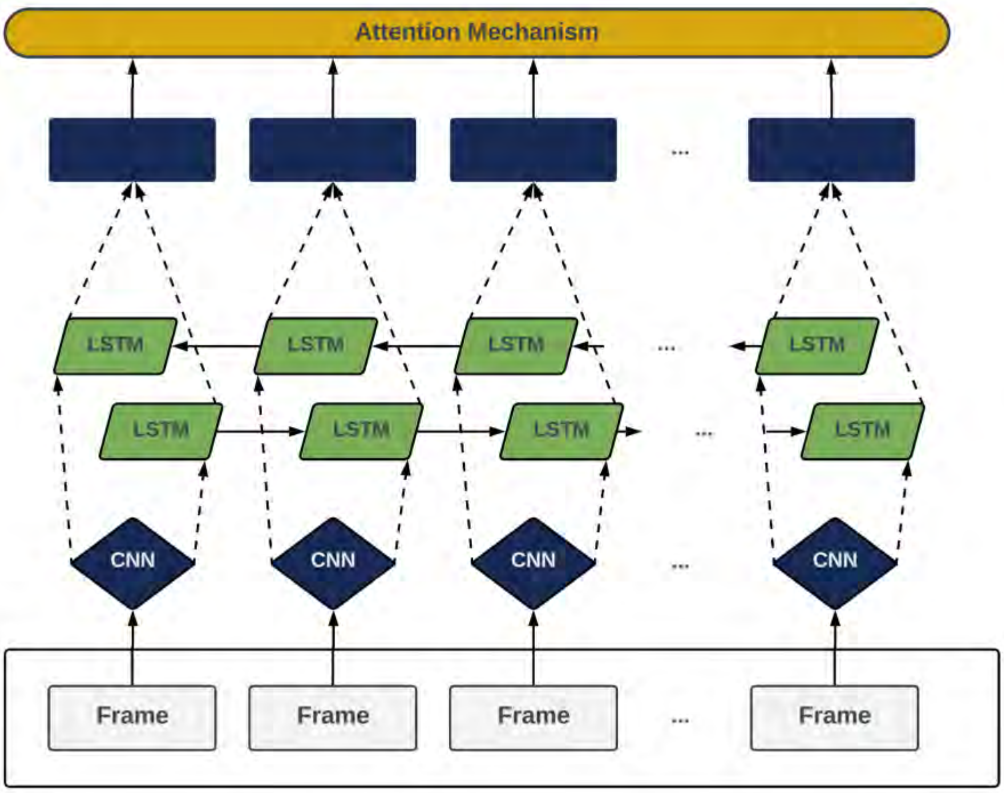

Fig. 1. Schematic of RCNN architecture

To understand the essence of the second basic algorithm, it is necessary to consider the features of vector autoregression (VAR) in general. It can be represented as follows:

$$\Phi_0 y_t = \Phi_1 y_{t-1} + \ldots + \Phi_p y_{t-p} + \Theta_0 u_t + \Theta_1 u_{t-1} + \ldots + \Theta_q u_{t-q}, \quad (1)$$

where y_t – K-dimensional time series;

Φ_i, Θ_j – dimension matrices $K \times K$, $i = \overline{1,p}$, $j = \overline{1,q}$;

u_t – K-dimensional white noise vector with zero mean and the following non-degenerate covariance matrix $\Sigma = \mathbb{E}(u_t, u_t')$.

The above formula (1) shows that the classical family of VAR models forecasts only static variables. In order to take into account exogenous variables, we decided to use a modification of the error correction (abbreviated as EC). This adjustment is necessary when several endogenous variables have a common stochastic trend [13]. This is the case for the problem under consideration.

The general formula for the modified EC-VAR family of algorithms is as follows:

$$\Phi_0 \Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Psi_i \Delta y_{t-i} + \sum_{j=0}^{q} \Theta_j u_{t-j}, \quad (2)$$

where $\Pi = -\left(\Phi_0 - \Phi_1 - \ldots - \Phi_p\right)$; $\Psi_i = -\left(\Phi_{i+1} + \ldots + \Phi_p\right)$, $i = \overline{1, p-1}$.

The integration and mobility of the selected target model will provide the ability to take into account the neighborhood of the target element of the time series. In this case, the problem is similar to the one identified for CNN, as the family of autoregressive models does not provide for the full consideration of the historical context.

3.2 Target indicators

The Social Disruption Profile (SDP), as already mentioned, is divided into 4 indicators, each of which involves a separate processing algorithm.

The prevalence (SDO) will be determined by analyzing social networks with a search by keywords selected by the user of the model being developed. Determining the geolocation of the posts (where possible) will allow us to calculate the number of regions where the social disaster is mentioned. If this number reaches 10 (Europe, Asia, North America, Central America, South America, Australia, Oceania, North Africa, South Africa and Central Africa), the algorithm will indicate the prevalence at 100%, or 1.

After consulting with the expert group, it was decided to limit the maximum possible time of the active phase of the social shift to 365 days. If more time has passed since the first news about the described disaster, the duration indicator (SDD) will be set at 1, if less time has passed, it will be determined as a fraction of the selected maximum.

Sector-specific features (SDF) are processed using sentiment analysis to determine how prepared the entity responsible for a particular project decision is for a social disaster, while the indicator also covers the reaction of the population. The Ukrainian language is inherently polymorphic, which complicates the classical processing process. However, we will consider this a limitation for the proposed model. The general processing algorithm is as follows:

- cleaning the text description from words without a significant lexicographic load;
- creating a dictionary of key lemmas and finding the frequency characteristics of each word form;

- determination of the polarity of each word and correction of frequency values;
- aggregation and subsequent normalization of the obtained data in the range from 0 to 1, where 0 means the situation has a negative emotional description, 1 means a positive one.

The Severity Level (SDS) is a subjective numerical indicator set by the user of the developed algorithm in the range from 0 to 100 (integer values only). The final result is then normalized.

The four indicators are combined as follows:

$$SDP = \frac{SDO \times SDS \times SDD}{SDF} \quad . \tag{3}$$

The Target Audience Profile (TAP), in addition to the indicators outlined in the previous section, also takes into account the SDP indicator calculated using formula (3).

The maximum possible size of the target audience (TAS) was set at 100,000 people. It will be processed similarly to the SDD indicator.

The need to adjust behavior based on existing neoclassical economic paradoxes (TAX), which imply an increase in demand in a crisis, is a binary indicator (0 – no need to apply, 1 – need to apply). This indicator is determined by the model user, as well as the degree of trust (TAT), for which the limits are set similar to SDS.

The algorithm for processing the textual description of society (TAF) is similar to the above, but instead of determining the polarity of each lemma, the words are sorted according to the concept of emotions proposed by Robert Plattschik. The result is aggregated and normalized in the range from 0 to 1, where 0 means that negative emotions prevail in the target audience, and 1 means that positive emotions prevail. The general formula is as follows:

$$TAP = \left(\frac{TAF \times TAT \times \left(1 + TAX\right)}{TAS} \right)^{SDP} \quad . \tag{4}$$

The Business Environment Profile (BEP), according to the described methodology, consists of three indicators. At the same time, the SDP adjustment should also be taken into account.

The global economic system financial stability indicator (BWFS) is defined as a weighted average of three elements expressed in shares:

- changes in global GDP relative to the beginning of the social shift;
- changes in the S&P 500 index relative to the beginning of the social shift;
- changes in prices for basic energy resources.

According to the macroeconomic theory proposed by Friedman, when forecasting one's own business activities, it is necessary to consider the GDP of the country in which these activities are carried out. Although the solutions aimed at implementing the concept of "smart cities" are relatively isolated, the current level of globalization indicates the need to adjust the assessment of stability in relation to the world as a whole.

The energy price index has a direct impact on the logistics of any company and, accordingly, on the prices of their products. Since the data on products or the consumer price index will not necessarily be targeted in forecasting, it is necessary to take into account the impact of the company's reactions to the growth in the cost of contracts with counterparties, which is why this indicator is considered.

The local economic system stability indicator (BLFS) has similar elements to the BWFS, which are extrapolated to a limited area:

- changes in regional GDP relative to the beginning of the social shift;
- changes in the consumer price index relative to the beginning of the social shift;
- the rate of devaluation of the target currency.

The latter element is needed to take into account the extent to which the national currency has depreciated both against itself and against the world's most influential currencies – dollar, euro, yuan, yen, and pound sterling.

Business readiness (BR) is defined as follows:

$$BR = \frac{s_t^2 \times IAI \times FSI}{HHI}, \tag{5}$$

where N is the number of companies in the selected market;

s_t is the market share owned by company t;

FSI is the company's financial stability indicator;

IAI is the company's innovation activity indicator;

HHI is the Herfindahl–Hirschman index.

The overall indicator is calculated using the following formula:

$$BP = \left(BWFS \times BLFS \times BR\right)\frac{1}{SDP} \ . \tag{6}$$

The final indicator of the information environment (IEA) is a reflection of the number of fabricated news items related to the topic of the target urban decision or related topics relative to the total amount of information. The classification is carried out using another RCNN model, the parameters of which are defined as follows:

- the kernel size is 3;
- step size is set to 1;

- the parameter for adding insignificant zeros will not be applied, as well as the offset parameter, in order not to lose the context of the news;
- the filter dimension is set to 5´5´1.

The above four indicators serve as external data. To test the possibility of using them, we conducted a Granger causality test [14]. It was found that the correlation between the values of one variable and the past values of another allows us to consider them as external indicators.

4 Parallelization

To implement parallelization, it was decided to use MapReduce technology, which consists in dividing the original data set into separate nodes. Based on this idea, the key elements of the built model are the mapping and reduction functions. The most popular implementations are Spark-based and Hadoop-based. In this paper, we chose the second option, which has an additional pair of similar functions, but within each node, to speed up the interaction with databases [15]. This is a positive feature of the chosen approach, given the large amount of diverse information that needs to be processed.

The proposed solution can be presented as shown in Figure 2.

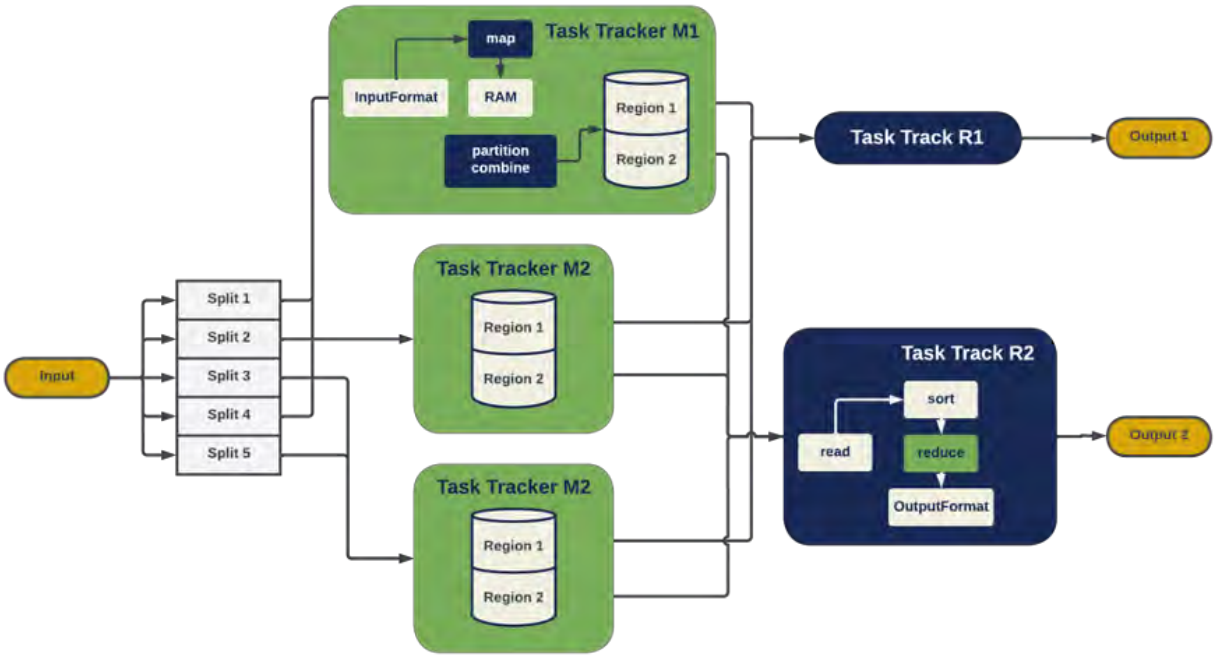

Fig. 2. Diagram of MapReduce technology based on Hadoop

For the RCNN architecture, the first step is the CNN layer. In this layer, the weights are iteratively adjusted by calculating their partial gradients after each set of training data is propagated through the network. Thus, parallelization during the training phase can be achieved by dividing the data into several chunks. Then, each data chunk is passed to multiple CNNs, and each CNN is trained independently in parallel. After that, the results are aggregated using a reducer to obtain the final results, which are then used to update the weights for the next iteration.

After the CNN layer is finished, the aggregated data is transferred to a bidirectional recurrent neural network. To speed up the process, you can divide the work of two neural networks between two nodes. In this case, the reduction function will actually serve as a function of aggregating the results of the two networks.

In the case of vector autoregression, although the overall calculation result depends on all the data, parallelization can be achieved by distributing the window load. The calculation of the integrated average can be performed on individual nodes and then aggregated. This will avoid the need to wait for the most time-consuming (in terms of CPU time) tasks to be completed.

5 Testing the approach

To test the effectiveness of the proposed approaches, the implementation was carried out on a stable environment. In terms of parallelization, the nodes copied the local hardware, and their number was set to 4.

The datasets for checking news falsification were created in-house based on the processing of news related to the implementation of an electronic ticket in Kharkiv and the introduction of the "smart city" concept in Kyiv. Data for forecasting with project targets were also generated semi-automatically. The following were considered as targets: the dynamics of expenses and income; the level of involvement of the target audience; and the efficiency of intermediate tasks.

The obtained values were combined into 3 separate data sets.

After expert evaluation, the following indicators were selected as key performance criteria:

- accuracy with an importance coefficient of 16;
- saving the time of the target algorithm (taking into account preprocessing) with an importance factor of 8;
- saving the minimum allowable amount of target data to achieve "accuracy" of more than 80% with an importance factor of 4.

The weighting factors for linear additive convolution are calculated based on the importance coefficients.

Since the issue at hand is prediction, not classification, accuracy will be measured using the normalized inverse root mean square error. The time savings will also take into account the parallelization proposed above, in order to offset the loss that accompanies the use of the data preprocessing algorithm. The minimum allowable volume savings are measured in terms of the number of elements in the time series and normalized relative to the extreme values. Figure 3 shows the results of 5 measurements of the target algorithm's time savings, rounded to whole seconds for normal attempts and to tenths in the case of the average value.

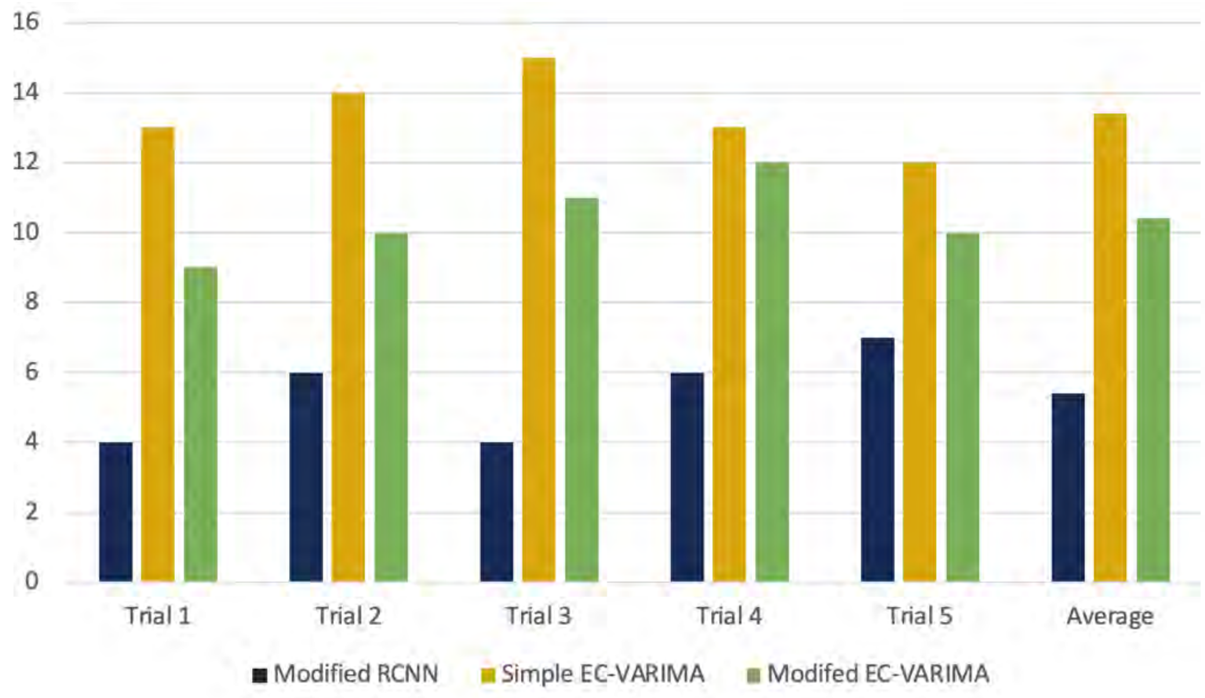

Fig. 3. Results in terms of time savings

As can be seen from Figure 3, the fastest algorithm is the simple EC-VARIMA, followed by the modified one. This result is achieved due to the parallelization of the model itself and all the preprocessing steps. For the accuracy indicator, the situation is different: the most accurate algorithm (as shown in Figure 4) is the modified RCNN. At the same time, one can notice the instability of the basic algorithms without taking into account external indicators. This corresponds to the hypothesis mentioned above.

The final indicator is data volume savings. It should be noted here that the two baseline models did not achieve the required result of the minimum accuracy result when gradually increasing to 500000 elements. Therefore, for these algorithms, the savings value is 0. For the modified RCNN, the minimum allowable value is 50,000 elements, and for the modified EC-VARIMA, it is 100,000.

These results can be presented in the form of the following Table 1, taking into account their normalization and rounding to the hundredths.

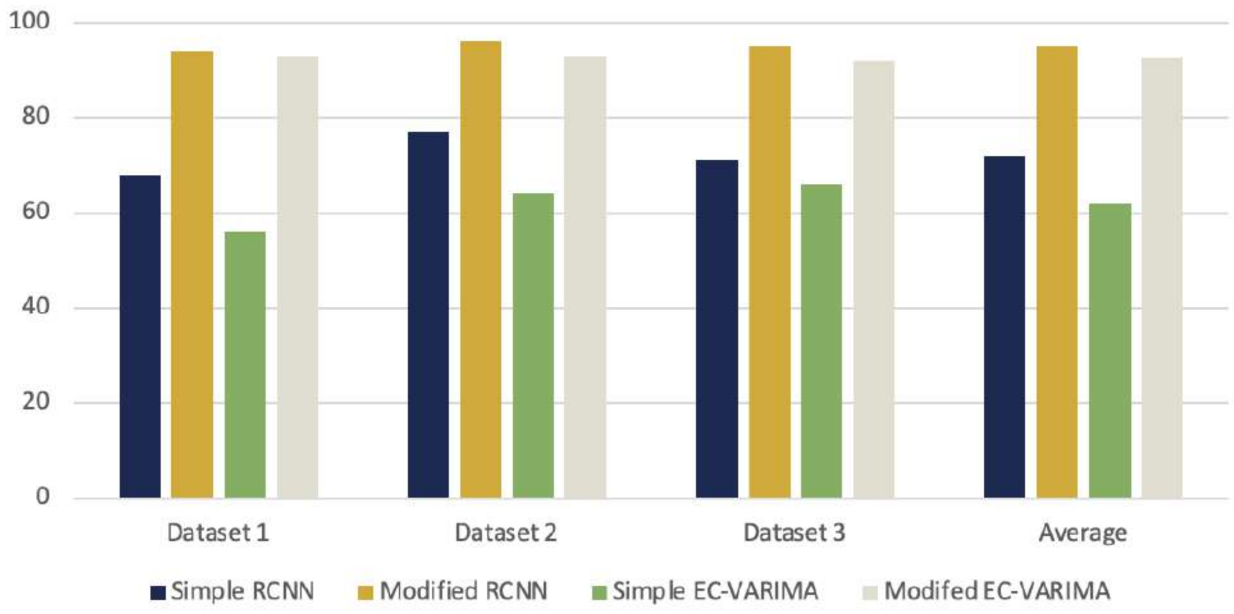

Fig. 4. The result in terms of "accuracy"

Table 1

Processed results of the experiment

Model	Accuracy	Time saving	Data saving
Simple RCNN	0.72	0.00	0.00
Simple EC-VARIMA	0.62	1.00	0.00
Modified RCNN	0.95	0.40	0.90
Modified EC-VARIMA	0.93	0.78	0.80

Based on the results obtained, we calculated the value of linear additive convolution with weighting coefficients. For Simple RCNN, the value was 0.41, for Simple EC-VARIMA – 0.64, for Modified RCNN – 0.79, and for Modified EC-VARIM – 0.87.

6 Conclusions

The analysis of the industry allowed us to identify a hybrid neural network consisting of a combination of recurrent and convolutional subnets, as well as vector autoregressive integrated moving average as simple models that do not require significant computing power. To be able to take into account the impact of social shifts on the process of developing and implementing targeted project solutions, 4 key indicators were identified

- profile of the social disaster
- profile of the target audience,;

- profile of the business environment (both global and local);
- the information environment, which reflects the intensity of the impact of fabricated information on the target concept.

The use of algorithms for their processing causes the problem of speed. To mitigate this problem, we used Hadoop-based MapReduce technology. Experimental results have shown that it has reduced the speed gap between simple and modified models. In addition to saving time, accuracy and saving the minimum allowable amount of data to achieve 80% accuracy were also considered as target indicators.

Taking into account the obtained values of linear additive convolution, it can be noted that the proposed approach to parallelization and pre-processing of external data gives the desired result, increasing the efficiency of using simple models. At the same time, the forecast accuracy is high for both modified algorithms. However, due to its simplicity, the modified EC-VARIMA is more effective given the selected set of indicators.

Thus, the approach described above allows for effective forecasting of the economic performance of information-sensitive socially oriented systems during emergencies. This, in turn, may allow for a timely response to crisis phenomena and changes in management policy.

References

1. G2, Best IT Risk Management Software, 2024. URL: https://www.g2.com/categories/it-risk-management
2. E. Flaherty, T. Sturm, E. Farries, The conspiracy of Covid-19 and 5G: Spatial analysis fallacies in the age of data democratization, Soc Sci Med. 293 (2022) no. 114546. DOI: 10.1016/j.socscimed.2021.114546
3. P. Marcelo, Conspiracy theories falsely tie Maui wildfires to ‘smart cities’ and tech conferences, AP News, 2023. URL: https://apnews.com/article/fact-check-maui-hawaii-wildfires-smart-cities-387327837046
4. U. A. Butt, R. Amin, M. Mehmood, H. Aldabbas, M. T. Alharbi, N. Albaqami, Cloud Security Threats and Solutions: A Survey, Wireless Personal Communications. 128 (2022) pp. 387–413. DOI: 10.1007/s11277-022-09960-z
5. K. Srinivas, Process of Risk Management, IntechOpen, 2019. DOI: 10.5772/intechopen.80804
6. S. Yakovlev, A. Khovrat, V. Kobziev, Using Parallelized Neural Networks to Detect Falsified Audio Information in Socially Oriented Systems, in: Proceedings of the International Scientific Conference "Information Technology and Implementation", IT&I ‘23, Kyiv, Ukraine, 2023, pp. 220–238. URL: https://ceur-ws.org/Vol-3624/Paper_19.pdf

7. R. Deng, F. Duzhin, Topological Data Analysis Helps to Improve Accuracy of Deep Learning Models for Fake News Detection Trained on Very Small Training Sets. Big Data and Cognitive Computing. 6 (3) (2022) no. 74. DOI: 10.3390/bdcc6030074
8. A. Choudhary, A. Arora, Linguistic feature based learning model for fake news detection and classification. Expert Systems with Applications. 169 (2021) no. 114171. DOI: 10.1016/j.eswa.2020.114171
9. R. Tolosana, R. Vera-Rodriguez, J. Fierrez, A. Morales, J. Ortega-Garcia, Deepfakes and beyond: A Survey of face manipulation and fake detection. Information Fusion. 10 (11) (2020) pp. 131–148. DOI: 10.1016/j.inffus.2020.06.014
10. M.A. Alonso, D. Vilares, C. Gómez-Rodríguez, J. Vilares, Sentiment Analysis for Fake News Detection. Electronics. 10 (11) (2021) no. 1348. DOI: 10.3390/electronics10111348
11. A. Breuer, R. Eilat, U. Weinsberg, Friend or Faux: Graph-Based Early Detection of Fake Accounts on Social Networks, in: Proceedings of the Web Conference, WWW '20, Association for Computing Machinery, Taipei, Taiwan, 2020, pp. 1287–1297. DOI: 10.1145/3366423.3380204
12. T. Xia, X. Chen, A Discrete Hidden Markov Model for SMS Spam Detection. Applied Science. 10 (14) (2020) no. 5011. DOI: 10.3390/app10145011
13. M. Akkaya, Vector Autoregressive Model and Analysis. Handbook of Reseach on Emerging Theories. Springer. (2021) pp. 197–214. DOI:10.1007/978-3-030-54108-8_8
14. T. Xia, X. Chen, Granger Causality: A Review and Recent Advances. Annual Review of Statistics and Its Application. 9 (2022) pp. 289-319. DOI: 10.1146/annurev-statistics-040120-010930
15. A. Khovrat, V. Kobziev, Using Recurrent and Convulation Neural Networks to Indentify the Fake Audio Messages, in: Proceedings of the International Conference on Methods and Systems of Navigation and Motion Control, MSNMC '23, IEEE, Kyiv, Ukraine, 2023, pp. 174–177. DOI: 10.1109/MSNMC61017.2023.10329236

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AUTOMATION SYSTEM FOR PRODUCT IDENTIFICATION BASED ON THE INTERNET OF THINGS TECHNOLOGY

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The purpose of the study is to increase the efficiency of identification of finished products in production. The object of research is the process of product identification using IoT technology. The subject of research is a software tool for product identification using IoT technology. The methods and technologies of product identification are analyzed. The existing commercial solutions for IoT-based product identification systems are reviewed, their structure, technical parameters, functionality and features of their use are investigated, and the advantages and disadvantages of these systems are identified. A structural diagram and algorithm for the operation of the product identification subsystem have been developed. The components of the system are selected, their design and functional features are described, and their technical characteristics are given. The system is implemented as a web application that provides automated collection, processing and transmission of information about identified products for further monitoring and analysis of this data.

With increasing competition and changes in the production environment, new approaches to production management and control are needed. The Industrial Internet of Things (IIoT) allows collecting and processing large amounts of data in real time, which ensures a quick response to changes and optimization of production processes. This study focuses on existing methods, technologies, and systems for automated accounting and identification of finished products, as well as the possibilities of their improvement using IIoT technology.

Product identification systems are complex technological solutions that enable accurate identification and tracking of products at different stages of their life cycle. The main components of such systems are:

a) product identifiers:

1) barcodes – graphic images consisting of black and white stripes of different thicknesses. Each bar or gap between them represents certain information that can be read by a special scanner;

2) RFID tags (Radio Frequency Identification) – tags that use radio waves to transmit information to the reader. They can be active (with a built-in power supply) or passive (powered by the reader's field);

3) NFC tags (Near Field Communication) – tags that allow the exchange of information over short distances (up to 10 cm), usually used in mobile devices;

4) QR codes – two-dimensional codes that can store more information than barcodes. They are easily read by smartphone cameras and special applications;

b) means of reading identifiers:

1) barcode scanners – devices that use a laser or camera to read information from barcodes;

2) RFID readers – devices that read information from RFID tags using radio waves. They can be stationary or portable;

3) NFC readers – NFC-enabled devices or mobile phones that allow you to read information from NFC tags;

4) cameras for reading QR codes – mobile phones or other devices with a camera that use special applications to recognize QR codes;

c) databases and data management systems:

1) databases – systems for storing information about products, including their identifiers, characteristics, location, etc. They can be local or cloud-based;

2) database management systems (DBMS) – software that provides creation, management and access to databases.

3) application programming interfaces (APIs) – tools for integrating identification systems with other enterprise information systems, such as ERP (Enterprise Resource Planning) or WMS (Warehouse Management System);

d) software for processing identification information:

1) software for reading and processing data – programs that allow reading information from identifiers, transferring it to the database and processing it;

2) analytical tools – software for analyzing the collected data, which allows to receive reports, identify trends and make informed decisions based on the data;

e) network equipment and infrastructure:

1) network routers and switches – devices that connect the components of the identification system to each other and to other enterprise systems;

2) wireless networks (Wi-Fi, Zigbee, Bluetooth) – technologies for data transfer between mobile and stationary components of the system.

In general, product identification systems are based on the integration of hardware and software components that ensure accurate and efficient reading, transmission, storage, and processing of product information. Implementation of such systems allows to increase the accuracy of accounting, reduce the risk of errors, optimize logistics processes and increase the overall efficiency of enterprise management.

Product identification process

The devices that make up the subsystem of interaction with the environment must read the necessary parameters and transmit them for further processing.

In today's world, automatic identification and data capture (AIDC) technology exists to perform such tasks. This term refers to methods of automatically identifying objects, collecting data about them, and transferring it directly to computer systems without human intervention. An object identifier consists of information that allows you to establish an association with this object. This information can be presented in the form of an image, sound or biometric parameters of a person.

The task of automatic identification is to obtain data by processing an image or electromagnetic waves. To collect the data, a converter is used that converts the received information in the form of an image or audio recording into electrical signals that are further processed by a computer. The computer compares the incoming information with an existing database or independently identifies the object.

Data acquisition can be performed using various methods. The following are the existing technologies for automatic object identification and data collection:

– barcode
– radio frequency identification (RFID)
– magnetic stripe;
– optical character recognition (OCR);
– smart cards;
– voice recognition.

Among these technologies, barcodes, radio frequency identification and optical character recognition are widely used to identify food and non-food products.

Optical character recognition is often used when working with documents, but there is also the practice of identifying goods by the image of the packaging. This method is convenient because the user only needs a camera connected to a computer system that will process the image. However, the problem is that it requires a powerful neural model that has been trained on a large number of photos of various products to work correctly. Given the dynamism of the retail market, the emergence of new products, rebranding, or changes in packaging design, the model needs to be constantly updated. This leads to significant time spent on creating and updating the product image dataset and keeping the model up to date.

Product identification is a broad category of labeling that includes functions such as product traceability, brand protection, and how to display information about the product.

The vast majority of food and non-food products produced for retail are labeled in accordance with international standards.

Using Internet of Things (IIoT) technology in product identification systems

The Industrial Internet of Things (IIoT) is a network of interconnected computer systems and connected production facilities with built-in sensors and software for data collection and exchange. These systems enable remote monitoring and control in an automated mode without human intervention.

The use of IIoT technologies in finished goods accounting systems is important for enterprises seeking to improve the efficiency and accuracy of production management. The analysis includes various aspects, such as the use of sensor technologies for accurate data collection, means of ensuring reliable communication, as well as innovative solutions to optimize the management and control of finished goods.

The IIoT technology review covers the study of advanced tools used to connect and control industrial processes. This includes the use of various sensors, data collection and processing tools, and networking technologies for efficient information exchange.

Sensor technologies are used to measure parameters of production processes, such as temperature, pressure, humidity, etc. This data provides accurate and timely information for management decision-making.

Data collection and processing tools organize and analyze large amounts of information coming from sensors and other sources. Data analysis helps to identify trends, predict production scenarios, and increase the efficiency of production processes.

Network technologies provide communication between all devices and production systems, creating a single structure for data exchange. This includes the use of cloud services, IoT protocols, and other innovative methods of information transfer. Communication technologies, such as 5G, NB-IoT, and Wi-Fi, determine the speed and reliability of data transfer between devices.

Cybersecurity in the context of IIoT is a critical aspect, as the growing number of connected devices requires secure information exchange in industrial networks. Protecting the confidentiality and integrity of data is a key cybersecurity objective. The use of data encryption helps prevent unauthorized access to confidential information. Controlling data integrity helps to avoid changes or loss of important production data. Authentication and authorization play an important role in implementing cybersecurity in the IIoT, allowing you to verify the identity of devices and users and manage access levels to systems and data. Measures to protect against attacks and vulnerabilities are important for the security of IIoT systems. Regular monitoring and analysis of potential threats allows you to respond to possible attacks in a timely manner and prevent their consequences.

Benefits of implementing IIoT in finished product accounting systems:

– real-time monitoring: IIoT technologies allow you to constantly monitor finished products in real time, quickly identify deviations, manage inventory and respond to changes in the production process;

– accuracy and automation of accounting: automated systems based on IIoT ensure high accuracy of finished goods accounting, avoiding errors that occur during manual accounting and providing reliable data;

– optimization of inventory management: IIoT systems allow you to effectively track and manage the level of finished goods inventory, avoid excessive stocks, reduce warehouse maintenance costs and improve production planning;

– product quality assurance: monitoring of product quality parameters using sensors and IIoT tools allows for prompt detection of quality deviations, which facilitates timely intervention and improvement of the quality of finished products;

– cost reduction and optimization of production processes: automation with the help of IIoT technologies simplifies many production operations, which reduces labor costs and optimizes work processes;

– improving data-driven decisions: collecting and analyzing large amounts of data creates productive analytical tools that improve decision-making in the management of finished products;

– ensuring cybersecurity: IIoT technologies can include cybersecurity measures that protect finished goods data from unauthorized access and cyberattacks.

Implementation of IIoT technologies in finished goods accounting systems helps to increase the efficiency and competitiveness of the enterprise.

Figure 1 shows examples of IIoT systems.

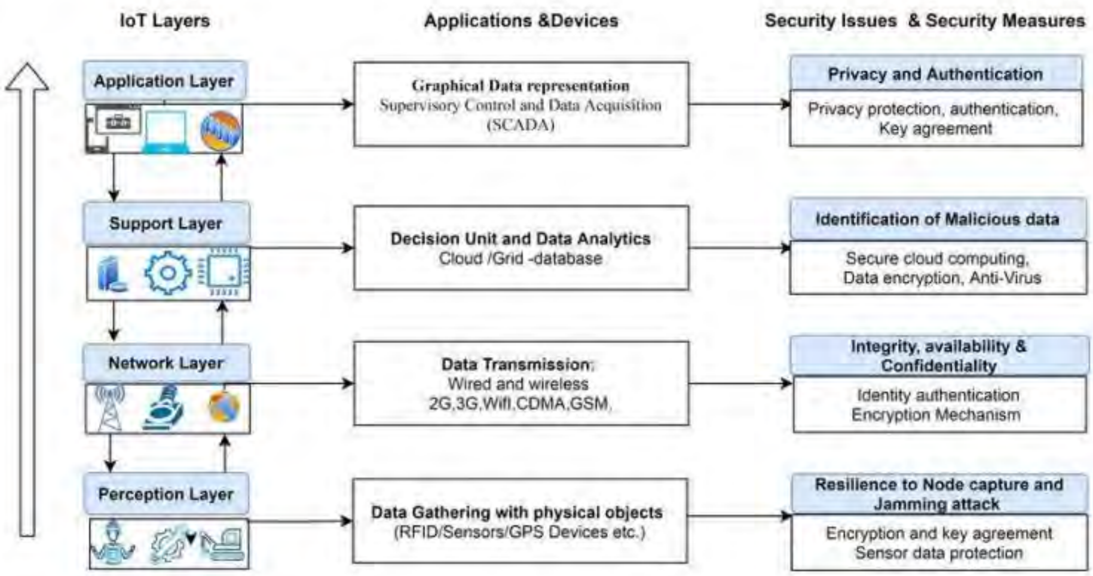

Fig. 1. Examples of IIoT systems

Overview of existing commercial solutions for IIoT-based product identification systems

The world's largest retail chains, such as Wal-Mart Stores Inc., Tesco PLC, and Metro AG, have already recognized the benefits of RFID and are actively implementing it in their distribution centers and warehouses. For example, 40 factories of Ford Motor Co. are equipped with radio identification systems. The British company Tesco has installed more than 4 thousand first-generation readers and 16 thousand antennas to collect data from the radio labels of goods passing through the dock gates of its English warehouses. Tesco also uses radio frequency tags on Gillette razor blades, which allows it to track every product in the warehouse and on the sales floor. If the effectiveness is confirmed, radio frequency tags can be used for many products in the future. This will greatly simplify the work of staff with information and improve customer service. With the help of RFID, it is easy to determine the number of products on the shelves and their expiration date.

The German company Metro started a trial project in November 2005, in which 100 suppliers installed RFID tags with destination data in 10 wholesale stores and 250 warehouses. Metro's first RFID project was aimed at solving the problem of out-of-stock, which can result in an average loss of 8% of retailers' annual revenue, which is about $93 billion a year. The use of RFID at the warehouse level can reduce the number of out-of-stock items on the shelves by 15 to 20%. The project was completed in October 2007, and all deliveries in the 180 German Metro Cash & Carry and Real stores, as well as in the distribution centers and warehouses of Metro Group Logistics (MGL), are fully automated. This was the first example of large-scale practical use of RFID in Europe, which helped to save about $28 million in 2007.

According to a study by the American system integrator Alinean, the use of RFID in warehouses helps prevent errors in deliveries, increases order processing speeds by 20 to 30%, and reduces operating costs by 2–5%, resulting in an increase in annual revenue of 2 to 7%. RFID makes it much easier to track or locate goods in the supply chain, which reduces losses at this stage by 18%.

Simon Langford, Wal-Mart's global RFID strategy manager, estimates that RFID and bar coding will coexist over the next 10–15 years. All the current projects of the world's largest retailers (Wal-Mart, Metro, Target) on the use of RFID technology are limited to the use of tags for labeling pallets, boxes and crates of goods. In particular, in June 2003, Wal-Mart demanded that 100 of its largest suppliers switch to RFID technology for labeling boxes, crates and pallets by 2005. In August 2003, Wal-Mart announced that by 2006 all suppliers would be required to use RFID tags to label boxes, crates, and pallets to ensure a more efficient system of interaction.

In late April, Wal-Mart launched an RFID pilot project in its distribution center and seven centers on the outskirts of Dallas, Texas. This decision is important for the further implementation of this technology. According to Sanford C. Bernstein, after full implementation of RFID technology, Wal-Mart will be able to save up to $8.4 billion annually by reducing manual labor, eliminating sales losses from out-of-stocks, and increasing the efficiency and transparency of its supply chain.

History shows that if Wal-Mart makes a decision, everyone else follows suit. In the 80s, Wal-Mart played a crucial role in the spread of barcoding technology. Although barcodes were standardized in 1973, by 1984 only 15 thousand product manufacturers were using them. After Wal-Mart's intervention, by 1987, 75,000 suppliers were using barcodes.

Existing identification methods and technologies

Barcode identification technology

The barcode was invented in 1949 by Bernard Silver and Norman Woodland, graduate students at the Drexel Institute of Technology. They received a patent for their invention in 1952. However, barcodes were not used in retail until 1967, when barcode scanners began to be introduced in grocery stores in the United States. The principle of coding is that numbers and letters are represented as stripes of different widths. Today, most barcodes are rectangular in shape, while the original design included concentric circles of varying thickness.

Today, barcodes are widely used in various fields. For the average person, they are best known for labeling goods in stores, which speeds up and simplifies the process of delivering goods from the manufacturer through stores to the buyer. But this is not their only use. For example, retail membership cards also use barcodes to identify customers who shop at specific stores. This approach allows for individualized marketing and a better understanding of the shopping pattern from the store's perspective.

The vast majority of existing methods of tracking goods are based on barcode identification. For example, barcodes are used to mark rental cars, airport luggage, waste at nuclear power plants, postal items, etc.

In the medical field, barcodes are widely used. They are used both for patient identification and for keeping medical records (recording each visit to the doctor in a digital format). Even the prescription of medicines can be supported by a barcode and read at the checkout in a pharmacy to display a specific list of medicines.

Barcodes use a one-dimensional coding scheme. The stability of the code is ensured by the height of the bars. That is, if part of the character is damaged, the sequence will still be read correctly. This characteristic is very important, since it is the product packaging that is most often damaged. The code contains information about the manufacturer, product category, and product number. However, it does not contain information about the price, production date, etc. It is only an identifier that requires all the necessary information to be obtained from other data sources, such as a store database or a manufacturer's warehouse.

Types of barcodes

There are many varieties of barcodes, which are divided into two main types: 1D and 2D barcodes. One-dimensional (1D) barcodes are the most common and are usually used on packages and labels. This type of coding is called one-dimensional because the information is stored in one plane – the width of the bars and spaces. The height of the bars does not matter for the information, but only ensures the stability of the code. The longer the message, the longer the barcode. One-dimensional codes are suitable for transmitting a small amount of information, such as a product identification code, which can be used to retrieve all the necessary information from a database. The most common one-dimensional barcode standard in Europe is EAN-13, as shown in Figure 2.

Fig. 2. An example of a message in the form of an EAN-13 barcode

It is worth noting that often the decoded information is placed under the barcode for manual entry, for example, if the product packaging is damaged, the cashier can manually enter the numerical code into the cash register system.

Two-dimensional (2D) barcodes are an advanced technology of one-dimensional codes. They are also called matrix or two-dimensional barcodes. The main difference is that the information is stored in two dimensions – vertically and horizontally. Graphically, these codes look like a set of specially ordered dots, squares, circles, or hexagons. A rectangular 2D barcode can contain thousands of characters, which allows you to compactly place a large amount of information. This is convenient for use in logistics structures, where the address, contact information, and names of the recipient and sender of the parcel can be placed in the code [1].

The most common standard for two-dimensional barcodes is the QR code. Due to their popularity, QR codes are supported by standard smartphone cameras, allowing anyone to read the codes and interact with the information. For example, by encoding a website address into a QR code, you can quickly navigate to the site using your smartphone. Or, if the code, as shown in Figure 3, encodes the SSID of a Wi-Fi network and password, the smartphone will try to automatically connect to this network.

```
WIFI:S:<SSID>;T:<WPA|WEP|>;P:<password>;H:<true|false|>;
```

Fig. 3. Format of recording information in a QR code for connecting to Wi-Fi

Figure 4 shows an example of a QR code that contains the necessary information to access a Wi-Fi network with SSID "Test_WiFi" and password "32168421".

Fig. 4. QR code with information for connecting to a Wi-Fi network

Two-dimensional barcodes have a significant advantage over one-dimensional barcodes not only because of the amount of information they can hold. Matrix barcodes are also error-correcting, which allows you to correctly decode information even if the code is partially damaged. In particular, QR codes have built-in error correction using Reed-Solomon codes, which are often used in computer RAM controllers and when writing and reading information from optical disks.

Barcode scanners

To read information from barcodes, special devices are used – barcode scanners. These are optical devices that decode data from printed barcodes and transfer it to a computer or other processing devices. The scanner design includes a light source, a lens, and optical sensors that convert optical signals into electrical signals. Scanners are also equipped with integrated circuit decoders that analyze the barcode image and transmit the decoded data to the output port.

There are many types of barcode scanners, each suitable for specific tasks and applications. For example, scanners can be stationary or portable. Stationary scanners are typically used at cash registers, while portable scanners are convenient for warehouses where employees can move from one item to another to scan. Modern barcode scanners can be classified by the following technologies:

– handheld scanner
– laser scanner
– LED scanner;
– scanner built into the camera;
– omnidirectional scanner.

A handheld scanner looks like a pen with a built-in light source and a photodiode. To read a barcode, you need to slide the pen across all the barcodes at a constant speed. During the scan, the photodiode measures the intensity of the reflected light and determines the width of the bars and the distance between them. The black bars absorb light, and the white bars reflect it, allowing the photodiode to generate a signal based on the level of reflected light. This signal represents the barcode in the form of electrical impulses.

The main advantage of a handheld scanner is its compactness. However, the scanning process is less convenient for large volumes of barcodes, as the user needs to constantly run the pen over the barcode surface to read it correctly.

Laser scanners function in much the same way as pen scanners, with the difference that they use a laser beam as a light source. In addition, they use a mirror or prism to direct the beam after it is reflected from the barcode back to the surface to be read. As with a pen scanner, a photodiode is used to analyze the intensity of the reflected light. With both of these types of scanners, the light emitted changes its brightness rapidly depending on the bars being read, and the use of photodiodes to recognize the code by light intensity is only suitable for pre-known signal modulation.

LED scanners (also known as CCD or LED scanners) use arrays of hundreds of microsensors arranged in a row at the top of the scanner. Each sensor measures the intensity of the light directly in front of it. Each individual sensor is very small in size, but because they are arranged in a row, the output electrical signal is generated by sequentially increasing the voltage across each sensor.

An important feature of LED scanners is that they measure the intensity of light around the white and black bars of the barcode. While the previously discussed technologies measure only the reflected light of a certain frequency generated by the scanner itself.

Camera scanners in mobile devices are considered an advanced method for the average user to scan barcodes. For the most part, this technology allows you to scan two-dimensional barcodes, such as QR or Data Matrix, using a smartphone camera. Among such scanners, it is worth noting those that use high-quality industrial cameras to capture and recognize multiple barcodes simultaneously. All codes that fall into the camera frame are decoded immediately using ImageID technology [2].

Multidirectional barcode scanners use a sequence of straight or curved lines to scan in different directions, forming a star-shaped Lissajous to cross all barcode lines. Most of these scanners use a laser as a light source. Unlike simpler linear scanners, multidirectional scanners can read a barcode from any angle. Typically, these scanners are used at supermarket checkouts, where products are scanned through a glass or sapphire window. These scanners have proven themselves in commercial environments and can range from short-range scanners to industrial conveyor scanners that read information from a distance of several meters [3]. The operation of such a scanner can be seen in Figure 5.

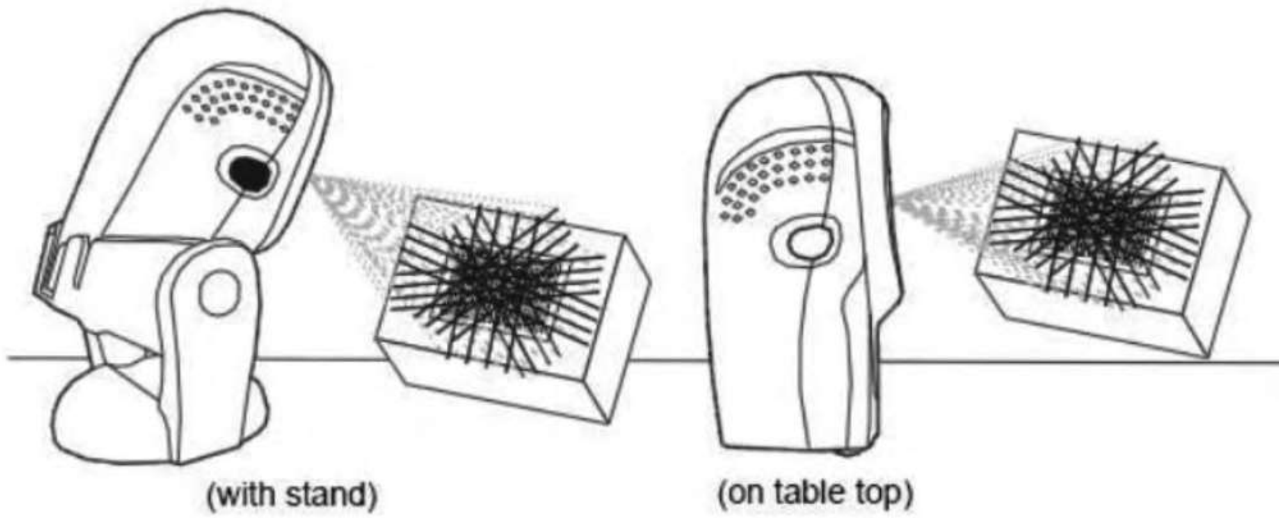

Fig. 5. Beam scattering of a multidirectional scanner

It is this barcode scanning technology that is considered to be the most reliable when codes are damaged, including poor print quality or damage to the barcode surface. Figure 6 shows the types of RFID tags.

Fig. 6. Types of RFID tags

Passive tags do not contain a battery. They use the energy that the electromagnetic wave from the reader induces in the antenna to turn on the chip and transmit data back to the reader. Passive tags reflect energy from the reader or receive and temporarily store energy to generate a tag response to the reader. The tag's antenna absorbs the radio wave energy and directs it to the chip. That is, the larger the antenna area, the more energy it can absorb or catch waves at a greater distance from the radio wave source.

Active tags have their own power source, usually a battery, to run the chips and transmit data to the reader. An active tag allows for weak reception and can generate a high-level signal to transmit back to the reader. The active tag is in sleep mode until it receives a wakeup signal from the reader. As soon as the tag receives the wakeup signal, the storage medium enters the working mode. After the data transaction is complete, the tag goes back to sleep. Since active tags have a battery, they can transmit data without requiring power from the reader. Therefore, they have a much longer reading range than passive tags. On the other hand, because they contain a battery, their lifespan is limited [4].

Semi-active or semi-passive tags, depending on the manufacturer, also have a built-in battery. In this case, the battery is used only for the operation of the chip. Like a passive tag, a semi-active tag uses the energy in the electromagnetic field to wake up the chip and transmit data to the reader. These tags are sometimes called "Battery Assisted Passive".

Each tag has its own tag identifier (TID) programmed into it, which is a unique serial number that is written into the tag by the manufacturer. The tag can also have a memory bank for storing a unique identifier for tracking the product to which the tag will be attached. This is called an electronic product code or EPC.

The EPC is stored in the chip's memory and usually takes up 96 bits of data. The first 8 bits are a header identifying the protocol version. The next 28 bits identify the organization that controls this label (GS1 organization number). The next 24 bits are the identifier of the class to which the product belongs. The last 38 bits are the unique serial number of the tag itself. The last two fields are filled in by the organization that manufactured the tag [5]. The entire code can be used as a key to a database that identifies the item to which the tag is attached.

There is no universal label for all applications. In most cases, it is the tag's antenna that determines the application. Some tags need to work only in a specific frequency range, while others need to deliver the best power when attached to things that are not adapted to wireless communication (e.g. liquids and metals). Antennas can be made of different materials. They can be printed, etched, stamped with conductive ink, or even attached to paper with steam.

RFID tags with memory functions range from simple RO tags to tags with intelligent cryptographic functions. There are tags that have a memory range from a few bytes to about 4 MB of memory. It depends on what type of tag, passive or active, is chosen and what standard was followed in its production.

An RO tag (read-only) has a pre-programmed serial number stored in its memory. The serial number is specified during the manufacture of chips. The user cannot change this serial number or write new data to the tag. When the tag enters the reader's query zone, it sends its serial number and will do so continuously until it leaves the reader's zone. Data communication is unidirectional; data cannot be transferred from the reader to the tag. When using RO tags, the serial number of the tag of the product with which it is associated must be paired with the appropriate software [6].

RW-tag (read-write). This type of label involves writing new information to the label or overwriting existing information. You can write information to the tag only when it is in the read zone. At the same time, of course, you can read information from the tag. RW tags usually have a pre-programmed serial number that cannot be overwritten. But unlike RO tags, RW tags have a memory space where the user can place their own information. The RW tag has limited write cycles depending on the type of memory it uses.

A WORM label (Write Once Read Many) is a label that is in between RO and RW. The name implies that you can create a record only once and then read it many times. When data is written to a label, it is locked, and you can only read information from it [7].

RFID readers

RFID readers are devices that power tags and communicate with them wirelessly and transmit data to software. These devices support bi-directional communication with the devices to which the tags are attached within their range. Readers can perform a large number of tasks, including simple continuous inventory, filtering (searching for a tag according to specified criteria), recording data in specific tags, etc.

RFID tag readers can identify and locate up to 1000 tags per second. The readers can be stationary or mobile and use an integrated antenna to receive data from the tags. Reader chips can be embedded in devices such as handheld readers, smart vending machines, product tracking devices, mobile devices, etc.

Stationary readers must have an antenna that sends energy via radio waves and data with commands to the tags. Since these readers are often used for automation, they can support additional connections to external sensors or to light devices to notify users when a reading is complete. Typically, these devices are connected to a host or network to transmit data from the tags to higher-level applications [8].

Antennas that emit linear electric fields have a long range and high power level that allows the signal to pass through different materials to communicate with the tags. But linear antennas are sensitive to the position of the tags. Depending on the angle or location of the tag, readers with linear polarization antennas may communicate better or worse with the tag.

The choice of antenna is also determined by the distance between the RFID reader and the tag to be read. The reader's antenna can operate either in the near field (short wave range) or in the far field (long wave range). In short-wave systems, the tag is read at a distance of less than 30 cm and uses magnetic communication to transfer energy. Also, in near-field systems, the quality of communication is not affected by the presence of dielectrics such as water or metal in the field.

In readers with far-field antennas, the distance between the tag and the reader exceeds 30 cm and can even reach several tens of meters. Antennas of this type use electromagnetic communication. Thus, dielectrics can degrade the quality of communication between the reader and the tag.

RFID reading distance

The maximum reading distance of a physical tag depends on the power of the RFID reader, the power of the antenna, the actual integrated circuit used in the RFID tag, the material and thickness of the material the tag is covered or protected with, the type of antenna the tag uses, the material to which the tag is attached, and more.

Although the theoretical reading range of RFID tags may be listed in the specification as 5 meters (ideal conditions), in reality, it may be as little as 1 meter if the tag is attached to an object that is on a metal surface surrounded by water and electromagnetic waves (not ideal conditions).

In general, the maximum reading distances for RFID tags are as follows:

– 125 kHz and 134.3 kHz. Low-frequency passive RFID tags – reading distance of 30 cm or less – usually 10 cm, unless a very large tag is used, which can have a reading distance of up to 2 meters when attached to metal;

– 13.56 MHz. High frequency passive RFID tags – maximum reading distance of 1.5 meters – usually less than 1 meter. A single or multi-port reader and special antennas can be used to extend the reading range to a tag with a longer distance or wider RFID reading area. To get more than 1 meter, you need a reader with an RFID output power of more than 1 W;

– 860 MHz to 960 MHz. Ultra-high frequency passive RFID tags – minimum reading distance of more than 1 meter. For example, Gen2 tags can have a reading range of up to 12 meters, but newer generations of chips with a plus antenna increase this distance to more than 15 meters. Gen2 tags can have frequencies of 860 MHz or 902 MHz. Gen2 EPCglobal tags have a frequency range from 860 MHz to 960 MHz. Battery-equipped Gen2 Semiactive tags are semi-passive (semi-active) tags with a reading range of up to 50 meters. Gen2 Semiactive tags are just entering the market;

– 860 MHz to 960 MHz. Integrated circuits of the 3rd and 4th generations. The new generations of integrated circuits (Monza4, Higgs3, and NXP G2XM) are now available in a variety of embedded designs. The use of a different silicon crystal provides up to 40% more sensitivity while reducing RF interference. This means that tags that use the new generation of silicon can have a reading range of more than 16 meters according to FCC regulations for 4 W EIRP [9];

– 433 MHz. Ultra-high-frequency active RFID tags – reading range up to 500 meters;

– 2.45 GHz. Ultra-high frequency active RFID tags – reading range up to 100 meters. There are several different modulations for 2.45 GHz. These active tags can also provide real-time location information.

General description of the system

The system's functioning is based on the fact that there is always information about what products are available at a given time in the store/warehouse, etc. In other words, the system tracks when the products appeared and when they were used, sold, or disposed of.

An important parameter of this system is the suitability of goods for identification. In the previous sections, it was noted that most goods are labeled by manufacturers using barcodes. This method is the cheapest, as it requires only printing a barcode on the package, which has a small area and consists of only black and white stripes of different thicknesses. There are other types of identification, but they require the use of additional devices, which increases the cost of manufacturing the product.

But in terms of usability, barcode identification has certain disadvantages, namely:

– to read a barcode, you need to have direct access to the code itself. Any obstacle will make it impossible to read the code correctly.

– barcodes do not have the ability to record and read additional data other than the identifier;

– barcodes require too much human time and work, as each barcode must be scanned individually;

– barcodes have a low level of security because they can be easily falsified;

– barcodes are easily damaged because they are printed on the outside of product packaging.

Therefore, to increase the degree of automation of the process, it was decided to use an identification tool that does not require human intervention. Radio frequency identification (RFID) was chosen as this technology.

A significant advantage of increasing automation is that to use this method, the user only needs to attach an RFID tag to any type of product. From that moment on, this product can be entered into the accounting system. This makes it possible to add even those products whose packaging does not have a barcode. RFID tag readers react instantly when a tag comes within their range. There is no need to fix the tag in a certain way under the reader, but only to bring it to the minimum required distance.

Any type of product has a certain time of existence from the moment it is produced or purchased to the moment it is disposed of or sold. This is the life cycle of the product in the company's warehouse. As noted, in order to determine which item should be purchased/produced again, it is necessary to track when it was used or disposed of. That is, the system should detect when the life cycle of these products has ended.

To monitor the life cycle, it was proposed to rely on the identifier assigned to the product at the stage of entering the system. For this purpose, it is necessary to identify products at the exit from the warehouse or near it.

In the context of the software and hardware complex being developed as a warehouse product monitoring system, the integration of radio frequency identification technology into the system will allow users to avoid unnecessary operations to add input data to the system. To identify products as recycled/sold, the user only needs to place an RFID reader near the warehouse exit in advance.

However, the use of RFID results in increased costs for the user. Unfortunately, RFID tagging of goods in stores is rarely seen today, as it is not always feasible. Only valuable goods are subject to this method of labeling.

Still, the trend toward replacing barcodes with RFID tags is progressing globally. This year, Kroger, the third largest retailer after Wal-Mart and The Home Depot, introduced a new store format where RFID tags are used instead of barcodes for accounting. Together with Microsoft, they have implemented payment at the checkout via a mobile application using NFC chips [10].

Such events with the participation of world-famous companies in the field of marketing are evidence that in the future the world may abandon the use of barcodes in favor of RFID tags. Therefore, we can say that for today's potential users of the system under development, the inconvenience associated with the need to independently label goods with radio frequency tags is only temporary. In the future, when RFID labeling is provided by retailers or even manufacturers, users will not need to spend time and money on labeling goods themselves.

The software is designed in such a way that it can process data from any of the devices – an RFID scanner or a smartphone. This provides a fairly wide range of alternatives in the context of modern product identification tools. The received identifier will be transmitted to the server via the Internet and processed by the software.

In the developed hardware and software complex, the software part should be responsible for processing information coming from physical devices and presenting it in a user-friendly manner.

The most optimal way to implement this is to create a web application. To identify the user, the web application provides for account registration.

The software and hardware complex is designed for use in premises where it is necessary to automate warehouse logistics. The hardware part of the complex consists of two devices. One of them should be placed at the exit of the warehouse, as it is responsible for recording the fact of disposal/sale of a product unit.

The other device will be used to mark products with radio frequency tags. With its help, the user will record the appearance of a certain RFID tag in the system, and then associate it with a certain product from among those already available in the monitoring system.

Both devices are autonomous units as they have their own power source – a battery that can be charged via the micro-USB interface. This mobile approach makes it easy to place these two devices in any room without the need to provide them with stationary power.

Block diagram of the subsystem and algorithm of user interaction with it

The radio frequency identification subsystem includes the ability to add tags to new products, track tags of existing products, and remove tags of sold/disposed products. Its block diagram is shown in Figure 7.

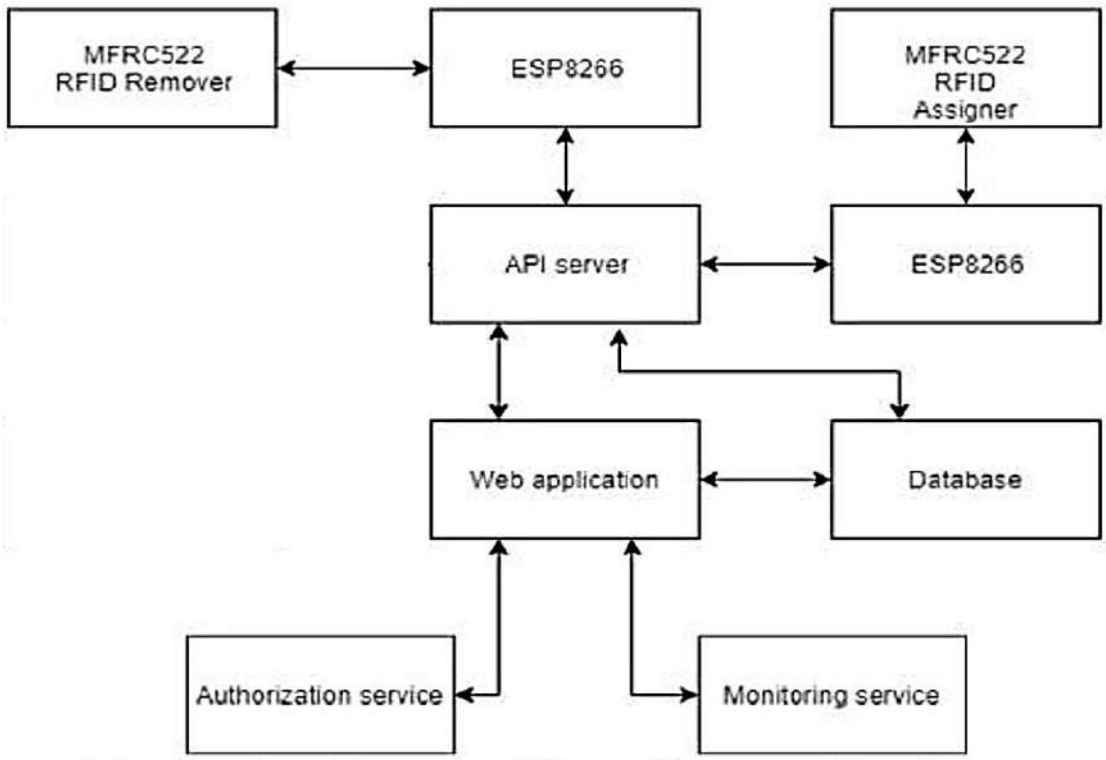

Fig. 7. Block diagram of the product identification subsystem

The location of the tag removal and addition subsystems remains unchanged – the device is located at the entrance and exit of the warehouse. As soon as a tag appears within the range of the RFID reader, it immediately reads it and sends the identifier data to the server for further processing. To solve the problem of the absence of marking goods with radio frequency tags, a similar device is used – an RFID tag reader. The main task of this device is to register an RFID tag in the system. This requires special sticker tags. Each tag scanned by this device becomes visible to the monitoring system but is not yet tied to a specific product. Such a tag can be called "free". To bind a tag to a product, the user sticks it on the product packaging. Then, in the web application, the corresponding button is clicked opposite the desired product, linking it to the free label. Now the system knows that the label with a certain identifier is tied to a specific product. Thus, the user can label all available products using the advantages of radio frequency identification.

Implementation of the software part

Description of API methods

The software part of the system provides an open API (application programming interface) for interacting with remote devices and functions as a web server for client applications. An API is an interface or protocol for communication between a client and a server that simplifies client-side software development. This interface has predefined methods and a format for responding to requests to these methods. This means that a developer working on software for hardware devices knows what data and in what format should be sent to the server to get the desired response.

The system's API is developed using MVC Core and is a dedicated controller that provides the following public methods for interacting with the hardware and the client application:

– GetProduct;
– AddUserProduct;
– AddUnassignedRfid;
– BindUnassignedRfidToUserProduct;
– UserProductToBin;
– UserProductToBinByRfid.

Below is a description of each API method and all the necessary parameters to work with it.

GetProduct. Provides data about the product: its ID, name, and a brief description.

HTTP request: GET /api/get-product.

The URL parameters of the GetProduct method request are shown in Table 1.

Table 1

GetProduct method

code	Type: string
	Description: product barcode

If the request is successful, the response body will look like this in JSON format:

{
success: <bool>, product: {
id: < product ID >, title: < product name > , description: < product description >
}
}

AddUserProduct. Adds a product to the monitoring subsystem for the corresponding user.

HTTP request: POST /api/add-user-product

The URL parameters of the AddUserProduct method request are shown in Table 2.

Table 2

AddUserProduct method

userId	Type: string
	Description: user ID
	Type: int
	Description: product identifier
	Type: int
	Description: number of product units

If the request is successful, the response body will look like this in JSON format:

{success: true }

AddUnassignedRfid. Adds a free RFID tag to the system. In this state, the tag waits until the user assigns it to a specific product through the web application interface.

HTTP request: POST /api/add-unassigned-rfid.

The URL parameters of the AddUnassignedRfid method request are shown in Table 3.

Table 3

AddUnassignedRfid method

rfid	Type: string	
	Description: RFID tag identifier	
	Type: string	
	Description: user ID	

If the request is successful, the response body will look like this in JSON format:

{success: true }

BindUnassignedRfidToUserProduct. Binds a free label to an existing product in the monitoring subsystem for the current user. The corresponding record is added to the database

HTTP request: POST /api/bind-unassigned-rfid-to-user-product.

The URL parameters of the BindUnassignedRfidToUserProduct method request are shown in Table 4.

Table 4

BindUnassignedRfidToUserProduct method

userProductId	Type: int
	Description: identifier of the record in the monitoring subsystem to which the RFID tag will be attached

If the request is successful, the response body will look like this in JSON format:

{success: true, message: "RFID tag successfully attached to product"}

UserProductToBin. Removes a certain number of products associated with a certain user from the monitoring system. If there are no more such products (all units have been disposed of/sold), the record is completely deleted from the database.

HTTP request: POST /api/user-product-to-bin.

The URL parameters of the UserProductToBin method request are shown in Table 5.

Table 5

UserProductToBin method

userId	Type: string
	Description: user identifier
	Type: int
	Description: product identifier
quantity	Type: int
	Description: number of product units

If the request is successful, the response body will look like this in JSON format:

{success: true }

UserProductToBinByRfid. Performs the same actions as the UserProductToBin method. The search criterion for finding a record to delete is another record that links an RFID tag and a product. This record is located by the tag ID passed to the request. After the item is successfully removed from monitoring for the current user, the record linking the RFID tag and the item is deleted from the database. The RFID tag with the corresponding ID can be used again to link to another item.

HTTP request: POST /api/user-product-to-bin-by-rfid.

The URL parameters of the UserProductToBinByRfid method request are shown in Table 6.

Table 6

UserProductToBinByRfid method

rfid	Type: string
	Description: RFID tag identifier

If the request is successful, the response body will look like this in JSON format:

{success: true }

Using the above methods, the entire business logic of the software and hardware automation complex is implemented. All devices that interact with the goods in one way or another send the received data as parameters to the API methods via the Internet.

Client web application

The client side is presented as a web application consisting of several pages. The main page is the central page and contains links to the pages for adding and deleting products via smartphone, a list of available products in the warehouse, and a button for recording voice commands. The list of goods is generated from the database and displays the goods available in the monitoring subsystem for the current user. Each item in the list includes the name of the product and the number of available units. At the end of each line, there is a functional menu with the following options:

– attach RFID tag: by clicking this option, a free RFID tag will be associated with the selected item and the corresponding record will be added to the database;

– edit: this action redirects the user to the edit page, where you can change the number of available items. This allows you to easily add or delete items in the process of maintaining warehouse accounting;

– delete: this action deletes the record of the selected item from the database for the current user.

The web application supports voice control, which can be more convenient for users compared to scanning barcodes with a smartphone camera. This functionality is especially useful for people with disabilities. For basic interaction with goods, voice control supports two commands: adding and removing goods from the monitoring subsystem. The commands should be pronounced clearly, according to the name of the product displayed in the web application, since the search is carried out by the name, not by the identifier on the package.

To use voice control, press the red button on the home page (Fig. 8). This activates the device's microphone and starts recording the voice command. Next, the user must say the command in the format: action (adding or deleting) and the name of the product to which this action should be applied.

A pop-up window will display the result of command recognition. Since even modern algorithms do not always recognize the Ukrainian language accurately, it is appropriate to confirm the action in this way. If the command was recognized correctly, the corresponding requests are automatically sent to the web application API. The user will see a message about the successful completion of the operation. If the voice command is recognized but does not match the template, the user will receive a notification about this, as well as the text of the recognized command on the main page.

To implement human speech recognition in a web application, the Web Speech API is used. This API consists of two main components: speech synthesis and speech recognition. Speech synthesis is available through the SpeechSynthesis interface, which allows programs to play human language text through built-in speakers. This can be done using different voices and with intonation features, such as emphasizing bold text with intonation.

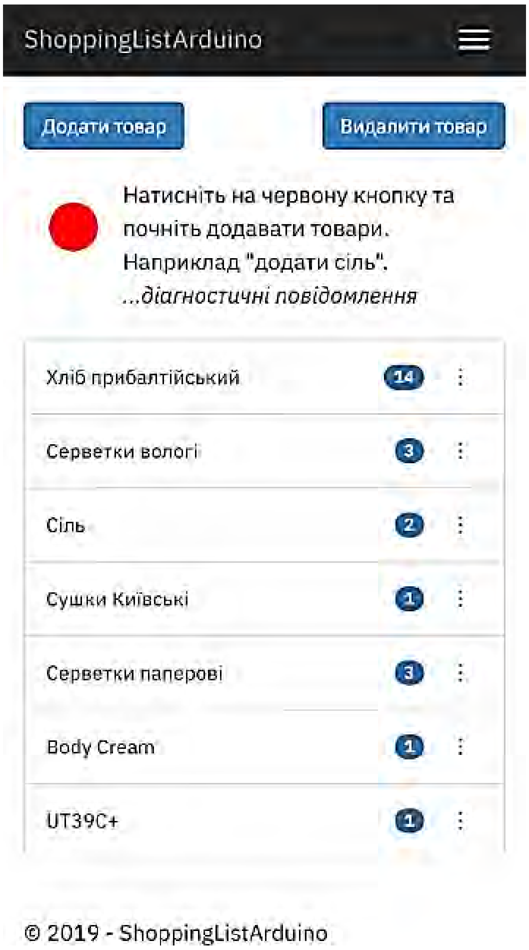

Fig. 8. Home page of the web application

Speech recognition is implemented through the SpeechRecognition interface, which allows you to detect and interpret human speech from audio recordings made by the device’s microphone. The SpeechRecognition object is created by the interface constructor, which allows you to recognize the speech context in the recording. The SpeechGrammar interface is a container for a set of grammars that a web application should recognize and is defined using the JSpeech Grammar Format (JSGF).

JSpeech Grammar Format is a cross-platform way to represent grammars for speech recognition. These grammars help speech recognition systems determine what to listen for. In other words, the grammar creates a message template that the speech recognition system is guided by.

For the Chrome browser, the SpeechRecognition interface uses server resources for recognition, meaning that the audio is sent to a web service for processing. Thus, this operation requires an internet connection.

In order to add new products to the internal database of the web application, you need to go to the corresponding page. The link to it is located in the main menu. This page contains a list of all items in the database. A screenshot of this page is shown in Figure 9.

In addition to the list of products already in the database, the page contains a link to the page for adding new products. By clicking on it, the user must fill out a form with three fields (Figure 10). In this form, you must specify the identification code, product name, and description for each field. When the user submits the form, the added product will instantly appear in the updated list of available products in the web application database.

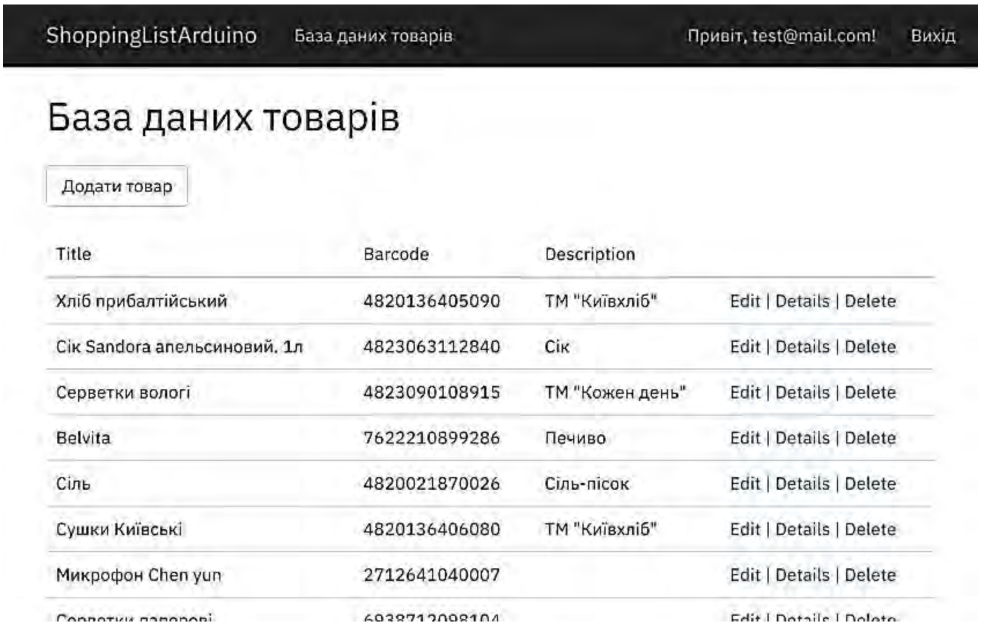

Fig. 9. List of all names in the database

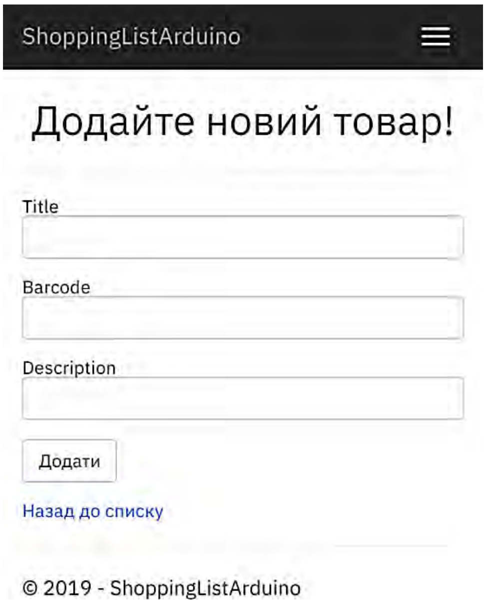

Fig. 10. Form for adding new products to the web application database

Hardware implementation

The hardware consists of two devices that are designed to automate the process of removing products after they have been sold or disposed of. As described above, all of these operations can be performed using a smartphone via a web application. But this will create additional inconvenience, as in this case, it is necessary to have a smartphone at hand at the time of each user action. Let's take a closer look at these devices.

To transfer data via the Internet, the module must connect to the user's Wi-Fi network. Usually, the standard library for working with ESP8266 requires explicit programming of the SSID and password of the access point to which the module connects during initialization. This creates inconveniences for the user, since it is quite difficult to change the firmware of the ESP8266 module every time the access point is changed. To solve this problem, we decided to add a corresponding behavioral template to the program.

At startup, the module scans for available access points within the antenna range. If no SSID and password are stored in the module's memory, the module switches to web server mode and creates its own access point. The user connects to this access point using a mobile phone. Then a web page opens, usually located at http://192.168.4.1.

This page displays all available access points within the module's coverage area. The user selects the desired access point and enters its password. In this way, the user provides the Wi-Fi module with information about the access point to which it is to connect. The access point data is stored in the module's flash memory, and the module automatically reboots. During the next initialization, the module matches the access points stored in the flash memory with those available in real time. After that, the module connects to the network it knows and starts executing its program. The access point configuration page for the ESP8266 module is shown in Figure 11.

To transfer data to the API of the web application program part via the Internet, the ESP8266 Wi-Fi module was selected. However, since the scanner module requires 4 digital pins to communicate via the SPI interface and one digital pin for the RC522 RST module, the standard ESP-01 module is not suitable. Among the various options, the ESP-12E module was chosen, which has more ports, increased flash memory and a more powerful antenna.

Fig. 11. Access point configuration page

Conclusions

The main goal of the research is to increase the efficiency of identification of finished products in production. The proposed product identification system allows to improve the approaches and methods used to collect, analyze and record data on finished products during movement using IoT technology.

The technological feature that distinguishes the proposed automation system is the support of an alternative, more advanced method of product identification. The Radio Frequency Identification (RFID) method proved to be the most suitable for this role. The identification process includes identifier creation, reading, processing, analysis, and integration of data. The use of the Internet of Things (IIoT) technology significantly expands the capabilities of identification systems by providing continuous monitoring and automation of data processing. In general, the work performed demonstrates the possibility and effectiveness of using IIoT technology to develop product identification systems, which can significantly improve management and accounting processes at the enterprise.

Reference

1. Nevliudov, I., Sliusar, A., Khrustalova, S., Khrustalev, K. and Kosenko, V., (2023). Comparison of the effectiveness of barcoding and RFID technologies in logistics processes. У: 2023 2nd International Conference on Innovative Solutions in Software Engineering (ICISSE), 29 November 2023, Ivano-Frankivsk, Ukraine. Ivano-Frankivsk: Vasyl Stefanyk Precarpathian National University. p. 181–190.
2. Pen-type barcode reader [online]. Bournetocode. [Accessed 26 July 2024]. Access mode: https://www.bournetocode.com/projects/AQA_AS_Theory/pages/img/pen-type-reader.jpg
3. Beam scattering of the Motorola LS9208 multidirectional scanner [online]. Barcodedatalink. [Accessed 26 July 2024]. Access mode: http://www.barcodedatalink.com/media/bakery/images/scan%20omnidirectional%20good%20scan.jpg
4. Hesseldahl, A., (2023). A Hacker's Guide To RFID [online]. Forbes. [Accessed 25 July 2024]. Access mode: http://www.forbes.com/commerce/2004/07/29/cx_ah_0729rfid.html
5. Fedorchuk, A. O. and Fedorchuk, A., (2021). Computerised system for organising access to premises based on RFID technology. [Accessed 5 August 2024]. Bachelor's thesis, Ternopil National Technical University named after Ivan Puluj. Access mode: http://elartu.tntu.edu.ua/handle/lib/35562
6. Hulme, G. and Claburn, T. RFID's Security Challenge [online]. Informationweek. [Accessed 5 August 2024]. Available from: http://www.informationweek.com/story/showArticle.jhtml?articleID=52601030&tid=13690
7. Drozdovskyi, L. I., (2022). Contactless information systems based on RFID technology. MS thesis. Sumy State University. Access mode: https://essuir.sumdu.edu.ua/bitstream-download/123456789/89292/1/Drozdovskiy_mag_rob.pdf [Accessed 5 May 2024].
8. Signals from different types of antennas [online]. Impinj. [Accessed 5 August 2024]. Available: https://www.impinj.com/media/2209/polarization-graphics_ch2.png
9. RFID Card Maximum Read Distance [online]. Uinta6. [Accessed 5 August 2024] Available: https://www.uinta6.k12.wy.us/site/handlers/filedownload.ashx?moduleinstanceid=610&dataid=2363&FileName=Card%20Info.pdf
10. Khrustalova, S. and Vyshvanyuk, S., (2023). Development of a structural diagram of an automation module based on RFID technologies. VIIth International Conference Manufacturing & Mechatronic Systems 2023, 19 October 2023, Khrakiv, Ukraine. Kharkiv: Kharkiv National Univesity of Radio Electronics. p. 22–25.

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FORMALISATION OF THE PROCEDURE FOR SELECTION, EVALUATION AND DECISION-MAKING WHEN FORMING A PROJECT TEAM USING A PHENOMENOLOGICAL MODEL

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The development of any modern production is impossible without taking into account the human factor. Companies seeking to have more competent, proactive, flexible employees should intensify their human resource management system, which includes the selection and recruitment of employees, their training and development, career planning and management, motivation of their work with well-deserved rewards, and strengthening of teamwork.

Introduction

Today, interest in human resource management, group studies, and teamwork has grown significantly, as teamwork and the work of each employee individually play a leading role in achieving tangible results in a project, helping to maintain companies' competitive advantages and efficiency.

The main factor in the competitiveness of any project team is the level of professionalism and creativity of its employees. Human resources are the most valuable resource, and developing their potential is an important strategic task of project team management. Modern organisations need employees who can do their job well in the face of organisational change, help others do the same, and quickly create a collaborative atmosphere.

A group is known to be formed of several interacting employees, each of whom is an independent personality. In the process of solving common practical problems, people enter into complex relationships with each other as a whole. The dynamics of the relationship between an individual and a group seems to be quite complex. To understand and evaluate these relationships, one should take into account both the properties that occupy a certain status and play a certain role in the group and the composition, content of activities and level of organisation of the group, as well as other wider social associations.

Along with general psychological manifestations, a personality has individual psychological properties: temperament, character, abilities, i.e., properties that constitute his or her individual originality. A person always brings his or her individual qualities to the processes of work and group interaction. A manager needs to know and take into account the individual qualities of people in order to implement an individual approach to them, to train them more successfully, to adapt them to the conditions of professional work and group interaction, and to optimally stimulate the effective performance of team members. Managers need to understand that each person is unique and has his or her own strengths and weaknesses. It is the ability to take into account the individual characteristics of employees that allows you to create an atmosphere of mutual understanding and successfully implement an individual approach to them.

In the context of certain work tasks, people evaluate each other primarily by the level of intelligence formed by the system of cognitive processes. In particular, every manager should be demanding of the qualities of his or her own intelligence, as well as of the mental abilities of his or her subordinates when assessing their suitability for the position and the nature of the production tasks they perform. Knowledge of personality traits is necessary for predicting individual and group behaviour and for the correct placement of personnel. Therefore, managers in management systems need to determine these qualities in the production environment by observing and analysis of the activities.

Features of the human resources interaction process in the project

Today, the development and improvement of the labour market at the national level is becoming an important issue. In this context, the company's strategy in recruiting, training and managing staff plays a key role and is designed to help achieve the organisation's goals.

Until the 1970s, HR management in developed countries was focused solely on the current needs of the organisation. Under this approach, employers expected to have access to the required number of employees without the need for long-term specialised training. An oversupplied labour market provided employers with this opportunity, and staff turnover was not considered a task. However, with the increasing mental workload of organisations and the shortage of highly skilled professionals, it has become important to focus on both current needs and the long-term perspective when building resources. This requirement applies to all types of resources, including human resources [1–3].

Today, a significant number of companies distinguish human resource management and planning as an independent type of human resource management. Thus, human resource management is carried out as a process of implementing certain targeted functions that are closely interrelated and form an integral functional system of human resource management in an organisation. Personnel is beginning to be considered as the main material (intellectual) resource of the company, which primarily determines the success of the entire organisation and, to a large extent, its market value. This has led to increased attention to strategic issues of organisational management, including in HR policy. After all, in order to achieve optimal functioning, the company must choose the most appropriate and adapted strategy, which, in turn, should be built on strong positions and the use of opportunities, including human resources.

Effective work of any labour collective is possible only if there is high cohesion, which allows to consider a particular group as a collective. The problem of psychological integration of a group is one of the most difficult in modern management systems. Studies conducted within the framework of the activity-based concept have investigated two main issues. On what basis does an initially nominal community of individuals forming a team become a truly productive team capable of effectively solving production problems? What tools ensure the psychological integrity and unity of the team?

The psychological compatibility of staff plays an important role in achieving project goals. There are several levels of psychological compatibility, determined by both the personality traits of employees and the content and complexity of the professional tasks being solved. Psychophysiological compatibility is expressed in the similarity of natural properties of people: temperament, physical endurance, efficiency, emotional stability. Psychological compatibility is manifested in the coincidence of character traits, professional interests, level of intellectual development, and personal qualities. Socio-psychological compatibility is expressed in the similarity of personal properties necessary for social interaction based on commonality and worldview: communication skills, integrity, social attitudes, political views, value orientations [4–7].

If people coincide in all three levels of compatibility, we can speak of their full psychological compatibility. If the characteristics mismatch, a psychological barrier arises when project team members do not want to cooperate in any area.

Methodologically, the starting point for addressing these issues is the idea of socially determined joint activity as the main systemic factor of any social group [8]. It is in the context of educational and professional activities that business and emotional relationships are formed, common group values and norms of behaviour are developed. An integral consideration of the work team requires a holistic study of the system of intra-group activity in the unity of all its aspects.

Thus, although the orientational and goal-oriented aspects of cohesion are the leading ones in the activities of groups with a professional orientation, the emotional sphere of group life and the corresponding emotional cohesion are important conditions for group activity.

The level of cohesion of a particular group can be quantified using the Jacob Levy Moreno sociometric method. Based on the results of the sociometry, the group cohesion coefficient (1) can be derived by counting the number of mutual choices received by all group members [9].

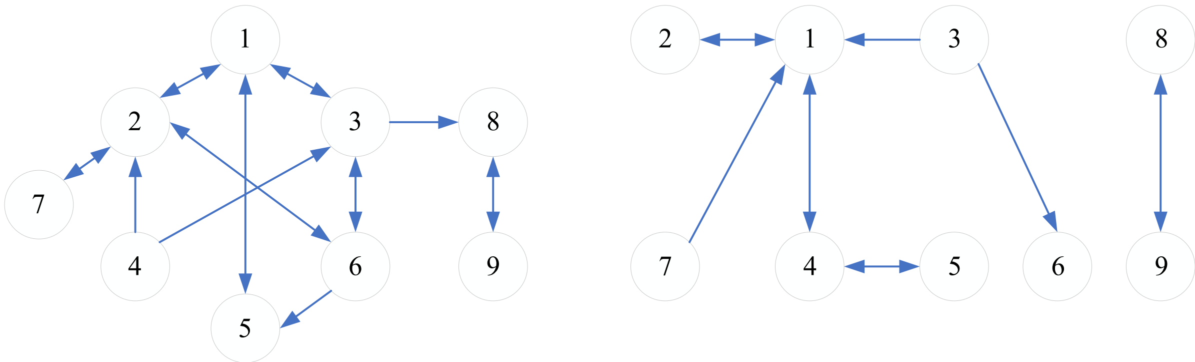
$$Q = \frac{\sum P}{0,5n(n-1)} \tag{1}$$

where $\sum P$ – is the number of mutual positive choices;

n – the total number of possible elections in the team.

The more such links there are, the more the group acts as a synthetic whole, firmly connected not only by external influences (orders, regulations) but also by interpersonal intra-group ties (traditions, sympathies, and the desire for cooperation), which makes such a group highly durable, stable, and productive.

Figure 1 shows diagrams of cohesive (a group with a high level of internal interconnectedness and common goals) and diffuse (a group with looser and blurred boundaries) groups. The diagrams show that in the two groups of 9, in the first case (a) there is a high level of cohesion through single and mutual elections that connect all employees into a single structure. In the other case (b), there is a low level of cohesion: there is a core group of three employees (1, 4 and 5), the other four are connected only to the leader, and two are completely isolated, forming a dyad that is cut off from the rest of the group. Groups with a low level of cohesion are easily disintegrated either by external influences or by the slightest internal conflict.



a) b)

Fig. 1. Levels of group cohesion: a) high; b) low

Clustered groups can be more effective in achieving common goals and meeting the needs of participants because they can provide more support and interaction. On the other hand, diffuse groups can be more flexible and versatile, as participants can move in and out of them freely and have a wider range of communication. It is important to be able to manage and balance both types of groups to achieve work-life success. The deeper the incompatibility of employees, the higher the likelihood of conflicts and, as a result, the breakdown of the project team. To implement a programme for forming productive working groups, it is necessary to study people, taking into account not only their orientation and individual psychological characteristics, but also their efficiency and compatibility in the team.

Thus, in the process of solving common tasks, employees must come into contact in order to coordinate their actions. The level of such coordination affects their labour productivity and the performance of work tasks. In turn, this level of coordination is a production variable depending on the degree of employee compatibility.

A formalised model of the decision-making process task in the formation of a project team

One of the possible ways to formalise the procedure for selecting, evaluating and making decisions when forming a project team is to use a phenomenological model. This approach makes it possible to describe the procedure in general terms, regardless of the specifics of the types of work performed, the competencies of the performers and the organisational structure of the enterprise. The phenomenological model makes it possible to systematise the general procedure for analysing candidate characteristics of different content and with the necessary detail.

The mathematical model of the decision-making procedure for selecting personnel for inclusion in a project [10] is formulated as follows. We introduce the following notation:

Z is the task of selecting personnel for the project;

X is the set of required types of work in the project;

R is the set of performers of similar types of work in previous projects;

V – a set of assessments of the characteristics of candidates for the project.

The choice of the list of criteria for evaluating project candidates is determined by the specifics of the project, traditional requirements for employees of the organisation, and other circumstances. To compile a generalised list of requirements, you can use the term "ideal employee", based on the list of characteristics and criteria for their assessment adopted by the organisation to describe the specifics of the planned work, required competencies and personal characteristics. The criterion for evaluating candidates for the project is the closeness of the candidate being evaluated to the "ideal employee". Then, some candidate evaluation function can be considered as a reflection of the Cartesian product in a set of evaluations and a function of the best value of the selection score. In this case, the task of selecting personnel for a project can be viewed as choosing the following option (candidate):

$$x^{*} \in X \subset X \tag{2}$$

where $F\left(x^{*}, r\right) \cup Q(r)$ at any $r \in R$, where X – lots of pre-selected candidates.

In this case, x^* can be considered a solution to task Z if at $r \in R$ the similarity score $F\left(x^*, r\right)$ is a ratio$\cup$ to the boundary value $Q(r)$ of this r. Thus, task Z is defined by the following set: (X, R, F, Q). An element x^* from X is a solution to Z and is expressed by the predicate:

$$P\left(x^*, Z\right) = x^* \tag{3}$$

where x^* − a solution to task Z.

In practice, there may be situations when candidates need to be selected only for certain characteristics and evaluation criteria depending on the specifics of individual production operations or critical technological processes, using special equipment.

Then this task can be formulated within the framework of the case considered above for the general task Z. In this case the task Z_m which is being considered, is defined by a set of characteristics $(X_m, R_m, F_m, Q_m$, belonging X to $X_m\left(X = X_m\right)$. Thus, the task Z_m is considered as a separate variant of the task Z on the set X_m.

Based on similar considerations, it is possible to further detail the characteristics of the candidate description, focusing on the most important partial indicators required to perform specific types of work. In this case, detailing the characteristics of the candidates forms an independent task Z_j, which can be characterised by the following indicators $\left(X_j, R_j, F_j, Q_j\right)$ [10].

A variety of tasks Z_j, can be represented by some vector $\overline{S_r} = \left(x_1, \ldots x_N\right)$ $j = \overline{1, N}$. The obtained value S_r allows to determine $x_r \in X_r$ and $x_r = T_r\left(S_r\right)$ where T_r − operator for selecting a solution to a particular task from a variety of candidates Z_j.

Continuing to detail the criteria for assessing candidates, we will obtain a multi-level hierarchical structure of assessments, which has such properties as hierarchy, coordination of higher-level tasks with lower-level tasks of detailed description and modifiability of the characteristics of the candidate description, i.e. their compatibility.

The set of tasks for selecting candidates to form a project $\otimes$ team in terms of set theory can be represented as a Cartesian product of sets using the following expression:

$$\otimes \in R * M * D \times W * \Gamma * L * \bar{P} * \left\{Z_j \middle| j = \overline{1,N}\right\} * \{Z_m\} * \\ * \left\{\otimes'_j \middle| j = \overline{1,N}\right\} * \left\{\otimes''_j \middle| j = \overline{1,N}\right\} * \{\otimes_m\} * \{CP\} * \{TP\}, \tag{4}$$

where $\{TP\}$ − a variety of possible solutions for selecting a candidate for the project;

M − a variety of local lower-level characteristics;

$D, W, \bar{P}$ − a variety of possible solutions to selection tasks based on local criteria;

$$D = \left\{xD_j \middle| D_j = \left\{d_j^p\right\},\ j = \overline{1,N}\right\}$$

$$W = \left\{XW_j \middle| W_j = \left\{W_j\right\}, j = \overline{1,N}\right\},\ \bar{P} = \{\bar{p}\};$$

Γ, L − a variety of input coordinating signals for local lower-level tasks.

$$\Gamma = \left\{x\Gamma_j \middle| \Gamma_j = \left\{v_j\right\}, j = \overline{1,N}\right\},\ L = \{l\}$$

$\{CP\}$ − a variety of operators for evaluating and selecting candidates based on local lower-level criteria (lower-level mathematical models for assessing psychological, personal characteristics, competencies, etc.):

$$CP : R \times M \to \{TP\}.$$

Then the task of selecting candidates from the available set can be formulated as follows:

– for lower-level tasks:

$$Z_j : R * \mathit{\Gamma}_j * D_j \to M_j,\ j = \overline{1,N};$$

− for the tasks of selecting candidates by classes (groups) of parameters (personal, competences, etc.):

$$Z_m : R * L_m * \left\{W_j I_j = {}^{-}\left(\overline{1,N} \to \left\{x\mathit{\Gamma}_{-j} \middle| -j = {}^{-}\left(\overline{1,N}\right)\right\}\right)\right\};$$

− for top-level tasks:

$$Z_n : R * \bar{P} \to L.$$

Next, we define the composition of operators for solving the tasks of the lower level of the hierarchical system for the following tasks Γ:

$$Q'_j : R * \left\{xM_j\right\} j = \overline{1,N} \to D_j$$

$\otimes_j = \{Q'\},\ j = 1, N$ − task solving operator Z_j

$$Q_j : R * \left\{xM_j \middle| j = \overline{1,N}\right\} \to D_j$$

where, $\otimes''_j = \left\{Q''_j\right\},\ j = \overline{1,N}$ − a variety of information conversion operators from the second level of the hierarchy for tasks Z_j.

$$Q''_j : R * \left\{ xD_j \middle| j = \overline{1,N} \right\} * \left\{ x\Gamma_j \middle| j = \overline{1,N} \right\} \rightarrow W_j$$

The coordination of tasks at different levels is characterised by the degree of coherence of information exchange processes between the levels of the decision-making hierarchy.

A formal description of this principle can be provided by the following restructured representation of operators Z_j, Z_m:

$$\forall_{ji} \in \Gamma_j : Z_j\left(\delta_j\right) : R * D_j \rightarrow M_j,\ j = \overline{1,N}; \quad (5)$$

$$\forall l \in L : Z_m(l) : R * \left\{ XW_j \middle| j = \overline{1,N} \right\} \rightarrow \left\{ \Gamma_j \middle| j = \overline{1,N} \right\} \quad (6)$$

Expressions (5), (6) define the dependence of operators Z_j, Z_m on the coordinating signals δ_i and L, coming from the higher level.

Higher-level coordination is ensured by the requirement that there is a common solution to the upper-level task and a set of selected lower-level tasks, which can be formally represented as the expression:

$$\left(\forall_j = \overline{1,N} \exists\left(\partial_j, m_j\right) \wedge \exists(l) : \left\lfloor P\left(m_j, Z_j\left(\partial_j\right)\right) \wedge P\left(\partial_j, Z_m(l)\right) \wedge P(l, Z) \right\rfloor \quad (7)$$

The coordination of hierarchy levels in the procedures of information exchange under the system in special programme-oriented teams should be confirmed by a system of coordinated functional goals and objectives between the levels of the hierarchy of candidate characteristics. The final portrait of the candidate (top level) is formed on the basis of the characteristics of the lower level in the class of professional, personal, psychological and other characteristics according to the relevant set of evaluation criteria. The characteristics of this level, in turn, are formed from a set of lower characteristics inherent in the assessment of the corresponding level. Thus, it can be argued that the task of the higher level is to form the candidates' grades on the basis of the grades for the characteristics of the lower levels, which are selected through a system of coordinating signals of a substantive functional nature. This procedure is ensured by the requirement of compatibility of the informational and functional content of the simultaneously used candidate assessments in the project. Thus, the task of compatibility is determined by the same goals and criteria for assessing the characteristics of the methods of coordinating the levels of the hierarchy, etc.

To formally describe the above, we use a certain operator f_m, that converts l into signals that provide the process of selecting and deciding on the inclusion of a candidate in the project based on the testing.

$$f_m : L \to M; \left(m_j, j = \overline{1,N}\right) = f_m(l)$$

Assuming that the inverse operators f_m^{-1}, that make it possible to determine l from m_j are known, then

$$(l) f_j^{-1} = \left(m_j, j = \overline{1,N}\right).$$

Then the principle of compatibility in the hierarchy system can be written as the following expression (8):

$$\begin{aligned} &\left(\forall_j = 1,N\, \exists\left(\partial_j, m_j\right) \wedge \exists(l) : P\left(m_j, Z_j\left(\partial_j\right)\right) \wedge P(M) \Rightarrow \right. \\ &\Rightarrow \left[P\left(m_j, Z_j(\partial)\right) \wedge P\left(f_j^{-1}\left(m_j, j = \overline{1,N}\right)\right), Z \right]. \end{aligned} \quad (8)$$

Interpretation of expression (8) at the verbal level is determined by the statement that lower-level Z_j tasks can be considered adjusted relative to the global task Z if they are adjusted, first of all, relative to the task Z_m (nearer level).

In a number of practical situations, in the process of making decisions on the selection of candidates, it is not possible to ensure the coordination of assessments at different levels due to insufficient information for the required completeness of the assessment, i.e. the exchange system is not provided with the necessary coordinating signals. In this case, it is necessary to take into account the required set of coordinating signals $\overline{\Gamma}, \overline{L}$ and the required number of task characteristics $\left\{\overline{Z_j}\right\}, j = \overline{1,N}$ and tasks $\left(\overline{Z_m}\right)$, under which (9) and (10) are coordinated. To describe the procedure for making a choice decision in conditions of insufficient coordination, we introduce the following indicators:

$P_1 =$ (condition (9) is satisfied),

$P_2 =$ (condition (10) is satisfied).

Then the modifiability requirement (the ability of the hierarchy to change to ensure coherence) can be represented as the following expression:

$$\exists\left(\overline{\Gamma} \subseteq \Gamma \overline{L} \subseteq L; \left\{\overline{Z_j}\right\} \subseteq \left\{Z_j\right\}, j = \overline{1,N}; \left\{\overline{Z_m}\right\} \leq \left\{\overline{Z_m}\right\}:\right.$$

$$\left(\forall\left(\partial_j \in \overline{\Gamma}, L \in \overline{L}; Z_j \in \left\{\overline{Z_j}\right\}, Z_m \in \left\{\overline{Z_m}\right\}\right) \to \left[P_1 \wedge P_2\right]\right.$$

Thus, by fulfilling conditions (7) and (8) for the selection of appropriate subsets at the hierarchy levels, if necessary, it is possible to achieve compatibility and coordination of selection tasks during decision-making procedures for the formation of project personnel.

Conclusions

Existing research on the analysis of human resource management methods proves that selecting personnel for the project team based on professional characteristics alone does not allow for an objective assessment of the personnel's professional suitability. Currently, when forming the composition of project working groups, more and more attention is being paid to assessing the psychological qualities of candidates and selecting personnel based on professional and personal psychological characteristics. The combination of these types of qualities in candidates can create a symbiosis that will allow achieving the project's goals and objectives more effectively.

It has been established that the main criterion for including candidates in the project team is their qualifications and work experience, but it is also necessary to take into account factors related to team cohesion, the specifics of the work organisation, etc. Such a method of forming a project team can be based on multi-criteria optimisation models, which, unlike existing methods, allows taking into account not only the professional competencies of employees but also the personal and psychological characteristics of candidates in various combinations of their combinations, which contributes to the quality of the team's performance of project tasks depending on the specifics of the project requirements.

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References

1. Ukrainian Project Management Association. available: http://upma.kiev.ua/en/main/about/ (last accessed 07.0.2024).
2. Yevtushenko, H. (2019), "Formation of the project team and organization of its effective work (theoretical aspect)", Eastern Europe: Economics, Business and Management, 4(21), P. 77–82. URL: http://www.easterneurope-ebm.in.ua/ index.php/en/issue-21-2019
3. Galli B. J. (2022), Effective Motivation Theories and Strategies for Project Management Environments. International Journal of Applied Logistics. Vol. 12. Iss. 1. P. 1–18. DOI: https://doi.org/10.4018/IJAL.302095
4. Tchaikovsky, I., Tchaikovsky, M., Chaikovska, I., Chaikovskyi, M. (2021), "Development of an economic-mathematical model of project team formation in modern conditions: knowledge

aspect", Bulletin of the Khmelnytskyi National University, No. 3, P. 129–147. URL: http://elar.khmnu.edu.ua/jspui/handle/123456789/11880
5. Ivanovska, K. (2021), "Evaluation of the effectiveness of methods for supporting decision-making in the process of forming project teams", Materials of the XIV International Scientific and Practical Conference "Information Technologies and Automation-2021", Kharkiv National University of Radio Electronics, P. 310–312. URL: https://card-file.ontu.edu.ua/server/api/core/bitstreams/c4b2c36a-bfa6-4ac6-83fa-207df330913a/content
6. rochukhan, D. (2021), "Implementation of the application for surveying members of project teams", Weapons systems and military equipment, 3 (67), P. 130–135. DOI: 10.30748/soivt.2021.67.18
7. Balash, L., Sodoma, R., Kovalchuk, O. (2023), "Intelligent systems for forming project teams in safety-oriented systems", Innovative Technologies and Scientific Solutions for Industries, No. 2 (24), P. 5–15. DOI: https://doi.org/ 10.30837/ITSSI.2023.24.005
8. Malyarets, L., Iastremska, O. Tutova, A. (2022), "Determination of priority qualitative factors of stimulation of the work of enterprise top managers", Innovative Technologies and Scientific Solutions for Industries, No. 2 (20), P. 75–85. DOI: https://doi.org/10.30837/ITSSI.2022.20.0759
9. Jacob Levy Moreno's Psychodrama As a Work Technique For Treating Patients in Group and Individual Psychotherapy. Current Tasks of Psychiatry 19(4).2018. DOI: 10.2478/cpp-2018-0019
10. Kosenko, N., Dotsenko, N., Chumachenko, I. (2019), "Information technology of the project management of team building in the context of competency-based approach", monograph, Beketov National University of Urban Economy, Kharkiv: O. M. Beketov NUUE, P. 1–134 p. URL: http://eprints.kname.edu.ua/53217/

DOI: https://doi.org/10.30837/MMP.2024.117

A DECISION SUPPORT SYSTEM TO IDENTIFY PRIORITY PROJECTS FOR THE CREATION AND DEVELOPMENT OF MEDICAL FACILITIES IN THE REGION

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The main components and stages of the approach to identifying priority projects for the creation and development of medical institutions in the region are substantiated. It is envisaged to determine the maximum value for stakeholders by coordinating the amount of investment with the budgets of individual medical projects. This is done on the basis of ensuring that the required amount of investment is received in individual projects that do not exceed the approved budget, which is formed from various sources of investment. The use of the proposed approach will increase the efficiency of medical project management and ensure compliance with the needs of the population and resource capabilities. Based on the proposed approach, a decision support system has been developed to identify priority projects for the creation and development of medical institutions in the region. The system is a web application written using HTML (HyperText Markup Language), CSS (Cascading Style Sheets), JavaScript, and jQuery to simplify manipulation of the DOM, and Chart.js to visualize data in the form of graphs. Based on the developed decision support system, priority projects for the creation and development of medical institutions in the region have been identified for the given conditions of the project environment. Project managers should take into account the priority and give preference to projects with the highest value, maximizing the benefits for stakeholders with minimal resource costs.

Introduction

The creation of effective hospital districts in certain regions is one of the main challenges in ensuring the health of the population of communities and providing them with quality healthcare services [1–3]. Currently, Ukraine is experiencing socioeconomic changes due to the war and reforms. At the same time, due to limited resources, there is a need to implement innovative projects, taking into account the dynamic project environment and value for their stakeholders. This is why it is expedient to develop and implement new tools that will ensure high-quality planning processes with the ability to accurately identify priority projects for the creation and development of medical institutions in the region. This should take into account both the needs of society and limited budgetary resources.

When implementing projects and their development portfolios in various industries, project managers use appropriate decision support systems (DSS) [4–6]. They make it possible to automate and optimize decision-making processes based on the consideration and analysis of many factors of the project environment. Currently, the expediency of creating a DSS is quite relevant for determining priority projects for the creation and development of medical institutions in the region [7–9].

Their use contributes to the effective implementation of projects for the creation and development of medical institutions in the region, as well as the development of medical infrastructure.

Our research presents the approach, algorithm, and results of the development of the SPRP for identifying priority projects for the creation and development of medical institutions in the region. This system ensures maximum value for stakeholders by aligning the amount of investment with the budgets of individual medical projects. This is done based on ensuring that the required amount of investment is received in individual projects that do not exceed the approved budget [10–12]. At the same time, investment sources are properly distributed among priority projects for the creation and development of medical institutions in the region. The use of the proposed approach will increase the efficiency of medical project management and ensure their compliance with the needs of the population and resource capabilities.

Purpose and task statement

The purpose of the research is to propose an approach to identifying priority projects for the creation and development of medical institutions in the region, to develop a decision support system on its basis, and to use it to study the impact of project environment components on the selection of priority projects. In accordance with this goal, the paper should solve the following tasks:

1) to substantiate the main components and stages of the approach to identifying priority projects for the creation and development of medical institutions in the region;

2) to develop a decision support system for identifying priority projects for the creation and development of medical institutions in the region;

3) to identify priority projects for the creation and development of medical institutions in the region for the given conditions of the project environment based on the developed decision support system.

An approach to identifying priority projects for the creation and development of medical institutions in the region

The proposed approach to identifying priority projects for the creation and development of medical institutions in the region is based on maximizing value for stakeholders through effective alignment of investments with the budgets of specific medical projects. To do this, first of all, the formation of the necessary knowledge to identify projects for the creation and development of medical institutions is carried out [13–15].

To identify projects for the creation and development of healthcare facilities, one should have knowledge of the changing project environment, knowledge of project product formation, knowledge of healthcare legislation, and knowledge of project management:

$$P_{in} = f\left(K_c, K_f, K_h, K_p\right), \quad (1)$$

where P_{in} – the process of identifying projects for the creation and development of healthcare facilities;

K_c – knowledge of the state of the changing project environment of projects for the creation and development of healthcare facilities;

K_f – knowledge of actions to form project products;

K_h – knowledge of healthcare legislation;

K_p – knowledge of project management.

Knowledge K_c about the state of the changing project environment is an important component for the successful initiation of healthcare facility construction and development projects. They are formed on the basis of data on the state of the changing project environment of healthcare facilities creation and development projects. In particular, these data are used to develop models for predicting the number of diseases by different population groups, the occurrence and course of epidemics and various types of diseases, as well as the availability and level of medical services, etc.

Integration of knowledge from different fields is an important condition for successful identification of healthcare facility development projects. This knowledge is necessary to understand both the existing state and the specifics of its transition to the desired state, as well as to assess the risks and opportunities associated with healthcare facility creation and development projects.

In general, the stage of identification of projects for the creation and development of healthcare facilities in the region is described by the following expression:

$$P_{in} \in \left(A_{st} \to I_{CC} \to F_{st} \to F_{pr}\right), \quad (2)$$

where P_{in} – the process of identifying projects for the creation and development of healthcare facilities in the region;

A_{st} – analysis of stakeholders in the projects for the creation and development of healthcare facilities in the region;

I_{CC} – identification of contradictions and conflicts of interest between stakeholders in the projects for the creation and development of healthcare facilities in the region;

F_{st} – formulation of stakeholders' needs to change the current state of the medical system;

F_{pr} – formation of projects for the creation and development of healthcare facilities in the region.

The formulated set of i-th projects $\{P_{ri}\}$ for the creation and development of medical institutions in the region requires further evaluation of their value for stakeholders.

The next stage involves quantifying the value of the formulated set of i-th projects $\{P_{ri}\}$ for the creation and development of medical institutions in the region. For this purpose, computer modeling methods are used to predict intermediate value indicators. The criteria for the value of k-th projects for the creation and development of medical institutions in the region are the ratio of benefits $\left(B_{sti}^{mk}\right)$ for stakeholders from individual m-th medical systems to the costs $\left(C_{pi}^{mk}\right)$ incurred to create these benefits:

$$V_{pi}^{mk} = B_{sti}^{mk} \big/ C_{pi}^{mk} , \tag{3}$$

where V_{pi}^{mk} – value for i stakeholders from individual m-th medical systems due to the implementation of k-th medical projects;

B_{sti}^{mk} – benefits for i stakeholders from individual m-th medical systems due to the implementation of k-th medical projects;

C_{pi}^{mk} – costs incurred to create benefits from m-th medical systems due to the implementation of k-th medical projects.

Basic value V_{pb}^{mk} from implementation for i-th stakeholders from individual m-th healthcare systems through the implementation of k-th healthcare projects:

$$V_{pb}^{mk} = \frac{1}{n} \sum_{i=1}^{n} V_{pi}^{mk} , \tag{4}$$

where V_{pb}^{mk} – is the basic value from the implementation of k-th medical projects;

n – is the number of stakeholders who benefit from individual m-th medical systems due to the implementation of k-th medical projects.

The greatest basic value V_{pb}^{mk} for stakeholders from individual m-th healthcare systems through the implementation of k-th healthcare projects is provided by those projects that allow to obtain maximum benefits $B_{sti}^{mk} \to \max$ for i-th stakeholders at the minimum cost $C_{pi}^{mk} \to \min$ incurred to create these benefits:

$$V_{pb}^{mk} = f\left(\left\{B_{sti}^{mk}\right\},\left\{C_{pi}^{mk}\right\}\right) \to \max . \tag{5}$$

Based on the determined basic value V_{pb}^{mk} for stakeholders from individual m-th medical systems through the implementation of k-th medical projects, priority projects are selected for a given hospital district.

Priority k-th projects for the creation and development of healthcare facilities in the region are identified based on their ranking in descending order of basic value V_{pb}^{mk} for stakeholders:

$$V_{pb}^{m2} \geq V_{pb}^{m4} \geq \ldots \geq V_{pb}^{mk} . \tag{6}$$

This ensures the creation of a vector of priority projects for the creation and development of medical facilities in the territory of hospital districts. Let us describe the determination of the priority k-th projects for the creation and development of medical institutions in the region, which are subsequently ranked in descending order of basic value V_{pb}^{mk} for stakeholders. In this case, the set of projects is known $P = \{p_1, p_2, \ldots, p_n\}$, as well as the basic value V_{pb}^{mk} for different stakeholders for each of them. Then the vector of priority projects P_P is defined as:

$$P_P = \left(p_{(1)}, p_{(2)}, \ldots, p_{(k)}\right). \tag{7}$$

where $p_{(z)}$ – is a medical project that has the z-th basic value in terms of quantitative value;

k – is the number of priority medical projects to be implemented, units.

To form a vector of priority projects, medical projects $p_{(z)}$ are ranked by their basic value V_{pb}^{mk} in descending order. That is, for i from 1 to k. Thus, the ranking formula is as follows:

$$V_{(i)} = \max\left\{V_j \mid\ p_j \in P \setminus \left\{p_{(1)}, p_{(2)}, \ldots, p_{(i-1)}\right\}\right\}, \tag{8}$$

where $V_{(i)}$ – is the medical project with the highest underlying value.

Once found, this project is removed from the set P_P. The procedure is repeated until the k-th number of priority medical projects are identified. This allows us to form a vector of priority projects P_P, which includes the k-th number of medical projects with the highest basic values for stakeholders.

To coordinate the amount and sources of investment with the budgets of priority projects for the creation and development of medical institutions in the region, you should specify the k-th number of medical projects, the budget B_i of each i-th medical project (where $i \in \{1, 2, \ldots, k\}$, the amount of investment I_i for each i-th project and the amount of available investment S_i for each i-th project from all sources.

The amount of investment I_i for each i-th medical project should not exceed its budget B_i:

$$I_i \leq B_i \text{ for all } i \in \{1, 2, \ldots, k\}. \quad (9)$$

The amount of investment I_i for each i-th medical project should be equal to the sum of available investments S_i from all sources:

$$I_i = S_i \text{ for all } i \in \{1, 2, \ldots, k\}. \quad (10)$$

If S_i it consists of several sources of investment (e.g., state budget (D_i), local budget (L_i), private investment (P_i), and other sources (O_i), then:

$$S_i = D_i + L_i + P_i + O_i \text{ for all } i \in \{1, 2, \ldots, k\}. \quad (11)$$

Thus, the following system of equations (9–11) is used to match the amount of investment I_i with the budgets B_i of the i-th medical projects. These equations ensure that each i-th healthcare project receives the required amount of investment I_i that does not exceed the approved budget B_i. At the same time, investment sources should be properly distributed among priority projects.

Results of the development of a decision support system for identifying priority projects for the creation and development of medical institutions in the region

A number of tools have been selected to develop a decision support system for identifying priority projects for the creation and development of medical institutions in the region, which is a web application. It is a web application developed in the Replit integrated development environment (IDE).

As for the architecture of the decision support system for identifying priority projects for the creation and development of medical institutions in the region, the client side (Frontend) uses HTML and CSS for marking up and styling the page, JavaScript for dynamically adding projects to the list, processing events, and sending requests to the server, jQuery for easier manipulation of DOM elements, Chart.js for graphing and visualizing the results of the analysis. At the same time, the server side (Backend) involves the use of PHP to process POST requests from the client side, process project data and sort them based on the calculated value. It is planned to use the php://input file to receive data from the POST request and temporarily store it in the computer's memory.

The user interface (UI) of the decision support system provides for users to enter data on the characteristics of projects for the creation and development of healthcare facilities in the region through a form that includes fields with their name, budget and its sources of revenue (state budget, municipal budget, private investment, other sources), benefits and costs (Fig. 1).

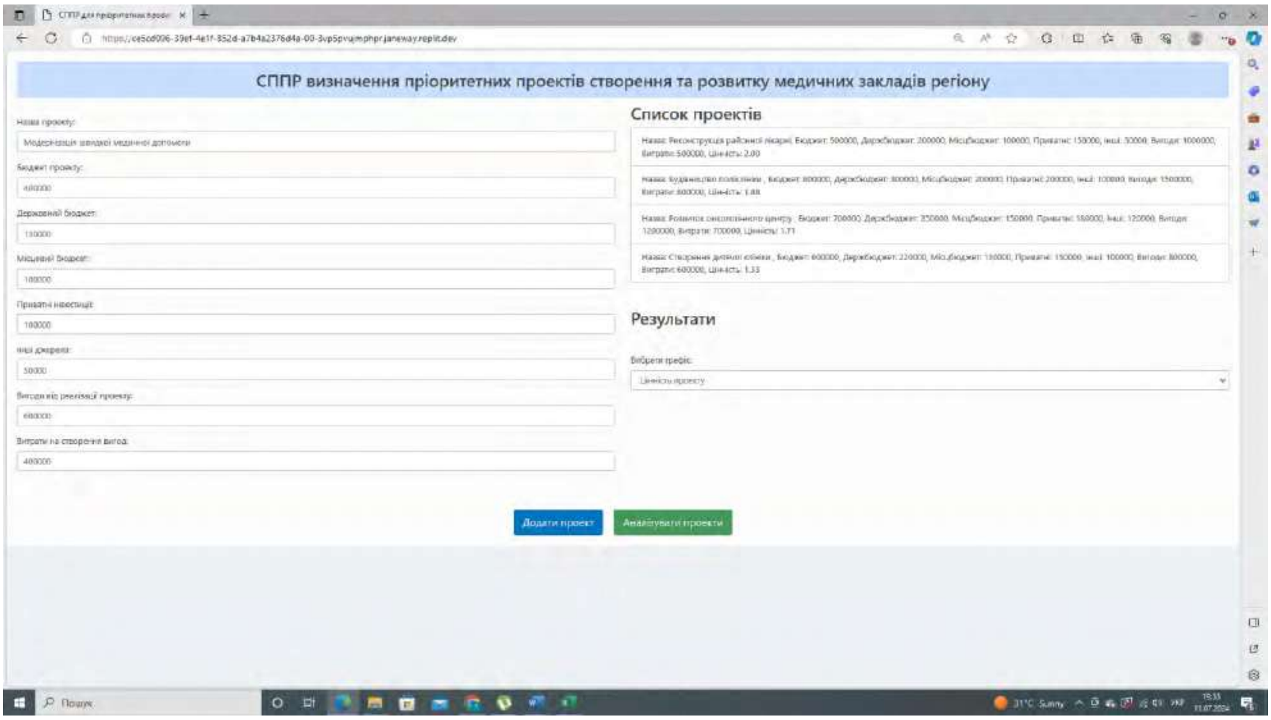

Fig. 1. User window of the decision support system for identifying priority projects for the creation and development of medical institutions in the region

There is an "Add project" button that allows you to add project characteristics to the list of projects on the client side. Data processing is performed after clicking the "Analyze projects" button. In this case, the data on the characteristics of individual projects for the creation and development of medical institutions in the region are sent to the server using an AJAX request. The PHP script on the server receives data on the characteristics of individual projects for the creation and development of medical institutions in the region, processes them, sorts them by the value of the specified projects, and returns the results back to the client side.

On the client side, the results are displayed as a list of priority projects for the creation and development of medical institutions in the region sorted by value. At the same time, Chart.js is used to build a graph with priority projects.

The peculiarity of the decision support system for identifying priority projects for the creation and development of medical institutions in the region is that users can add new projects and see them in the list without reloading the page. The system automatically calculates the value of each project based on benefits and costs, sorts them and displays the results. The use of Chart.js to visually represent priority projects helps users better understand data and make management decisions. At the same time, the proposed decision support system has a simple and intuitive interface that allows project managers to quickly enter data and get results.

The results of using a decision support system to identify priority projects for the creation and development of medical institutions in the region

The proposed decision support system was used to identify priority projects for the creation and development of medical institutions in the region. Initial data for the implementation of this management process are presented in Table 1. In this table, the costs of creating benefits are equal to the project budget, and the benefits of project implementation are reflected as the value that stakeholders receive from each project.

The project budget is calculated as the sum of the state budget, local budget, private investment, and other sources of funding. The costs of creating benefits are equal to the project budget, and the benefits of project implementation reflect the value that stakeholders receive from each project. We have obtained a schedule of priority projects for the creation and development of medical institutions in the region, sorted by their value (Fig. 2).

It was found that the reconstruction of the district hospital has the highest value (2.0). At the same time, the benefits are twice as high as the costs of implementing this project. The projects to build a polyclinic and develop an oncology center have high values close to 2.0, which also indicates high efficiency. Establishing a children's clinic has the lowest value (1.333), but is still profitable to implement. The results indicate that the projects of reconstruction of the rayon hospital and construction of a polyclinic have the highest value and are prioritized for priority funding and implementation. They will bring the greatest benefits to stakeholders at the optimal cost of their implementation. Project managers should prioritize and give preference to projects with the highest value, maximizing stakeholder benefits at the lowest cost.

Table 1

Initial data for determining priority projects for the creation and development of medical institutions in the region, USD

Name of the project	State budget	Local budget	Private investments	Other sources	Costs of creating benefits	Benefits from project implementation
Reconstruction of the district hospital	200000	100000	150000	50000	500000	1000000
Construction of a polyclinic	300000	200000	200000	100000	800000	1500000
Development of an oncology center	250000	150000	180000	120000	700000	1200000
Creation of a children's clinic	220000	130000	150000	100000	600000	800000
Modernization of the ambulance service	150000	100000	100000	50000	400000	600000

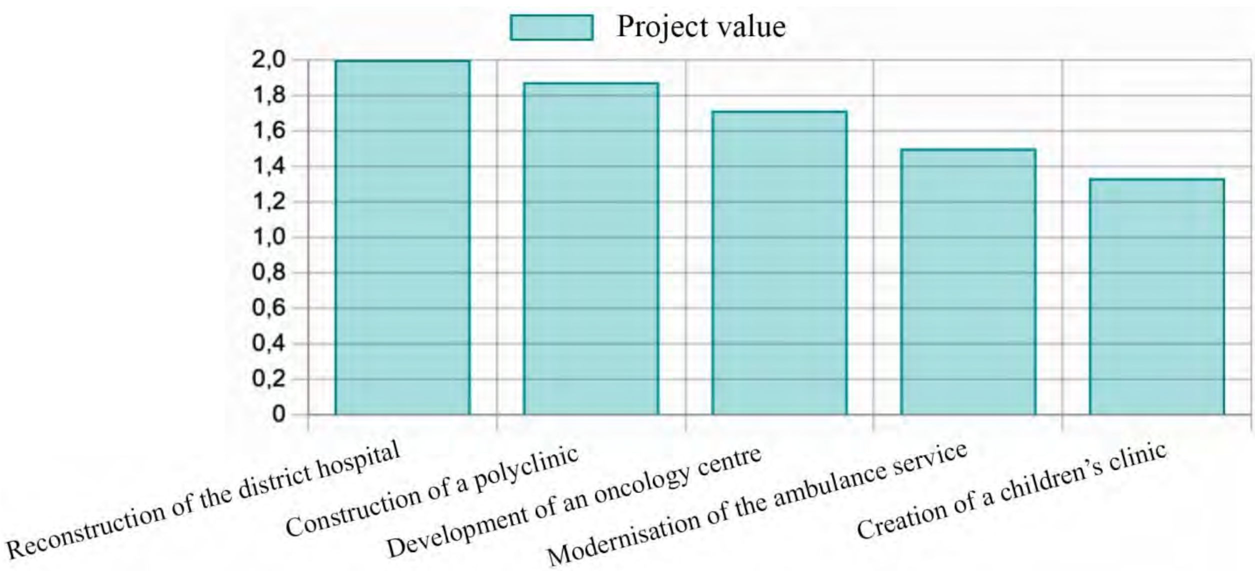

Fig. 2. Graph of priority projects for the creation and development of medical institutions in the region sorted by their value

In general, the identification of priority projects for the creation and development of healthcare facilities in the region using the proposed decision support system allows project managers to obtain information about them, which makes it possible to focus on higher priority projects to quickly obtain benefits for stakeholders. Based on the analysis, project managers make decisions about the need to find and attract additional sources of funding to ensure the stability of project budgets. Conducting a cost-benefit analysis for stakeholders is the basis for increasing the efficiency of using available resources. The following recommendations will help project managers effectively manage projects for the creation and development of healthcare facilities, ensuring maximum benefit for the region's stakeholders at the optimal cost of resources.

Conclusions

1. The substantiated main components and stages of the approach to identifying priority projects for the creation and development of medical institutions in the region involve determining the maximum value for stakeholders by matching the amount of investment with the budgets of individual medical projects. This is done on the basis of ensuring that the required amount of investment is received in individual projects that does not exceed the approved budget, which is formed from various sources of investment. Using the proposed approach will increase the efficiency of medical project management and ensure their compliance with the needs of the population and resource capacities.

2. Based on the proposed approach, a decision support system has been developed to identify priority projects for the creation and development of medical institutions in the region. It is a web application that is written using HTML (HyperText Markup Language) and CSS (Cascading Style Sheets), which are used to structure the web page, as well as styling and design, including the Bootstrap 4 library to create an adaptive design. In addition, we used the JavaScript programming language to add dynamic behavior and interactivity to our web page, as well as jQuery to simplify DOM manipulation, Chart.js to visualize data in the form of graphs.

3. On the basis of the developed decision support system, priority projects for the creation and development of medical institutions in the region for the given conditions of the project environment are identified. It is established that for a given project environment, the reconstruction of the district hospital has the highest value (2.0). At the same time, the benefits are twice as high as the costs of implementing this project. Project managers should consider prioritizing

and giving preference to projects with the highest value, maximizing benefits for stakeholders with minimal resource costs.

References

1. O. Malanchuk, A. Tryhuba, I. Tryhuba, I. Bandura, A conceptual model of adaptive value management of project portfolios of creation of hospital districts in Ukraine. CEUR Workshop Proceedings, 2023, 3453, pp. 82–95.
2. I. Chumachenko, A. Bondarenko, N. Dotsenko, O. Bondarenko. Agile transformation in a healthcare environment: the methodology of project-oriented management. Collection of scientific papers "ΛΌГOΣ", 390–392.
3. O. Malanchuk, A. Tryhuba, I. Tryhuba, R. Sholudko, O. Pankiv, A Neural Network Model-based Decision Support System for Time Management in Pediatric Diabetes Care Projects, in: IEEE 18th International Conference on Computer Science and Information Technologies (CSIT), 2023, pp. 1–4.
4. O. Kovalchuk, D. Kobylkin, O. Zachko, Digitalization of HR-Management Processes of Project-Oriented Organizations in the Field of Safety. CEUR Workshop Proceedings, 2022, 3295, pp. 183–195.
5. S. Bushuyev, N. Bushuyeva, D. Bushuiev, V. Bushuieva, Cognitive Readiness of Managing Infrastructure Projects Driving by SMAR Tification. 2022 IEEE European Technology and Engineering Management Summit, E-TEMS 2022 – Conference Proceedings, 2022, pp. 196–201.
6. S. Bushuyev, N. Bushuyeva, D. Bushuiev, V. Bushuieva. Integrated Intelligence Model for Assessment Digital Transformation Project, in: SIST 2023 – 2023 IEEE International Conference on Smart Information Systems and Technologies, 2023, pp. 42–46.
7. V. Piterska, O. Kolesnikov, D. Lukianov, K. Kolesnikova, Development of the Markovian model for the life cycle of a project's benefits. Eastern-European Journal of Enterprise Technologies 5, 2018, 4(95), pp. 30–39.
8. O. Zachko, V. Grabovets, I. Pavlova, M. Rudynets, Examining the effect of production conditions at territorial logistic systems of milk harvesting on the parameters of a fleet of specialized road tanks, in: Eastern-European Journal of Enterprise Technologies, 2018, 5(3-95), pp. 59–69.
9. R. Ratushnyi, P. Khmel, E. Martyn, O. Prydatko, Substantiating the effectiveness of projects for the construction of dual systems of fire suppression. Eastern-European Journal of Enterprise Technologies, 4(3-100) (2019) 46–53. DOI: https://doi.org/10.15587/1729-4061.2019.175275
10. L. Chernova, A. Zhuravel, L. Chernova, N. Kunanets, O. Artemenko, Application of the Cognitive Approach for IT Project Management and Implementation. International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2022, 2022 – November, pp. 426–429.
11. H. Olekh, K. Kolesnikova, T. Olekh and O. Mezentseva, Environmental impact assessment procedure as the implementation of the value approach in environmental projects. CEUR Workshop Proceedings 2851, 2021. 206-0216.

12. A. Tryhuba, R. Ratushny, I. Tryhuba, N. Koval, I. Androshchuk, The model of projects creation of the fire extinguishing systems in community territories, in: Acta universitatis agriculturae et silviculturae mendelianae brunensis. 68(2) (2020) 419–431. DOI: 10.11118/actaun202068020419
13. V. Boyarchuk, O. Boiarchuk, N. Pavlikha, N. Kovalchuk, Study of the impact of the volume of investments in agrarian projects on the risk of their value (ITPM-2021) In: CEUR Workshop Proceedings, 2021, 2851, pp. 303–313.
14. N. Dotsenko, Y. Husieva, I. Chumachenko, A. Galkin, H. Kuchuk, H. Padalko, A. Bondrenko. Application of coordination approach to change management in medical industry Agile transformation projects. Information systems in project and program management : Collective monograph edited by I. Linde. European University Press. Riga: ISMA, 2023. P. 48–56.
15. O. Bashynsky, T. Hutsol, A. Rozkosz, O. Prokopova. Justification of Parameters of the Energy Supply System of Agricultural Enterprises with Using Wind Power Installations. E3S Web of Conferences, 2020, 154, 06001.
16. V. Boyarchuk, V. Tymochko, S. Bondarchuk, Model of assessment of the risk of investing in the projects of production of biofuel raw materials. International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2020, 2, pp. 151–154, 9322024.
17. I. Teslia, O. Grygor, I. Khlevna, N. Yehorchenkova, O. Yehorchenkov. Structure and functions of supporting subsystems in management of project-oriented businesses of companies. International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2021, 2, pp. 379–382.
18. V. Piterska, S. Rudenko, A. Shakhov, Development of the method of formation of the architecture of the innovation program in the system Univers- State- Business. International Journal of Engineering and Technology(UAE), 2018, 7(4.3 Special Issue 3), pp. 232–239.

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INTEGRATING DECISION SUPPORT TECHNIQUES INTO AGILE PROJECT MANAGEMENT

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The processes of decision-making in projects on the basis of the value-oriented paradigm are considered. It is determined that in projects decision-making processes should be considered from the position of dominant value memes in the organization. Value-oriented approach makes it possible to more correctly determinate the value of the project product. An analysis of decision-making methods in projects has been proposed, taking into account the influence of the value level of the decision-maker. It is determined that such analysis should contribute to the integration of soft and hard approaches in making project decisions. The findings focus on how decisions in projects align with the dominant values of decision-makers. The issue of the impact of AI-based decision-making automation on the creation of knowledge in project management is considered.

Introduction

Decision-making in project management is used throughout the project life cycle, and is usually carried out under conditions of incomplete input data. Examples are decision-making tasks in the development of investment projects, selection of suppliers or contractors, optimization of project product implementation options, project implementation monitoring, etc. As the complexity and scale of projects increases, the cost of decision-making increases, the consequences of mistakes become more serious, and appealing to the intuition of managers is not always justified.

The successful transition of the system from the current state to the planned one in the best way demonstrates the correct management decision and describes the discipline of project management, which consists of a set of management decisions made. However, the use of mathematical methods of decision-making in project management does not always make it possible to correctly solve the problem, since the choice of decision occurs under limited time conditions and by the totality of heterogeneous contradictory indicators, which, even in the presence of different methods of decision support, is a rather complex problem [1–3].

Analysis of recent researches and publications

Over the past few decades, methods of decision support based on the use of optimization problems have been developed [4, 5]. When using optimization methods, traditional project design models are classified according to what input data they take into account, and how. In this regard, deterministic and stochastic models with elements of uncertainty are distinguished [6]. Deterministic models, in turn, are divided into linear, nonlinear, dynamic and graphic. It is necessary to supplement this classification with models that take into account different types of uncertainty based on the theory of fuzzy sets [7]. This classification should also take into account single-criteria and multi-criteria task statements. When considering multi-criteria tasks for the formation of projects, it is most often proposed to take into account profit, the need for investment, risks, as well as the dynamics of these indicators as criteria [8, 9].

With the current rapid changes in the environment, modern enterprises face an acute problem of improving their own management system [10]. For a long time, functional and process approaches were used to analyse the development of systems [11, 12]. However, over time, experts have come to the conclusion that enterprises that pay less attention to financial performance and concentrate more on creating organizational value get better results [13, 14]. In recent years, the category of "value" has been increasingly used as a criterion for the effectiveness of the enterprise’s development through projects, while the very concept of "value" is changing with the development of human civilization.

Within the framework of management science, it is customary to distinguish between hard and soft paradigms [15, 16]. The terms "hard" and "soft" reflect two different approaches that have had a strong impact on the development of both academic and practical disciplines. Each of these terms refers to two different paradigms, including specific values, ways of seeing the world, and approaches to practice. Hard methods emphasize the search for objective knowledge, while soft approaches derive from the subjective interpretation of knowledge [18]. The differences between hard and soft include general concepts of the essence of the project, the degree of its success and the satisfaction of the project stakeholders [13, 15, 18]. The value of the project product is the personal perception by stakeholders of the project product ability to create benefits for them due to its unique properties in social, economic, political, or spiritual aspects [19]. Yeoh [20] observed that the acceptance of the product goes beyond technical quality by extending to soft criteria. The value of soft ideas in project models is highlighted by Williams [21] in his study.

The aim of the article is to study the manifestations of the hard to soft paradigm in the science of project management, the integration of hard and soft methods of decision support, the consequences of value influence on decision-making processes in projects.

Methodical materials of the study

Decision-making theory and project management are closely related, as they are used in the transformational process of the system's transition from one state to another. This process can be considered in two aspects: rational and human. In the rational approach, decision-making in a variety of economic situations is usually associated with profit maximization. This is considered rational behaviour in economic decision-making. Rational process and analysis must be logical and algorithmic. If these minimum requirements are not met, that is, if a person has been even slightly, influenced by personal emotions, feelings, or moral norms, then the analysis is considered an irrational criterion. But as modern research shows, no human being ever satisfies these criteria. Therefore, it can be assumed that a person very often acts irrationally, guided not only by the desire to make money, but also by emotions, feelings, and moral norms [23, 24]. As the winner of the Nobel Prize in Economics in 2017, Richard Thaler, said, the theory of rational choice (when a person always chooses the highest profit) is too simple a model, that turns our world into a miserable platform for battles for profit, rejecting other aspects of human life [25]. Taking into account the dominant organizational values allow us to identify the deep motives of the activities of subjects at different levels that make project decisions.

To solve intellectual problems, knowledge from a specific subject area is increasingly used, presented in a certain standard form, and algorithms for their processing are compiled. This is how intelligent decision support systems are formed in various spheres of human activity. Now artificial intelligence algorithms can be considered as another representative of preparation and decision-making, which fully meets the requirements of rational behaviour, but gives rise to a significant number of ethical and legislative questions.

In recent years, project management has been abandoning rigid hierarchical management structures and moving to agile project-oriented systems, which is enshrined in new project management standards [26]. Starting from the 3rd edition, PMBoK has adapted the description of processes to the possibility of using an agile approach to project management [1]. The principles of the agile project management approach described by the Agile Manifesto have gained worldwide recognition and influenced the development of an agile project management methodology. One of the 4 agile main principles is "individuals and interactions over processes and tools" [27]. A continuation of the agile project culture is the study of the mental space of projects, as well as the development of a formalized description of such a space, which allows influencing the success of projects and programs [28]. The main differences between classical and agile project management are presented in Table 1.

The essence of decision-making is the development of an action plan to solve a problem. A problem is always characterized by certain conditions, which are called situations. Identification and description of a problem situation provides initial information for setting a decision-making problem.

Table 1

Classical and agile values of project management

Classical values	Agile values
Hierarchical structures	Horizontal structures
Emphasis on financial and material resources	Emphasis on human resources
Centralization and dependency	Flexibility and autonomy
Management on rules and directives	Management through organizational values
Emphasis on processes	Emphasis on communication
Orientation to internal processes	Taking into account external factors and customer orientation
Compliance with Contact rrequirements	Customer collaboration over contract negotiation
Adaptation fee	Performance reward

The result of the problem is a solution or the choice of the optimal alternative from a set of admissible solutions, focused on the conscious goals achievement. A decision is said to be optimal if it provides an extremum (maximum or minimum) of the selection criterion for the individual decision-maker or satisfies the principle of agreement for a group of persons. A generalized characteristic of a solution is its effectiveness as the ratio of the degree of goals achievement to the costs of achieving them. The greater the degree of goals achievement and the lower the costs of their implementation are, the more effective is the solution [29, 30]. For individual decision-making, the task looks like this:

$$\langle S_0,\ T,\ R\ |\ S,\ A, L,\ Y, f,\ k,\ Y^* \rangle \ , \tag{2.1}$$

where to the left of the vertical line are the known parameters:

S_0 – briefly describes the content of the problem to be solved;

T is the time allotted for decision-making;

R are the resources required to make a decision.

To the right of the vertical line are unknown parameters: $S = (S_1,\ \ldots,\ S_n)$ is a set of alternative (mutually exclusive) situations that complement the definition of the problem situation and reduce the initial uncertainty of the task.

$A=(A_1, \ldots, A_k)$ are the goals that are solved in a problem situation. The description of goals is carried out qualitatively (content) and quantitatively (a set of indicators), among which the most important are: criteria for achieving goals; indicators of the degree of goals achievement; priorities.

$L=(L_1,\ldots, L_p)$ are many restrictions (financial, material, legal, etc.).

$Y=(Y_1, \ldots, Y_m)$ is a variety of alternative solutions, from which a single optimal or acceptable solution is chosen Y^*. Decisions are described in a meaningful and formal way as a set of characteristics, which necessarily include the resource characteristics for the implementation of decisions.

$f(A, S, Y)$ – Decision-Maker preference function.

k – Criterion for choosing the best solution.

Y^* – the optimal solution.

So, the decision-making task of an individual decision-maker is formulated as follows. Under the conditions of the problem situation S_o, the available time T and resources R, it is necessary to define S_o by the set of alternative situations S, to formulate the set of goals A, constraints L, alternative solutions Y, to assess the advantages of solutions and to find the optimal solution Y^* from the set Y using the formulated selection criteria k.

For a group of decision-makers, the decision-making task looks like this:

$$\langle S_o, T, R \mid S, A, L, Y, F(f), G, Y^* \rangle, \qquad (2.2)$$

where S_o, T, R, S, A, L, Y, Y^* are the same designations as for the individual decision-maker's task. $F(f)$ is a function of group preference, which depends on the vector of individual preferences of group members $f=(f_1,f_2,\ldots,f_d)$, d is the number of experts in the group. G is the rule (principle) of harmonization of individual preferences for the formation of group advantage (for example, the principle of votes majority, etc.).

So, the task of group decision-making is formulated as follows. Under the conditions of the problem situation S_o, the available time T and the resources R, it is necessary to determine S_o by the set of alternative situations S, to formulate the set of goals A, constraints L, alternative solutions Y, to make an individual assessment of the advantages of decisions, to build a group function of preferences $F(f)$ and on the basis of the chosen principle of agreement G to find the optimal solution Y^*, that satisfies the group's preference. Generalized stages of the decision-making process in projects are shown in Fig. 1.

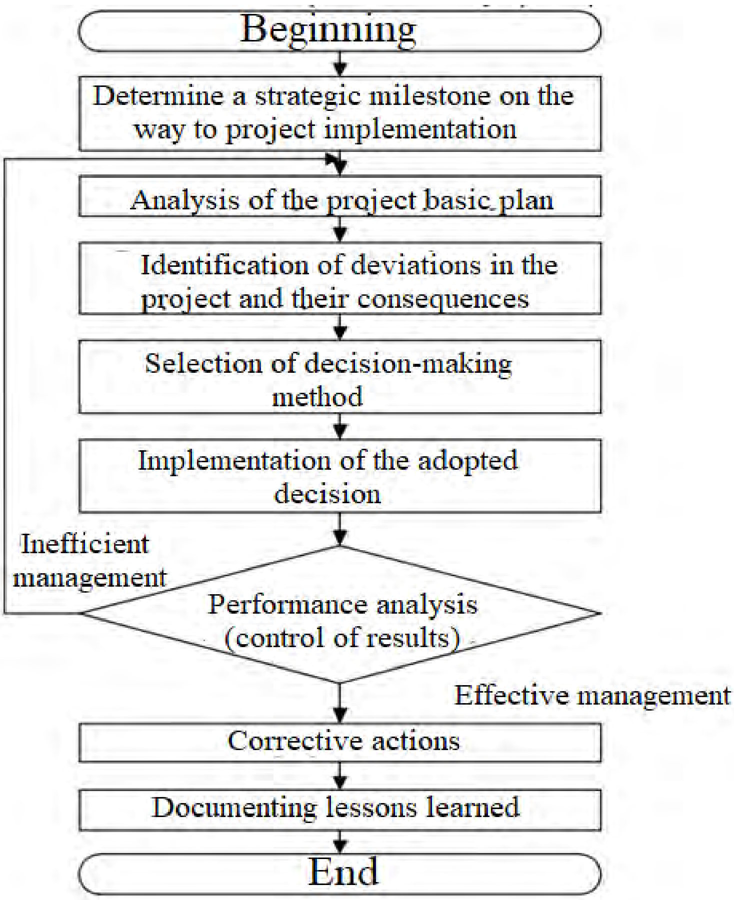

Fig. 1. Stages of the decision-making process in project

Results of the study

In the process of preparing and choosing a decision, it is necessary to take into account two sides: the formalized one, due to the mathematical rules of the decision-making process, and the subjective side, due to the peculiarities of the behaviour of the person making the managerial decision. Taking into account the influence of the "human factor" is provided by descriptive models, in which the behavioural characteristics of the decision-maker are decisive. They reveal the motives and factors (values) influencing the strategy and tactics of decision-making. Taking into account the individuality of perception of the world and life experience, it can be argued that each person has his own unique "model of the world" depending on what he considers valuable in this world [6].

To move from one level of values to another level, the decision-maker is motivated by difficulties in choosing possible alternatives. In some cases, it maybe one's own subjective doubts, and in another, it may be the objective need to solve the problem taking into account changes in the environment. The more complex the object to be managed, the higher the value level of decision-making required [31]. At the same time, each level corresponds to a certain reflexive-mental mechanism of decision-making, which takes into account the internal ranking of values and their criteria of a decision-maker person. From the point of view of the value-oriented approach, the role of the project manager is a product of his value memes, which are successfully adapted to the activities of the organization. In this context, the project manager plays the role of a photocopier who replicates value project memes into the project plan [31, 32].

Let us consider in more detail the influence of dominant values in decision-making methods (Table 2).

Table 2

Value orientations of decision-making in projects

Level of values	Type of thinking	Value memes	Principles of decision-making	Comments
1	2	3	4	5
Purple	Clans	Belonging to a clan as a guarantee of well-being	Customs and traditions. Council of Elders. Mystical signs. The Clan Always Benefits	Traditional-semantic level of decision-making. Decisions are made based on the opinion that the clan leader always knows best how to act in the best interests of the clan
Red	Self-centred	The desire for profit and power	Tough diktat. Unquestioning submission. The strong appropriate all the benefits to themselves	Conceptual level of decision-making. At this level, subjective desires are departed from and strict concepts are used. As a form of thinking, this level reflects the subordination of the weak to the stronger
Blue	Obedience to law and hierarchy	Commitment to order and law, patriotism	Orders from the authorities. Compliance with regulations. Benefits accrue to the most righteous	Task-problem level of decision-making. Decision-making is carried out according to a pre-known algorithm in accordance with the regulations of the management system

Continuation of the table

1	2	3	4	5
Orange	Materialistic, result-oriented	Striving for Success Through Innovation	Finding the best options. Result-oriented. The most successful one has benefits	Individual semantic level of decision-making. Decision-making is based on logical reasoning, creative thinking and common sense. Involvement of the experts
Green	Focus on preserving the environment, consensus, interpersonal relations	Harmonious social environment, equality of opportunity	Consensus-building. Everyone must cooperate. Every opinion must be taken into account. Public Benefit	Communicative and semantic level of decision-making. Decisions are made on the basis of communicative interaction of all stakeholders through understanding and consensus
Yellow	Systemic and integrative, focus on quality of life	Synergetic Integration Acceptance of Diversity	Knowledge comes first. High ethical standards. Solving paradoxes. The most competent benefit	Universal-ontological level of decision-making. It requires a systematic vision of the world, the integrity of the representation of the object of management in the interaction of all its parts

Because project managers should not be limited to monitoring projects and returning them to a controlled state. They must possess the skills necessary to make non-standard creative decisions with the ability to effectively influence the direction and course of the project. In reference models with fixed decision-making algorithms, it is possible to calculate the amount of input influence at which the system moves along the desired trajectory. This is how neural networks can compute values any functions to predict risks and project outcomes, allowing us to take timely preventive measures.

In practice, neural networks are well suited for classification, optimization, and forecasting problems.

However, there are a number of disadvantages associated with the use of neural networks to solve problems of information identification. The main one is that a neural network requires a large amount of factual information to train (the number of observations is from 50 to 100).

For analytical tasks in projects, this cannot always be ensured. In addition, implicit learning leads to the fact that the structure of connections between neurons becomes "incomprehensible". It becomes difficult to answer the question of how the neural network gets the result. This phenomenon can be called the "logical opacity" of neural networks trained according to implicit rules [33]. Even a well-trained neural network is a "black box", i.e., a system in which only input and output quantities are available to an external observer, and its internal processes that take place in it are unknown. The implementation of artificial intelligence in project management is considered useful for providing more accurate estimates, simplifying workflows, automating repetitive tasks. However, AI-based decision-making raises important questions about its ethical use, safety, and responsibility in decision-making. Therefore, the use of AI in agile projects, where the main role is played by people and not processes, should be very careful. Because in this way we can lose such a valuable component of creating innovations as live human communications. In projects, we must constantly remember that the project product is created for people, and not for rationally thinking machines.

Conclusions

The achievement of the value-oriented direction of project management should enrich project managers with an understanding of the laws of transformation of the surrounding world through design. Establishing compliance with the established practices of value-based project management has shown that decision-making processes should be considered from the standpoint of a fundamentally new paradigm – on the basis of dominant value memes in the organization. The application of the above provisions makes it possible to take into account the level of dominant values in projects at certain moments of their implementation and to more correctly calculate the value of the project product. AI tools greatly assist project managers in controlling and monitoring projects. However, AI's lack of ethical considerations and transparency suggests that project managers should still be careful when interpreting results. The proposed analysis of decision-making methods in projects should contribute to the development of professional competence of project managers.

Future Research

As there are still many uncertain issues in the value-based project management methodology, we propose to continue research on value creation in different types of project organizations. We also propose to investigate how the use of artificial intelligence in project decision-making processes can affect projects that have a social focus. We believe that now there is a need for active cooperation of trade unions, non-governmental organizations and individual researchers on the consequences of using artificial intelligence in decision-making processes and studying possible dangers on this path.

References

1. Project Management Body of Knowledge Guide (PMBOK® Guide). American National Standard ANSI/PMI 99-001-2004 / Ed. by S. D. Bushuev. – 3rd ed. – Project Management Institute USA, 2004. – 388 p.
2. A. Akhavan Tabassi, D. Bryde, E. Mustafa Kamal, and J. Dowson, Challenges For Project Management In The 21st Century. 2019. DOI: 10.15405/epms.2019.12.63
3. R. K. Wysocki, Effective Project Management: Traditional, Agile, Extreme, 5th edition. Indianapolis, Ind: Wiley, 2009.
4. A Guide to the Management of Innovative Projects and Programs: vol.1, version 1.2 / transl. from English under the editorship of S. D. Bushuev. – K. : Nauk. Svit, 2009.– 173 p.
5. Management of Innovative Projects and Programs Based on the P2M Knowledge System: Monograph // Yaroshenko F.A., Bushuev S.D., Tanaka H. – Kyiv: Summit-Kniga, 2012. – 272 p.
6. Molokanova V.M. Value-oriented portfolio management of organization development: abstract. Doc. Tech. Sci., Spec. : 05.13.22 – management of projects and programs / V. M. Molokanova – K. : MES KNUCA, 2015. – 40 p. (in Ukrainian).
7. Coffin, M. A and B.W. Taylor. Multiple Criteria R&D project selection and scheduling using fuzzy logic. Computer&Operations Research, 23, pp. 207–221.
8. Morteza Ghobakhloo. Industry 4.0, digitization, and opportunities for sustainability. Journal of Cleaner Production. Vol. 252. 2020. DOI: https://doi.org/10.1016/j.jclepro.2019.119869
9. A.J. Shenhar and D. Dvir, "Project Management Research – The Challenge and Opportunity", Proj. Manag. J., vol. 38, no. 2, pp. 93–99, Jun. 2007, DOI: 10.1177/875697280703800210
10. Radulescu, C.Z., Radulescu, M., Filip, F.G., et al. Decision analysis for the project selection problem under risk 9th IFAC Symposium on Large Scale Systems: Theory and Applications 2001 (LSS'01).
11. H. Kerzner, Project Management: A Systems Approach to Planning, Scheduling, and Controlling, 11th edition. Hoboken, New Jersey: Wiley, 2013.
12. Delisle C.L. Would the real project management language stand up / C.L. Delisle, D. Olson. Int J Project Manage 22 – 2004 – №4. − pp. 327–337.
13. Garcia A.B. Voting on the agenda: the key to social efficient meetings / A. B. Garcia, J. Kunz, M. Fischer. Int J Project Manage 23 – 2005 – №1. − pp. 17–24.

14. Bushuev, S.D., Bushueva, N.S. "Formation of value in the activities of project-oriented organizations." Coll. Sciences. Works. Ed. V. A. Racha. – 2009 – №3 (31). – P. 5–14.
15. P. Oakley, "How the name date (Harvard) reference style in papers shows an underlying interpretivist paradigm whilst numeric references show a functional paradigm?", Systemist, vol. 25, no. 1, pp.25–30, 2003.
16. J. Mingers, "The contribution of critical realism as an underpinning philosophy for OR/MS and systems", Journal of the Operations Research Society, vol. 51, pp. 1256–1270, 2000.
17. J. Pollack, "The changing paradigms of project management", International Journal of Project Management, vol. 25, pp. 266–274, 2007.
18. G. Midgley, Systemic intervention: philosophy, methodology, and practice, 1-st ed. New York, USA: Plenum, 2000.
19. Rach V.A., Hladka O.M. Value-oriented strategic milestone decisions in real estate development projects. – Lugansk: SNU Publishing House. V.Dalia, 2009. – № 3. – P. 161–168.
20. Wateridge, "The role of configuration management in the development and management of Information systems/Technology (IS/IT) projects", International Journal of Project Management, vol. 17, no. 4, pp. 237–241, 1999.
21. K. T. Yeo, "Critical failure factors in information system projects", International Journal of Project Management, vol. 20, no. 3, pp. 241–246, 2002.
22. L. Williams, "The need for new paradigms for complex projects", International Journal of Project Management, vol. 77, no. 5, pp.269–273. 1999.
23. James R. Chapman. Project Management Scalable Methodology Guide. Human Resources Management. Доступно: www.hyperthot.com
24. Gemünden, H. G. (2014). Project management as a behavioural discipline and as driver of productivity and innovations. Project Management Journal, 45(6), 2–6. DOI: http://dx.doi.org/10.1002/pmj.21466
25. Thaler R. Toward a positive theory of consumer choice / J. of Economic Behaviour and Organization. 1990. № 1. P. 39–60.
26. ICB: IPMA Competence Baseline / Retrieved from: http://ipma.ch/resources/media/ipma-publications/ipma-competence-baseline/
27. Manifesto for Agile Software Development. Accessed: Jun. 04, 2023. [Online]. Available: https://agilemanifesto.org/
28. Sliger, M. (2008). Agile project management and the PMBOK® guide. Paper presented at PMI® Global Congress 2008–North America, Denver, CO. Newtown Square, PA: PMI.
29. Zlaugotne, B., Zihare, L., Balode, L., Kalnbalkite, A., Khabdullin, A., Blumberga, D. (2020), «Multi-Criteria Decision Analysis Methods Comparison», Environmental and Climate Technologies, No. 24, Issue 1, P. 454–471. DOI: 10.2478/rtuect-2020-0028
30. Greco, S., Ehrgott, M., Figueira, J. R. (2016), «Multiple criteria decision analysis. State of the Art Surveys», Publ. Springer, New York, 1346 p.
31. S.D. Bushuev, EV Verenich, R.F. Yaroshenko. Formal model of the mental space of a project or program, Radioelectronics, Informatics, Management. 2017. No. 1, P. 153–160.
32. Don E. Beck, & Chris K. Cowan. (2010) Spiral Dynamics: Managing Values, Leadership and Change. Open World, 2010.
33. I. Suleimenov, Y. Vitulyova and A. Bakirov, "Hybrid Number Systems: Application for Calculations in Galois Fields," 2022 3rd Asia Conference on Computers and Communications (ACCC), Shanghai, China, 2022, pp. 126–130, DOI: 10.1109/ACCC58361.2022.00028

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SIMULATION OF TRANSPORTATION LOGISTICS DURING THE PERIOD OF A SPECIAL STATE

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Introduction

The state of war in the country forced to review the logistics processes of transportation [1-6]. There are new areas in logistics that need to be explored for effective transportation planning in the face of military threats. Especially important are the directions of logistics, which are related to the transportation of weapons and military equipment (WME) to the front line and the transportation (evacuation) of the population to the rear from the front-line areas. Therefore, the topic of the proposed publication is relevant, in which optimization models are created for the rational choice of transportation routes under martial law conditions. The purpose of the research is to create models for applied information technology research of logistics processes of transporting goods and people during the period of the country's martial law. Tasks that are solved in the work:

– creation of optimization models for planning transportation of WME to the front line;

– creation of optimization models for planning the evacuation of the population to the rear.

1 Optimization model for planning transportation of weapons and military equipment to the front line

One of the urgent tasks, which is related to the implementation of effective operational and tactical actions on the battlefield, is the formation of the necessary reserves of weapons and military equipment (WME) for the front line. The front line includes actual military local zones (MLZ) in which active combat operations are conducted. It is necessary to form the necessary stocks of anti-terrorist weapons in the MLZ for conducting successful operational and tactical actions. Therefore, the task of finding relatively safe ways of supplying WME to the frontline in conditions of military threats is urgent. To solve the given problem, we will use the integer (Boolean) programming method. Let's enter a variable x_{ijk}:

$$x_{ijk} = \begin{cases} 1, \textit{ if the j-th way of supplting WME to i-th MLZ} \\ \textit{with k-th warehouse of logistics components} \\ \textit{(transshipment, storage, distribution, temporary stop, etc);} \\ 0, \textit{ otherwise.} \end{cases}$$

At the same time, it is necessary to: $\sum_{j=1}^{n_i} \sum_{k=1}^{m_j} x_{ijk} = 1$, which means the mandatory choice of a specific way of supplying WME to i-th MLZ from k-th composition of logistics components, where N is the number of MLZ on the front line; m_j is the number of possible warehouses of logistics components per j-th way of supply; n_i is the number of possible ways of supplying military goods to i-th MLZ.

Let's introduce the main logistics indicators for evaluating and choosing a possible option for transporting MLZ to the front line:

1. R are the risks of supplying MLZ to the frontline, in conditions of military threats.
2. T is the time required for the supply of MLZ to the front line.
3. W are the stockpiles of weapons, which are formed on the front lines to fulfill the actual operational and tactical tasks of the military leadership.

Let's present the indicators R, T, W taking into account the variables x_{ijk}:

$$R = \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} r_{ijk} x_{ijk},$$

where r_{ijk} is the risk of delivering military cargo to i-th MLZ on j-th way of supply from k-th composition of logistics components.

$$T = \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} t_{ijk} x_{ijk},$$

where t_{ijk} is the time required for the transportation of military cargo to i-th MLZ for j-th way with k-th possible composition of logistics components.

$$W = \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} w_{ijk} x_{ijk},$$

where w_{ijk} is the number of batches of WME that can be moved by j-th possible way of delivery from k-th composition of logistics components to i-th MLZ.

We will create optimization models for solving the task of forming WME stocks on the front line for effective combat operations on the battlefield.

1. Minimization of the risks of the formation of WME stocks in the conditions of the actions of military threats:

$$\min R\,,\ R=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} r_{ijk}x_{ijk}\,,$$

while fulfilling the restrictions:

$$T\le T^{*}\,,\ T=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} t_{ijk}x_{ijk}\,,$$

where T^{*} is the permissible (planned) time of delivery of WME to the front line.

$$W\ge W^{*}\,,\ W=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} w_{ijk}x_{ijk}\,,$$

where W^{*} is a stockpile of anti-aircraft weapons, which must be formed to fulfill the actual operational and tactical tasks of the military leadership.

2. Maximization of WME stocks on the front line for successful combat operations:

$$\max W\,,\ W=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} w_{ijk}x_{ijk}$$

while fulfilling the restrictions:

$$R\le R^{*}\,,\ R=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} r_{ijk}x_{ijk}\,,$$

where R^{*} is the acceptable risk of the supply of WME in the conditions of the actions of military threats.

$$T\le T^{*}\,,\ T=\sum_{i=1}^{N}\sum_{j=1}^{n_i}\sum_{k=1}^{m_j} t_{ijk}x_{ijk}\,.$$

It is possible to formulate a multi-criteria optimization problem using indicators R, T, W.

In this case, it is necessary to form a complex indicator:

$$K=\alpha_R\overset{\vee}{R}+\alpha_T\overset{\vee}{T}+\alpha_W\overset{\vee}{W}\,,$$

where α_R, α_T, α_W are the "weights" of indicators R, T, W, $\alpha_R+\alpha_T+\alpha_W=1$.

$\check{R}$ is a normalized indicator R:

$$\check{R} = \alpha_R \frac{R - R_{\min}}{R^* - R_{\min}},$$

where $R_{\min}$ is the minimum value of the indicator R after its optimization.

$\check{T}$ is the standardized indicator of delivery time:

$$\check{T} = \alpha_T \frac{T - T_{\min}}{T^* - T_{\min}},$$

where $T_{\min}$ is the minimum time value T after its optimization.

$\check{W}$ is a normalized indicator W:

$$\check{W} = \alpha_W \frac{W_{\max} - W}{W_{\max} - W^*},$$

where $W_{\max}$ is the maximum value of the WME stock after its optimization.

It is necessary to find:

$$\min K = \alpha_R \check{R} + \alpha_T \check{T} + \alpha_W \check{W} = \alpha_R \frac{R - R_{\min}}{R^* - R_{\min}} + \alpha_T \frac{T - T_{\min}}{T^* - T_{\min}} + \alpha_W \frac{W_{\max} - W}{W_{\max} - W^*} =$$

$$= \frac{\alpha_R}{R^* - R_{\min}} \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} r_{ijk} x_{ijk} + \frac{\alpha_T}{T^* - T_{\min}} \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} t_{ijk} x_{ijk} -$$

$$- \frac{\alpha_W}{W_{\max} - W^*} \sum_{i=1}^{N} \sum_{j=1}^{n_i} \sum_{k=1}^{m_j} w_{ijk} x_{ijk} - \frac{\alpha_R R_{\min}}{R^* - R_{\min}} - \frac{\alpha_T T_{\min}}{T^* - T_{\min}} + \frac{\alpha_W W_{\max}}{W_{\max} - W^*}.$$

2 Optimization models for planning evacuation transportation to the rear

The modern war led to the evacuation of the population from the front-line zone to the rear. Migration processes have arisen, for which it is necessary to create logistical evacuation chains. Therefore, the study of evacuation flows is relevant to assess the ability of the transport network to carry out the planned transportation of people to temporary places of residence (TMR). While planning evacuation processes, it is necessary to form a set of places (M), which can receive the population, with their capabilities to meet social needs. Then, it is necessary to form ways of transporting people, in conditions of risks (R) military threats, estimate the cost (W) and plan time (T) evacuation. Let's create an optimization model, which can be used to determine rational ways of evacuating the population (F) from the front-line zone to possible places of temporary residence in the conditions of the country's martial law. Let's enter an integer (Boolean) variable x_{plk}:

$$x_{plk} = \begin{cases} \textit{1, if the transportation of people to thep-th place} \\ \textit{of residence will be carried out using the l-th transportation} \\ \textit{route with the k-th warehouse of logistics components (temporary stop,} \\ \textit{transition from one route to another, distribution of evacuation flows, etc.);} \\ \textit{0, otherwise.} \end{cases}$$

As the main logistical indicators of the evacuation process, we will consider:

1. The time required to evacuate people (T).
2. The cost of the population evacuation process (W) .
3. Risks of military threats (R) .
4. Number of population to be evacuated (F) .

Taking into account the variables x_{plk}, the logistic indicators of population evacuation are as follows:

$$T = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} t_{plk} x_{plk},$$

where m_p is the number of possible ways to evacuate the population to p-th place TMR; n_l is the number of possible warehouses of logistics components for their use on l-th way of transportation; t_{plk} is the time required to move people to p-th place of the TMR taking into account l-th selected evacuation route and k-th composition of logistics components.

$$W = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} w_{plk} x_{plk},$$

where w_{plk} is the cost of transporting people to p-th possible place of TMR, taking into account the chosen one l-th way of transportation and k-th composition of logistics components.

$$R = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} r_{plk} x_{plk},$$

where r_{plk} is the risk of transporting people, in conditions of military threats, in p-th possible place of TMR taking into account the chosen one l-th way of transportation and k-th composition of logistics components.

$$F = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} f_{plk} x_{plk},$$

where f_{plk} is the number of the population that will be directed to p-th place of the TMR taking into account the chosen one l-th way of transportation and k-th composition of logistics components.

The following formulations of the optimization problem are possible, which are related to the evacuation of the population to the rear:

1. Minimize the time required to evacuate the population:

$$\min T,\ T = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} t_{plk} x_{plk},$$

taking into account the limitations:

$$W \le W^*,\ W = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} w_{plk} x_{plk},$$

$$R \le R^*,\ R = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} r_{plk} x_{plk},$$

$$F \ge F^*,\ F = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} f_{plk} x_{plk},$$

where W^* is the planned cost of the population evacuation process; R^* is the permissible risk of the evacuation process, which is associated with possible actions of military threats; F^* is the planned number of the population that will be evacuated from the front-line zone to the rear.

2. To maximize the number of the population that will be evacuated from the front-line zone to the rear:

$$\max F,\ F = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} f_{plk} x_{plk},$$

taking into account the limitations:

$$T \le T^*,\ T = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} t_{plk} x_{plk},$$

$$W \le W^*,\ W = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} w_{plk} x_{plk},$$

$$R \le R^*, \ R = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} r_{plk} x_{plk},$$

where T^* is the planned time for population evacuation.

3. Minimize the risks of population evacuation:

$$\min R, \ R = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} r_{plk} x_{plk},$$

taking into account the limitations:

$$T \le T^*, \ T = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} t_{plk} x_{plk},$$

$$W \le W^*, \ W = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} w_{plk} x_{plk},$$

$$F \ge F^*, \ F = \sum_{p=1}^{M} \sum_{l=1}^{m_p} \sum_{k=1}^{n_l} f_{plk} x_{plk}.$$

A multi-criteria formulation of the population evacuation optimization problem is possible. To do this, we will introduce a complex criterion in the form of an additive composition of logistic indicators T, W, R, F:

$$Q = \alpha_T \check{T} + \alpha_W \check{W} + \alpha_R \check{R} + \alpha_F \check{F},$$

where α_T, α_W, α_R, α_F are the «weights» of indicators T, W, R, F $\alpha_T + \alpha_W + \alpha_R + \alpha_F = 1$; $\check{T}$, $\check{W}$, $\check{R}$, $\check{F}$ are the normalized values of indicators T, W, R, F:

$$\check{T} = \frac{T - T_{\min}}{T^* - T_{\min}},$$

$$\check{W} = \frac{W - W_{\min}}{W^* - W_{\min}},$$

$$\check{R} = \frac{R - R_{\min}}{R^* - R_{\min}},$$

$$\check{F} = \frac{F_{\max} - F}{F_{\max} - F^*}.$$

It is necessary to minimize the complex criterion Q:

$$\min\ Q,\ Q=\alpha_T \check{T}+\alpha_W \check{W}+\alpha_R \check{R}+\alpha_F \check{F}=\frac{\alpha_T}{T^*-T_{\min}}\sum_{p=1}^{M}\sum_{l=1}^{m_p}\sum_{k=1}^{n_l} t_{plk}x_{plk}+$$

$$+\frac{\alpha_W}{W^*-W_{\min}}\sum_{p=1}^{M}\sum_{l=1}^{m_p}\sum_{k=1}^{n_l} w_{plk}x_{plk}+\frac{\alpha_R}{R^*-R_{\min}}\sum_{p=1}^{M}\sum_{l=1}^{m_p}\sum_{k=1}^{n_l} r_{plk}x_{plk}-$$

$$-\frac{\alpha_F}{F_{\max}-F^*}\sum_{p=1}^{M}\sum_{l=1}^{m_p}\sum_{k=1}^{n_l} f_{plk}x_{plk}-\frac{\alpha_T T_{\min}}{T^*-T_{\min}}-$$

$$-\frac{\alpha_W W_{\min}}{W^*-W_{\min}}-\frac{\alpha_R R_{\min}}{R^*-R_{\min}}+\frac{\alpha_F F_{\max}}{F_{\max}-F^*},$$

where $T_{\min}$, $W_{\min}$, $R_{\min}$, $F_{\max}$ are the extreme values of indicators after their optimization.

3 Optimization models for taking preventive measures against the influence of military threats during the transportation of goods and people

The outdated transport infrastructure has a large number of vulnerabilities that affect the disruption of the transportation of goods and people, especially during the period of martial law, under the conditions of military threats.

The following main existing vulnerabilities can be identified:

– physical and moral aging of components of the transport network (bridges, intersections, viaducts, highways, etc.);

– bottlenecks that lead to the accumulation of goods and people (transport queues, temporary stops, redistribution according to transportation directions, etc.);

– places where climatic phenomena occur more often (flooding, mud avalanches, soil disturbances, etc.).

During the period of martial law, the country may become vulnerable due to possible actions of military threats (arrivals of missiles, drone attacks, bombings, etc.), which leads to disruptions in transportation, occurrence of emergency situations, disasters with loss of life.

Therefore, the topic of the proposed research is relevant, in which the influence of military threats on the vulnerability of the transport infrastructure, which is used for transportation to the front and to the rear in the period of the country’s martial law, is simulated.

The purpose of the research is to create models for assessing the impact of military threats on the vulnerability of transport infrastructure (TI), for the formation of preventive actions aimed at reducing the risks of the impact of threats on planned transportation both to the front and to the rear.

To research the influence of military threats on IT, we will form a chain of sequence of actions in the form of: modeling the emergence of a military threat $\rightarrow$ excitation of possible vulnerabilities $\rightarrow$ modeling of the scale of TI violations in the form of damages (material and human) $\rightarrow$ formation of a set of preventive actions to reduce or neutralize the effects of military threats.

A set of preventive actions (M) depends on: the scale of violations; losses (P), which arise; from military threats (V); set of vulnerabilities that are excited (W). To assess the effect of military threats, we will form a set of indicators:

1. The risks of military threats – R;

2. Expenses for the elimination of possible losses from the action of military threats – Z;

3. The time required to carry out preventive measures to minimize or neutralize the actions of military threats – T.

We will use integer (Boolean) programming to simulate the impact of military threats on IT. Let's enter a Boolean variable x_{epk}:

$$x_{epk} = \begin{cases} \textit{1, if the occurrence of the e-th threat triggers the p-th set} \\ \textit{of TI vulnerabilities, for which it is necessary to form the k-th set} \\ \textit{of preventive actions;} \\ \textit{0, otherwise.} \end{cases}$$

Then, taking into account the variables x_{epk} indicators R, Z, T have the form:

$$R = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} r_{epk}\, x_{epk},$$

where V is the number of possible threats; r_{epk} is the risk of e-th military threat, which excites p-th composition of vulnerabilities that lead to use k-th composition of necessary preventive actions; n_p is a set of preventive actions for neutralization p-th composition of vulnerabilities; m_e is a set of possible compositions of vulnerabilities that can be excited upon occurrence threats.

$$Z = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} z_{epk} x_{epk},$$

where z_{epk} are the costs of carrying out k-th component of preventive actions to eliminate possible damages that occur during excitation p-th composition of vulnerabilities from the action of e-th threats.

$$T = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk},$$

where t_{epk} is the time required for implementation k-th composition of preventive measures necessary to eliminate possible damages that occur during excitation p-th composition of e-th threats.

In the conditions of the state of war in the country, it is extremely necessary to minimize the time (T) to carry out preventive actions regarding the possible influence of military threats on transportation both to the front and to the rear. Therefore, it is necessary:

$$\min T, \; T = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk},$$

taking into account the limitations:

$$Z \le Z^*, \quad Z = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk} \; .$$

Acceptable risks to prevent military threats:

$$R \ge R^*, \; R = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk},$$

where R^* is the assessment by experts of risks for the emergence of military threats to IT.

In conditions of limited capabilities of the country, it is necessary to minimize costs Z to carry out preventive measures against possible actions of military threats.

In this case, it is necessary:

$$\min Z, \; Z = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} z_{epk} x_{epk},$$

taking into account the limitations:

$$T \le T^*, \; T = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk},$$

where T^* is the planned time of the risks of preventing military threats for the implementation of preventive measures against the possible impact of military threats.

$$R \geq R^*,\ R = \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk}\ .$$

A multi-criteria formulation of the task of planning preventive actions to the influence of possible military threats is possible.

Let's introduce a complex indicator Q:

$$Q = \alpha_R \cdot \check{R} + \alpha_z \cdot \check{Z} + \alpha_T \cdot \check{T}\ ,$$

where α_R, α_z, α_T are the «weights» of indicators R, Z, T; $\check{R}$, $\check{Z}$, $\check{T}$ are the values of indicators R, Z, T:

$$\check{R} = \frac{R - R^*}{R_{\max} - R^*},$$

where $R_{\max}$ is the experts' pessimistic assessment of the risk of military threats affecting IT.

$$\check{Z} = \frac{Z - Z_{\min}}{Z^* - Z_{\min}},$$

$$\check{T} = \frac{T - T_{\min}}{T^* - T_{\min}}\ .$$

It is necessary to minimize the complex indicator (Q) to find a compromise solution among indicators R, Z, T:

$$\min\ Q, Q = \alpha_R \cdot \check{R} + \alpha_z \cdot \check{Z} + \alpha_T \cdot \check{T} =$$

$$= \frac{\alpha_R}{R_{\max} - R^*} \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} r_{epk} x_{epk} + \frac{\alpha_z}{Z^* - Z_{\min}} \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk} +$$

$$+ \frac{\alpha_T}{T^* - T_{\min}} \sum_{e=1}^{v} \sum_{p=1}^{m_e} \sum_{k=1}^{n_p} t_{epk} x_{epk} - \frac{\alpha_R \cdot R^*}{R_{\max} - R^*} - \frac{\alpha_z \cdot Z_{\min}}{Z^* - Z_{\min}} - \frac{\alpha_T \cdot T_{\min}}{T^* - T_{\min}}.$$

Conclusions

In the work, research of the logistics processes of transportation during the period of the country's martial law was carried out. Current areas of research related to the transportation of military cargo to the front line, as well as the evacuation of the population from the front-line zone to the rear, are separated. The main logistic indicators that must be used to evaluate transportation processes under the conditions of military threats have been formed (transportation time, transportation risks, transportation cost, the number of the population being evacuated). Optimization models have been created for choosing rational routes of transportation to the front line and to the rear. Local optimization of logistics indicators was carried out, taking into account limitations on the permissible time and risk of transportation. Multi-criteria models were created for finding compromise solutions for transportation logistics.

Used mathematical methods and models: system analysis, methods of transport logistics, integer (Boolean) optimization, multi-criteria optimization, methods of expert evaluation.

The scientific novelty of the research is related to the creation of a complex of original optimization models, which can be used to analyze and plan the logistics of transporting weapons and military equipment to the front and evacuating the population to the rear.

The proposed approach is the basis for the creation of applied information technology for the planning of transportation logistics both to the front and to the rear, taking into account possible military threats, during the period of the country's martial law.

References

1. Fedorovych O.E., Zapadnya K.O., Ivanov M.V. Using a precedent approach to formulate an action plan to increase the competitiveness of a developing enterprise / O.E. Fedorovych, K.O. Zapadnya, M.V. Ivanov // Radioelectronic and computer systems. – 2016. – No. 1 (75). – P. 114 – 118.
2. Fedorovych O.E., Pronchakov Y.L. Method of forming logistics transport interactions for a new portfolio of orders of distributed virtual production / O.E. Fedorovych, Y.L. Pronchakov // Radioelectronic and Computer Systems. – 2020. – No. 2(94). – P. 102–108.
3. Fedorovych O.E, Slomchynskyi O.V, Puydenko V.A Research of logistics of production management of high-tech products of a virtual enterprise / O.E. Fedorovych, O.V. Slomchynskyi, V.A. Puydenko // Aerospace Engineering and Technology. – 2018. – No. 4 (148). – P. 107 – 115.
4. Fedorovych O.E, Haidenko A.A, Puydenko V.A. Planning of freight transportation in conditions of increased risks / O.E. Fedorovych, A.A. Haidenko, V.A. Puydenko // Aviation and Space Engineering and Technology. – 2017. – No. 6 (141). – P. 98 – 102.
5. Fedorovych O.E, Urusky O.S, Lutai L.M, Zapadnya K.O Optimization of the life cycle of creating new equipment in conditions of competition and stochastic behavior of the market for high-tech products / O.E. Fedorovych, O.S. Urusky, LM Lutai, KO Zapadnya // Aerospace Engineering and Technology. 2020 – No. 6 (166) – P. 80 – 85.
6. Alexiev O. P., Alexiev V. O., Neronov S. M. Multi-agents in the virtual management of the transport process / O. P. Alexiev, V. O. Alexiev, S. M. Neronov // Bulletin of Kharkiv National Automobile and Highway University. 2023 – Issue 100 – P. 15 – 18.

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CONVEYOR LINE DEVELOPMENT FEATURES FOR PHARMACEUTICAL PRODUCTS INDUSTRIAL LOGISTICS

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This section of the monograph examines the key stages of designing and creating an automated sorting system in the pharmaceutical industry. The main focus is on developing the scheme and selecting the supporting modules for assembling the line layout, as well as creating a control system based on the Siemens S7-1200 programmable logic controller (PLC). The work presents detailed photographs of the assembled layout, which allows visualizing the final design result. In addition, an electrical circuit for connecting the PLC, a functional diagram for connecting the conveyor sections, and a plan for their placement have been developed and presented, which ensures a comprehensive understanding and implementation of the project for automating sorting processes in the pharmaceutical industry.

Introduction

In modern conditions, the pharmaceutical industry faces increased demands for product quality and efficiency of production processes. One of the key elements of automation in this area is a conveyor line for sorting pharmaceutical products. The importance and relevance of research related to the development of such lines is due to the need to ensure high sorting accuracy and minimize the human factor, which is critical to maintaining quality standards and increasing productivity. The use of automated systems allows you to optimize sorting processes, increase the speed and accuracy of task performance, and ensure flexibility in adapting production lines to various types of products. The development of a scheme and the selection of supporting modules for the conveyor line layout, as well as the creation of a control system for this line, are key stages that determine the efficiency and reliability of the entire system. These tasks require deep analysis, a systematic approach and the use of modern technologies, which emphasizes the relevance and importance of the research presented in this collective monograph.

1. Development of a scheme and selection of supporting modules for a pharmaceutical product sorting line layout

Designing an automated control system layout for a pharmaceutical sorting conveyor line requires careful justification of the technical parameters selection in relation to the specifics of the industry.

Here are some key factors that need to be taken into account during the design development process:

– standards and regulations – the selected technical parameters comply with all applicable standards and regulations in the pharmaceutical industry; this includes safety requirements, production cleanliness, as well as traceability and quality control requirements;

– sorting requirements for pharmaceutical products; this may include different packaging shapes, sizes, weights and other parameters that may affect the selection of technical solutions for effective sorting;

– a high standard of cleanliness and hygiene; the pharmaceutical industry requires selection of such technical parameters that ensure ease of cleaning, disinfection and maintaining sterility during operation.

– speed and throughput requirements; it is necessary to determine the required sorting speed and line throughput in accordance with production needs; considering the possibility of scaling the system for higher productivity in the future;

– traceability and quality control systems; implementation of product traceability and quality control systems at each stage of sorting; this is important to ensure compliance with quality standards in the pharmaceutical industry;

– integration with other systems; compatibility and ease of integration of the automated control system with other production systems, such as packaging, labeling and warehousing systems;

– energy saving and sustainability; technical parameters that can ensure energy saving and reduce environmental impact, which is important for pharmaceutical companies that adhere to the principles of sustainable development.

Based on the analysis of the selection of technical parameters, the following industrial conveyor line for sorting pharmaceutical products scheme was developed, which is shown in Figure 1.

The general scheme of the conveyor line for sorting pharmaceutical products is shown in Fig. 1. Let us note the following main elements of the conveyor belt in the scheme:

1 – vertical elevator for moving packages between floors (Fig. 1b), it acts as an actuator for sorting identified packages on the transportation floors;

2 – rollers, as an element of the roller conveyor, serve to move the package in space;

3 – conveyor zone with a belt element – a table, in this zone the presence recognition and identification of the package will be performed using the computer vision system;

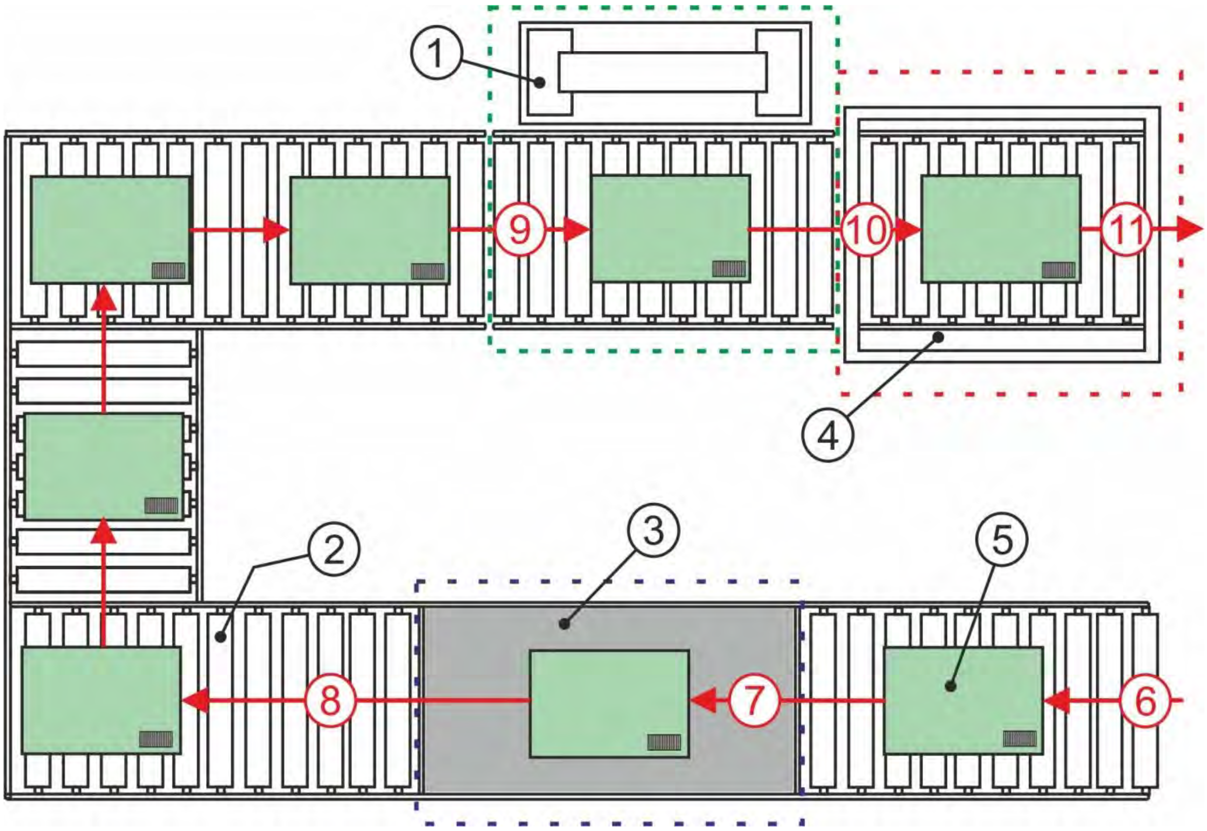

Fig. 1. Industrial Conveyor Line for Sorting Pharmaceutical Products Scheme

4 – vertical conveyor on the 3rd floor for sorted packages;

5 – packaging on the conveyor line. It is also necessary to consider the main events affecting the package, for ease of rendering we will present them as red arrows;

6 – arrival of an unidentified object on the conveyor line from the accumulator;

7 – identification of an object using a computer vision system;

8 – movement of the identified object along the conveyor;

9 – sorting of the identified object using a vertical elevator by levels;

10, 11 – movement of the identified object to a specified storage facility.

There are several key reasons for including a vertical lift in an industrial conveyor line layout for sorting pharmaceutical products:

– space optimization; vertical lifts allow for the efficient use of vertical space in production facilities; this is especially important in the case of limited space, where maximizing every square meter plays a key role; vertical lifts allow for the efficient transport of products between different levels, reducing the need for large horizontal spaces;

– product safety; in the pharmaceutical industry, product safety is a priority; vertical lifts ensure gentle movement of products between floors, which is especially important for fragile or vibration-sensitive pharmaceutical products; this helps prevent damage and maintain a high standard of product quality;

– sorting to different levels; vertical lifts allow for the organization of a sorting layout at different levels of production; this can be useful if pharmaceutical products require different processing or sorting steps at different floors of the conveyor line; such a structure reduces the movement of products along the horizontal conveyor, improving the efficiency and speed of the process;

– compliance with cleanliness and hygiene standards; vertical lifts can be easily integrated into pharmaceutical cleanliness and hygiene systems; they provide quick access for maintenance and cleaning, which meets the strict standards set in this industry.

– flexibility in line setup; vertical lifts provide flexibility in setting up the conveyor line to adapt to different production needs; this allows for quick changes to the sorting line in case of changes in the product range or production processes.

In accordance with the developed scheme (Fig. 1) of the industrial conveyor line for sorting pharmaceutical products, we will select the main elements.

Drive roller conveyor is designed for automated transportation of the product along its working surface. The general view of the drive zones in the automated conveyor system is shown in Figure 2

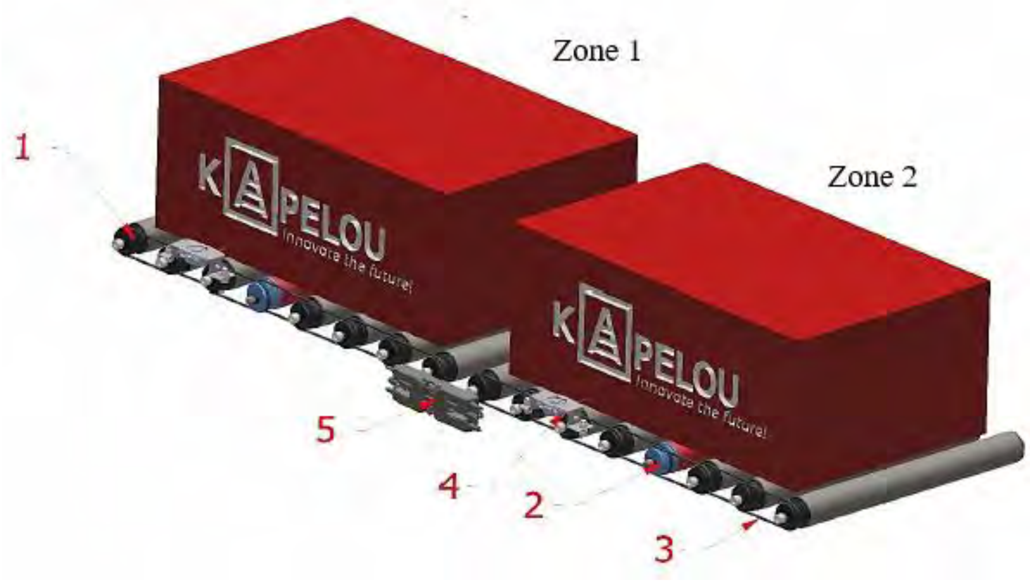

Fig. 2. General view of drive zones in an automated conveyor system

It consists of the following elements: a set of driving rollers (2) with an electric drive and driven rollers (1), connected synchronously by belt drives (3). The control of the inclusion of drive zones is provided with sensors (4). The operating principle of the driven accumulation roller conveyor is alternately switching on/off the drive rollers in the logical zones of the conveyor by means of control boards (5) connected to each other, representing a network for ensuring the exchange of information through the main controller of the system. The main feature of the accumulation conveyor is that only those logical zones that are currently involved in the transportation of the product operate. Zones that are not currently involved in the transportation of the cargo are in standby mode. The main technical parameters of the drive zones (Fig. 2) are given in Table 1

Table 1

Main technical parameters of drive zones

Characteristic	Value
Standard conveyor zones length (mm)	1000
Minimum conveyor zones length (mm)	800

The direct drive roller conveyor is an effective technical solution for transporting pharmaceutical products. It is characterized by a simple design, high reliability and cost-effectiveness. Direct drive eliminates the need for complex mechanisms and moving parts, which reduces the risk of breakdowns and facilitates maintenance. Due to the direct transmission of torque from the motor to the rollers, the conveyor ensures precise and smooth movement of goods, as well as efficient use of energy. Fewer moving parts reduce noise levels, which is important in conditions where compliance with noise standards is required. The general appearance of the direct drive roller conveyor model 487 is shown in Figure 3, and its main technical characteristics are given in Table 2.

Fig. 3. General view of the direct drive roller conveyor model 487

Table 2

Main technical characteristics of the direct drive roller conveyor model 487

Characteristic	Value
Purpose	Product transportation
Conveyor type	Cumulative
Conveyor motion type	Roller
Operating speed range	from 0,5 up to 1,0 m/s
Max. load	35 kg/good
Normal width between profiles	487 mm
Product transport side	Short
Type of rollers	Cylindrical
Roller coating	Galvanized steel
Roller diameter	50 mm
Step between rollers	100 mm
Belt type	2 PJ 336
Color of metal structures	Galvanized steel
Zone motor control element	Dual-zone controller
Zone control sensors	Optical

The straight drive roller conveyor (Fig. 4) is designed for automatic transportation of products along its working surface in a straight-line direction. The general appearance of the straight drive roller conveyor model 687 is shown in Figure 4, and its main technical characteristics are in Table 3.

Fig. 4. General view of direct drive roller conveyor model 687

Table 3

Main technical characteristics of direct drive roller conveyor model 687

Characteristic	Value
Purpose	Product transportation
Conveyor type	Cumulative
Conveyor motion type	Roller
Operating speed range	from 0,5 up to 1,0 m/s
Max. load	35 kg/good
Normal width between profiles	687 mm
Product transport side	Short
Type of rollers	Cylindrical
Roller coating	Galvanized steel
Roller diameter	50 mm
Step between rollers	100 mm
Belt type	2 PJ 336
Color of metal structures	Galvanized steel
Zone motor control element	Dual-zone controller
Zone control sensors	Optical

A diverter (or diverter valve) in a conveyor line is a device designed to direct the flow of materials or products in a certain direction on a conveyor. Its main purpose is to divide the flow into two or more parts to redirect materials to the desired location or to another part of the production process. Within the framework of the developed layout, it is proposed to use a diverter 90^{o} model DU90-W36L38-2-SS, the general appearance of the diverter is shown in Figure 5, and its technical characteristics are in Table 4.

Fig. 5. The diverter 90^{o} model DU90-W36L38-2-SS general view

Table 4

Main technical characteristics of diverter 900 model DU90-W36L38-2-SS

Characteristic	Value
Purpose	sorting of products
Conveyor type	lifting
Conveyor motion type	ribbon
Dimensions, (Length x Height x Width)	430.6 x 385 x 168,3 mm
Operating speed	max 1 m/s
Max. load	2,5–30 kg
Control module	dual zone controller
Color of other metal elements	galvanized steel
Number of engines	2 шт.
Number of tape strips	2 шт.
Conveyor base	487 mm
Drop angle	90º
Body color	RAL 9005 (black)
Color of ribbons	RAL 5012 (blue)
Work surface	ribbon
Ribbon, (Д x Ш)	15 x 888 mm

The vertical conveyor is a lifting mechanism. It is a static frame with a power drive for moving the lifting carriage with a straight drive roller section of the conveyor along a straight frame guide by means of a belt transmission. It is designed for vertical movement and sorting of products in the conveyor system. The general appearance of the vertical conveyor is shown in Figure 6, and its technical characteristics are in Table 5.

Table 5

Main technical characteristics of the vertical conveyor

Characteristic	Value
Purpose	Vertical transportation, sorting of products
The conveyor type on the carriage	Roller
Transport mode	1 продукт/цикл
Productivity	Up to 300 cycles/hour
Minimum possible loading height	+0,50 m
Maximum weight of transported product	Up to 35 kg
Type of transmission	Toothed belt
Engine	NORD
Engine power	3,0 kW
Engine color	RAL 9006 (grey)
Voltage	220…242 V(Δ) / 380…420 V(Y) 50 Hz

Fig. 6. Vertical conveyor general view

The straight drive roller section on the vertical conveyor plays an important role in ensuring efficient transportation of goods or materials in the vertical direction. The straight drive roller section on the vertical conveyor moves by a lifting carriage connected to the drive via a belt transmission. The general appearance of the straight drive roller section on the vertical conveyor is shown in Fig. 7, and its technical characteristics are in Table 6.

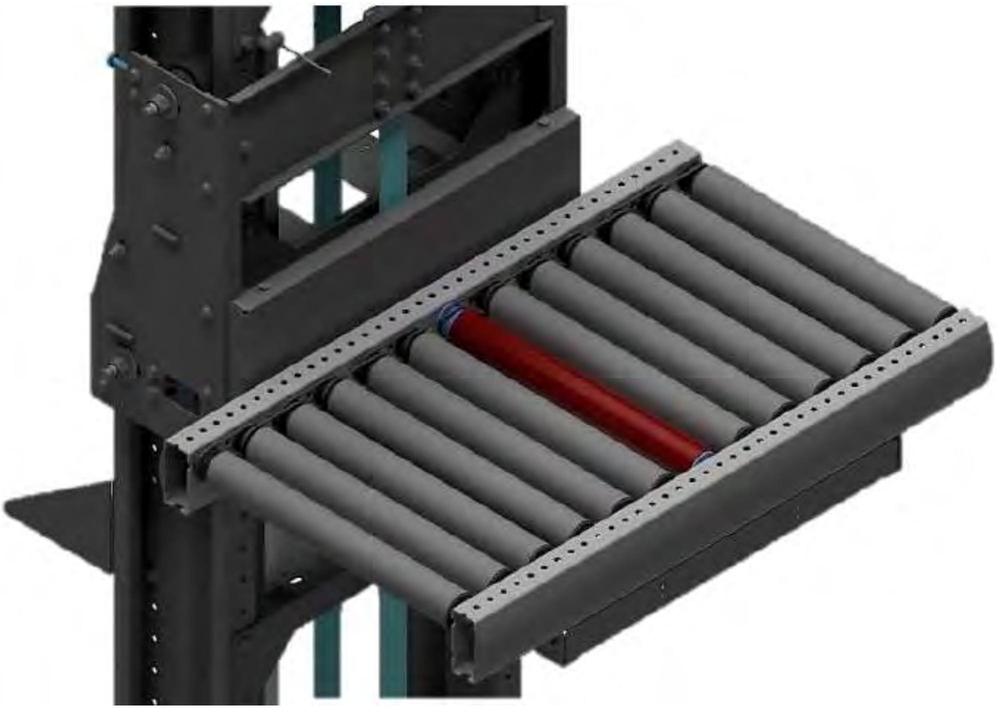

Fig. 7. The direct drive roller section on a vertical conveyor general view

Table 6

Main technical characteristics of the direct drive roller section on the vertical conveyor

Characteristic	Value
Purpose	Product transportation
Conveyor motion type	Roller
Operating speed range	From 0,5 up to 1,0 m/s
Normal width between profiles	487 mm
Product transport side	Short
Type of rollers	Cylindrical
Roller coating	PVC
Roller diameter	50 mm
Step between rollers	75 mm
Belt type	2 PJ 286
Color of metal structures	Galvanized steel
Control element	Controller Eqube
Zone control sensors	Optic

The stop and start plates in a roller conveyor are designed to ensure the safety and efficiency of the material handling system. Stop plates prevent loads from rolling away and provide a controlled stopping area, which is important for safe handling and loading of materials. Start plates control the start of the load movement, preventing abrupt starts and increasing the efficiency of loading and unloading. Both elements contribute to compliance with safety standards and increase the durability of conveyor equipment. The general appearance of the stop and start plates is shown in Figure 8.

a) b)

Fig. 8. General view of stop and start plates for roller conveyor: a) stop plate; b) starting plate

The stop plate (Fig. 8a) is used to prevent the transported product from falling at the blind ends of a driven or non-driven roller conveyor. The stop plate coating is galvanized steel. The starting plate (Fig. 8b) is installed in places where the product is loaded onto the conveyor and is used to protect a person from damage to clothing on moving parts of the conveyor and to prevent impact of the rollers when installing the transported product from the beginning of the line. The starting plate coating is galvanized steel.

2. Development of a control system for a conveyor line for sorting pharmaceutical products

After analyzing and selecting the main working elements for the conveyor lines for sorting pharmaceutical products, we can begin to develop an automated control system. At the first stage, we will develop a structural control diagram for the conveyor lines for sorting pharmaceutical products, which is shown in Figure 9.

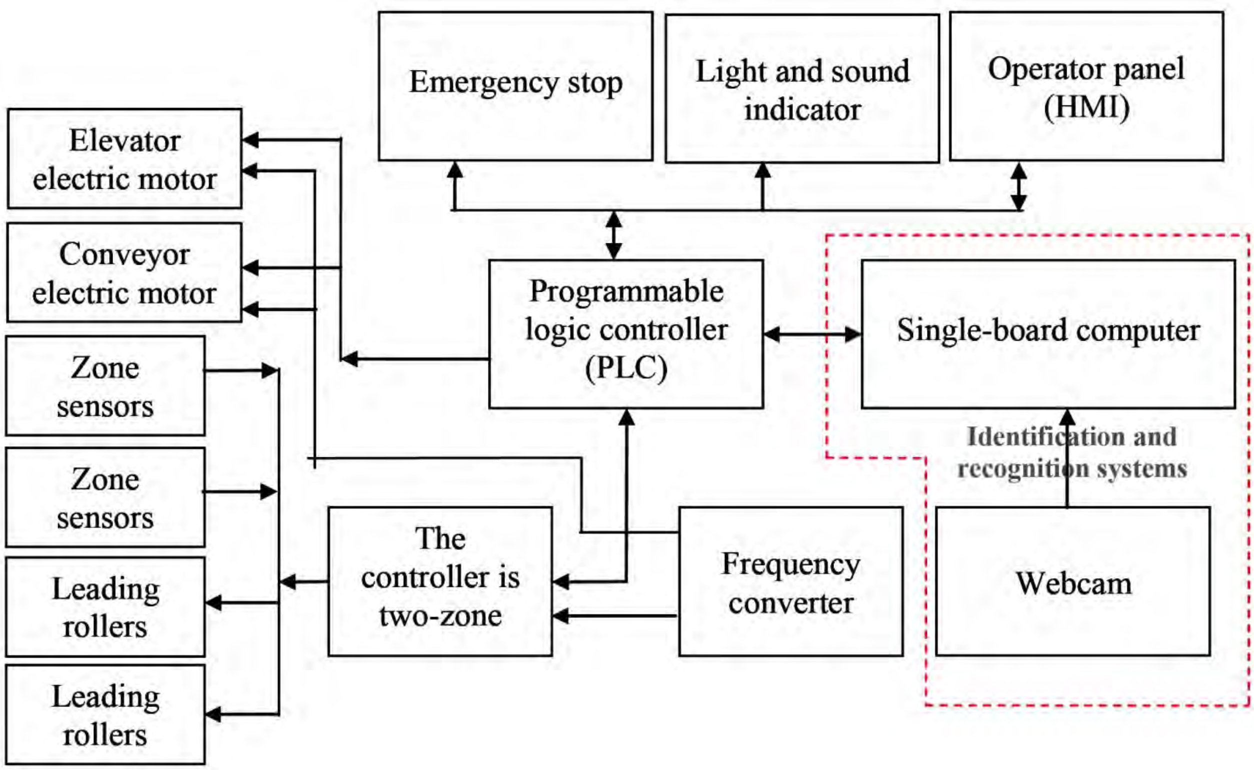

Fig. 9. Control diagram of the conveyor line for sorting pharmaceutical products

In the control scheme of the pharmaceutical sorting conveyor line, the following elements perform key functions:

– Elevator Electric Motor is responsible for the vertical movement of goods along the conveyor, ensuring efficient sorting into different levels;

– Conveyor Electric Motor is responsible for the movement of the conveyor belt, moving goods along the sorting line;

– Zone Sensors are used to detect the presence or absence of goods in different zones of the conveyor. This information can be used to activate other elements of the system;

– Leading Rollers ensure stable movement of goods along the conveyor belt and help to control their position.

– The controller is two-zone – it controls the entire system, including coordination of conveyor movement, activation of sorting zones and interaction with other control elements;

– Frequency Converter regulates the speed of the electric motors, providing flexibility in conveyor control and adaptation to various conditions;

– Program Logic Controller controls the logic of the entire system, ensuring coordination between the various elements based on pre-defined software rules;

– Emergency Stop provides a mechanism for immediate stopping of the conveyor in case of emergency situations or the need to safely stop work;

– Light and Sound Indicator is used to visually and audibly alert the operator to the system status, possible problems or events requiring attention;

– Operator Panel (HMI – Human-Machine Interface) provides the operator with the ability to interact with the system, displays information about the conveyor operation, allows you to configure parameters and respond to events;

– Single-board computer is the central control device that processes data and controls the entire conveyor system; it can process information from sensors, make decisions based on software algorithms and interact with other controls;

– Webcam is used for visual monitoring of the sorting process. It can be used to capture images of products, analyze them using computer vision or visual quality control; the webcam can also be used to identify products by their appearance.

We will analyze and select hardware modules for the implementation of the layout of the automated control system for the conveyor line of sorting pharmaceutical products, based on the developed scheme (Fig. 9). At the first stage, we will select the Program Logic Controller (PLC). During the analysis of the technical characteristics and requirements for the developed control system of the conveyor line of sorting, it was proposed to use the following PLC, the general appearance of which is shown in Figure 10, and a comparison of their basic characteristics is given in Table 7.

a) b) c)

Fig. 10. General view of selected PLCs:
a) PLC Siemens s7-1200; b) MELSEC iQ-F; c) CompactLogix 5370

Table 7

Comparison of the main technical characteristics of PLC Siemens s7-1200, MELSEC iQ-F, CompactLogix 5370

Characteristic	PLC		
	Siemens s7-1200	MELSEC iQ-F	CompactLogix 5370
Manufacturer	Siemens	Mitsubishi Electric	Rockwell Automation
Type	Microcontroller	Microcontroller	Microcontroller
Number of discrete inputs	32 – 256	8 – 128	16 – 256
Number of discrete outputs	24 – 256	8 – 128	16 – 256
Number of analog inputs	8 – 32	8 – 32	8 – 32
Number of analog outputs	4 – 16	4 – 16	4 – 16
Maximum frequency of discrete inputs	100 kHz	100 kHz	100 kHz
Maximum frequency of discrete outputs	100 kHz	100 kHz	100 kHz
Maximum analog input frequency	100 kHz	100 kHz	100 kHz
Maximum frequency of analog outputs	100 kHz	100 kHz	100 kHz
Maximum program memory	128 кВ – 1 MB	128 кВ – 1 MB	128 кВ – 1 MB
Maximum data memory	128 кВ – 1 MB	128 кВ – 1 MB	128 кВ – 1 MB
Operating temperature	–25 – 60 °C	–25 – 60 °C	–25 – 60 °C

To implement the layout of the automated control system for the pharmaceutical sorting conveyor line, the Siemens s7-1200 PLC was selected. This choice was made based on a comparison of the technical characteristics of the three PLCs under consideration: Siemens s7-1200, MELSEC iQ-F and CompactLogix 5370. All three PLCs have a wide range of inputs and outputs, which allows you to connect various sensors and actuators necessary for the conveyor line to them. The Siemens s7-1200 offers a wider range of inputs and outputs than the MELSEC iQ-F and CompactLogix 5370. This allows you to connect a larger number of sensors and actuators to it, which may be necessary in the case of a complex conveyor line. The PLCs support a high frequency of discrete and analog signals, which ensures high accuracy and speed of system operation. The Siemens s7-1200 supports a higher frequency of analog signals than the MELSEC iQ-F and CompactLogix 5370. This may be important for conveyor lines that require high control accuracy. To implement complex conveyor line control algorithms, a large amount of program and data memory is required. Siemens s7-1200 has a large amount of program and data memory, which allows creating complex control algorithms. MELSEC iQ-F and CompactLogix 5370 also have a large amount of program and data memory, but less than Siemens s7-1200.

Based on the comparison of the technical characteristics of the three PLCs under consideration, it can be concluded that the Siemens s7-1200 PLC is the optimal choice for implementing the layout of an automated control system for a pharmaceutical sorting conveyor line. This PLC has a wide range of inputs and outputs, high frequency of discrete and analog signals, large memory capacity of programs and data, a wide range of operating temperatures and a degree of protection against moisture and dust, as well as a wider price range than competitors.

Let's analyze and select a dual-zone controller. During the review of technical characteristics, the following dual-zone controllers were selected: ConveyLinx Ai2, ConveyLinx Dual Zone, ConveyLinx Ai3, the general appearance of which is presented in Figure 11, and a comparison of their technical characteristics in Table 8.

a) b) c)

Fig. 11. General view of dual-zone controllers:
a) ConveyLinx Ai2; b) ConveyLinx Dual Zone; c) ConveyLinx Ai3

Table 8

Comparison of the main technical characteristics of ConveyLinx Ai2, ConveyLinx Dual Zone, ConveyLinx Ai3

Characteristic	Dual-zone controllers		
	ConveyLinx Ai2	ConveyLinx Dual Zone	ConveyLinx Ai3
Speed control range	from 0 up to 100%	from 0 up to 100%	from 0 up to 100%
Speed control resolution	0,10%	0,10%	0,10%
Maximum acceleration value	10 m/s²	10 m/s²	10 m/s²
Maximum deceleration value	10 m/s²	10 m/s²	10 m/s²
Input signal range	0–10V, 4–20mA, discrete signals	0–10V, 4–20mA, discrete signals	0–10V, 4–20mA, discrete signals
Degree of protection against moisture and dust	IP65	IP67	IP65

ConveyLinx Dual Zone also meets all the requirements, but has a higher price (from $ 1,500). ConveyLinx Ai3 has a wider range of input signals (HART and CANopen signals are added), but it has a lower degree of protection against moisture and dust (IP65). Thus, ConveyLinx Ai2 is the optimal choice for the implementation of an automated control system layout for a pharmaceutical sorting conveyor line. It has all the necessary technical characteristics, as well as an affordable price.

To save energy and the ability to regulate the speed of such mechanisms as a vertical conveyor, a SIEMENS G120 PM240-2 frequency converter is used (Fig. 12). A frequency converter is an electronic device for changing the frequency of electric current (voltage). It converts the input sinusoidal voltage of a fixed frequency and amplitude into an output pulse voltage of variable frequency and amplitude using PWM (pulse width modulation). Thus, by smoothly increasing the frequency and amplitude of the voltage supplied to the stator windings of an asynchronous electric motor, it is possible to ensure smooth regulation of the rotation speed of the electric motor shaft.

The main technical characteristics of the SIEMENS G120 PM240-2 frequency converter are presented in Table 9.

The operator panel is designed to display information about the system status, control and handling of emergency situations. The operator panel also allows the system settings to be changed by qualified personnel of the system supplier during service and/or warranty maintenance of the equipment. The general appearance of the selected Siemens SIMATIC HMI operator panel is shown in Figure 13, and the main technical characteristics are in Table 10.

Fig. 12. Frequency converter SIEMENS G120 PM240-2

Table 9

Main technical characteristics of the SIEMENS G120 PM240-2 frequency converter

Characteristic	Value
Supply voltage	Three-phase design
Power	Up to 4 kW
Power frequency	47…63 Hz
Output frequency	0–200 Hz
Torque overload	150% during 1 minute
Protection class	IP20
Operating temperature range	–5 … +40 °C
Relative humidity	Up to 95%, without condensation

The conveyor system operates in a fully automatic mode and requires human intervention only in case of emergency and abnormal situations. As a result, it is necessary to include signaling and control devices located on the panels and along the conveyor line in the conveyor system.

Sound and light indicators are placed on each floor of the vertical conveyor and along the conveyor line in such a way as to provide sound and light notification to all personnel involved in working with the conveyor system. It is also necessary to implement an emergency stop of the system if there is an immediate threat to human life and health, since its activation leads to an immediate stop of the system.

Fig. 13. General view of the selected Siemens SIMATIC HMI operator panel

Table 10

Main technical characteristics of the Siemens SIMATIC HMI operator panel

Characteristic	Value
Nominal supply voltage	24V DC
Сеть	Profinet
Built-in interface	USB-Host
Configuration languages	32
Availability of vector graphics	yes
Number of colors	65536
Data archiving	USB Stick
Protection class	IP20
Operating temperature range	–20 … 60 °C
Relative humidity	10…90 %, without condensation

During an emergency on the conveyor line, you must press any emergency stop button "Emergency stop". The Emergency stop buttons are located on the yellow push-button posts along the conveyor line, as well as on the control panel. The general appearance of the sound and light indicator and the emergency stop button "Emergency stop" is shown in Figure 14.

a) b)

Fig. 14. General view of the light and sound indicator
and the emergency stop button "Emergency stop":
a) Light and sound indicator; b) Button "Emergency stop"

Based on the selected equipment shown in Figures 3–8 and the diagram of the conveyor line for sorting pharmaceutical products (Fig. 1), the following plan for the placement of conveyor sections was developed, which is shown in Figure 15.

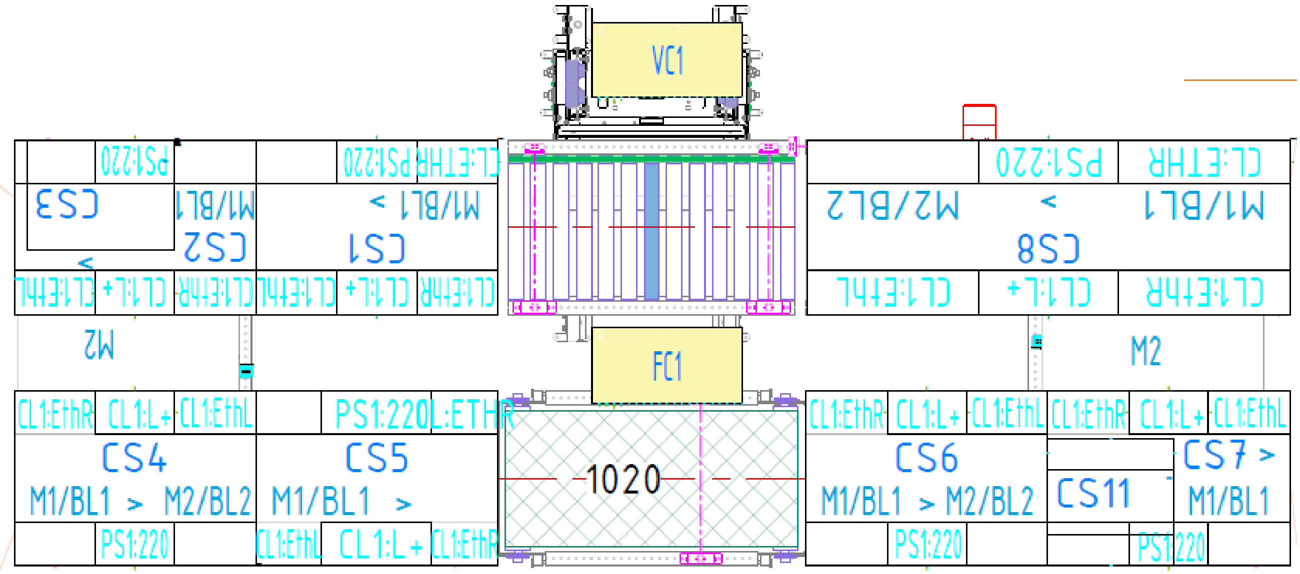

Fig. 15. Conveyor section layout plan

Based on the technical characteristics and specifications of the selected hardware modules for the implementation of the automated control system layout for the pharmaceutical conveyor sorting line, a functional connection diagram of the conveyor sections was developed, which is shown in Figure 16.

The electrical connection diagram of the PLC Siemens s7-1200 is shown in Figure 17.

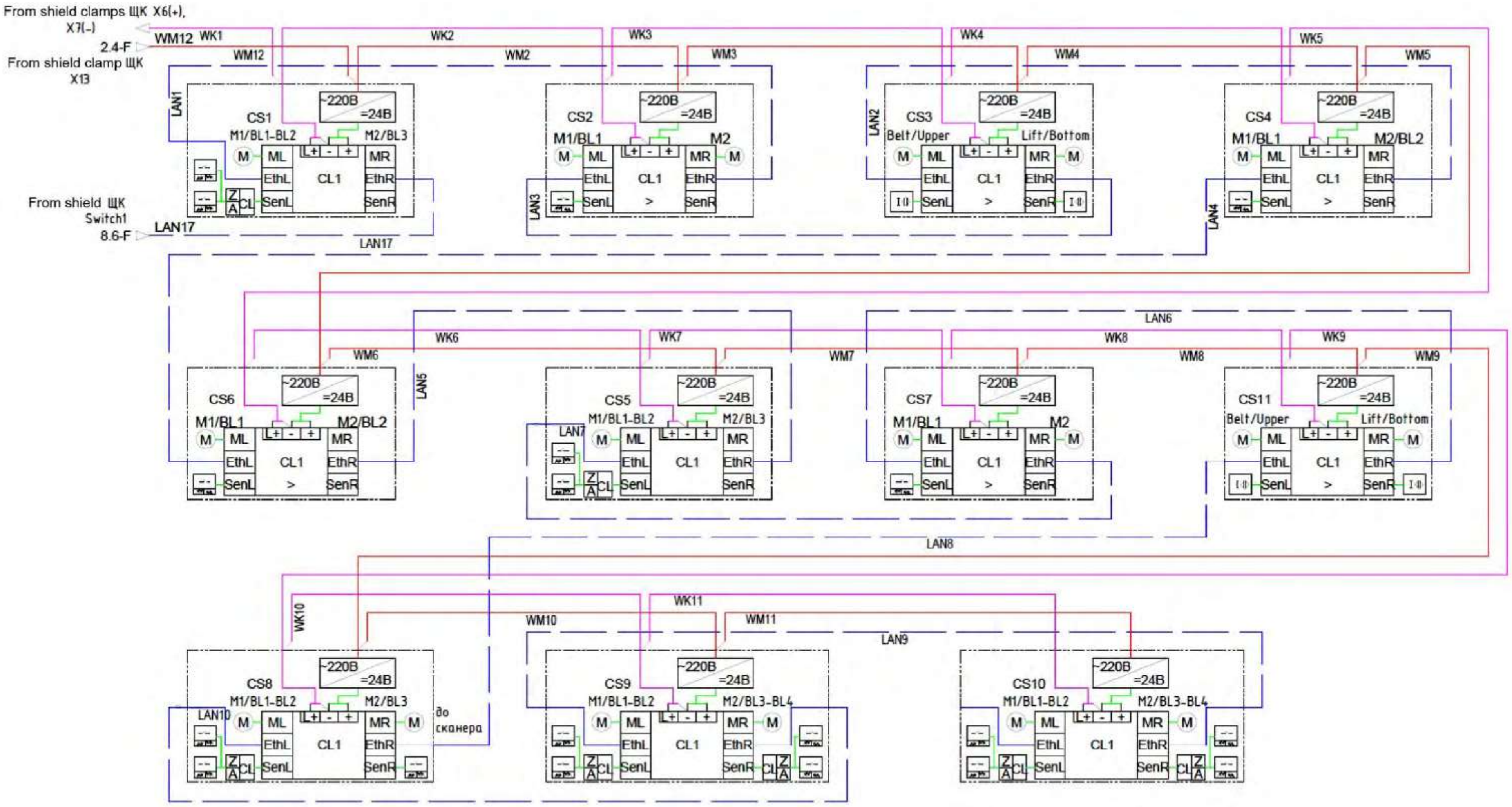

Fig. 16. Functional diagram of the conveyor sections connection

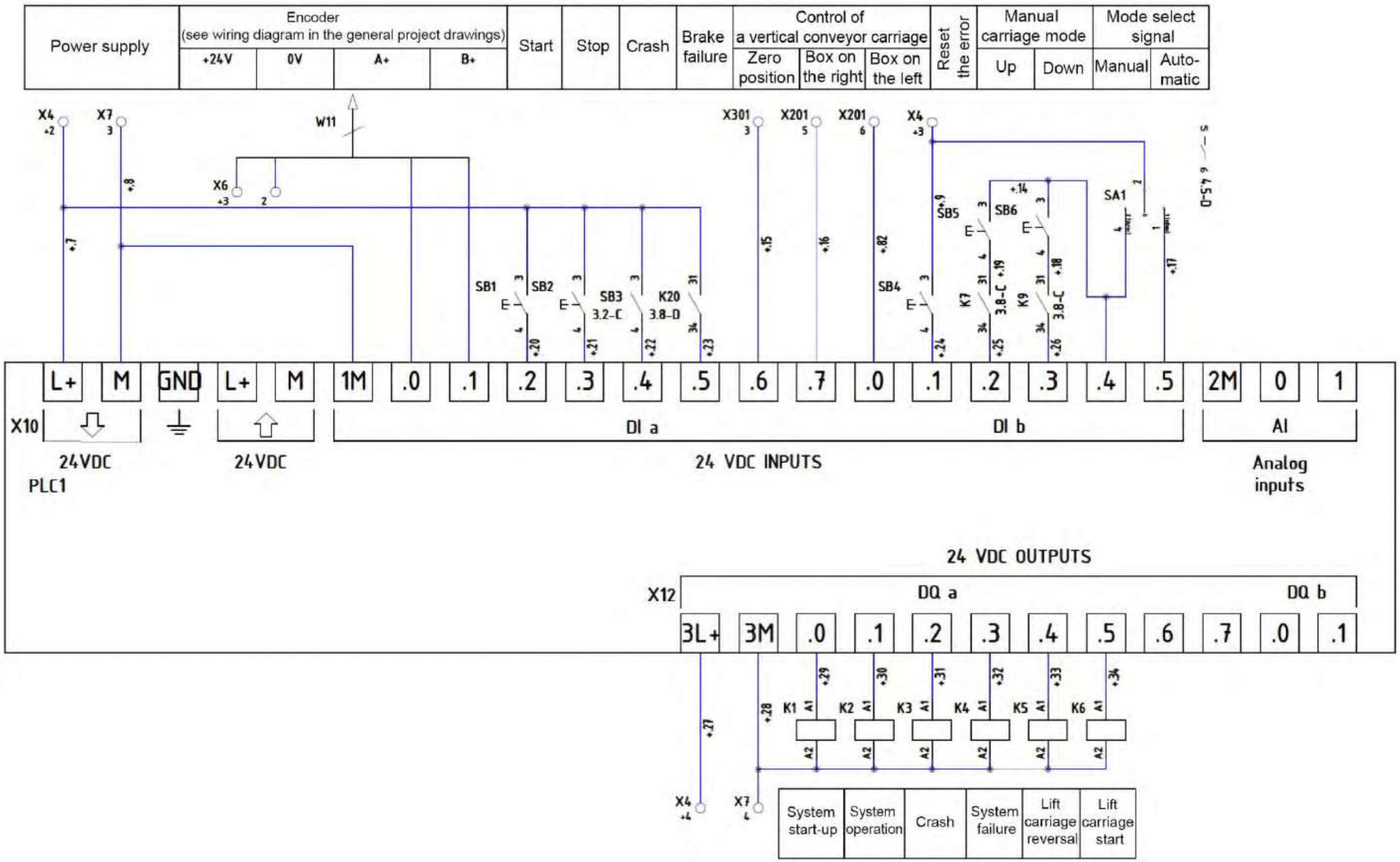

Fig. 17. Electrical connection diagram of PLC Siemens s7-1200

On the basis of the conducted work a model of a pharmaceutical conveyor line for sorting was assembled, implemented on the PLC Siemens s7-1200 control system. The general appearance of the model is presented in Figure 18.

a)

b)

c)

d)

Fig. 18. General view of the layout of the pharmaceutical conveyor line for sorting: a) general view of the layout; b) type of tiers for sorting; c) conveyor control system; d) vertical elevator in the general conveyor system

Conclusions

As a result of the conducted research and development presented in this work, important results were achieved in the field of creation of conveyor lines for sorting pharmaceutical products. The layout diagram of the line was developed and implemented taking into account the requirements for reliability and efficiency, which allowed to optimize the choice of supporting modules and ensure their interconnected operation. Particular attention was paid to the creation of a control system based on PLC Siemens S7-1200, which ensured a high level of automation and flexibility in managing the sorting process. The developed electrical circuit for connecting the controller, the functional diagram for connecting the conveyor sections and the plan for their placement made it possible to create a complete and reliable system that meets modern standards in the pharmaceutical industry. Photos of the assembled layout confirmed the correctness of the adopted engineering solutions and their successful implementation. Thus, the work made a significant contribution to the development of automation technologies for sorting pharmaceutical products, which helps to increase the productivity and quality of production processes.

References

1. Nevliudov, I., Yevsieiev, V., Maksymova, S., Klymenko, O. (2023). Features of Wave Algorithm Application in Warehouse Logistics Transport Systems. Information systems in project and program managemen : Collective monograph edited by I. Linde – European University Press. Riga: ISMA, 2023. – P. 251–261.
2. Nevliudov, I.S., Yevsieiev, V.V., Maksymova, S.S., Omarov, A.O.M., Klymenko, O.M. (2023). Conveyor Belt Object Identification: Mathematical, Algorithmic, and Software Support. Applied Mathematics & Information Sciences: An International Journal. – 2023. – Vol. 17, No. 6. – P. 1073–1088.
3. Maksymova, S., Nevliudov, I., Yevsieiev, V., Klymenko, O., Vzhesniewski, M. (2023). Shuttle-based storage and retrieval system 3d model improvement and development. Journal of Natural Sciences and Technologies, 2(2), 232–237.
4. Nevliudov, I., Maksymova, S., Nevliudova, V., Vzhesniewski, M., Klymenko, O. (2023). Software development for small details production warehouse automated system. Scientific Collection «InterConf». – 2023. – P. 320–323.
5. Nevludov, I., Yevsieiev, V., Maksymova, S., Klymenko, O., Vzhesnievskyi, M. (2022). Analysis of Software Products for Simulation Modeling of the Operation of the System of Shuttles for Warehousing. Manufacturing & Mechatronic Systems 2022 : proceedings of the VIst International Conference, Kharkiv, October 21–22, 2022 : thesises of reports / [ed. by I. Sh. Nevlyudov (chief editor)]. – Kharkiv : [electronic version], 2022. – P. 24–26.
6. Nevliudov, I., Yevsieiev, V., Maksymova, S., Klymenko, O., (2023). Using Mecanum Wheels for Radio Shuttle. Multidisciplinary Journal of Science and Technology, 3(3), 182–187.
7. Nevliudov, I., Yevsieiev, V., Maksymova, S., Klymenko, O., (2023). Development of a Hardware Module for Programming Microcontrollers Based on the Cortex-M Architecture. Multidisciplinary Journal of Science and Technology, 3(3), 171–181.
8. Nevliudov, I., Maksymova, S., Klymenko, O., Bilousov, M. (2023). Development of a mobile robot prototype with an interactive control system. Системи управління, навігації та зв'язку. Збірник наукових праць, 3(73), 128–133.
9. Salawu, G., Bright, G., Onunka, C. (2020). Modelling and simulation of a conveyor belt system for optimal productivity. International Journal of Mechanical Engineering and Technology (IJMET), 1(11), 115–121.

10. Friso, D. (2020). Conveyor-belt dryers with tangential flow for food drying: Mathematical modeling and design guidelines for final moisture content higher than the critical value. Inventions, 5(2), 22.
11. Wojtkowiak, D., Talaśka, K., Wilczyński, D., Gorecki, J., Domek, G. (2021, November). Design issues related to the construction of automatic devices for conveyor belt perforation. In IOP Conference Series: Materials Science and Engineering (Vol. 1199, No. 1, p. 012101). IOP Publishing.
12. Jia, H., Wu, K., Wang, Y., Sun, Y. (2020). Conveyor belt structure of belt dryer: Analysis and optimization. Engineering Failure Analysis, 115, 104686.
13. Tupkar, R., Kumar, D., Sakhale, C. (2024). Material selection and parametric evaluation for medium duty belt conveyor: A review on current status and future directions. Materials Today: Proceedings.
14. Bajda, M., Hardygóra, M. (2021). Analysis of the Influence of the Type of Belt on the Energy Consumption of Transport Processes in a Belt Conveyor. Energies, 14(19), 6180.
15. Hrabovský, L., Blata, J., Hrabec, L., Fries, J. (2023). The detection of forces acting on conveyor rollers of a laboratory device simulating the vertical section of a Sandwich Belt Conveyor. Measurement, 207, 112376.
16. Kulinowski, P., Kasza, P., Zarzycki, J. (2021). Influence of design parameters of idler bearing units on the energy consumption of a belt conveyor. Sustainability, 13(1), 437.
17. Zohra, F. T., Dey, S., Salim, O., Masoumi, H., Karmakar, N. (2020, October). Design and analysis of a UHF RFID crack sensor for health monitoring of mining conveyor belt. In 2020 27th International Conference on Telecommunications (ICT) (pp. 1–5). IEEE.

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AUTOMATION OF THE GROUP FORMATION PROCESS FOR EDUCATION APPLICANTS TO STUDY ELECTIVE EDUCATIONAL COMPONENTS

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The paper analyzes the main provisions on the formation of an individual educational trajectory of education applicants, identifies the main functional requirements for a software tool designed to automate the process of forming groups of education applicants according to their choice of educational components. The structure and algorithm of the software tool were developed. The data to be stored are determined and the structure of the database is developed. The developed software tool allows you to keep records of selected elective disciplines and generate reporting forms.

Introduction

Education is the basis of intellectual, spiritual, physical and cultural development of an individual, his or her successful socialization, economic well-being, and the key to the development of a society united by common values and culture, and the state [1].

The purpose of education is the comprehensive development of a person as an individual and the highest value of society, his or her talents, intellectual, creative and physical abilities, the formation of values and competencies necessary for successful self-realization, the education of responsible citizens capable of making conscious social choices and directing their activities to benefit other people and society, enriching on this basis the intellectual, economic, creative, cultural potential of the Ukrainian people, raising the educational level of citizens to ensure sustainable development of the country.

Social relations arising in the process of realization of the constitutional human right to education, rights and obligations of individuals and legal entities involved in the realization of this right are regulated by the Law of Ukraine "On Education". The Law of Ukraine "On Higher Education" provides for the right of higher education applicants to choose academic disciplines within the limits provided for by the relevant educational program and curriculum in the amount of not less than 25 percent of the total number of ECTS credits provided for this level of higher education [2–4].

Elective components (elective disciplines or elective courses) of a higher education program are disciplines offered to higher education applicants by a higher education institution to better meet their educational and qualification needs and to effectively use the capabilities of the institution, etc. The choice of disciplines of a particular educational program is made by the applicant in the process of forming an individual educational trajectory.

Implementation of the principles of the law on higher education requires IT support. Specific procedures and algorithms can be implemented more efficiently using the functions of an integrated university management information system.

In the process of studying, students choose the disciplines of a particular educational program in the course of forming their individual educational trajectory. The task of processing the submitted data is extremely complex and important.

In this paper, we propose to automate the process of forming groups for studying selective components using the developed software tool. The use of this information system will allow to build an individual learning trajectory by automating the procedure for selecting disciplines [2].

1 Stages of the group formation process for studying selective components

The process of selecting elective components (disciplines) by educational applicants is quite long and complicated in terms of organizing the collection and processing of information, as well as its further use in the educational process. Currently, Ukraine has not implemented centralized systems or tools that would facilitate and speed up this process. The selection procedure is organized by the dean's office, usually through an online survey of students, summarizing the results by faculty in conjunction with the academic department. The mechanism of realization of the students' right to choose disciplines includes the stages shown in Fig. 1.

Students choose disciplines from the list of elective disciplines of the educational program by forming an individual list within the specified period. The selection process is controlled by group supervisors to ensure that all applicants participate in the selection procedure. The data on students' choice is processed by the dean's office and within the specified timeframe, it submits to the academic department generalized information on the number of students who have chosen the appropriate elective discipline in each academic group and includes it in the working curricula.

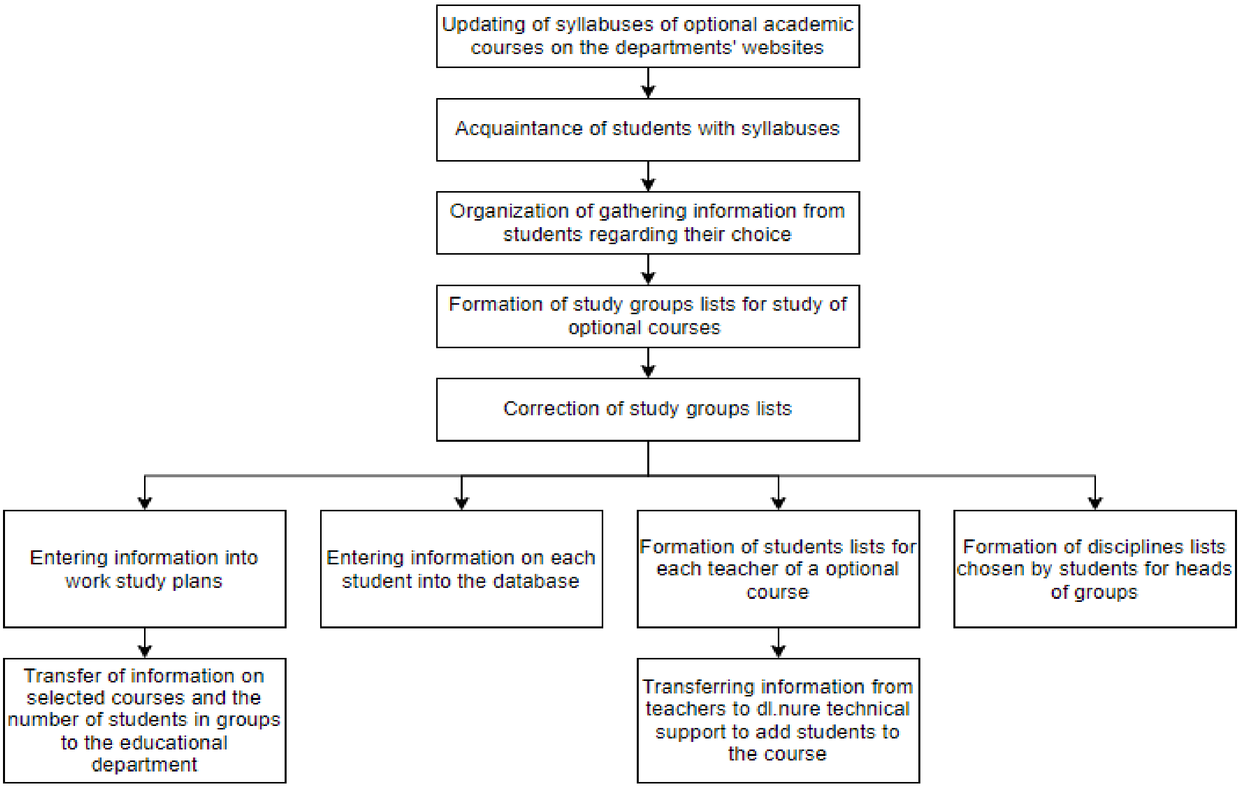

Fig. 1. Stages of group formation for studying elective disciplines

2 Description of the software structure

The software modules included in the group formation automation software for studying elective components are shown in Fig. 2.

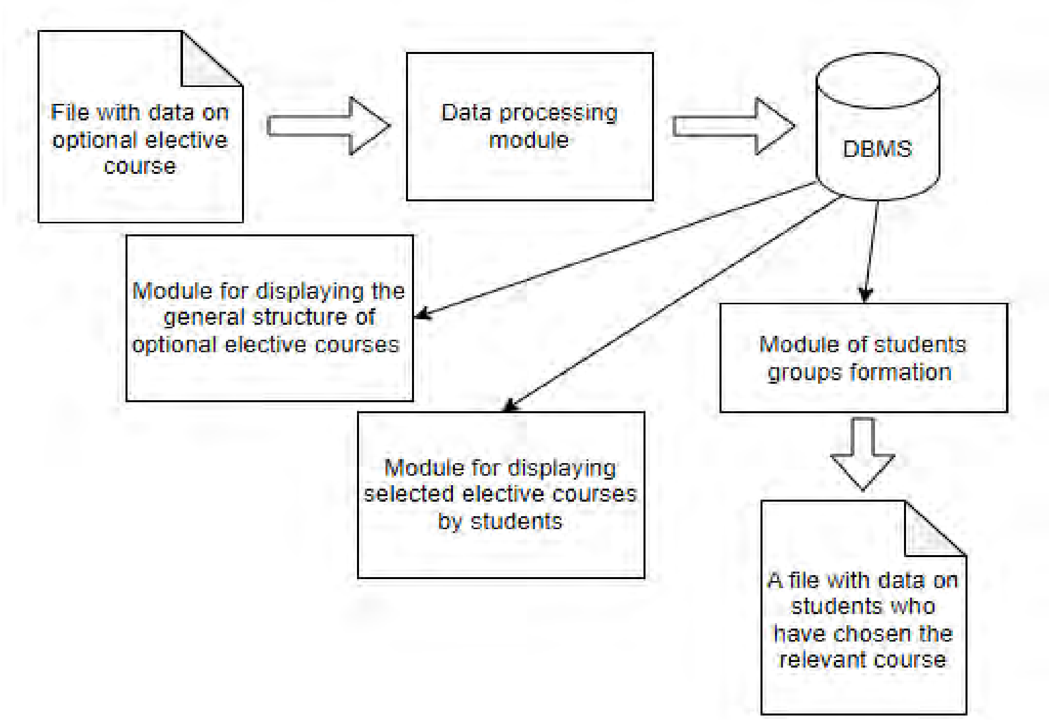

Fig. 2. Program modules included in the software

The file with data on the selected elective disciplines is sent to the data processing module. The file contains tables of education applicants and selection results in Microsoft Exel format.

The data processing module processes the Excel file and stores the information in a database table. It is designed to automate the process of processing information received from education applicants and storing this data in a database table. With this module, you can increase productivity and reduce the time required to process large amounts of data.

The module provides automatic processing of data from an Excel file and saving it in a database table without the need to manually copy and paste information rows. This allows you to use time efficiently and reduce the possibility of errors when entering data manually. In addition, the data processing module allows you to regularly process data from an Excel file and automatically update the information in the database table in case of information changes.

After analyzing the input information, the data is distributed to the appropriate tables and saved to the database. With the collected data structure, the module for displaying the general structure of the selected elective disciplines allows the operator to generate a report in the form of a relationship, as shown in Fig. 3.

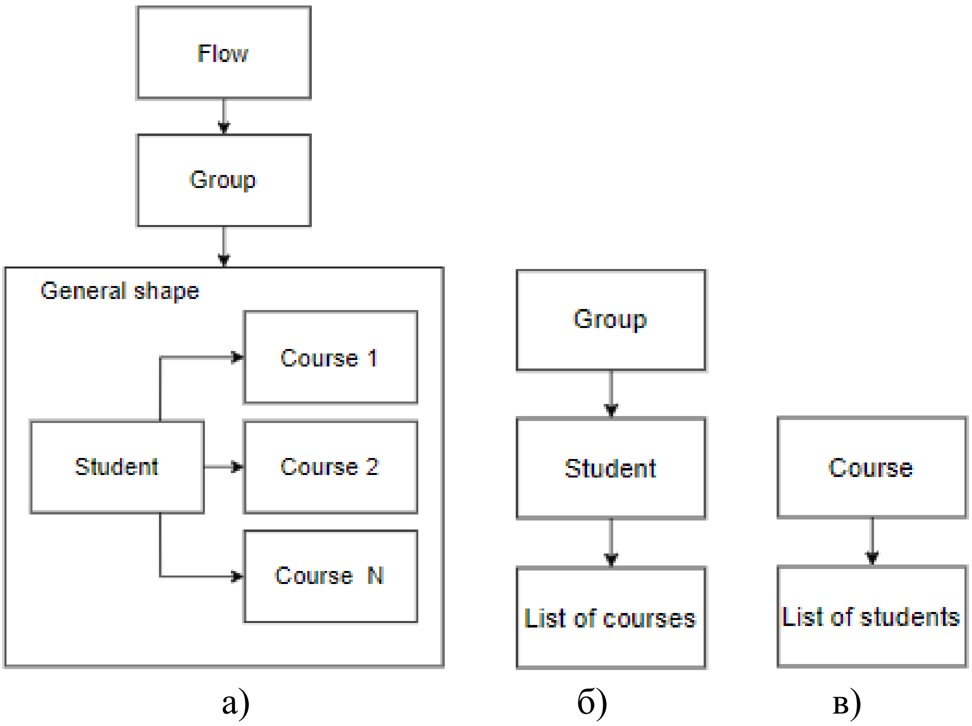

Fig. 3. Relationships:
a) "Flow-Group-Student-General choice";
b) "Group-Student-List of disciplines";
c) "Discipline-List of students"

In this form, you can analyze general information for each student in the group. In the reporting table, you need to display a list of selected disciplines for each student in the group. Moving between group streams allows you to group information in relation to each academic group in the selected stream. Each student can be assigned several disciplines that he or she chooses in the process of forming elective components. Therefore, this way of presenting information makes it possible to assess the overall result of curriculum development.

To perform the operational tasks of providing information services, to present a list of selected disciplines by a particular student, it is necessary to develop another program module – "Module for displaying selected elective disciplines by students", which will implement the relationship "Student – List of disciplines" (Fig. 3, b). Each block in the figure shows a separate type of information that the program should provide when sequentially reproducing the specified relationship.

For example, the "Group" block should provide the user with a list of academic groups available for work. After selecting a particular group, the "Student" block is formed. This block is responsible for displaying students who are members of the academic group. The last block "List of disciplines" provides information about the elective disciplines chosen by the student.

The next program module "Group formation of students" implements the relationship "Discipline – list of students" (Fig. 3, c).

This model is designed to perform the main function – group formation of students for elective components. As a result of this module, a list of students who have chosen a particular discipline is formed.

In accordance with the structure of the program modules, it is necessary to implement the function of exporting the generated list to a new file in Microsoft Excel format for transfer, for example, to the distance learning management department to create a corresponding group in the DL cloud environment.

3 Development of the program operation algorithm

The program operation algorithm is shown in Fig. 4. The program consists of several modules, according to the structure shown in Fig. 2. At the first stage of the program, the Microsoft Excel file is opened, which contains data on all students of academic groups participating in the selection of elective components. If the file is selected correctly, the file structure analysis function is launched. If you select an incorrect file, you need to return to the previous step of selecting the information source.

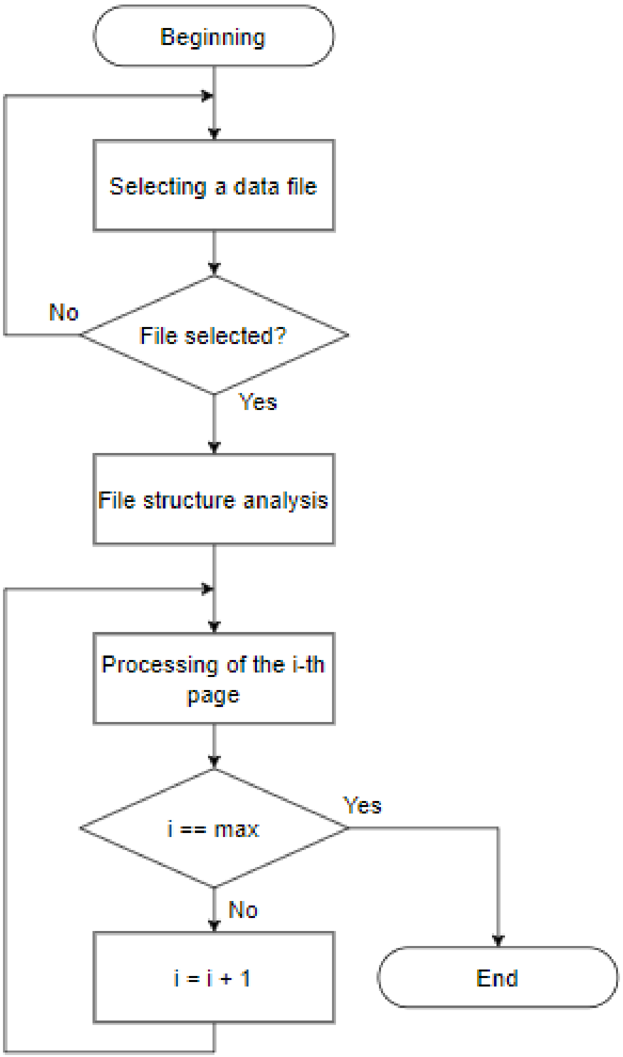

Fig. 4. Algorithm of the program operation

At this stage, a list of pages is created to perform a sequential analysis of each of them. The following information is collected on each page:

– student's email address;

– last name, first name and patronymic of the student;

– the code of the group in which the applicant is studying;

– names of disciplines by semester.

All data is collected sequentially for each student and each group [4, 5]. Also, the stream to which each group belongs is determined. The above functions are performed in the subroutine "Processing the i-th page of the file".

After processing each page, the maximum value of the available pages in the file is checked. If not all pages have been processed yet, the current index "i" is incremented by one and the above steps are repeated again. If all the pages are processed, the main algorithm for automating data collection and analysis is completed.

Figure 5 shows the algorithm of the subroutine "Processing the i-th page of the file".

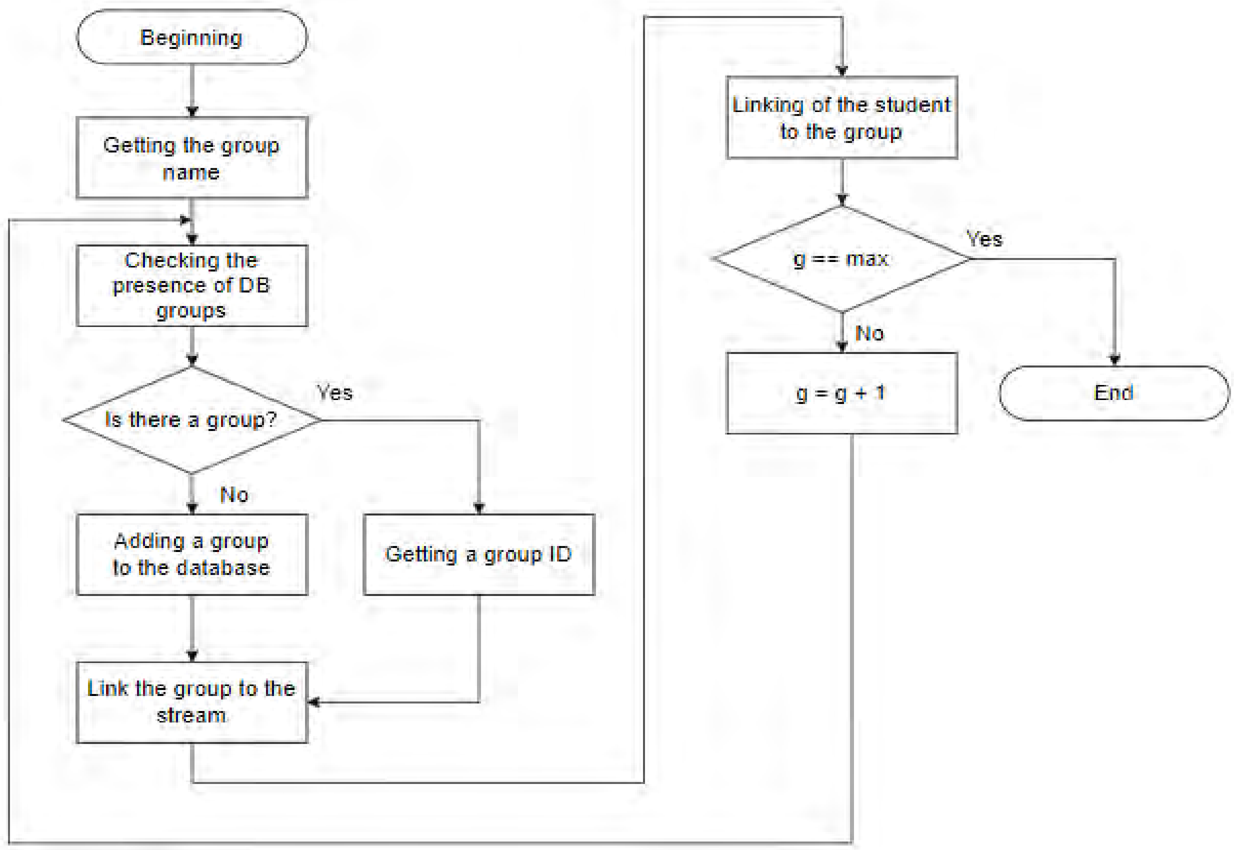

Fig. 5. Algorithm of the subroutine "Processing the i-th page of the file"

At the beginning of the subroutine, the first row of the table contained on the page to be processed is accessed. Each row contains information about the academic group and the name of the student who belongs to it.

After checking the availability of the current group in the database, one of the following actions is performed

– if the group is not found in the database, then such a group is added to the database and the identifier of the new group is obtained;

– if a group is found in the database, its identifier is obtained.

After receiving the group identifier, a certain student, whose information is found in the current row, is linked to the database. The group is also linked to the stream.

The next step is to check the current row number and determine whether we have reached the end of the table with the academic groups of education applicants. If all the rows of the table have been processed, the subroutine terminates, if there are still rows left, the next one is processed.

Figure 6 shows the algorithm of the subroutine for processing information about disciplines. This subroutine searches all the columns of the table to obtain data on the disciplines chosen by the higher education applicant.

The first step is to determine the number of columns containing the names of the disciplines. The number of disciplines may vary depending on the student's study stream and the semesters in which the elective disciplines are selected. Also, the set of certain disciplines depends on the curriculum.

Having received the first name of the discipline, we check its availability in the database. If the discipline is not found in the database, then such a discipline is added to the database and its identifier is obtained. If the discipline is found in the database, its identifier is obtained, after which the discipline is linked to a specific student by making the appropriate entry in the database. Next, it is checked whether there are any columns in the table that have not yet been processed. If so, the next column is processed. If all columns have been processed and all the disciplines selected by the student have been saved to the database, the subroutine is terminated.

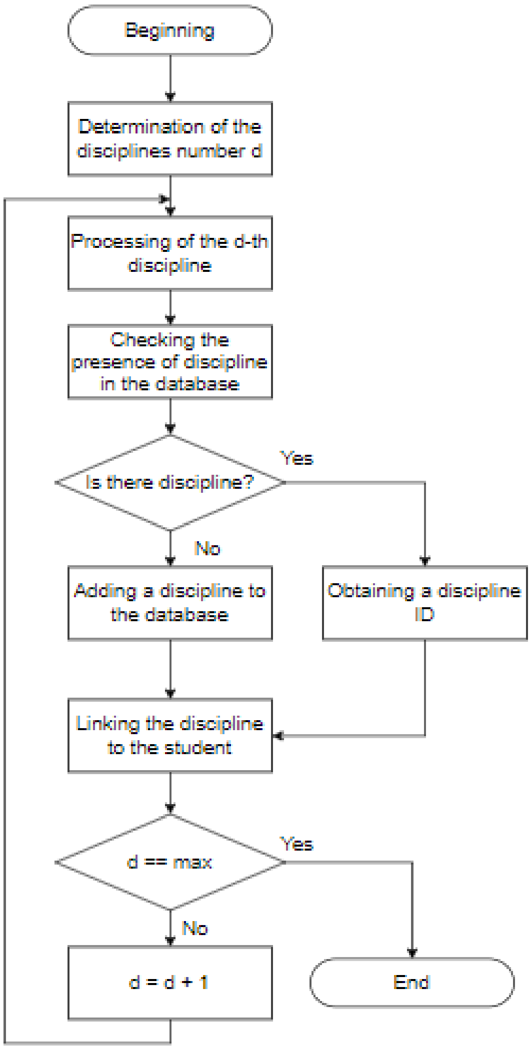

Fig. 6. Algorithm of the subroutine for processing information about disciplines

The general structure of the database is shown in Fig. 7. The connection between the tables is made by key fields. The main table is "Vybor" – the results of the selection of educational applicants elective components. The "Vybor" table refers to the reference books: the list of students ("Student"), the list of disciplines ("Disciplina") and the list of flows ("Flow") by the corresponding key fields: ID_Student, ID_Disciplina, ID_Flow. The table with the list of students links each education applicant to the corresponding group using the ID_Group field. In turn, groups are associated with flows using a special GroupFlow table and the ID_Flow and ID_Group fields.

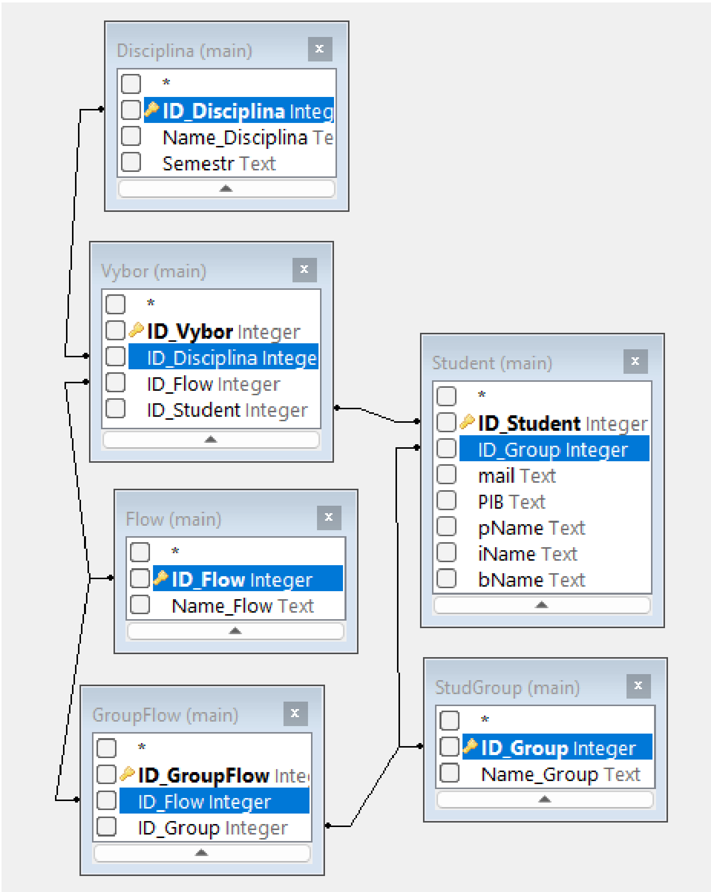

Fig. 7. General structure of the database

4 Description of the program's graphical interface

The program was developed using the C# programming language and the Visual Studio development environment from Microsoft.

The developed program has three tabs:

– general information on groups;

– disciplines chosen by students;

– students who have chosen a particular discipline.

Fig. 8 shows an example of the program interface for viewing general information on groups.

In this example, you can see the button for importing data from an MS Excel file and three workspaces:

– a list of streams

– a list of groups in the stream;

– a complete list of all disciplines chosen by students.

In Fig. 8 and the following, in order to protect the personal data of higher education applicants, the names of students and their mailing addresses are protected from viewing. For this purpose, a special software function has been developed that analyzes the input data and applies a mask before displaying it on the screen. Full information is available only to the dean's office staff.

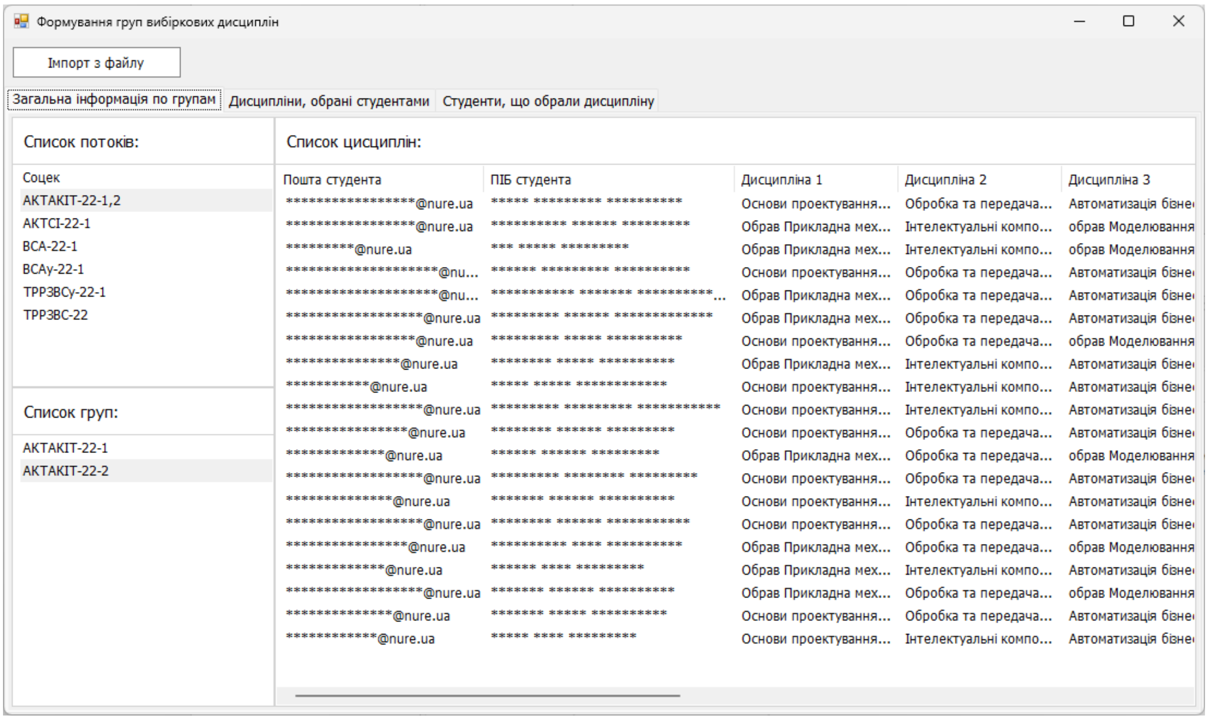

Fig. 8. An example of the program interface for viewing general information on groups

Fig. 9 shows the program interface in the mode of viewing selected disciplines by a particular student.

In this interface, you can also select three work areas:

– a list of all registered academic groups;

– list of students in the selected group;

– a list of disciplines selected by the specified student.

In this mode, it is possible to select any student from the list and find out information about his or her choice in a convenient data presentation format.

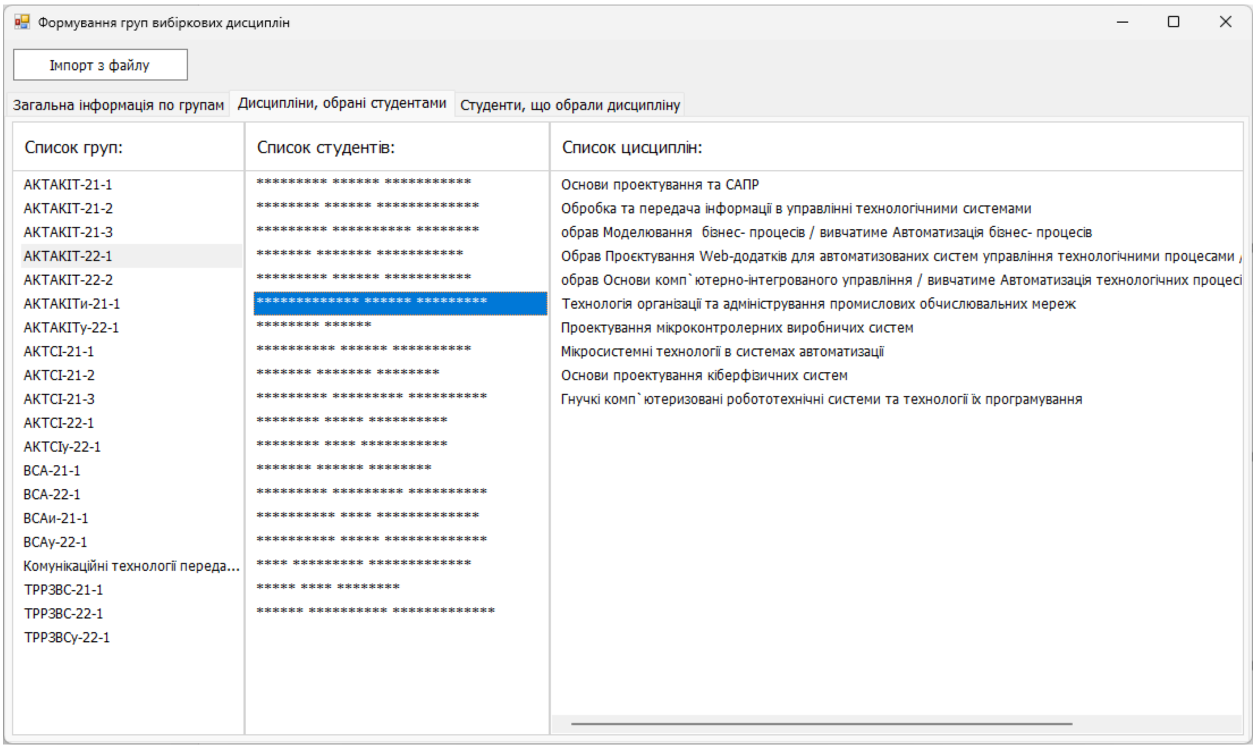

Fig. 9. The program interface in the mode
of viewing selected disciplines by a particular student

Fig. 10 shows an example of the program interface in the mode of viewing lists of students who have chosen a particular discipline.

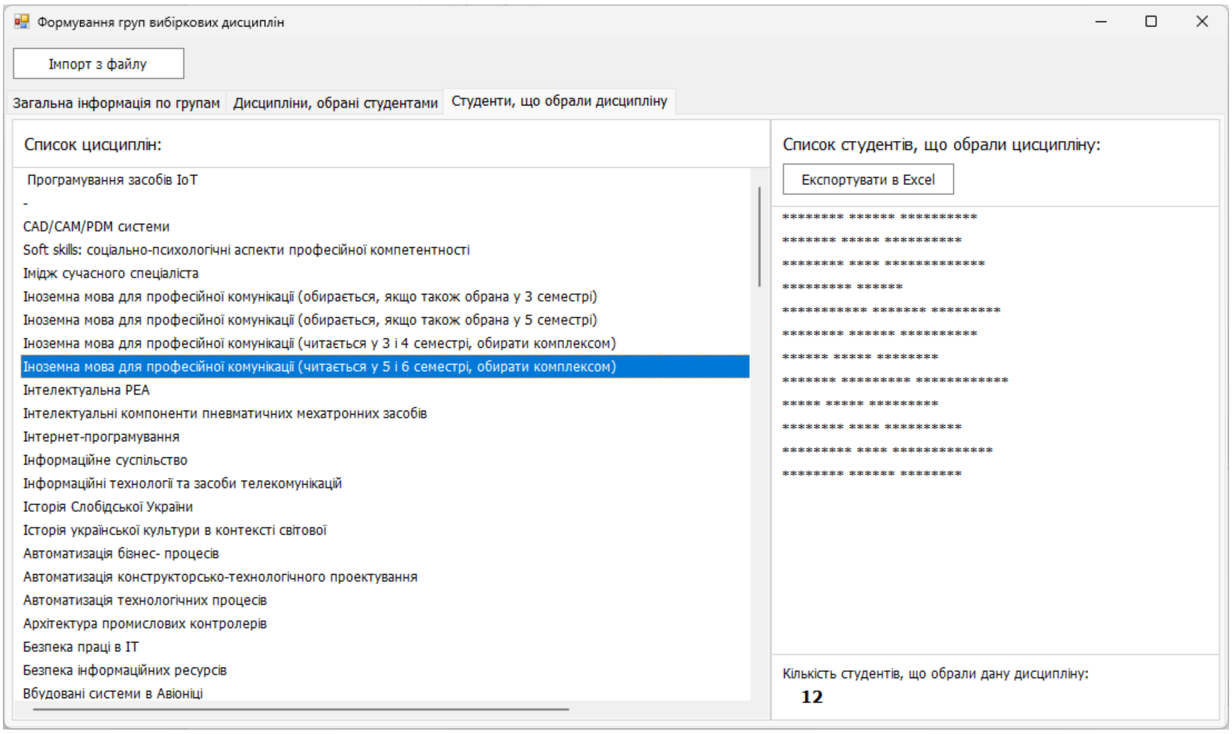

Fig. 10. An example of the program interface
in the mode of viewing lists of students who have chosen a particular discipline

The graphical interface in this mode has two working areas:

– a list of disciplines that participated in the selection;

– a list of students who have chosen the specified discipline.

In this mode it is very convenient to analyze the lists of students who have chosen each of the disciplines.

The possibility of automated generation of a statement with a list of students who will study the selected discipline is also implemented. This list can be sent to the teacher or to the department that organizes distance learning.

Conclusions

Thus, the developed software tool for automating the process of group formation of elective components of education applicants helps to solve organizational problems that arise when building individual educational trajectories of students.

An in-depth analysis of the subject area allowed us to identify the stages of the group formation process for studying elective components. An analysis of the main provisions on the formation of an individual student's educational trajectory was carried out, during which the main functionality of the software tool was determined.

The algorithm of the software and the structure of the database are developed. The data to be stored are determined, namely: information about elective disciplines; information about the flows of groups of educational directions; information about academic groups; information about students; information about the choice of elective disciplines made by students.

References

1. Law of Ukraine "On Education" (Information of the Verkhovna Rada (VVR) (Zakon Ukrayiny "Pro osvitu" (Vidomosti Verkhovnoyi Rady (VVR)), 2017, № 38-39, st. 380). – https://zakon.rada.gov.ua/laws/show/2145-19#Text
2. Methodological foundations of the creation, implementation and development of the integrated information system of university management: monograph I edited by Ph.D. physics and mathematics Science, Dr. Biol. Sciences, Prof. S. V. Chernyshenko, candidate physics and mathematics of Science, Assoc. Yu. I. Vorotnytskyi. 2015. P. 333. ISBN 978-966-657-576-3
3. Law of Ukraine "On Higher Education" (Information of the Verkhovna Rada (VVR) (Law of Ukraine "On Higher Education" (Information of the Verkhovna Rada (VVR)), 2014, №37–38, st. 2004). https://zakon.rada.gov.ua/laws/show/1556-18#Text
4. Criterion "Learning and teaching" in the accreditation of educational programs (Kryteriy "Navchannya ta vykladannya" pry akredytatsiyi osvitnikh prohram). https://naqa.gov.ua/

5. Regulations on the organization of the educational process in KhNURE (Polozhennja pro organizaciju osvitnogo procesu v HNURE). https://nure.ua/wp-content/uploads/Main_Docs_NURE/polozhennja-pro-organizaciju-osvitnogo-procesu-v-hnure.pdf
6. Nevliudov I. Sh., Novoselov S. P., Sychova O. V. The use of digital duplicates of technical automation tools for the development of software and technical complexes of ACS TP: Training manual (Zastosuvannya tsyfrovykh dviynykiv tekhnichnykh zasobiv avtomatyzatsiyi dlya rozroblennya prohramno-tekhnichnykh kompleksiv ASU TP). 2023, P. 267. ISBN 978-617-8059-95-8, DOI: 10.30837/978-617-8059-95-8
7. Alessandro Del Sole. Xamarin with Visual Studio: Launch your mobile development career by creating Android and iOS applications using .NET and C# (English Edition). BPB Publications, 2022, P. 468 – ISBN 9355511876, 9789355511874.
8. Multiplatform Avalonia .NET Framework Programming Advanced Concepts in Easy Samples // CodeProject. For those who code. https://www.codeproject.com/Articles/5317055/Multiplatform-Avalonia-NET-Framework-Programming-A
9. Multiplatform XAML/C# Miracle Package: Avalonia. Comparing Avalonia to WinUI based Solutions] // CodeProject. For those who code. https://www.codeproject.com/Articles/5366945/Multiplatform-XAML-Csharp-Miracle-Package-Avalonia
10. Inherit styles in avalonia // Code Project. For those who code. https://www.codeproject.com/Questions/5327287/Inherit-styles-in-avalonia

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RISK MANAGEMENT IN PROJECTS FOR THE CONSTRUCTION OF WEAPONS AND MILITARY EQUIPMENT

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The relevance of the article is based on the high level of unpredictability and risk in projects for the creation of weapons and military equipment, especially during the period of the full-scale invasion of Ukraine by the Russian Federation. The purpose of the study is to develop a mechanism for risk management in projects for the creation of weapons and military equipment in Ukraine. The author analyses the implementation of typical activities during the management of a project to create (modernise) a sample of weapons and military equipment (WME), taking into account the stages (relevant stages) of project implementation, consisting of: requirements formulation, development, implementation, and operation. It is noted that it is equally important to ensure the required level of quality when managing a project to create (modernise) a WME sample. At the same time, it is necessary to take into account the influence of external factors on the properties (indicators) of the WME sample and its internal factors. It is also noted that external factors of influence on the domestic WME samples being created (modernised) are factors (objects) of the external environment that affect the sample and are not its internal elements, as well as change its properties and determine the general requirements for it (operational and strategic, operational and tactical, system engineering). It is emphasised that effective management at defence industry enterprises, taking into account the internal and external environment, especially under conditions of uncertainty and risk, requires the use of project management models and methods, and the process of project risk management usually involves the following procedures: risk management planning; risk identification; qualitative and quantitative risk assessment; risk response planning; risk monitoring and control.

Introduction

The development of new models of military equipment and weapons in the context of full-scale military aggression is an urgent task.

As the authors note [1, p. 19], "...constantly gaining experience and optimising the structure, management system, logistics, forms and methods of armed struggle, today the Armed Forces of Ukraine (AFU) are an alloy of professionalism and courage, clear management decisions, thanks to international partners, the level of equipment with high-tech weapons is constantly growing, which proves its effectiveness on the battlefield every day".

Effective management at defence industry enterprises, taking into account the internal and external environment, especially in conditions of uncertainty and risk, requires the use of project management models and methods [2, p. 248].

The object of study of this paper is the risk management processes in the defence industry.

The subject of the study is risk management in projects for the development of weapons and military equipment.

Review of scientific literature

According to Professor O. Butnik-Siverskyi, "...in the current conditions of martial law, innovations are of particular importance, as they are the basis of industrialisation, which plays a key role in diversifying the economy and overcoming its structural weakness. Industry, in particular the military-industrial complex, is the engine of innovation, productivity growth and exports [3, p. 50].

Equipping the Armed Forces with the latest types of weapons and military equipment (WME) depends, in particular, on the ability of the defence industry to introduce the latest technologies, ensure a high scientific and technical level, novelty, patentability and patent purity of WME samples [4, p. 43].

The war, in which Ukraine is conducting a comprehensive defence to repel the large-scale hybrid aggression of the Russian Federation, combines the features of network-centric armed struggle, wars of the fourth and sixth generations. Ways and means of warfare are constantly being supplemented by innovative methods and improved with the help of new technologies [5, p. 29].

The Guide to Managing Risks, Issues and Opportunities for Defence Acquisition Programmes defines risks as "...Risks are probable future events or conditions that could adversely affect programme objectives related to cost, schedule or performance [6, p. 9].

"Project risk is a potential, quantifiable probability of unfavourable situations and related consequences in the form of additional costs, loss of resources, loss of income, and losses during project implementation" [7, p. 158].

"...Risk management is the activity of the management and employees of an institution to identify, assess, determine how to respond to identified and assessed risks, review identified and assessed risks to identify new and changed risks" [8, p. 18].

The relevance of the chosen topic is due to the high level of unpredictability and risk in projects for the creation of weapons and military equipment, especially during the period of a full-scale invasion of the country by the Russian Federation.

The purpose of the study is to develop a risk management mechanism for arms and military equipment projects in Ukraine.

Presentation of the main material

The implementation of typical activities during the project management of the creation (modernisation) of a sample of weapons and military equipment (WME), taking into account the stages (relevant stages) of project implementation, consists of: requirements formulation, development, implementation, operation. At each stage of the sample's condition, certain complex measures are taken:

– analysis of external factors affecting the properties of the sample under study;

– development of the concept for creating and shaping the technical outline of the sample;

– preparation and approval of organisational documents for the creation of the sample;

– implementation of an advance design to determine the basic requirements for the sample;

– development of the tactical and technical task (TTT);

– development of a preliminary design;

– development of a technical design;

– development of working design documentation;

– submission of the sample for testing;

– training of personnel for the sample maintenance and its application;

– commissioning and adjustment works;

– conducting preliminary tests;

– conducting state tests;

– commissioning;

– analysis of the functioning of the sample (amendments to the documentation);

– checking its current scientific and technical level;

– carrying out repair or restoration work;

– making a decision to dispose of the sample;

– making a decision on the need to modernise the sample;

– making a decision on the need to develop a new sample [9, p.15].

Equally important when managing a project to create (modernise) a WME sample is ensuring the required level of quality. In this case, it is necessary to take into account the impact of external factors on the properties (indicators) of the WME sample and its internal factors.

External factors of influence on the domestic WME samples being created (upgraded) are factors (objects) of the external environment that affect the sample and are not its internal elements, as well as change its properties and determine the general requirements for it (operational and strategic, operational and tactical, system engineering).

Uncertainty and risk during the development of WME prototypes have an ambiguous impact on the effectiveness of the development (modernisation) of

WME prototypes. Some of them directly affect the design elements of the prototype, while others affect the duration of its operation or determine the conditions of its use, which affects the overall effectiveness of WME use.

When managing a project to create (modernise) WME samples, risks must be taken into account, including risk assessment and management.

Ensuring a high level of quality of complex weapons and military equipment (WME) of the Armed Forces of Ukraine (AFU) is one of the most important issues during their development. This process must be managed at all stages of the life cycle (LC).

The requirements to meet the development (modernisation) deadlines and to be cost-effective in project management are crucial for the state customer, the Ministry of Defence of Ukraine, as well as for the enterprises of the domestic military-industrial complex (MIC) due to the limited time available for the development of a large range of WME, preparation of their production, possible complications in the conditions of armed conflict regarding the import of WME and ammunition, as well as significant resource constraints at all stages of the life cycle inherent in the conditions of a special period [9, p. 15].

Therefore, managing the project of creating complex WME samples using the lean principle is a top priority.

Risk is inherently linked to decision-making. Decisions are made under conditions of certainty (the outcome of a decision is known), risk (there is a certain probability that an event will occur and some assessment can be made), and uncertainty (the probability and consequences of an event cannot be predicted. Decision-making processes in project management take place under conditions of uncertainty, that is, under the influence of factors such as incomplete knowledge of the situation, the presence of chance, and force majeure. Thus, project implementation takes place under conditions of uncertainty and risk. These two categories are interrelated [10, p. 24].

Uncertainty is incomplete or inaccurate information about the conditions of project implementation, including related costs and results. Sources of uncertainty include:

– the stochastic nature of the processes taking place in business and society;

– the lack of information necessary to justify and make project decisions;

– the influence of subjective factors on decision-making (the level of qualifications of executors, their psychological state, deliberate concealment of information, etc.)

According to the degree of probability of an event occurring, we distinguish between complete uncertainty, partial uncertainty, and complete certainty. All aspects of life and business involve risks. In general, risk reflects our lack of knowledge about future events. We call favourable events opportunities and unfavourable events threats. Risk is the possibility or threat that the results of specific actions may deviate from the expected ones. Project risks are a set of risks that threaten the implementation of an investment project or may reduce its effectiveness (commercial, economic, budgetary, social, environmental, etc.); a set of circumstances under which the probability of achieving the project's goals is reduced or eliminated; a set of risks that threaten the economic efficiency of the project, which is expressed in the negative impact of various factors on cash flows. Risk has three main attributes:

1) a risk event;
2) probability;
3) consequence (risk effect) [10, p. 25].

There are several types of events that pose a risk to a project:

– Cases that may occur.
– Cases that will have major consequences if they occur.
– Events that are beyond your control.
– Things you know very little about.

There are two types of risk associated with project preparation and implementation: systematic and unsystematic. Systematic risk refers to factors external to the project, such as the state of the economy as a whole, and is beyond the general control of the project. Examples of systematic risk include political instability and taxation conditions, i.e. factors related to government actions. Other types of systematic risk reflect the impact of competitive environment factors, such as overall market demand, the level of competition, and prices for raw materials and labour in the industry. These factors must be considered because the project is too small to influence changes in these factors. An unsystematic risk is one that is directly related to the project. The level of profitability of production, the period of construction start and the construction process itself, the cost of fixed capital and productivity are all types of unsystematic risk. Other types of unsystematic risk include external factors that can be controlled or influenced within the project. These include project staff salaries, sales prices for project products, supplier prices for raw materials, and even government taxes, such as customs and excise duties, and other types of taxes.

An approved equilibrium with the client is achieved if the contractor has named and fixed time (deadlines) and resources (estimates) based on the requested parameters. It should be borne in mind that any change in one of the sides of the triangle necessarily entails a change in the remaining two.

Project management involves more than just acknowledging the existence of uncertainty and risks and analysing the damage. Project risks can and should be managed. Risk management is a set of methods for analysing and neutralising risk factors. Risk management is a subsystem of project management. Risk management is the process of identifying, analysing risks and making decisions that include maximising the positive and minimising the negative consequences of risk events; it includes processes related to risk management planning, risk identification and analysis, risk response, and risk control and management within a project. The purpose of project risk management is to increase the likelihood of positive events for the project goals and reduce the likelihood of adverse events [10, p. 26].

According to the PMBOK, the following project risk management processes are distinguished:

– Risk management planning – selection of approaches and planning of project risk management activities;

– Risk identification – identifying risks that may affect the project and documenting the characteristics of these risks;

– Qualitative risk analysis – the process of prioritising risks for further analysis or action, performed by assessing and comparing their impact and likelihood of occurrence;

– Quantitative risk analysis – the process of numerical analysis of the impact of identified risks on the project objectives as a whole;

– Risk response planning – development of possible options and actions that contribute to increasing favourable opportunities and reducing threats to achieving project objectives;

– Monitoring and controlling risks – monitoring risks, identifying remaining risks, implementing the project risk management plan, and evaluating the effectiveness of risk mitigation actions [11].

Figure 1 shows an algorithm for a comprehensive risk assessment. The main indicators that characterize the risk of project implementation may include: the probability of financial losses to the customer if the project is not completed (stopping work before its completion or failure to achieve the results envisaged by this project) or the probability of project failure; mathematical expectation of financial losses to the customer if the project is not completed, i.e. the average value of the customer's useless financial costs until a negative result is obtained, which does not allow further design or to consider that the project

In the absence or insufficient probabilistic data from previous developments, it is necessary to use an approach based on risk assessment under non-stochastic uncertainty [9, p.17].

To assess the risks of implementing WME prototype projects and risk management, it is necessary to develop a scientific and methodological apparatus adequate to these tasks, which requires appropriate software that will automate the risk management process.

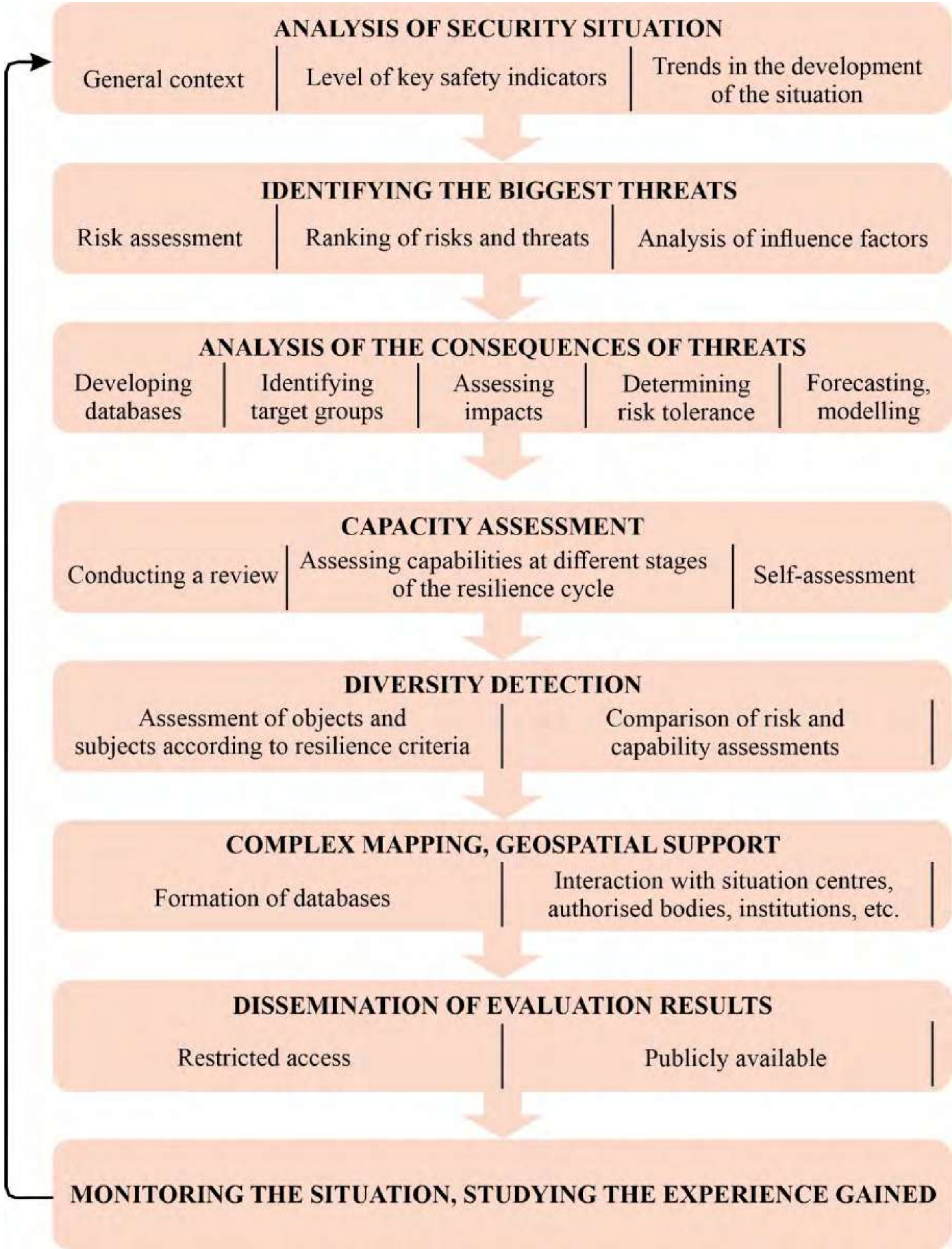

Fig. 1. Algorithm for comprehensive risk and capability assessment, threat identification and vulnerability detection [9, p. 17]

The overall process of implementing a WME sample development project should be systematically streamlined and considered as a dynamic system object of targeted management, taking into account the manifestation of risk factors.

Figure 2 shows a general description of the risk management process.

Fig. 2. General description of the risk management process [6, p. 25]

This figure shows an example of a 5-step management process that can be applied to a specific risk or issue. These steps can be applied at different stages of the programme/project life cycle, but the details of the specific activities will vary depending on the stage of the programme/project. The process of managing individual risks or problems takes place within the framework of the whole system, in which risks affect the structure and content of the programme/project. [6, c. 25]

Planning of the risk management process consists of activities aimed at developing, implementing and documenting measures to be taken within the programme/project to mitigate individual risks. This process should be described in the System Design Plan. For example, the Project Risk Management Process document should describe the expectations for programme risk management, the organisations involved in risk management (such as risk management committees, frequency of meetings and number of members), basic rules and assumptions, categories of potential risks, use of risk management tools, and training of programme staff. In addition, the programme's Risk Management Process document should specify how often the document will be reviewed and updated.

When managing projects, it is important to pay attention to risk identification in time when assessing the feasibility of making certain decisions. The purpose of risk analysis is to provide potential partners with the necessary information and data to make decisions about the feasibility of participating in the project and develop measures to protect against possible financial losses.

The organisation of risk analysis work can be carried out in the following sequence: selection of an experienced team of experts; preparation of special questions and meetings with experts; selection of risk analysis techniques; identification of risk factors and their significance; creation of a model of the risk mechanism; establishment of the relationship between individual risks and the cumulative effect of their action; distribution of risks among project participants; consideration of the results of risk analysis, most often in the form of a report.

Risk analysis is divided into two types: quantitative and qualitative. Quantitative risk analysis should make it possible to determine the number and size of individual risks and the risk of the project as a whole. Qualitative analysis identifies the factors, limits and types of risks. To analyse the risk, the method of analogy, the method of expert estimates, the calculation and analytical method and the statistical method are used.

The method of analogy involves the use of data from other projects that have already been completed. This method is used by insurance companies, which regularly publish data on the most important risk areas and costs incurred.

The expert method, also known as the method of expert judgement, for innovative projects can be implemented by studying the opinions of experienced managers and specialists. At the same time, it is advisable to establish indicators of the most acceptable, critical and catastrophic losses, taking into account both their level and probability.

The calculation-analytical method is based on theoretical concepts, although the applied risk theory is well developed only for insurance and gambling risk.

The statistical method was originally used in the PERT system to determine the expected duration of each task and the project as a whole. Recently, the most commonly used method is the statistical test method (Monte Carlo method). The advantages of this method include the ability to analyse and evaluate different ways of implementing a project.

When considering the methodology for determining risk, it should be noted that the starting point in project risk analysis is to establish the uncertainty inherent in the project’s cash flows. This analysis can be done in several ways, from informal judgement to complex economic and statistical analyses involving hand calculations to large-scale computer models.

The scenario method provides pessimistic estimates of the risk of an investment project. Therefore, it is recommended to use scenario analysis only in cases where the number of scenarios is normal and the values of the factors are discrete. If the number of scenarios is very large and the values of the factors are continuous, it is recommended to use simulation modelling.

The Monte Carlo method is based on the use of simulation models that allow you to create a certain number of scenarios that are consistent with the specified constraints for a particular project.

In practice, this method can only be applied with the use of computer programs that allow you to describe predictive models and calculate a large number of possible scenarios. The mathematical dependencies obtained in the calculation of economic efficiency indicators serve as forecast models. All variables that affect the final result should be identified as accurately as possible, with a description of the degree of these dependencies.

Now let's look at ways to reduce and counteract risks. There are the following groups of risk mitigation methods:

– technical methods based on the implementation of various technical measures, such as fire control systems, electronic banking, etc.

– legal methods, such as insurance, collateral, forfeit (fine, penalty), guarantee, deposit, etc.

– organisational and economic methods include a set of measures aimed at preventing risk losses in the event of unfavourable circumstances, as well as compensating for them in the event of losses [12, p. 130].

The most common methods of risk reduction are:

– distribution of risk between project participants;

– insurance;

– reserving funds to cover unforeseen expenses;

– neutralisation of partial risks;

– reducing the risk in terms of financing.

Risk allocation is carried out in the process of preparing the project plan and contract documents. A decision tree model can be used to quantify risk allocation in projects. In this case, each participant performs the scope of work planned by the project and bears the appropriate share of the risk in case of project failure. But the investor is at the greatest risk. Therefore, it should be borne in mind that the difficulty of finding an investor tends to increase with the degree of risk borne by the investor.

Risk insurance is a system of compensation of losses by insureds in the event of insured events from special insurance funds formed by insurance premiums paid by insureds. This is usually done through property and casualty insurance.

In addition to insurance, reinsurance and co-insurance may be used. Reinsurance is insurance under which an insurer transfers part of its risk liability to other insurers. The purpose of such a transaction is to create a stable and balanced "insurance portfolio" to ensure stable and profitable operation of insurance companies. Co-insurance is a method of levelling and distributing large risks among several insurers. Each of them enters into a separate agreement with the insured. However, there may be a leader insurer that takes on the functions of the organiser [12, p. 131].

Creating reserves of resources to cover unforeseen expenses allows you to compensate for the risk that arises during the project implementation process and, thereby, compensate for project failures. It is a way of dealing with risk, which involves establishing a correlation between the potential risks that affect the cost of the project and the amount of costs required to overcome project failures. Part of the reserve should always be in the hands of the manager, and the other part should be managed by other participants in accordance with the contract.

The first step in using this method is to assess the consequences of risks, i.e. the amounts to cover unforeseen expenses. All risk analysis methods can be used. The next step is to determine the structure of the contingency reserve and the purposes for which the reserve should be used.

Partial risks are risks associated with the implementation of individual stages (works) of the project, but which do not directly affect the project as a whole.

The project financing plan must take into account such risks as the risk of project unviability, tax risk, risk of non-payment of debts, and risk of project failure.

Risk management is carried out at all stages of the project life cycle through monitoring, control and necessary corrective actions. This is done by the project manager in close cooperation with all project participants [12, p. 132].

Figure 3 shows the main planning, management, and additional planning and risk management processes of the project for the creation of weapons and military equipment in Ukraine.

Open Plan is a professional project management system characterised, among other things, by powerful resource and budget planning tools that make it much easier to find the most efficient allocation of resources and schedule them.

Fig. 3. Conceptual model of risk management in projects for the development of weapons and military equipment

Risk analysis in Open Plan is implemented by the following means:

– procedures for entering optimistic and pessimistic parameter estimates for certain or all project activities;

– performing Monte Carlo risk analysis to calculate the probability of completing the project on time;

– preparing reports used to analyse the impact of uncertainty on project implementation.

The Monte Carlo simulation method used for risk analysis is a synthesis of sensitivity analysis and scenario analysis. This is a complex technique that has only a computer implementation.

Conclusions

The article considers the possibilities of reducing and counteracting risks. The most common methods of risk reduction are presented. A conceptual model of risk management in a project to create weapons and military equipment has been built. The professional project management system Open Plan is characterised by powerful tools for resource and budget planning, as well as risk analysis.

The use of the recommendations in the study will help bring the issue of risk management in arms and military equipment projects to a qualitatively new level.

Reference

1. Pevtsov H.V. Building up the testing capabilities of the Armed Forces of Ukraine in the context of repelling armed aggression. Collection of scientific works of the State Research Institute for Testing and Certification of Arms and Military Equipment, 2022. Issue 4 (14). P. 19–27.
2. Petrenko V.O., Sushko M.P. Risk management in projects for the creation of weapons and military equipment. Project management. Prospects for the development of project and neuro-management, management information technologies, technologies for the creation and use of intellectual property rights, technology transfer: Proceedings of the VI International Scientific and Practical Internet Conference (21–22 March 2024) / edited by V.O. Petrenko, V.M. Molokanova, H.K. Dorozhko; USUNT, UKRNET, Research Institute of the National Academy of Sciences of Ukraine – Dnipro: Ukrainian State University of Science and Technology, 2024. 796 p. P. 240–249. DOI 10.15802/978-617-7440-41-2
3. O.B. Butnik-Siverskyi Intellectual property as a component of the national security system. Section 6: electronic collection of materials. III International Scientific and Practical Conference "Kyiv-Dnipro Interbridge", Project Management. Effective use of the results of scientific research and object of intellectual property, 18 March 2021, Kyiv : Research Institute of Intellectual Property of the National Academy of Sciences of Ukraine, 2021. 158 p. P. 34–53.
4. Zaikivskyi O., Onistrat O. The role of intellectual property in ensuring the defence capability of the state. Part 2. Theory and practice of intellectual property, 2021. № 5. P. 33–53.
5. Grechaninov V.F., Morozov A.O., Zakalad M.A., Lopushansky A.V., Belyachenko O.V. Ways to achieve some tasks defined in strategic goals through the use of modern information technologies (creation of a unified system for managing defence resources of the Armed Forces of Ukraine). Mathematical machines and systems. 2022. № 3. P. 28–47.
6. Handbook "Guidelines for managing risks, challenges and opportunities for defence procurement programmes". Main Inspectorate of the Ministry of Defence of Ukraine in cooperation with the Department of Military Technical Policy, Development of Armaments and Military Equipment of the Ministry of Defence of Ukraine, 2022. 111 p.
7. Afanasiev M.V., Gontareva I.V.. Project management: a study guide. KH.: INZHEK, 2007. 272 p.

8. Methodological Manual "Organisation of Internal Control and Risk Management". The Main Inspectorate of the Ministry of Defence of Ukraine in cooperation with the General Staff of the Armed Forces of Ukraine, the Command of the Naval Forces of the Armed Forces of Ukraine and the Command of the Airborne Assault Forces of the Armed Forces of Ukraine. 2021. 275 p.
9. Demidov B.O., Velychko O.F., Kucherenko Y.F., Kutsak M.V. Project Management for the Development of Armaments and Military Equipment in the Face of Uncertainty and Risk Factors. Arms and Military Equipment, 2016, Issue 2 (10). P. 15–19.
10. Project management. Laboratory workshop: Study guide / compiled by B. Korniienko. Kyiv, 2023. 68 p.
11. Guide to the Project Management Body of Knowledge (PMBOK) 5th ed. USA (RMI), 2013. 586 p.
12. Mykytyuk P.P. Project management: A guide. [for students of higher educational institutions]/ P.P. Mykytyuk. Ternopil, 2014. 270 p.

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INFORMATION AND INNOVATION TECHNOLOGIES IN PROJECT MANAGEMENT FOR THE DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

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Information systems improve the efficiency, transparency, and security of processes, and facilitate informed decision-making. Information and innovation technologies for the development of territorial communities contribute to the intensification of social and economic processes in the territory by increasing the transparency of operations, monitoring and control over their implementation by a large number of stakeholders, and increasing the efficiency of economic and administrative decisions. At the same time, these indicators vary considerably depending on the type of community. Urban communities have more resources and opportunities to innovate, while rural and settlement communities face greater challenges due to limited resources and infrastructure.

In the modern world, information systems play a key role in the development of socioeconomic systems. They ensure effective project management, facilitate informed decision-making, and increase productivity. According to international indices, such as the Network Readiness Index (NRI) and the Global Innovation Index (GII), Ukraine is gradually strengthening its position in the field of information and communication technologies (ICT). For example, in 2022, Ukraine improved its performance in several key indices, indicating an increase in innovation potential (Fig. 1).

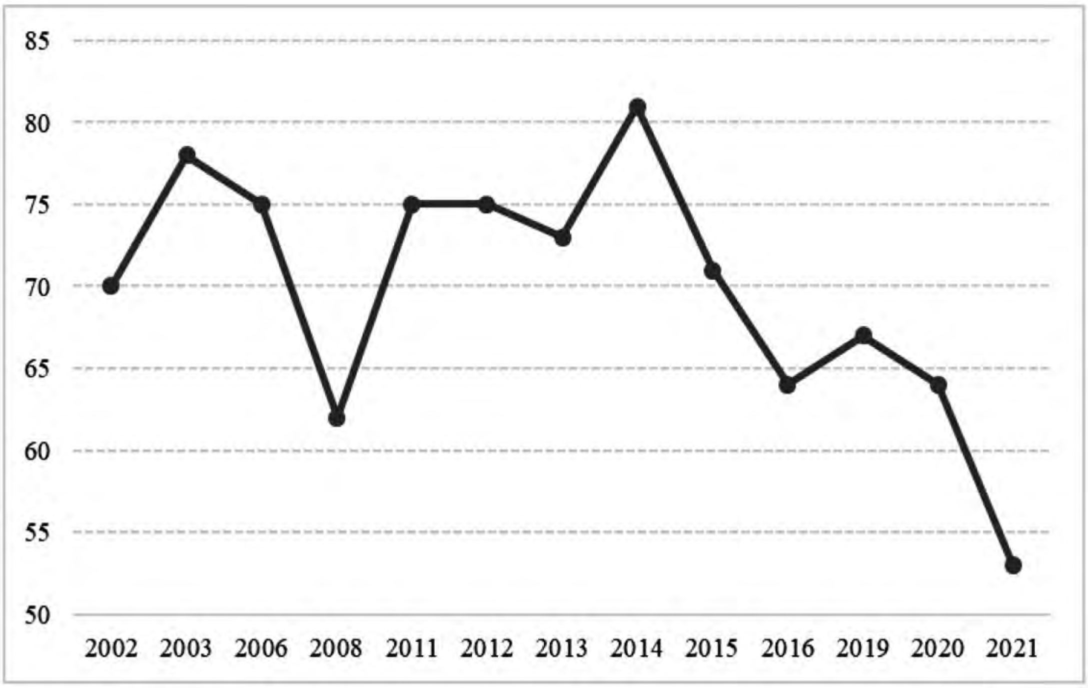

Fig. 1. Ukraine’s place in the NRI ranking
(*Source: compiled based on data from [13]*)

According to the State Statistics Service of Ukraine, the number of innovatively active enterprises is growing, which indicates an increase in the level of implementation of new technologies in various sectors of the economy [11]. During the COVID-19 pandemic, many business processes were transferred to the online environment, which accelerated the digital transformation of communities and territories, including the implementation of digital agendas and the development of digital infrastructure. In general, information systems (IS) as a set of hardware and software tools, methods, and procedures that collect, store, process, and transmit information are an integral part of modern project management.

The main areas of IS use in project management are as follows:

1) planning and control (IS allow for effective resource planning, task allocation, and monitoring of project implementation, provide access to up-to-date information in real time, which facilitates timely decision-making);

2) communication and collaboration (IS help improve communication between project participants by ensuring rapid exchange of information and documents, which is especially important for large projects with many stakeholders);

3) analysis and reporting (information and communication systems provide tools for analyzing data Therefore, the benefits of using IS for socio-economic development include increasing their efficiency by automating processes and reducing time and resources; improving the quality of decisions by providing access to up-to-date and accurate information and making informed decisions; reducing risks by identifying and minimizing them in a timely manner during the preparation, organization, and implementation of the project management process.

At the same time, the existing challenges and limitations, such as the cost of implementation, the need to ensure data security and protection of information from unauthorized access and cyberattacks, and the need to train staff, can sometimes be an obstacle for some organizations or require additional resources (Fig. 2).

Modern indicators of the functioning of innovative technologies in the management of projects for the development of socio-economic systems are as follows:

a) process automation, which includes automatic planning, resource allocation, progress monitoring, and report generation, which significantly increases the efficiency of project management;

b) the use of artificial intelligence (AI), in particular in analytical work with large amounts of data to identify trends, predict risks and optimize decisions, predict possible delays in the project and suggest ways to avoid them;

Strengths	**Weaknesses**
Active implementation of electronic services. High level of ICT infrastructure, availability of a developed infrastructure for the implementation of information and innovation technologies. Growing number of innovative enterprises and support from the government. Support from international organizations.	Uneven development, different levels of ICT development in urban, settlement and rural communities. The need to increase the level of digital literacy among the population. Low level of digital literacy among the population. Insufficient funding.
Opportunities	**Threats**
Expanding the use of artificial intelligence. Support from international organizations, possibility of receiving grants and technical assistance from international organizations. Development of digital services, introduction of new digital services to improve community management. Creation of a single state platform for electronic services.	Cyber threats. Cybersecurity, risks related to cybersecurity and data protection. Economic instability, the impact of economic instability on the financing of innovative projects. Lack of a clear strategy for digital transformation.

Fig. 2. SWOT-analysis of information and innovation technologies for community management in Ukraine
(*Source: own research*)

c) the introduction of cloud technologies to provide access to information from anywhere and at any time, which allows storing large amounts of data without the need for local infrastructure and improves communication and cooperation between project participants;

d) the accumulation of blockchain technologies to ensure transparency and security of transactions and data, tracking the implementation of tasks, managing contracts and ensuring compliance with regulatory requirements;

e) the establishment of the Internet of Things (IoT) and its use to collect data from various devices and sensors in real time to monitor the condition of equipment, control resources, and optimize production processes;

f) focusing on certain aspects of project management in the virtual and augmented reality (VR/AR) environment in terms of staff training, project visualization, and modeling of various scenarios to enhance understanding of complex processes and make informed decisions;

g) spreading Big Data analytics to obtain valuable information about trends and patterns in strategic decision-making. However, there is a fundamental difference in the use of information and innovation technologies in the development of territorial communities depending on their category, in particular in the process of large and complex projects (Fig. 3; Table 1, source: compiled by the authors based on [1–8]).

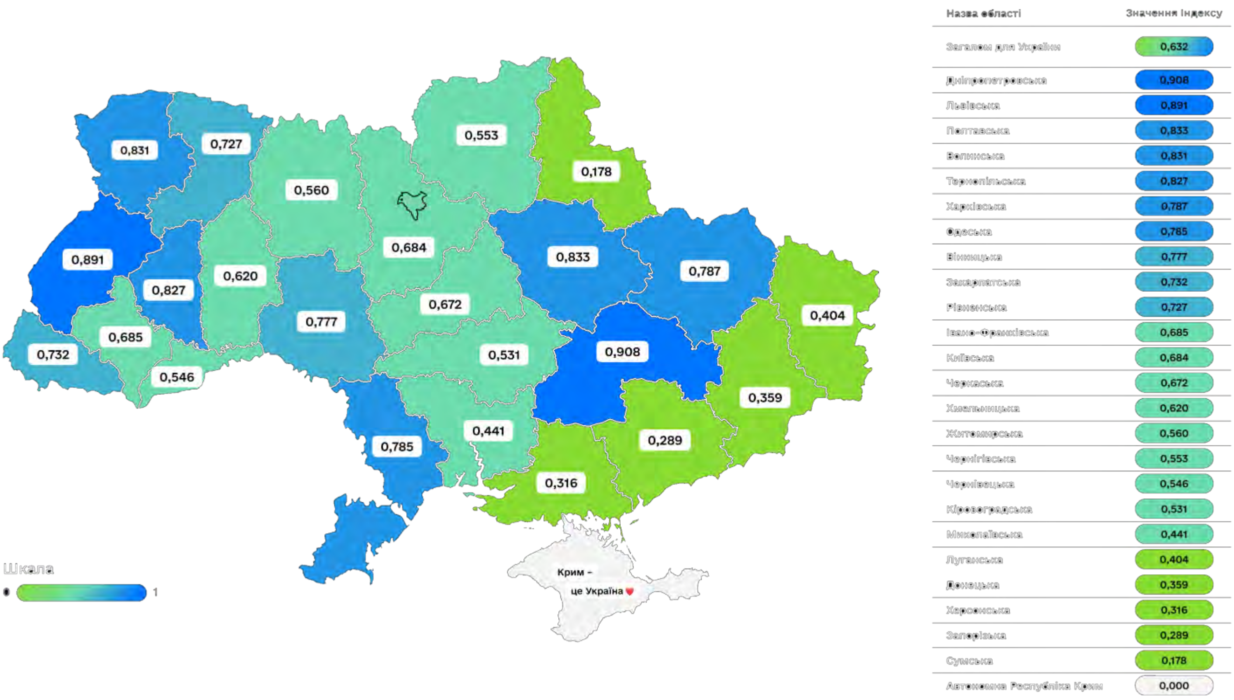

Fig. 3. Digital transformation index of Ukraine's territories in 2023
(*Source: compiled based on data from [8]*)

Table 1

Use of information and innovation technologies by communities

Feature	Cities	Settlements	Villages
1	2	3	4
Investment in innovation	Urban communities typically have larger budgets and invest more in information and innovation technologies, with investments in smart cities reaching billions of dollars in developed countries	Suburban communities have more limited budgets than urban ones, but still invest in infrastructure and technology development	Rural communities have the smallest budgets for investments in information and innovation technologies
Internet coverage	In urban areas, the level of access to high-speed Internet is much higher than in rural areas	The level of Internet access in settlements is usually lower than in cities, but higher than in rural areas	The level of Internet access in countryside is much lower than in urban and suburban areas

Continuation of the table 1

1	2	3	4
Innovation readiness	Urban communities are often leaders in the implementation of new technologies, such as smart transportation systems, energy and security management	Suburban communities often adopt technology to improve public services and resource management	Rural communities often face difficulties in adopting new technologies due to limited resources and infrastructure
Challenges	The main challenges include the high cost of implementation and the need to integrate different systems	Key challenges include limited financial resources and the need for staff training	The main challenges include low levels of digital literacy and lack of infrastructure
Assessment of the number of innovation and information infrastructure facilities	Urban communities usually have the largest number of innovation and information infrastructure facilities.	Suburban communities have fewer innovation and information infrastructure facilities than urban ones, but still a significant number	Rural communities have the smallest number of innovation and information infrastructure facilities
Administrative service centers (ASCs)	They are widespread in urban communities and provide access to a variety of public services	Many suburban communities have their own ASCs that provide access to administrative services	Many rural communities do not have their own ASCs, but they can use the services of mobile ASCs or contact the nearest village or city ASCs
Innovation hubs and technology parks, Internet centers, Internet access	Cities such as Kyiv, Lviv, and Kharkiv have several technology parks and innovation hubs that support startups and tech companies	Internet centers are often established in settlements to provide access to information resources	The level of Internet access in rural communities is much lower, which limits opportunities for the introduction of innovative technologies
Digital platforms and services, digital educational programs, digital educational initiatives	Urban communities are actively implementing digital platforms for managing urban resources and services	Suburban communities are actively implementing digital educational programs to improve the digital literacy of the population	Digital literacy programs are often held in rural communities, but their number and coverage are limited

The number of innovation and information infrastructure facilities varies significantly by community type. Urban communities have the largest number of such facilities, rural communities are in an intermediate position, and rural communities have the smallest number of facilities due to limited resources and infrastructure.

The territorial communities with a high level of innovation and information infrastructure in Ukraine include such urban areas as Kyiv (the capital of Ukraine is a leader in the implementation of innovative technologies, with numerous technology parks, innovation hubs, and administrative service centers; Kyiv is actively implementing smart city projects), Lviv (the city is known for its IT clusters and innovation initiatives that bring together more than 100 companies and actively promote the development of innovative infrastructure) [9]. Unique is the experience of such village councils as Novoborivska community in Zhytomyr region, which is known for its tourism and recreational potential and active implementation of innovative technologies for the development of local infrastructure, and Slavska community in Lviv region, which is actively developing tourism infrastructure and implementing digital technologies for managing resources and services; rural – Bilozirska community in Cherkasy region is known for its initiatives in the field of digital education and implementation of innovative technologies to improve the quality of life. These examples demonstrate how different types of communities can successfully implement innovative information technologies to improve the quality of life and develop local infrastructure [14].

The activation of territorial community development processes is proposed through the Digital Community project management mechanism, which aims to improve the efficiency of territorial community management through the introduction of modern information and innovation technologies. The main objectives of the project are as follows:

a) development and implementation of a digital platform for community management, which will include modules for electronic document management, budgeting, project management, and communication with residents;

b) training and professional development of local government employees in the field of information and communication technologies (ICT) and digital technologies;

c) development of digital infrastructure: providing access to high-speed Internet in all settlements of the community;

d) introduction of electronic services for The pilot announcement of the project implementation on the example of the Bronyky village council envisages the following stages of implementation:

1) analysis of community needs (conducting surveys and collecting data to identify key needs and problems);

2) development of terms of reference, determination of requirements for the digital platform and other project components;

3) selection of suppliers and partners, tendering and contracting with hardware and software suppliers;

4) development and testing of the platform, creation of a prototype, its testing and making necessary changes;

5) staff training through the organization of trainings and seminars for local government employees;

6) implementation of the project. The expected results of the project implementation are to increase the efficiency of community management, increase the transparency and accountability of local authorities, improve the quality of service delivery to residents, and stimulate local economic development through support for innovative enterprises. This project can be adapted to the specific needs of the community, taking into account its unique characteristics and challenges.

The estimated cost of implementing the Digital Community project includes the following elements: development and implementation of a digital platform ($2000), staff training ($500), development of digital infrastructure ($1500), implementation of electronic services ($1000), support for innovative startups ($1000), and the total project cost is $6000. Expected economic benefits: reduction of management costs by 20%, savings in the community budget (approximately $1200 per year), increase in work efficiency by 15%, increase in employee productivity, increase in revenues from new services – $500 per year. The total annual benefits of the project will amount to $1700, and the payback period will be 3.5 years. However, no less important is the project's environmental impact by reducing paperwork, reducing paper use by 80%, which contributes to forest conservation, reducing CO_2 emissions, and reducing transportation by 10%. Social benefits include improved access to services, increased availability of online services, and reduced time and costs for obtaining them. Staff and residents will be trained to improve their digital literacy. The introduction of electronic services will ensure greater transparency and accountability of local authorities. The availability of a digital platform will facilitate better communication between residents and authorities. Expected sources of funding may include the state budget, international donor organizations, the private sector, and NGOs. The assessment of the synergistic effect of cooperation between the authorities, local self-government, and the public sector is reflected in the econometric model of community budget growth (Y) depending on investments in public sector development $(X1)$ and the level of education of the population $(X2)$:

$$Y = \beta 0 + \beta 1 \times X1 + \beta 2 \times X2 + \varepsilon \ , \qquad (1)$$

where $\beta 0$, $\beta 1$, $\beta 2$ – regression coefficients;

ε – random error.

A graphical representation of the scenario analysis of the territory's development, provided that the existing trends are maintained (a), a project-based approach to management is applied (b), and all stakeholders cooperate, is shown in Fig. 4.

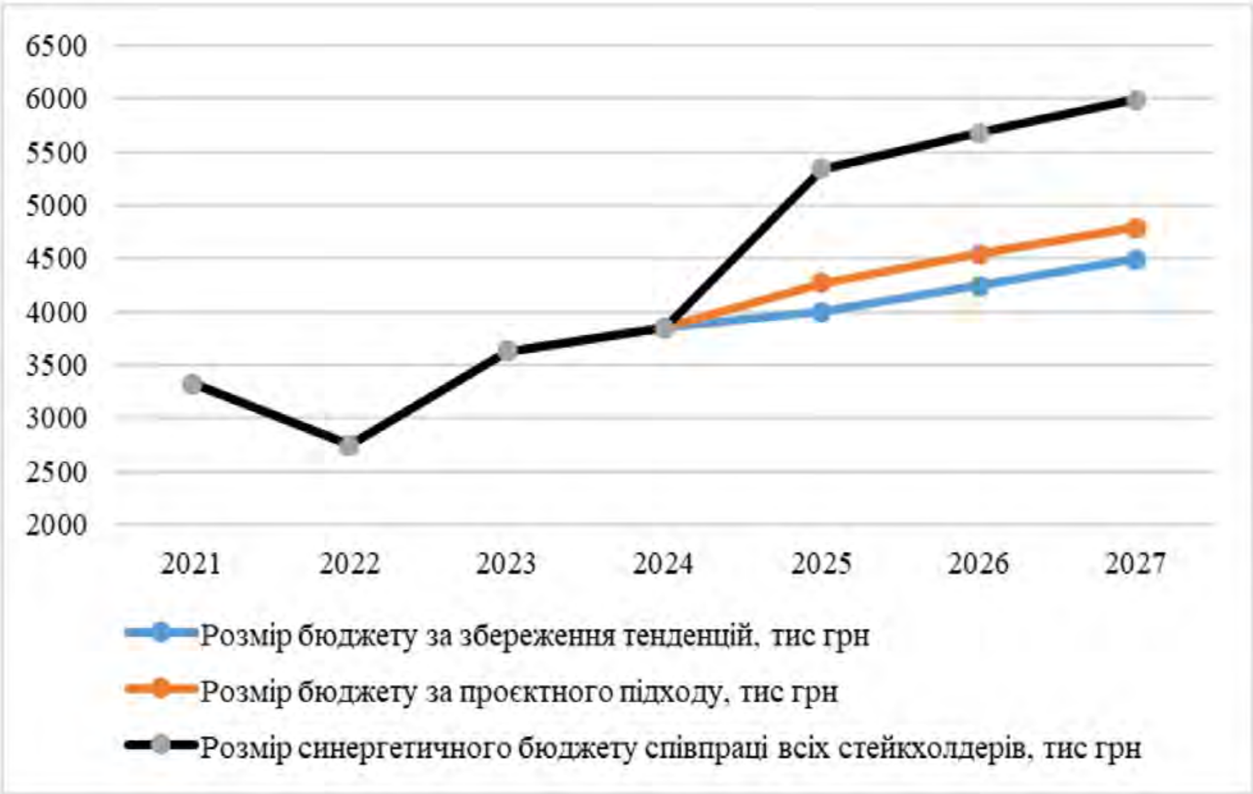

Fig. 4. Budget forecast for the Bronyky community
(*Source: own research*)

Thus, information systems are an integral part of modern project management for the development of socio-economic systems. They ensure effective planning, control, communication, and analysis, which contributes to the successful implementation of projects. Innovative technologies are significantly changing approaches to managing projects for the development of socio-economic systems. They increase the efficiency, transparency, and security of processes, and facilitate informed decision-making. However, for the successful implementation of these technologies, it is necessary to take into account possible challenges and limitations, such as cost, data security, and the need for staff training. Information and innovation technologies for the development of territorial communities contribute to the intensification of socio-economic processes in the territory by increasing the transparency of operations, monitoring and control over their implementation by a large number of stakeholders, and increasing the efficiency of economic and administrative decisions. At the same time, these indicators vary considerably depending on the type of community. Urban communities have more resources and opportunities to innovate, while rural and settlement communities face greater challenges due to limited resources and infrastructure.

References

1. Ecological rural tourism in the management of conflicts in business and communities. Tavriyskyi naukovyi vestnik. Series: Economics. 2024. №20. P. 332–343.
2. Plotnikova M., Kilnitska O., Kurylenko D. Formation of sustainable systems as a component of their socio-economic innovative development. Intelligent information systems in project management and the economy under martial law: Proceedings of the International Scientific and Practical Conference (September 13–16, 2022). Kharkiv: NURE, 2022. P. 15–18.
3. Yaremova M., Tarasovych L., Kilnitska O., Buluy O., Kravchuk N. Global trends in the development of a sustainable bioeconomy for rural growth in Ukraine. Scientific Horizons. 2024. Vol. 27(3). P. 117–129. DOI: 10.48077/scihor3.2024.117
4. Management of resources of territorial communities in the postwar period. Management and rational use of land resources in territorial communities in the postwar period: materials of the VII All-Ukrainian Scientific and Practical Conference (March 07, 2024). Kherson: KHSAEU, 2024. P. 40–44.
5. Ayfantopoulou G.; Toulumidis D.; Mallidis I.; Xenou E. A Quantitative Model of Innovation Readiness in Urban Mobility: A Comparative Study of Smart Cities in the EU, Eastern Asia, and USA Regions. Smart Cities. 2023. Vol. 6. P. 3337–3358. DOI: https://doi.org/10.3390/smartcities6060148
6. Afradi, K., Nourian, F.. Understanding ICT's impacts on urban spaces: a qualitative content analysis of literature. GeoJournal. 2022. Vol. 87. P. 701–731. DOI: https://doi.org/10.1007/s10708-020-10277-2
7. Tahmasebi F. The Digital Divide: A Qualitative Study of Technology Access in Rural Communities. AI and Tech in Behavioral and Social Sciences, 2023. Vol. 1(2). P. 33–39. DOI: https://doi.org/10.61838/kman.aitech.1.2.6
8. Results of digital transformation in the regions of Ukraine in 2023. Ministry of Digital Transformation of Ukraine. 2024. January 11. URL: http://surl.li/mhxmle
9. Innovative development of territorial communities in the context of the fourth technological revolution: priorities and prospects. National Institute for Strategic Studies. 2019. May 8. URL: http://surl.li/lshhtk
10. Analytical note. Overview of the situation regarding the implementation of partnerships between urban and rural territorial communities in the context of decentralization and changes in the state regional policy in Ukraine (summary). Institute of Civil Society. 2018. October 30. URL: http://surl.li/ylceoz

11. Innovative activity of enterprises. URL: http://surl.li/iejufu
12. Strategic foundations of innovative development of territorial communities. URL: http://surl.li/qznrqp.
13. Network Readiness Index 2020: Digital Transformation at a Glance. 2021. URL: http://surl.li/lbmmrs
14. Hickman D., Marushevsky G. Methodological recommendations for the implementation of strategic environmental assessment for urban planning documentation: presentation of the first draft Online meeting on September 29, 2021. URL: http://surl.li/tqfoye

DOI: https://doi.org/10.30837/MMP.2024.212

DETERMINING THE IMPACT OF VUCA-WORLD AND BANI-WORLD ON THE ACTIVITIES OF ENTERPRISES IN THE EXPERIENCE ECONOMY

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The relevance of the research is determined by the need to determine the basic models of functioning of the internal and external environment of enterprises both separately and in their interconnection and taking into account mutual influence. Since it is a recognized fact that the modern external environment is constantly transforming, becoming more complex and moving from one state to another, more complex, its main manifestations are VUCA-world and BANI-world, which is also typical for the Ukrainian economy. Therefore, the purpose of this study is to publish the developed methodology for determining the impact of VUCA-world and BANI-world on the activities of enterprises in the impression economy and to present the results of its practical testing. The object of the study is the course of influence of VUCA-world and BANI-world factors on the factors of the internal environment of domestic enterprises in the conditions of the experience economy. The subject of the study is to improve and further develop the theoretical, methodological and methodological support for the analysis of external environment factors according to the most common VUCA-world and BANI-world models and the factors of the internal environment of industrial enterprises in the context of the experience economy. The research methods used were analysis and synthesis, theoretical generalization, structural and logical analysis, systematic approach, multidimensional factor analysis, neural networks, and the method of additive convolution. The main results of the study are the developed methodology for determining the impact of VUCA-world and BANI-world on the activities of enterprises in the context of the impression economy and its practical testing, which includes the following stages: analysis and substantiation of factors and indicators of the internal and external environment of enterprises using the method of multivariate factor analysis; modeling of functional relationships between indicators of the internal and external environment separately and in their direct and inverse relationship using the method of neural networks; definition and p The conclusions of the study are as follows: proving the nonlinearity of the impact of VUCA-world and BANI-world on the activities of enterprises and vice versa through the built models of interconnection, which are nonlinear models of the multilevel perceptron; substantiation and rating of indicators of sensitivity of the internal and external environment of enterprises, selection of the top 3 from their composition; formation of proposals for managing the activities of enterprises in a complex nonlinear internal and external environment.

Introduction

Over the past 5 years, Ukraine has been experiencing 2 major economic and social crises, caused in 2019 by the COVID-19 pandemic and exacerbated in 2022 by a full-scale military invasion. These conditions pose a significant challenge to the external environment for businesses. In order to successfully withstand these conditions, business entities must constantly improve and develop their activities, adapting to the impact of external factors, and adapt their internal state by increasing the level of innovation. This is confirmed by the practice of developed countries, where innovations are the main driving force of socio-economic development, and economic relations are developing according to the latest economic models. One of the most promising models is the impression economy model, which focuses on the formation of positive impressions of the achievements and capabilities of enterprises by their stakeholders. The difficulty of the impression economy model is to take into account the transformation that takes place in the external environment of enterprises. Changes in the influence of the external environment are caused by its characteristics – variability, uncertainty, nonlinearity and fragility. Such changes are inherent in the economic relations of all countries of the world due to the transformation of the external environment of enterprises in the international economic environment of the globalized world, as noted by scholars [1–10]. The stable, expected, simple and defined SPOD-world has become inherent only in certain industries in certain countries. In general, the external environment in most industries and countries is becoming volatile, unknown, confusing, unclear, i.e., it is turning into a VUCA-world, fragile, weak, anxious, disturbing, nonlinear, inexplicable, incomprehensible, which corresponds also to the BANI-world, economic relations are gradually plunging into disorder, chaos, self-centeredness, turbulence, i.e., the DEST-world is beginning to form [3, 4]. In order to be successful in such a situation, enterprises must use adequate methods, management models based on in-depth studies of the composition of external environment factors, their sensitivity to change, and the internal environment to determine the possibility of their adaptation to the transformation process, which should be based on innovative processes. These issues have been studied by many scientists [4–7], who proposed certain measures to counteract the manifestation of the troubles of these worlds. However, this issue still remains open, since all aspects of the impact of these unstable worlds in relation to the innovative development of enterprises in terms of their ability to use and manage internal factors and influence external ones in the context of the impression economy have not been clarified and studied.

Therefore, the relevance of the chosen topic is beyond doubt. In this regard, the aim of the study is to publish the developed methodology for determining the impact of VUCA-world and BANI-world on the activities of enterprises in the conditions of the impression economy and present the results of its practical testing.

The object of the study is the course of influence of VUCA-world and BANI-world factors on the factors of the internal environment of domestic enterprises in the conditions of the experience economy.

The subject of the study is to improve and further develop the theoretical, methodological and methodological support for the analysis of external environment factors according to the most common VUCA-world and BANI-world models and internal environment factors of industrial enterprises in the context of the experience economy.

The research methods used are general scientific and special methods of cognition: analysis and synthesis, theoretical generalization, structural and logical analysis, systematic approach, multidimensional factor analysis, neural networks, additive convolution method, graphical method.

1 VUCA-world and BANI-world: characteristics and research methodology

The modern world is unpredictable, risky, and fragile. Nowadays, more and more scientists are devoting their attention to researching and studying this world. In scientific and economic circles, it is common to call this world the VUCA-world and the BANI-world. These worlds are different, but many scientists consider them together, as no exact boundary for their separation has been proposed. Work [4] notes that the VUCA-world is focused on the unpredictability of external and internal circumstances of society's development.

VUCA is an abbreviation of the English words: Volatility; Uncertainty; Complexity and Ambiguity. In this world, everything is changing rapidly, it is difficult to predict the future, the level of confusion, tension and chaos is growing, and problems are being formed due to the difficulty of understanding various facts and causes. However, this difficult world is being replaced by the BANI world, which is even more unpredictable than the previous one. The beginning of the BANI-world is considered to be the beginning of the Covid-19 period, as noted by Professor J. Cascio of the University of California [5]. The BANI world consists of four English words: Brittle; Anxious; Nonlinear and Incomprehensible. This world reflects the instability of systems that can unexpectedly change the direction of their action, i.e. "break", characterizes the growing level of stress and anxiety due to the unpredictability of events, their nonlinear development, when even minor changes can have significant consequences and situations that are difficult to understand or explain due to their complexity. Such conditions of the described worlds are characteristic of certain industries, geographical areas, and enterprises. It is impossible to assert that absolutely all economic relations have the characteristics described. There are certainly some parts of economic relations that still function in the SPOD world. Thus, economic relations are similar to certain unevenly arranged puzzles that seek to take their place in the world economy. However, most of these puzzles function in the VUCA world and the BANI world.

Global economic crises, pandemics, and wars have created new challenges that many countries, regions, and businesses have not been prepared for. Only those organizations that are able to change approaches to managing their activities, ensure high adaptability and flexibility can survive and continue to operate successfully in the market in the new conditions [3].

The presented results of the study on the behavior of enterprises in the process of functioning in unstable conditions of their work [6] are concentrated in a three-stage model that will help enterprises to be successful in the VUCA-world. In accordance with the model, it is advisable to define your VUCA-world, i.e., describe it, research it, identify factors; identify obstacles to ensuring adaptive behavior; implement practices that increase flexibility. The proposed three-stage model is indeed an interesting way to confront the changing and unexpected conditions of the external world. The first stage emphasizes the importance of managers understanding where their companies are in their development and where they stand. Only those who understand and correctly assess their advantages and disadvantages will be able to survive in VUCA-world. After identifying the weaknesses of their company, managers must assess what obstacles are preventing them from eliminating the shortcomings or will prevent them from eliminating them. And at the third stage, managers should not only make changes to eliminate the shortcomings, but also apply reasonable measures that will increase the flexibility and adaptability of the enterprise to unstable environmental conditions. In other words, it is advisable to model the behavior of the enterprise, identify the most sensitive indicators and influence changes in their values so that the enterprise follows a certain development trajectory.

There are also other models for adapting, taking into account or opposing the effects of the VUCA world and the BANI world. These models have the same names as their worlds and involve the use of appropriate methods. In order to reduce the negative impact of the VUCA-world, it is advisable to use the VUCA method [7], which means:

V – Vision forms an idea of where and why the company is moving, for what purpose, what risks it may face, values and business philosophy;

U – Understanding implies awareness of constant changes in business, which is the norm of existence, the reasons for which lie in the changing environment;

C – Clarity means eliminating unimportant things, focusing on strategic areas of activity, optimizing production and business processes;

A – Agility means rapid adaptation to environmental changes, formulating a list of alternatives for making operational and strategic decisions.

To reduce the negative impact of the BANI-world, it is proposed to use the BANI method, which focuses on the following:

B – Balancing is the search for balance in all processes of the enterprise. Managers are able to analyze changes in real time and make effective decisions. The company's management should stimulate effective interaction between structural units. Regular communication and information exchange help to ensure understanding and comfort with the purpose, scope, and expectations of the goals;

A – Adaptability – the ability to adapt quickly. The company's management should adapt and improve in accordance with changes and create new strategies, optimize the use of available resources, and employees should be ready to learn something new quickly;

N – Nous – the ability to use the principle of common sense, to look for optimal but creative ways to solve problems. Business units should be open to innovative ideas, look for new opportunities and be ready to introduce new products, services, methods, technologies, etc;

I – Intuitive – the ability to plan and predict in the face of uncertainty.

The unpredictability of the BANI world is accompanied by increased risks. Enterprise management should be focused on identifying and assessing the risks of its activities. Effective risk management will allow you to successfully perform work even in difficult economic and other conditions.

The worlds of VUCA and BANI intersect and create a certain symbiosis; it is impossible and inappropriate to consider them separately. Summarizing these two worlds, it can be concluded that the use of the VUCA method allows enterprises to be competitive in a changing business environment and ensure further development of their business activities. Over the past few years, the world has been characterized by turbulence and fragility, which are inherent in the BANI world. Thus, modern enterprises must respond quickly and invent new strategies and intensify innovation in a rapidly changing environment, while engaging intuition, emotional intelligence and developing creative thinking, which is inherent in such a model of economic relations as the experience economy [11].

In general, global economic relations are transforming into six models [11].

The first model is the exabyte economy, which combines devices, digital technologies, and human capital as its main components. After all, two-thirds of the world's population uses mobile phones, and more than half have access to the Internet. Under martial law in Ukraine, remote work has become widespread and is growing annually, new Internet services such as the Internet of Things are emerging, the speed of Internet networks is increasing due to 5G technology, and certain activities and services are practically moving into the online space, such as education, healthcare, trade, banking, financial settlements, office work, reference information, statistical data transmission, etc. Digitalization and digitalization trends are expanding to varying degrees to almost all types of activities.

The second model is the wellbeing economy, which is based on changes in the behavior of the population and its approaches to lifestyle, mental state, psychology of relationships, and physical health. Such changes affect the volume of production, provision of services by lifestyle-related industries, namely, healthy lifestyles, self-development, other psychological and organizational practices, behavioral changes that involve an increase in travel, namely, health, gastronomic, extreme, green, and educational tourism. In other words, due to changes in lifestyle and behavior, economic relations are undergoing transformations that expand opportunities and promote the development of service businesses, creative cultural industries, certain healthcare services, and sporting events, which expands not only individual national markets but also the global market for certain industries.

The third model of the economy is the carbon-neutral economy, characterized by environmental protection, which involves reducing CO2 emissions through the use of innovative products, technologies and investment models for the use of alternative energy sources and the latest types of energy resources.

The fourth model is the circular economy, which is based on consumerization, conscious consumption of products and use of services in an effort to extend their service life. The need for the formation and use of the circular economy is driven by the growth of the population and the need to provide it with food, goods, and services, the number of which is growing at a slower rate than the population growth rate. The functioning of a closed-loop economy or circular economy is aimed at reducing the negative impact on the external environment, lean production, and waste reduction.

The fifth model is the biogrowth economy, which involves limiting resources in an effort to ensure the welfare of the population and its comfortable living. Therefore, the biogrowth economy is aimed at the growth and introduction of genetic engineering achievements into production, the creation of new biomaterials capable of self-destruction, which will be useful in the processing of certain types of products into others.

The sixth model of economic relations is embodied in the experience economy, which, in terms of development prospects and sectoral scope, has the best result of implementation and forecasting of its development prospects. This is confirmed by the thesis that decision makers in both the production and service sectors are guided not only by rational information but also by subjective impressions, motives and expectations, since a management decision is objective and subjective in nature, as it is based on rational and emotional expected values and benefits. It is the essence of the decision-making motives that plays a leading role in this model. Industry affiliation determines the predominance of rational or emotional motives. In other words, in the impression economy, the positioning of business entities on the rational-emotional continuum varies depending on their industry affiliation, factors of influence, motivation, specifics of relations with partners and aspirations of partners, consumers and certain segments of the market and society interested in the functioning of business entities from the standpoint of their material value, social profitability and capacity. The social and emotional play a significant role in the impressions economy, while technological innovations fill them with new content and opportunities. This applies to the milestones of the national economy and involves the use of such achievements as artificial intelligence, 3D reality technologies, biogenic engineering, etc.

Thus, the experience economy is becoming a new promising model of economic relations in any sphere of production and services, based on the solvency of partners and consumers, their conscious consumption based on rational management decisions, and at the same time paying attention to greening with care for the environment, obtaining additional social, cultural, psychological, and experiential pleasures through the formation of experiences. That is, in the chain "raw materials – products – services – impressions", the value and added value increases with each element, i.e., it migrates from raw materials to impressions.

The impression economy is able to mitigate the challenges of the VUSA and BANI worlds to some extent by identifying factors and indicators that can convey positive impressions to consumers and partners of enterprises about the performance of enterprises and their future opportunities. In other words, the impression economy is the model that will allow to rebuild the national economy in the postwar period, so it is advisable to pay significant attention to its development and use it to achieve the success of enterprises.

In the current difficult conditions of martial law, Ukraine has a BANI world, which was not only caused by COVID-19 but also reinforced by the event that took place on February 24, 2022. A full-scale war in real time demonstrates the fragility and anxiety of the outside world. Considering these worlds, the authors of the study proposed a methodology consisting of a sequence of stages and methods that should be used by enterprises to ensure the success of their activities in the worlds under consideration, which are characteristic of the external environment in the current conditions of the impression economy model:

– analysis of external and internal environment factors, determination of the most relevant factors of priority importance, for this purpose it is advisable to use the method of modeling by multivariate factor analysis;

– determination of adequate models of the relationship between these factors; as a method of determining the relationship, it is advisable to use neural networks that are close in their algorithm to the process of human thinking, it is possible to hypothesize that such models and relationships between the factors of the internal and external environments of enterprises will be non-linear;

– in accordance with the selected and substantiated models, to forecast the values of indicators of the internal and external environment and to determine the most sensitive indicators characterizing the factors of the internal and external environment by rating;

– to make management decisions on changing the values of selected sensitive indicators, the impact of which will allow enterprises to adapt to the relevant changing world as soon as possible in the process of functioning of the impression economy model;

– to use change-sensitive indicators as a basis for forming positive impressions of the enterprise (according to the impression economy model), which are characteristic and necessary for the growth of their added value and profit at a faster rate compared to other models of economic relations development to start and continue productive cooperation with partners and relationships with consumers.

The proposed methodology can be applied to both the VUCA world and the BANI world, which proves its universality. The difference lies in the indicators selected to characterize these two worlds. It is the justification of the indicators that will take into account their peculiarities, while the process of managerial influence can be carried out according to the same algorithms and procedures.

Common to the life of enterprises in these two worlds is the proposal to intensify innovation activities, increase the level of innovation, which can significantly affect the formation of positive impressions of the enterprise among consumers and partners, its performance and opportunities. Thus, innovative development is the key to the success of enterprises, as noted by many scientists in their works [14, 21–30].

Any socio-economic system succeeds in its activities if it is in a state of consistent and steady development. Innovative development of an enterprise as an economic category is a set of relations that arise in the course of a targeted increase in the economic efficiency and competitiveness of an enterprise on the basis of qualitative changes that provide innovation [22].

The competitiveness of the national economy is one of the determining factors in ensuring sustainable development and well-being of the country, stability of the national economy in the context of global economic crises and a factor in raising social standards. In order to ensure the competitiveness of the national economy, both large and medium-sized and small enterprises must intensify their innovation activities [25].

The intensification of innovation is the main condition that ensures the development and improvement of production efficiency of enterprises, and thus contributes to their competitiveness. Implementation of innovative changes should take place on an ongoing basis, which requires management to manage these changes in a targeted and thoughtful manner. One of the reasons for the failure to implement innovative changes is the lack of effective organizational support for the activation of the innovation management system at the enterprise [27–29].

Many studies show that local authorities play an important role in stimulating innovation. In this case, not only direct investments from the local budget are important, but also the creation of favorable institutional and legal conditions for innovation [25, 28]. Funds from local sources are usually allocated on a competitive basis or by direct decision of local authorities. Informal mechanisms are also important, and their role is growing with the increase in funding.

An analysis of the factors that contribute to the intensification of innovation activities of enterprises shows that, first, the innovation process is market-oriented and should take into account the needs of both the national and global markets; second, the production of innovations must meet the level of effective demand; third, it is necessary to form an innovation infrastructure. On 14.03.2023, the Department of Investment, Innovation and Intellectual Property published information on the state of development of innovation infrastructure on the State website of Ukraine, where it was stated that Ukraine has created and is operating in accordance with the Strategy for the Development of Innovation Activities until 2030: industrial parks, technology parks, centers of innovation and technology transfer, commercialization centers, innovative business incubators, clusters, etc. However, their activities are hampered by the hostilities. In order to intensify innovation, it is necessary to restore state financial support by amending the legislative acts that regulate its receipt and in which its effect is suspended, to initiate the adoption of the draft law "On State Financial Support for Innovation", which would provide state financial support and benefits through the creation of venture capital funds at the regional and state levels. In order to make the right decisions in innovation, it is necessary to process a large amount of information. In this regard, it is advisable to create centers of innovative knowledge. Taking into account the unsatisfactory current state of marketing support of innovation activities of enterprises, which is aggravated by the low level of information support at enterprises and the decrease in the creative activity of employees, it is necessary to improve the work of marketing departments and to direct their activities to the implementation of innovative research [22], which would have a direct connection with the regional and the State Center for Innovative Knowledge. At the stage of intensification of innovation activity, it is important to quickly and efficiently perform each stage and phase of the innovation process, reflecting the transition of innovation to material production: from the initiation and implementation of basic research, prototyping and laboratory testing, to the organization of serial or mass production of new products and their implementation and maintenance. In addition to accelerating the quality of the stages, it is also very important not to spend more time than competitors at the intersections of stages and phases of the innovation process.

To intensify the innovation activities of enterprises, it is necessary to determine the direction, features and composition of the factors of influence of the external environment on the internal environment of enterprises, namely their innovation activities. In article [15], the authors refer to the internal influence as: production; economic; environmental; innovative and organizational and structural factors. They divided the external influence into the macro level, which is characterized by: scientific and technical; geographical; economic; environmental; social; state and political factors and the micro level, which includes suppliers and consumers. The authors of [16] propose a division into endogenous and exogenous factors of innovation potential. Thus, they include the following endogenous factors: history and image of the enterprise; strategic priorities; quality of management; marketing; production; financial condition and economic situation. The exogenous factors include the political and legal environment; economic environment; technological environment; scientific and technical environment; socio-cultural environment; and competitors.

The authors of [17] propose to divide internal factors into 5 groups: production factors; financial factors; market factors; organizational factors; and human factors. External factors are divided into macroeconomic, political, social, and environmental.

In addition, a balanced scorecard can also be used to identify the impact of factors on the company’s operations. A balanced scorecard is a system of strategic management of an organization based on measuring and evaluating the effectiveness of its activities by a set of indicators selected in such a way as to take into account all significant (from the point of view of strategy) aspects of the organization's activities (financial, marketing, production, etc.) [18].

Summarizing the proposals of scientists, as well as relying on the possibility of taking into account the quantitative values of the measurement of factors, their list can be presented as follows. The internal environment may include financial, material, technical and technological, human, information, innovation, marketing, and organizational factors. External factors include economic, scientific and technical, political, legislative, socio-demographic, environmental and geographical.

Since it is necessary to find the impact of VUCA-world and BANI-world on the enterprise's activities, it is necessary to understand that it is necessary to choose an analysis that will take into account the nonlinearity of these two worlds and, among a large amount of input information, will leave only those indicators that will have a high impact. In many cases, the performance indicator is influenced by more than one factor. There are complex interrelationships between the factors, so their impact on the performance attribute is complex. In this case, multivariate factor analysis can be used for mathematical modeling, which makes it possible to prioritize indicators and reasonably reduce their number without losing information. Multivariate factor analysis is a research method used to study and evaluate the impact of several variables (factors) on a dependent variable. This analysis helps to understand how different factors interact with each other and how they jointly affect the results [31, 32].

The advantages of this analysis are as follows: this method provides a comprehensive view of the impact of various factors on the results, which helps to make informed management decisions. Improves forecast accuracy by taking into account more variables and their interaction. Reduces the risk of simplistic analysis by taking into account more aspects of the problem.

Among the disadvantages is that the use of multivariate factor analysis requires a large amount of data and data quality for accurate results. There is a risk of creating an overly complex model that takes into account too many variables, which can lead to overfitting and poor generalizability of results. Conducting multivariate factor analysis can be very costly in terms of time and resources, especially for large and complex studies.

After obtaining the results of multidimensional factor analysis, which is able to reasonably limit the number of indicators by factors, the next step is to combine them into integrated indicators for internal and external environments using the same methodology to achieve comparability (ISP) by the additive convolution method [32]:

$$ISP = \sum_{i=1}^{n} C_{sign.i} \frac{X_{ac.i}}{X_{r.i}} \quad (1.1)$$

where, $C_{sign.i}$ is the significance coefficient of the i -th partial indicator;

$X_{ac.i}$ – actual value of the i -th partial indicator;

$X_{r.i}$ is the reference value of the i -th partial indicator;

n – number of partial indicators.

Having calculated the integral indicators for the internal and external environments, the next step is to find out whether the environments actually influence each other. To do this, you need to use the neural network method. Neural networks are one of the methods of machine learning, a subdivision of artificial intelligence (AI), and are the basis of deep learning algorithms. They are able to search for patterns in unstructured data and solve many problems [33].

Neurons process input signals using a specific activation function [34]. Neurons are organized into 3 layers: input layer, hidden layers, and output layer. Input layer: receives input data. Hidden layers: process input data through weighted connections. Output layer: generates the final result of processing. Activation functions characterize the types of connections between the internal and external environments. Since, according to proposals and hypotheses, the worlds under consideration are characterized by non-linear relationships, the most likely function is a multi-layer perceptron. A Multi-Layer Perceptron (MLP) is a type of artificial neural network consisting of at least three layers of neurons: an input layer, one or more hidden layers, and an output layer. It is one of the simplest and most common types of neural networks for classification and regression tasks.

Neural networks, in particular multilevel perceptrons, are appropriate for proving the nonlinearity of worlds because they are able to learn and model complex nonlinear relationships between variables. They effectively use nonlinear activation functions and multilayer architecture to detect and process nonlinear patterns in data, confirming that the real world contains complex relationships that cannot be reduced to simple linear models [33, 34].To apply neural networks, we chose the Statistica 10.0 application program, a statistical analysis package developed by StatSoft. In the same package, it is possible to determine the sensitivity rating of indicators by factors in order to model changes in their quantitative values with the greatest effectiveness of influence on the relationship between the internal and external environments of enterprises.

As the main indicators of the internal environment, it is advisable to choose those that characterize innovation activity, since world experience shows that in the most economically developed countries, innovation is a crucial condition for ensuring stable long-term economic development [35, 36]. For example, Japan's innovative development has the following features: enhanced government intervention in the management of innovative development; promotion of the acquisition of science and technology achievements of foreign countries by enterprises; close interaction of all stages of the innovation process; creation of togusan (large innovative business structures) to develop joint investment projects to penetrate new areas; financial support for science at universities; a system of preferential taxation and lending. The source of South Korea's economic growth is large industrial groups and government support for their innovative development. China is characterized by an imitation model of innovative development based on active imports of foreign technologies and their industrial assimilation for the purpose of manufacturing high-tech products. The country has created a streamlined system of centralized management, and a program-targeted approach to the development of scientific and technical programs is widely used [35, 39].

Germany, the United Kingdom, France, the United States, and Japan form the technological core of global development. Each of these countries is a world leader in terms of absolute expenditures on research and development. In other countries, tax incentives are used to stimulate scientific and technological progress. For example, preferential tax regimes have been introduced in the United States, Germany, the United Kingdom, Italy, Japan, and Brazil [38]. According to international experience, improving the system of innovation management at enterprises requires theoretical and practical research on the possibilities of stimulating innovation not only at the enterprise level, but also at the national level, in particular, ensuring favorable conditions for investment, improving innovation, economic and tax policies, strengthening legal guarantees [39–40]. An effective innovation management system is an efficient tool for the development of enterprises in the modern competitive environment. Innovative activity in an unstable world, such as the VUCA-world and the BANI-world, allows enterprises not only to survive but also to achieve long-term success. It allows to adapt to rapid changes, increase competitiveness, use resources efficiently, meet new market needs, ensure sustainability and open up new opportunities for development, attract consumers and attract profitable partners, so it is advisable for enterprises in the era of unstable worlds to use such a model of economic relations as the model of the experience economy, which allows to increase added value and profit at a faster pace than other models of economic development.

2 Modeling the relationship between the internal environment of enterprises and the external environment VUCA-world and BANI-world

In the process of building economic relations based on the impression economy model, it is necessary to clearly define which indicators should be used to convey information to consumers and partners in order to form positive impressions of the enterprise, its performance and expectations, due to which these stakeholders will seek to cooperate with business entities. This task is especially challenging in an unstable external environment – VUCA-world and BANI-world.

The modern economic world, where uncertainty, complexity and fragility are the norm, creates obstacles and challenges for business entities. In order to understand what exactly is happening in the external environment, where to direct management decisions and production capacities, and what innovations to implement, it is necessary to conduct an in-depth analysis of these two environments. To do this, it is advisable to use the methodology described in the previous subsection, which involves the following steps.

The first stage involves data collection. Using the literature sources analyzed in Section 1, data were collected for the primary system of indicators that objectively characterize the state of the internal and external environment for the period 2015–2023. Thus, in the internal environment, 24 indicators were identified, the average values of which for 10 food industry enterprises are presented in Fig. 2.1, in the external environment – 14 partial indicators, which are shown in Fig. 2.2, which were prepared for processing by the STATISTICA 10.0 application package.

The second stage consists in the use of multivariate factor analysis with the help of STATISTICA 10.0 application software.

The results of the analysis of the internal environment are shown in Figure 2.3, which presents the eigenvalues of the factors, their variance and cumulative variance, and Figure 2.4, which shows the factor loadings by partial indicators in the factors.

The value of cumulative variance is more than 70% [32]. it is possible to determine the number of factors to be considered. In this case, this value is 73.02% of the variance of the primary data, which is sufficient to continue the analysis. The corresponding number of factors to be considered is 3.

STATISTICA - [Дані: Таблиця (38v * 9c)]

Файл Правка Вид Вставка Формат Аналіз Добування Даних Графіка Сервіс Дані Вікно Довідка

Додати у Робочу книгу ▾ Додати у Звіт ▾ Додати у MS W

Calibri 11

	1 Absolute liquidity ratio	2 Return on total equity	3 Net profitability of sales	4 Capital turnover ratio	5 Financial stability ratio	6 Capital manoeuvrability ratio	7 Financial risk ratio	8 Fixed asset serviceability ratio
2015	0,02	0,08	0,72	15,74	0,01	1,00	146,45	0,00
2016	0,04	-22,39	-25,06	-8,23	-0,15	1,00	-7,69	0,00
2017	0,01	-61,02	-49,80	-3,43	-0,47	1,05	-3,12	0,82
2018	0,01	-7,57	-2,78	-6,25	-0,41	1,18	-3,44	0,95
2019	0,05	6,65	0,03	75,78	0,26	0,82	2,79	0,94
2020	0,02	1,43	0,48	-12,70	-0,20	1,95	-6,11	0,86
2021	0,05	2,87	1,66	11,16	0,18	0,23	6,30	0,78
2022	0,01	1,06	1,15	6,00	0,21	-0,09	4,76	0,71
2023	0,01	1,96	1,89	5,43	0,21	0,18	3,77	0,54

	9 Fixed asset renewal rate	10 Return on assets	11 Capital equipment	12 Share of material costs in the cost of production	13 Share of employees employed full-time	14 Share of employees aged 29 to 50 years	15 Share of employees with university degrees	16 Share of employees trained in new professions
2015	0,00	0,00	0,00		100,00	60,00	60,00	0,00
2016	0,00	0,00	0,00	37,98	100,00	50,00	68,75	6,25
2017	1,00	108,52	12,21	42,69	100,00	60,87	65,22	0,00
2018	0,75	44,70	32,71	68,11	100,00	61,36	68,18	2,27
2019	0,22	24,75	24,91	69,13	100,00	68,06	72,22	0,00
2020	0,70	14,18	75,88	52,62	100,00	59,15	61,97	0,00
2021	0,54	9,76	149,50	58,56	100,00	58,57	57,14	2,86
2022	0,25	4,29	200,31	44,57	95,38	67,69	41,54	0,00
2023	-0,26	5,02	122,38	59,14	95,16	58,06	46,77	0,00

	17 Share of employees who improved their skills in the reporting year	18 Share of labour costs in total production costs	19 Average annual output per employee	20 Share of employees performing R&D work	21 Share of trade mark expenses in total expenses	22 Share of innovative products (flavour) in the total volume of products shipped	23 Share of new technologies acquired abroad in total acquisitions	24 Share of production facilities modernisation in total expenditure
2015	0,00	25,20	0,00	13,33	9,69	0,00	0,00	0,00
2016	12,50	21,96	27355,82	18,75	0,39	0,00	0,00	3,09
2017	8,70	36,15	53465,57	21,74	0,07	5,24	0,00	0,26
2018	0,00	49,58	72274,00	15,91	0,06	0,00	0,00	2,22
2019	6,94	110,44	75444,35	11,11	0,06	0,00	0,00	0,47
2020	1,41	79,19	111981,55	11,27	0,01	0,00	2,52	7,14
2021	0,00	76,38	97233,35	8,57	0,04	4,36	1,77	0,07
2022	0,00	85,92	89047,57	7,69	0,11	15,75	0,00	4,95
2023	3,23	68,08	69471,11	8,06	0,01	0,00	0,00	0,25

Fig. 2.1. Baseline data on indicators of internal environment factors

	25 Nominal GDP of Ukraine	26 GNI	27 Inflation index	28 Economic decline index	29 Total turnover of business entities	30 Business freedom index	of active enterprises by type of economic activity (Code NACE	32 Taxes on income, profits, and capital gains	33 Taxes on goods and services	34 Economic freedom, overall index	35 Total population	36 Net migration	37 Number of registered unemployed	38 Human flight and brain drain index
2015	1979458	9,48E+10	143,3		92044,7	59	3	11,14907	40,00627	47	45154036	-21937	461,1	
2016	2383182	9,43E+10	112,4	7	102455	57	4	15,16648	44,54158	47	45004673	-54333	407,2	5,4
2017	2982920	1,14E+11	113,7	6,8	137116,4	62	3	14,50349	43,99258	48	44831135	-50447	352,5	5,2
2018	3558706	1,32E+11	109,8	6,6		63	7	16,35945	43,68816	52	44622518	-33273	341,7	4,9
2019	3974564	1,56E+11	104,1	6,5	172461,2	66	12	16,99131	40,36539	52	44386203	-7812	338,2	5,2
2020	4194102	1,60E+11	105	6,2	236868,6	61	13	16,41963	40,0977	55	44132049	-2173	459,2	5,5
2021	5459574	1,94E+11	110	6,8	181987,2	64	15	17,26709	43,35201	56	43822901	831	295	5,8
2022	5191028	1,69E+11	126,6	6,5		61	18	11,97265	26,2739	54	38000000	-6673580	186,5	5,9
2023	6437825		105,1	8,5								1784718	96,1	8,9

Fig. 2.2. Baseline data on indicators of external environment factors

Знач.	Власні значення (Таблиця даних1) Виділення: Головні компоненти Власн. Знач.	% загал. дисперс.	Кумулятивн. Власн. Знач.	**Кумулятивн. %**
1	9,300502	38,75209	9,30050	38,75209
2	4,657332	19,40555	13,95783	58,15764
3	3,567411	14,86421	17,52525	73,02186

Fig. 2.3. Results of multy/exploratory factor analysis by internal environment of enterprise

Змінні	Фактор. навантаження (Без. оберт.) (Таблиця даних1) Виділення: Головні компоненти (Зазначені навантаження >,700000) Фактор 1	Фактор 2	Фактор 3
Absolute liquidity ratio	-0,140321	0,172574	-0,780036
Return on total equity	-0,797132	0,134954	-0,391206
Net profitability of sales	-0,835105	0,052436	-0,276608
Capital turnover ratio	-0,396384	-0,085889	-0,668335
Financial stability ratio	-0,785418	0,464460	-0,317930
Capital manoeuvrability ratio	0,542290	-0,581389	-0,176527
Financial risk ratio	-0,826363	0,146271	-0,012052
Fixed asset serviceability ratio	-0,439107	-0,870559	0,027949
Fixed asset renewal rate	0,300342	-0,823406	0,269388
Return on assets	0,504127	-0,609427	0,292918
Capital equipment	-0,822029	0,252647	0,427626
Share of material costs in the cost of production	-0,482006	-0,453257	-0,544011
Share of employees employed full-time	0,570310	-0,500192	-0,500812
Share of employees aged 29 to 50 years	-0,618651	-0,434917	0,082561
Share of employees with university degrees	0,640333	-0,398443	-0,635396
Share of employees trained in new professions	0,539232	0,528756	-0,316065
Share of employees who improved their skills in the reporting year	0,746984	0,333766	-0,288074
Share of labour costs in total production costs	-0,857726	-0,247755	-0,297895
Average annual output per employee	-0,745276	-0,493474	0,097398
Share of employees performing R&D work	0,960295	-0,175779	0,067289
Share of trade mark expenses in total expenses	0,617845	0,669502	-0,125164
Share of innovative products (flavour) in the total volume of products shipped	-0,372401	0,185074	0,662814
Share of new technologies acquired abroad in total acquisitions	-0,220572	-0,369208	-0,065806
Share of production facilities modernisation in total expenditure	-0,051775	-0,062098	0,325673
Загал.дис.	9,300502	4,657332	3,567411
Загал.частка	0,387521	0,194056	0,148642

Fig. 2.4. Factor loadings of indicators for internal environment

To improve the result of selecting partial indicators in the factors, the primary data were rotated by the Varimax module, the result of the rotation is shown in Fig. 2.5.

	Фактор. навантаж (Вар.вихідн.) (Таблиця даних1) Виділення: Головні компоненти (Зазначені навантаження >,700000)		
Змінні	**Фактор 1**	Фактор 2	Фактор 3
Absolute liquidity ratio	0,658338	-0,151129	0,449087
Return on total equity	0,837877	0,285689	-0,151713
Net profitability of sales	0,759792	0,387489	-0,221879
Capital turnover ratio	0,664926	0,216199	0,349716
Financial stability ratio	0,903247	0,015055	-0,342930
Capital manoeuvrability ratio	-0,464606	0,161312	0,649133
Financial risk ratio	0,618335	0,334319	-0,458595
Fixed asset serviceability ratio	-0,039710	0,964938	0,137061
Fixed asset renewal rate	-0,676068	0,544128	0,296023
Return on assets	-0,750454	0,257353	0,286244
Capital equipment	0,372017	0,292542	-0,835733
Share of material costs in the cost of production	0,508724	0,580746	0,371017
Share of employees employed full-time	-0,245691	0,042968	0,874098
Share of employees aged 29 to 50 years	0,205352	0,710207	-0,179261
Share of employees with university degrees	-0,169365	-0,094632	0,966888
Share of employees trained in new professions	0,032349	-0,769629	0,277264
Share of employees who improved their skills in the reporting year	-0,196893	-0,720201	0,441491
Share of labour costs in total production costs	0,679107	0,645664	-0,088031
Average annual output per employee	0,259827	0,830176	-0,227456
Share of employees performing R&D work	-0,754873	-0,377831	0,494977
Share of trade mark expenses in total expenses	-0,091812	-0,908284	0,110557
Share of innovative products (flavour) in the total volume of products shipped	-0,106797	0,125936	-0,764847
Share of new technologies acquired abroad in total acquisitions	0,056167	0,419640	0,100224
Share of production facilities modernisation in total expenditure	-0,196815	0,115840	-0,245854
Загал.дис.	6,319219	6,061026	5,145001
Загал.частка	0,263301	0,252543	0,214375

Fig. 2.5. The result of the factor loadings of indicators analysis in the internal environment after factor rotation using the Varimax raw method

Based on the rule that the final system of indicators may include those that have a strong impact on the studied processes, characterized by factor loadings greater than 0.7 [32]. 2.5, these indicators are marked in red in accordance with the condition of the STATISTICA 10.0 software. Thus, according to the modeling results, the internal environment of enterprises is characterized by three latent factors.

The first factor includes the return on total capital; net profitability of sales; financial stability ratio; capital efficiency; and the share of employees engaged in R&D. In other words, the most important factor is the first one, which characterizes the integrated use of economic resources by enterprises, namely financial, material, i.e. fixed assets and human resources in the context of innovation.

The second factor includes the following indicators: fixed assets depreciation rate; share of employees aged 29 to 50; share of employees trained in new professions; share of employees who improved their skills in the reporting year; average annual output per employee; share of trademark costs in total costs. Since the vast majority of the indicators of the second factor characterize the quality of human resources and their intensive use, bordering on professional development, together with the quality of available production assets and brand expenditures, i.e., the maintenance of intellectual capital, the second factor can also be considered comprehensive, but with a focus on the quality of human and intellectual capital of enterprises, which corresponds to the focus of the impression economy model.

The third factor includes indicators of capital equipment; the share of full-time employees; the share of employees who have graduated from higher education institutions; and the share of innovative products in the total volume of shipped products. In other words, the third factor characterizes the extensive use of human resources and the results of innovative activities of enterprises, which are also responsible for the formation of positive impressions of the ability of enterprises to innovate, which correlates with the general objectives of the impression economy model.

The selected indicators are included in the final system of indicators of the internal environment of enterprises, on the basis of which the integral indicator of the internal environment is calculated using the method of additive convolution in accordance with the proposed methodology. It is worth noting that the best values by years for all enterprises were chosen as reference indicators, and the normalized values of their factor loads by years were used as coefficients of significance of partial indicators.

The calculated values of the integral indicator of the internal environment, which can be considered as the results of the use of the strategic potential of enterprises by years, are shown in Figure 2.6.

Applying the Harington scale, adjusted for the conditions of Ukraine [37], it can be noted that the integral indicator has an average level of use of the factors of the internal environment of enterprises to ensure their strategic potential. However, in 2019, 2020, and 2022, the value of the integral indicator moved to a high qualitative level, but only just crossing the line between medium and high levels. This makes it possible to conclude that there is an internal potential of enterprises that can be used in case of stabilization of the economic and military situation in Ukraine. The medium level of values of the integrated indicator of the internal environment can be explained by the fact that there is some competition in the market, enterprises do not pay enough attention to brand development, increasing the share of innovative products shipped, which are important factors for taking advantage of the impression economy and increasing their values.

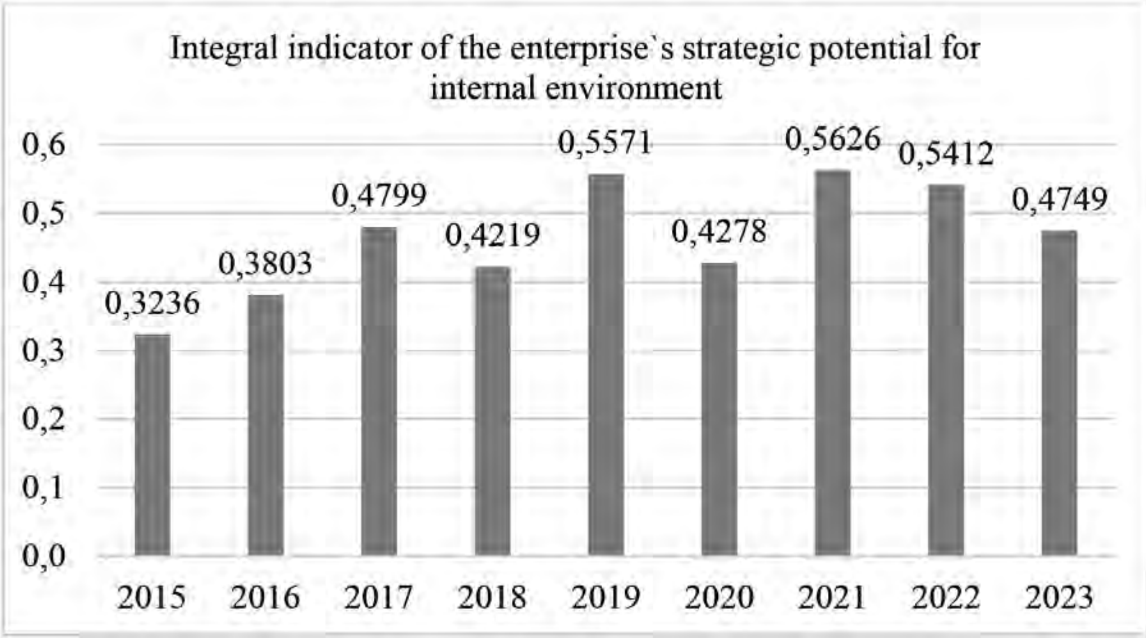

Fig. 2.6. Integral indicator of the internal environment of enterprises, i.e. their strategic potential for the period 2015-i2023

At the third stage, in accordance with the proposed methodology, the type of functional dependence between partial indicators of the internal environment and their integral indicator is determined, and the sensitivity of partial indicators to changes is determined using the neural network method. The type of functional dependence will allow to substantiate it, predict the value of strategic potential and prove the existence of internal links between factors in enterprises in accordance with a certain model of the world of economic relations. And the sensitivity of indicators will allow to focus the efforts of managers and owners of enterprises on those partial indicators, the change in the values of which will best affect the growth of the results of using the strategic potential of enterprises. That is, the most sensitive indicators will become the points of growth of the strategic potential due to the relevant use of factors of the internal environment of enterprises.

To use neural networks, the integral indicator of the internal environment is taken as a continuous objective function, and the values of selected partial indicators as a result of multivariate factor analysis are taken as a continuous input function. The result of neural network modeling for the internal environment is shown in Fig. 2.7.

As a result of using the neural network method, 5 models were built, according to Figure 2.7. The criteria for selecting models are the values of training performance (i.e., the correlation coefficient of the integral indicator with partial indicators) and training errors for each model. According to these criteria, the fifth model of the multilevel perceptron (MLP 15-11-1) is the best, because it has 11 hidden neurons, the highest value for learning performance (0.999592) and the lowest value for learning error (0.000002). Since the multilevel perceptron is a nonlinear model, this proves the nonlinearity of the influence of internal environment factors on each other and on the life of enterprises, as well as the fact that the hypothesis about the functioning of domestic enterprises in the BANI world is confirmed. The predicted values of the integrated indicator of the internal environment for each model are shown in Fig. 2.8.

Підсумки моделей (Таблиця даних у Робоча книга1)

N	Архітектура	Продуктивність навчання	Помилка навчання	Контрольна помилка	Тестова помилка	Алгоритм навчання	Функція помилки	Ф-я актив. прихованих нейр.	Ф-я актив. вихідних нейр.
1	MLP 15-15-1	0,905582	0,000445	0,000020	0,002483	BFGS 5	Сум. квадр.	Гіперболічна	Тотожна
2	RBF 15-3-1	0,591967	0,001364	0,004242	0,002884	RBFT	Сум. квадр.	Гауссіан	Тотожна
3	RBF 15-3-1	0,753386	0,002054	0,013024	0,001869	RBFT	Сум. квадр.	Гауссіан	Тотожна
4	MLP 15-14-1	0,830082	0,000713	0,001605	0,004648	BFGS 3	Сум. квадр.	Експонента	Логістична
5	MLP 15-11-1	0,999592	0,000002	0,007768	0,007027	BFGS 0	Сум. квадр.	Гіперболічна	Гіперболічна

Fig. 2.7. The result of neural network modeling of the internal environment of enterprises

Таблиця передбачених значень Integral indicator of the enterprise`s strategic potential for internal environment (Таблиця даних у Робоча книга1)
Вибірки: Навчальна

Спостереж номер #	Integral indicator of the enterprise`s strategic potential for internal environment Цільова	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 1. MLP 15-15-1	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 2. RBF 15-3-1	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 3. RBF 15-3-1	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 4. MLP 15-14-1	**Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 5. MLP 15-11-1**
2016	0,380280	0,392090	0,436293	0,486686	0,398518	0,380258
2017	0,479948	0,464427	0,451771	0,487617	0,441554	0,479948
2018	0,421947	0,465866	0,479614	0,488475	0,466456	0,421961
2019	0,557073	0,545861	0,476180	0,489313	0,544850	0,562133
2021	0,562641	0,509364	0,546649	0,489540	0,550687	0,561108
2022	0,541222	0,525251	0,497033	0,487969	0,535994	0,541188
2023	0,474934	0,501454	0,530506	0,488446	0,551556	0,474958

Fig. 2.8. Predicted (forecasted) values of the integrated indicator of the internal environment of enterprises according to the built models

Analyzing the fifth model, it can be confirmed that the calculated predicted values of this model do not differ significantly from the actual values of the integrated indicator of the internal environment, which confirms the good quality of the built and selected fifth model.

In accordance with the constructed neural network models, it is advisable to determine the sensitivity of the partial indicators included in them (Fig. 2.9).

In accordance with Fig. 2.9. and the rationality coefficient presented therein, the sensitivity of indicators is determined, which in economic terms demonstrates how many units the growth of the integrated indicator of the internal environment will change if the partial indicator changes by one. This means that the company's management should primarily manage those indicators that are the most sensitive. According to the rationality coefficient, the partial indicators were ranked, which is presented in Table 2.1.

Чутливість (Таблиця даних у Робоча книга1)
Вибірки: Навчальна

Мережі	Share of employees employed full-time	Financial stability ratio	Return on total equity	Share of innovative products (flavour) in the total volume of products shipped	Share of employees performing R&D work	Share of trade mark expenses in total expenses	Average annual output per employee	Share of employees who improved their skills in the reporting year
1.MLP 15-15-1	1,090	1,3696	1,3749	1,2004	1,1591	1,0966	1,0707	1,0027
2.RBF 15-3-1	1,019	1,0512	0,9611	0,9361	1,0232	1,0318	1,0364	0,9955
3.RBF 15-3-1	0,999	1,0039	1,0024	0,9987	1,0019	1,0020	1,0021	1,0012
4.MLP 15-14-1	1,015	1,1285	1,1160	1,0680	0,9195	1,0063	0,9934	0,9007
5.MLP 15-11-1	1253,429	695,2002	622,2457	383,2191	347,0873	113,2460	100,4827	100,2742
Середнє	251,510	139,9507	125,3400	77,4845	70,2382	23,4765	20,9171	20,8348

Мережі	Fixed asset serviceability ratio	Share of employees trained in new professions	Capital equipment	Return on assets	Share of employees aged 29 to 50 years	Net profitability of sales	Share of employees with university degrees
1.MLP 15-15-1	1,01388	1,14825	0,98701	1,001850	1,071361	0,946828	1,032736
2.RBF 15-3-1	1,02194	1,00187	0,98523	0,985194	0,940823	0,992572	0,963320
3.RBF 15-3-1	1,00198	1,00098	1,00005	1,000451	1,000736	1,000769	0,999166
4.MLP 15-14-1	1,00026	1,07876	1,00899	0,966728	1,013863	1,001373	1,010445
5.MLP 15-11-1	88,75458	24,89651	13,05529	9,991912	7,526922	3,823411	1,485664
Середнє	18,55853	5,82527	3,40731	2,789227	2,310741	1,552991	1,098266

Fig. 2.9. Sensitivity of partial indicators
of the internal environment according to the built neural network models

In accordance with Fig. 2.9. and the rationality coefficient presented therein, the sensitivity of indicators is determined, which in economic terms demonstrates how many units the growth of the integrated indicator of the internal environment will change if the partial indicator changes by one. This means that the company's management should primarily manage those indicators that are the most sensitive. According to the rationality coefficient, the partial indicators were ranked, which is presented in Table 2.1.

According to Table 2.1, the top 3 most sensitive indicators are: the share of full-time employees; financial stability ratio; and return on total capital. That is, these are the indicators that require the most attention from managers and business owners. Graphical visualizations of the scattering points of these indicators relative to the integral indicator (baseline) and the integral indicator (target) according to the selected model (MLP 15-11-1) are shown in Figs. 2.10 – 2.12, which also visualizes the nonlinearity of changes in the values of indicators and factors of the internal environment. environment.

Table 2.1

Sensitivity rating of internal environment indicators of the multilevel perceptron model (MLP 15-11-1)

Rank	Indicator name	Value
1	Share of employees employed full-time	1253,43
2	Financial stability ratio	695,20
3	Return on total equity	622,25
4	Share of innovative products (flavour) in the total volume of products shipped	383,22
5	Share of employees performing R&D work	347,09
6	Share of trade mark expenses in total expenses	113,25
7	Average annual output per employee	100,48
8	Share of employees who improved their skills in the reporting year	100,27
9	Fixed asset serviceability ratio	88,75
10	Share of employees trained in new professions	24,90
11	Capital equipment	13,06
12	Return on assets	9,99
13	Share of employees aged 29 to 50 years	7,53
14	Net profitability of sales	3,82
15	Share of employees with university degrees	1,49

Based on the results of a comprehensive analysis of the impact of VUCA-world and BANI-world on the internal environment of food industry enterprises, it is advisable to draw the following conclusions. The internal environment factors are characterized by an average level of utilization in relation to the strategic potential of enterprises in accordance with the challenges of fragility, uncertainty, instability, and turbulence of the external environment. After the full-scale invasion, the results have changed insignificantly, due to a certain resilience due to solvent consumer demand and the desire of partners to maintain cooperation with enterprises. Using the neural network method, it is substantiated that the factors of the internal environment are interdependent in a non-linear manner, their interrelationships correspond to the model of a multi-level perceptron.

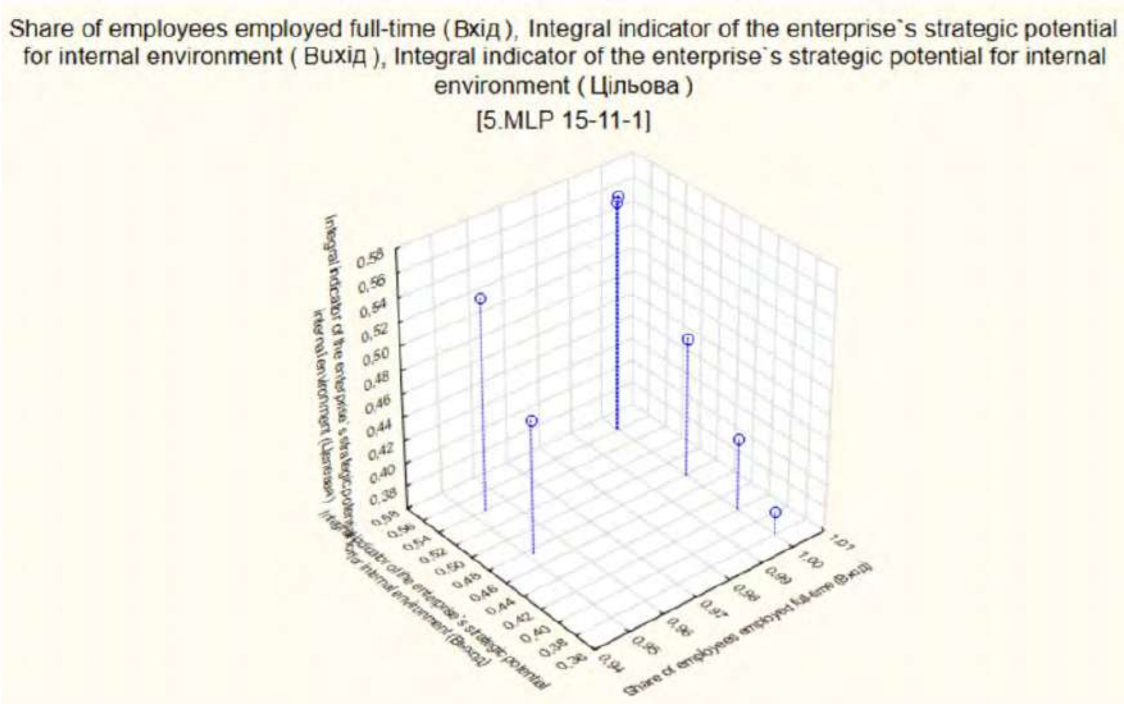

Fig. 2.10. Graphical visualization of the values of the share of full-time employees in relation to the integral indicator of the internal environment, i.e. strategic potential (Output) and the integral indicator of the internal environment, i.e. strategic potential (Target)

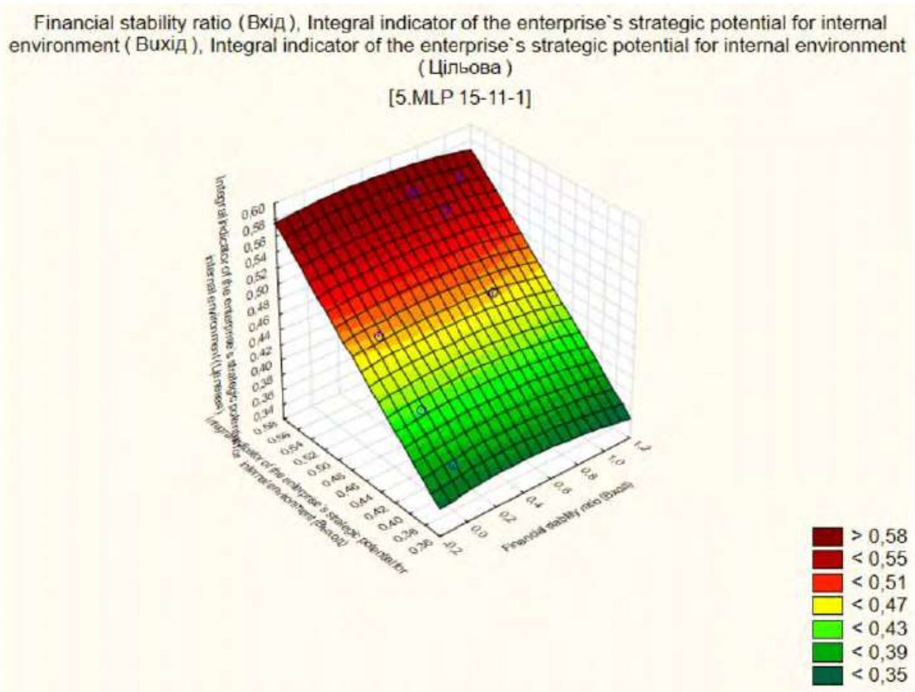

Fig. 2.11. Graphical visualization of the values of the financial stability ratio in relation to the integral indicator of the internal environment, i.e. strategic potential (Output) and the integral indicator of the internal environment, i.e. strategic potential (Target)

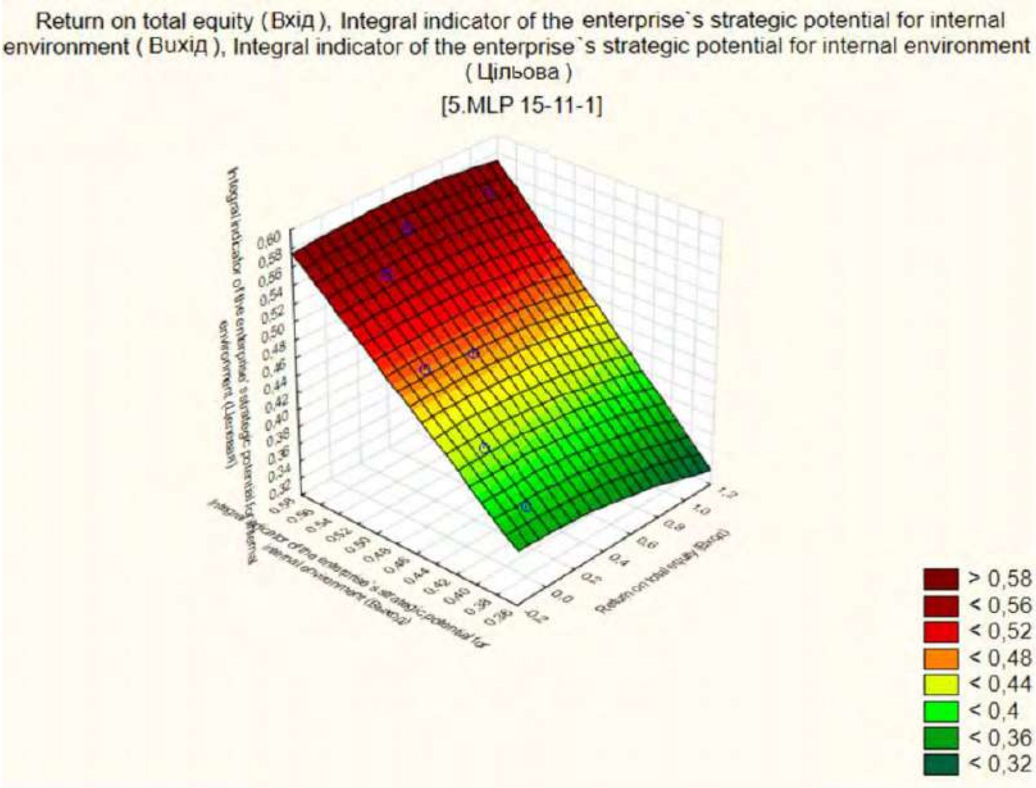

Fig. 2.12. Graphical visualization of the values of the return on total capital relative to the integral indicator of the internal environment, i.e. strategic potential (Output) and the integral indicator of the internal environment, i.e. strategic potential (Target)

In order to improve its market position in the VUCA-world and BANI-world, the management of enterprises needs to pay attention and take appropriate management measures to maintain and improve the most sensitive indicators: The most sensitive indicators and factors of the internal environment are the proportion of full-time employees; financial stability ratio; return on total capital. It is these factors that should be selected as the main ones for the primary managerial influence on improving the state of the internal environment of enterprises.

As for the external environment of the studied enterprises, the methodology of analysis remains unchanged, which is its advantage.

The application of multifactor analysis to the factors and indicators of the external environment of enterprises allowed us to determine the number of latent factors (Fig. 2.13) and the composition of the primary system of indicators by factor loadings after the Varimax rotation (Fig. 2.14). The composition of environmental indicators is determined by the possibilities of their calculation on the basis of official statistical information and is presented in Fig. 2.14.

Знач.	Власні значення (Таблиця даних1) Виділення: Головні компоненти			
	Власн. Знач.	% загал. дисперс.	Кумулятивн. Власн. Знач.	**Кумулятивн. %**
1	9,520661	68,00472	9,52066	68,00472
2	2,654740	18,96243	12,17540	86,96715

Fig.2.13. Results of multy/exploratory factor analysis by external environment

Змінні	Фактор. навантаж (Вар.вихідн.) (Таблиця даних1) Виділення: Головні компоненти (Зазначені навантаження >,700000)	
	Фактор 1	Фактор 2
Nominal GDP of Ukraine	0,982215	0,147434
GNI	0,965370	0,248787
Inflation index	-0,379237	-0,859205
Economic decline index	-0,227428	-0,954044
Total turnover of business entities	0,569744	0,750691
Business freedom index	0,652773	0,220965
Number of active enterprises by type of economic activity (Code NACE. Rev.2 11.03)	0,888493	0,428538
Taxes on income, profits, and capital gains	0,866619	0,337132
Taxes on goods and services	-0,286266	-0,937616
Economic freedom, overall index	0,889689	0,405859
Total population	-0,943746	-0,285996
Net migration	0,852618	0,519751
Number of registered unemployed	-0,556486	0,603056
Human flight and brain drain index	0,735692	-0,220872
Загал.дис.	7,725427	4,449974
Загал.частка	0,551816	0,317855

Fig. 2.14. The result of the factor loadings of indicators analysis in the external environment after factor rotation using the Varimax raw method

According to the value of the cumulative variance (86.97%), which is more than 70%, we can say that the number of factors characterizing the state of the external environment is 2. The results after rotation in Fig. 2.14 show that in the external environment, among the 14 input indicators, 12 indicators are the most important with factor loadings greater than 0.70. The first factor consists of 8 significant indicators, such as: nominal GDP of Ukraine; gross national income; number of operating enterprises by type of economic activity (NACE 2010 code: 11.03); taxes on income, profit and capital gains; general index of economic freedom; total population; net migration; and the index of population outflow (brain drain). Based on the composition of the first factor's indicators, it should be defined as a comprehensive one that characterizes economic performance. The second factor is formed by such indicators as: inflation index; economic recession index; volume of products (goods, services) sold by business entities: 11.03; taxes on goods and services. Based on the composition of indicators of the second factor, it can be perceived as a factor of destructive influence.

Thus, these are the most influential and adequate indicators of the state of the external environment, which describe the VUCA-world and the BANI-world and form a system of partial indicators of the external environment.

Using the method of additive convolution, it is advisable to combine the selected partial indicators into an integral indicator of the external environment. Its calculation is presented by years in Fig. 2.15.

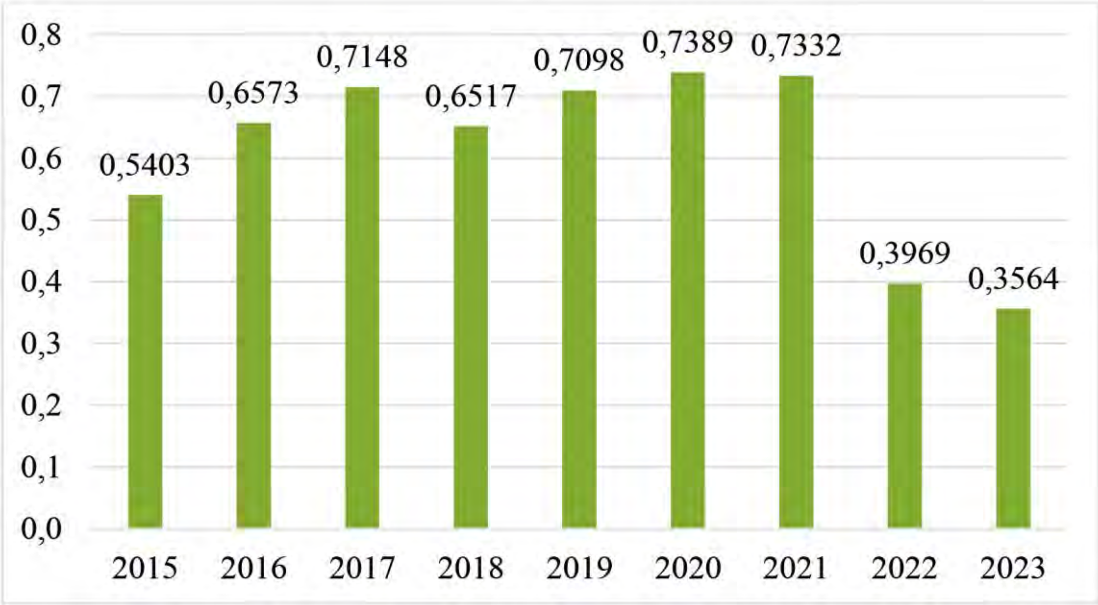

Fig. 2.15. Integral indicator of the external environment of enterprises for the period 2015–2023

The value of the integral indicator of the external environment indicates its high level (according to the Harington scale, adjusted for the business environment in Ukraine) for the period 2015-2021. In 2020 and 2021, the best results were observed, which indicates that the conditions for starting and doing business in Ukraine are attractive. However, after the beginning of the full-scale military invasion in 2022 and 2023, there was a sharp decrease in the value of the integral indicator and its fall into the middle interval of the Harington scale, which was adjusted for the conditions of Ukraine's economy, indicating a sharp decrease in the quantitative values of environmental factors by 1.85 times and its unattractiveness for business entities and the complexity of doing business.

In order to determine the functional relationship between the indicators of the external environment, the method of neural networks is used to build models that would adequately describe the state of the external environment of enterprises in Ukraine. The quantitative values of the integral indicator of the external environment are used as a continuous objective function, and partial indicators selected after applying multivariate factor analysis are used as a continuous input function. The result of modeling by the neural network method is shown in Fig. 2.16.

Підсумки моделей (Таблиця даних у Робоча книга1)

N	Архітектура	Продуктивність навчання	Помилка навчання	Контрольна помилка	Тестова помилка	Алгоритм навчання	Функція помилки	Ф-я актив. прихованих нейр.	Ф-я актив. вихідних нейр.
1	RBF 12-2-1	0,238867	0,010678	0,001960	0,009252	RBFT	Сум. квадр.	Гауссіан	Тотожна
2	MLP 12-10-1	0,883946	0,007229	0,000017	0,006695	BFGS 3	Сум. квадр.	Логістична	Тотожна
3	RBF 12-3-1	-0,933469	0,010678	0,001960	0,009252	RBFT	Сум. квадр.	Гауссіан	Тотожна
4	MLP 12-5-1	0,873931	0,004472	0,000013	0,000051	BFGS 4	Сум. квадр.	Експонента	Експонента
5	MLP 12-13-1	0,931873	0,007463	0,000078	0,000001	BFGS 4	Сум. квадр.	Гіперболічна	Експонента

Fig. 2.16. Characteristics of the models of the external environment of enterprises

Taking into account the values of the training performance criteria (0.931873) and the training error (0.007463), the best model is the fifth model of the multilevel perceptron (MLP 12-13-1), which is a nonlinear model with 13 latent neurons, which confirms the hypothesis that the VUCA-world and the BANI-world function in the Ukrainian economy with the predominance of the latter. the results of the predicted values of the integral indicator by this model. According to the selected model (and other built models), the predicted (expected) values of the integral indicator of the external environment of enterprises are presented in Fig. 2.17.

Таблиця передбачених значень Integral indicator of the enterprise`s strategic potential for external environment (Таблиця даних у Робоча книга1)
Вибірки: Навчальна

Спостереж номер #	Integral indicator of the enterprise`s strategic potential for external environment Цільова	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 1. RBF 12-2-1	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 2. MLP 12-10-1	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 3. RBF 12-3-1	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 4. MLP 12-5-1	**Integral indicator of the enterprise`s strategic potential for external environment - Вихід 5. MLP 12-13-1**
2016	0,657254	0,602861	0,615216	0,602861	0,731143	0,703266
2017	0,714808	0,602861	0,620504	0,602861	0,743396	0,719779
2018	0,651741	0,602861	0,603248	0,602861	0,690175	0,678647
2019	0,709768	0,602861	0,617664	0,602861	0,734594	0,723165
2021	0,733214	0,602861	0,609579	0,602861	0,712764	0,698978
2022	0,396875	0,602861	0,584154	0,602862	0,623397	0,636082
2023	0,356371	0,602861	0,527676	0,602862	0,406430	0,563843

Fig. 2.17. Estimated values of the integral indicator of the external environment of enterprises according to the built neural network models

Comparing the predicted values of the integral indicator based on the MLP 12-13-1 model with its actual values for the periods of 2022 and 2023, it is worth noting significant deviations. This means that the real external world is indeed fragile and incomprehensible, i.e., the BANI world. Therefore, it is very important for enterprises to pay attention to the composition and changes in sensitive environmental indicators and to adapt to them as quickly as possible or try to influence changes in their values as much as possible. The results of modeling the sensitivity of the indicators of the multilevel perceptron model (and other built models) are shown in Fig. 2.18.

The rating of sensitivity of the indicators of the external environment of enterprises according to the best model of the multilevel perceptron is presented in Table 2.2.

Чутливість (Таблиця даних у Робоча книга1)
Вибірки: Навчальна

Мережі	**Total turnover of business entities**	Nominal GDP of Ukraine	Total population	Human flight and brain drain index	Number of active enterprises by type of economic activity (Code NACE. Rev.2 11.03)	Net migration	Inflation index	Economic freedom, overall index	Economic decline index	GNI	Taxes on goods and services	Taxes on income, profits, and capital gains
1.RBF 12-2-1	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000
2.MLP 12-10-1	1,127794	1,064205	1,059962	1,051241	1,033728	1,008446	1,006611	1,034142	1,029566	1,013684	0,999158	1,011886
3.RBF 12-3-1	0,999999	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000
4.MLP 12-5-1	1,474524	1,152292	1,108475	1,079998	1,074334	1,072942	1,040683	1,022407	0,996664	1,001813	1,008458	0,989255
5.MLP 12-13-1	1,211490	1,052635	1,070776	1,074509	1,036902	1,007040	1,036340	1,018692	1,026078	1,011021	1,000378	1,003006
Середнє	1,162762	1,053827	1,047843	1,041150	1,028993	1,017685	1,016727	1,015048	1,010462	1,005304	1,001599	1,000829

Fig. 2.18. Sensitivity of indicators of the external environment of enterprises according to the built models

Table 2.2

Rating of sensitivity of environmental indicators according to the best multilevel perceptron model (MLP 12-13-1)

Rank	Indicator name	Value
1	Total turnover of business entities	1,2115
2	Human flight and brain drain index	1,0745
3	Total population	1,0708
4	Nominal GDP of Ukraine	1,0526
5	Number of active enterprises by type of economic activity (Code NACE. Rev.2 11.03)	1,0369
6	Inflation index	1,0363
7	Economic decline index	1,0261
8	Economic freedom, overall index	1,0187
9	GNI	1,0110
10	Net migration	1,0070
11	Taxes on income, profits, and capital gains	1,0030
12	Taxes on goods and services	1,0004

In accordance with Table 2.2, the top 3 most sensitive indicators of the external environment include: the volume of products (goods, services) sold by business entities: 11.03; population outflow (brain drain) index; total population. These indicators require managerial influence, as changes in their values will significantly affect the improvement of business results in the unstable BANI world. As for businesses, they can also influence the stabilization of the situation by adjusting the volume of products (goods, services) sold, paying attention to market research on consumer solvency, and increasing the desire to buy products or receive services by creating positive impressions of the performance of enterprises, which coincides with the main additional opportunities provided to business entities by the impression economy.

The growth of the population and brain drain index threatens businesses with the loss of qualified personnel and actual and potential customers. It is necessary to constantly monitor the population and its location to identify promising markets.

Graphical visualizations of the nonlinearity of environmental factors and points of scattering of environmental indicators with the highest sensitivity relative to the integral indicator (baseline) and the integral indicator (target) according to the selected model (MLP 12-13-1) are shown in Figs. 2.19 – 2.21.

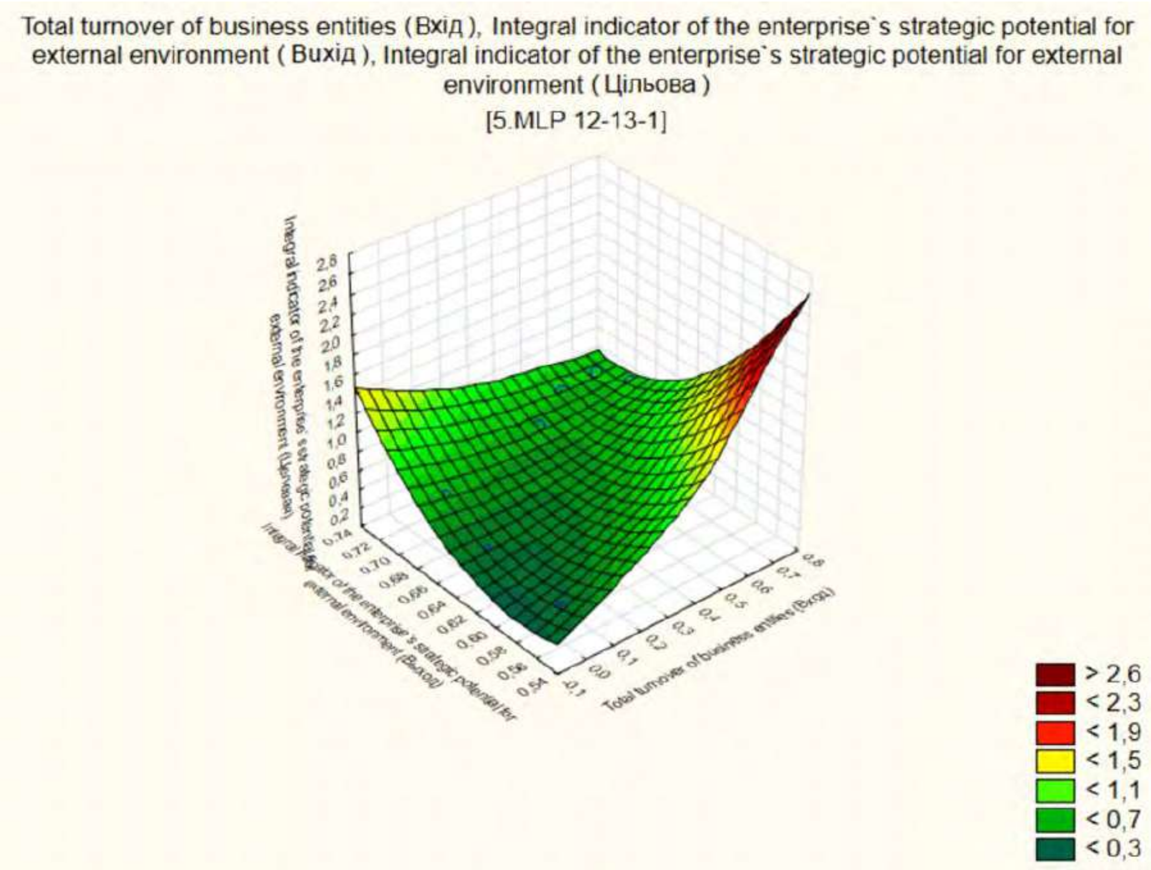

Fig. 2.19. Graphical visualization of the values of the indicator of the volume of products (goods, services) sold by business entities: 11.03 relative to the integral indicator of the external environment

Determination of factors, indicators of the external environment of enterprises and their functional interdependence proves the functioning of economic relations in Ukraine as VUCA-world and BANI-world with the predominance of the latter.

According to the results of the study, it can be concluded that after a full-scale military invasion, the external environment of enterprises has changed significantly and has moved from a high quality level to an average level, which significantly worsens the business environment and increases uncertainty, nonlinearity and fragility of its manifestation. It is possible to improve the situation by taking advantage of the impression economy to form positive impressions about the possibilities of the external environment, which can be presented as attractive in terms of compensating for business risk with higher sales profitability or other profitability indicators or other indicators of the use of economic resources that will be of interest to business owners, managers or investors in a risky environment.

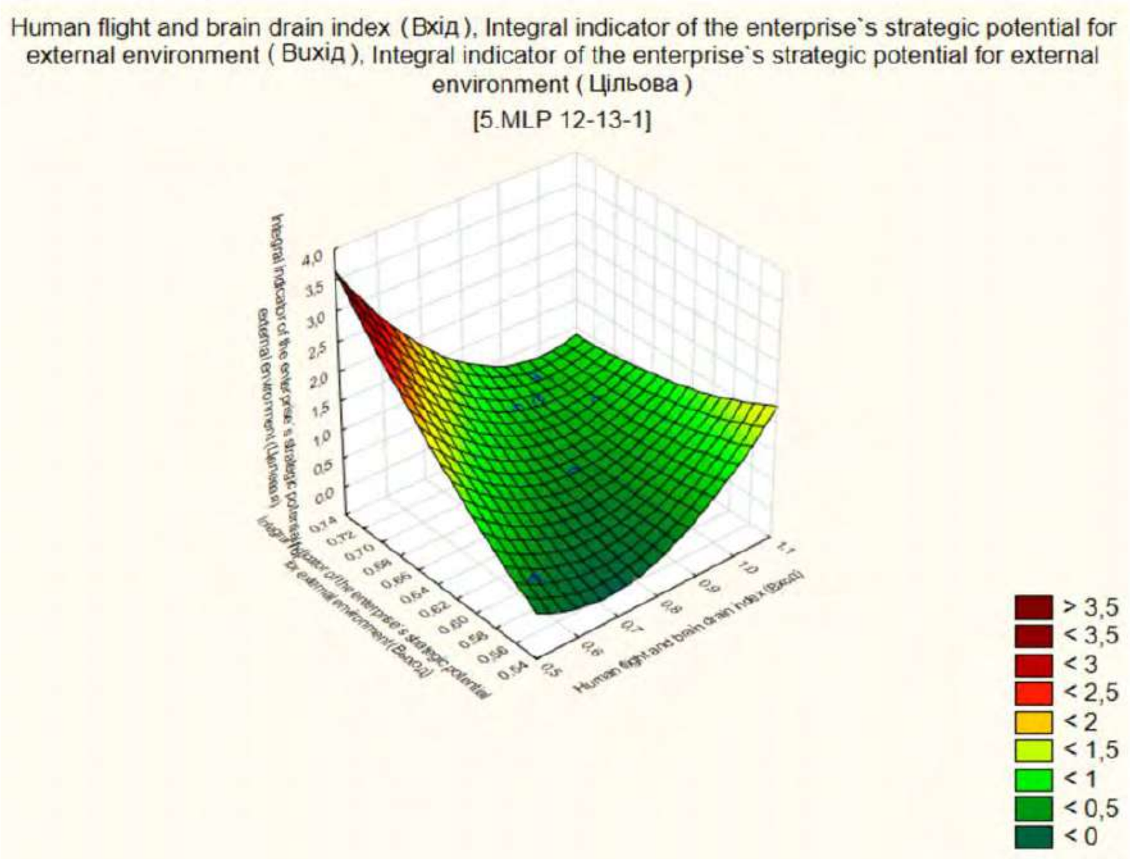

Fig. 2.20. Graphical visualization of the values of the population (brain) outflow index relative to the integrated indicator of the external environment

In addition to a separate study of the internal and external environments of enterprises, it is advisable to prove their mutual influence on each other using the neural network method. For this purpose, the value of the integrated indicator of the internal environment was used as a continuous objective function and the value of the external environment indicators as a continuous input function.

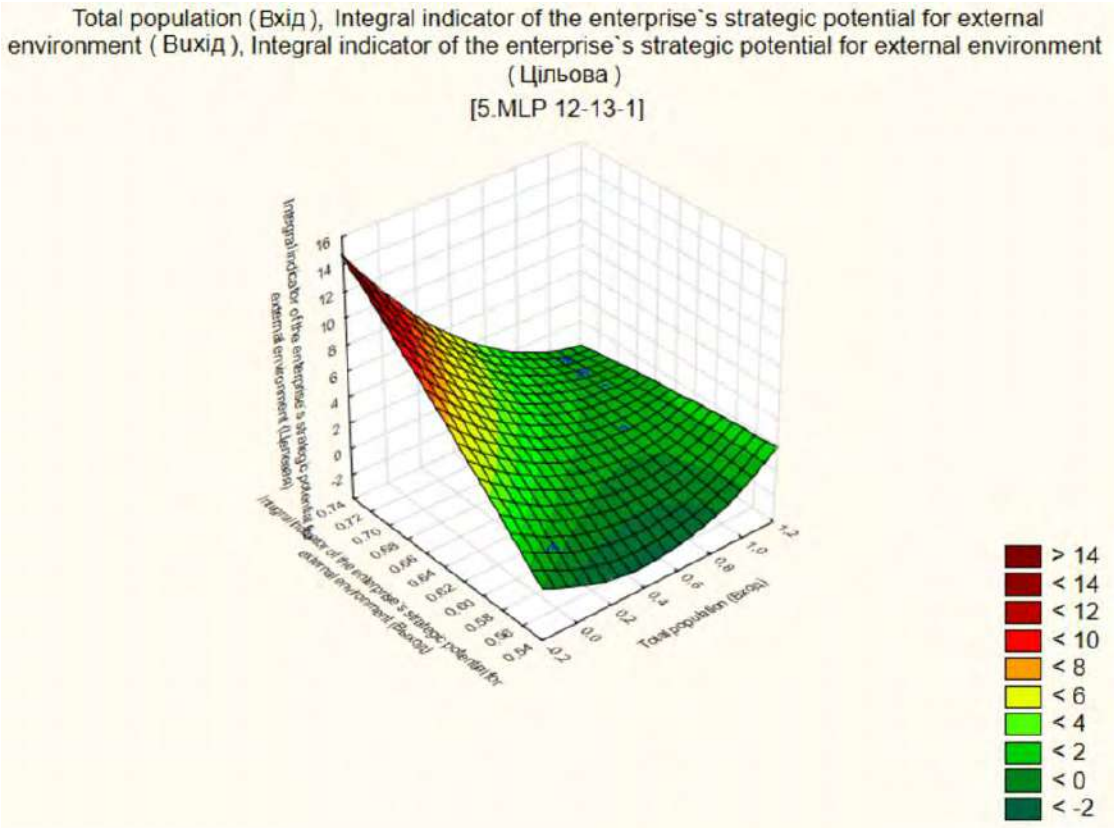

Fig. 2.21. Graphical visualization of the values of the total population indicator relative to the integral indicator of the external environment

The results of the models formed by the neural network method are shown in Fig. 2.22.

Підсумки моделей (Таблиця даних у Робоча книга1)

N	Архітектура	Продуктивність навчання	Помилка навчання	Контрольна помилка	Тестова помилка	Алгоритм навчання	Функція помилки	Ф-я актив. прихованих нейр.	Ф-я актив. вихідних нейр.
1	RBF 12-2-1	0,794645	0,000773	0,011865	0,007098	RBFT	Сум. квадр.	Гауссіан	Тотожна
2	RBF 12-2-1	0,604661	0,002098	0,013557	0,001831	RBFT	Сум. квадр.	Гауссіан	Тотожна
3	MLP 12-10-1	0,920524	0,000322	0,000002	0,008802	BFGS 4	Сум. квадр.	Логістична	Тотожна
4	MLP 12-11-1	0,995302	0,000035	0,001611	0,009093	BFGS 5334	Сум. квадр.	Експонента	Логістична
5	RBF 12-3-1	0,447162	0,001679	0,025335	0,002879	RBFT	Сум. квадр.	Гауссіан	Тотожна

Fig. 2.22. Models of the relationship between the integrated indicator of the internal environment and indicators of the external environment

The fourth model (MLP 12-11-1) is the best according to the values of the training performance criteria of 0.995302 and the training error of 0.000035. This and other models predicted the results of the predicted values of the integrated indicator of the internal environment (Fig. 2.23).

	Таблиця передбачених значень Integral indicator of the enterprise`s strategic potential for internal environment (Таблиця даних у Робоча книга1) Вибірки: Навчальна					
Спостереж номер #	Integral indicator of the enterprise`s strategic potential for internal environment Цільова	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 1. RBF 12-2-1	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 2. RBF 12-2-1	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 3. MLP 12-10-1	**Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 4. MLP 12-11-1**	Integral indicator of the enterprise`s strategic potential for internal environment - Вихід 5. RBF 12-3-1
2016	0,380280	0,428701	0,488292	0,408247	0,380280	0,462994
2017	0,479948	0,420960	0,488292	0,431906	0,479948	0,468469
2018	0,421947	0,470936	0,488292	0,450432	0,421947	0,453330
2019	0,557073	0,534622	0,488292	0,549609	0,562641	0,483650
2021	0,562641	0,577132	0,488292	0,562935	0,562641	0,496038
2022	0,541222	0,499305	0,488292	0,560477	0,562641	0,509837
2023	0,474934	0,486389	0,488292	0,461464	0,474934	0,543726

Fig. 2.23. Predicted values of the integral indicator of the internal environment in relation to the strategic potential of enterprises according to the built models

In accordance with the predicted values of the integrated indicator of the internal environment according to the best MLP 12-11-1 model and comparing them with its actual values, it can be stated that they differ insignificantly. That is, the companies responded to external changes in a sustainable and flexible manner.

As for determining the sensitivity of the indicators, according to the best multilevel perceptron model, they are shown in Fig. 2.24.

	Чутливість (Таблиця даних у Робоча книга1) Вибірки: Навчальна											
Мережі	**Nominal GDP of Ukraine**	Number of active enterprises by type of economic activity (Code NACE Rev.2 11.03)	Total turnover of business entities	Human flight and brain drain index	Net migration	GNI	Economic decline index	Total population	Economic freedom, overall index	Taxes on goods and services	Inflation index	Taxes on income, profits, and capital gains
1.RBF 12-2-1	1,2792	1,1888	1,15480	1,02200	0,95826	1,10500	0,99787	1,00833	1,01616	0,99464	0,92342	0,976433
2.RBF 12-2-1	1,0000	1,0000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,000000
3.MLP 12-10-1	4,0344	2,6275	3,24836	1,46990	0,96212	1,48325	1,03793	1,12057	0,97231	0,97489	1,00892	0,992968
4.MLP 12-11-1	141,5343	122,9342	77,40267	72,63175	66,98528	32,47401	30,77907	25,52927	25,41838	17,99181	16,97031	9,143599
5.RBF 12-3-1	1,0328	1,0583	1,22239	0,99844	1,04466	1,01203	0,97823	0,98348	0,98581	1,00382	1,05569	0,995217
Середнє	29,7761	25,7617	16,80564	15,42442	14,19006	7,41486	6,95862	5,92833	5,87853	4,39303	4,19167	2,621644

Fig. 2.24. Sensitivity of environmental indicators according to the best multilevel perceptron model.

According to the values of the rationality coefficients, the most sensitive indicators of the top 3 external environment are: nominal GDP of Ukraine; number of operating enterprises by type of economic activity (NACE 2010: 11.03); and volume of products (goods, services) sold by economic entities: 11.03. The last sensitive indicator of the volume of products sold was also in the top 3 in the previous analysis. This indicates that the company’s management needs to continuously monitor its changes and form positive impressions of products and services using the advantages of the impression economy model.

Graphical visualizations of the scatter points of the external environment indicators with the highest sensitivity to the integrated indicator of the internal environment (baseline) and the integrated indicator of the internal environment (target) according to the selected model (MLP 12-11-1) are shown in Figures 2.25 – 2.27.

Based on the results of the analysis of the interrelationships and the impact of external environment indicators on the value of the integrated indicator of the internal environment, i.e., the strategic potential of enterprises, the following conclusions can be drawn. According to the best model of the multilevel perceptron, the external environment, characterized by nonlinearity of influence, does have interrelations with the internal environment of enterprises. However, if an enterprise has a good understanding of what is happening in the external world and identifies and anticipates its changes, while implementing innovative activities to reduce the risk of negative impact by creating positive impressions of its activities, results and opportunities, it can successfully operate and be competitive in the BANI-world.

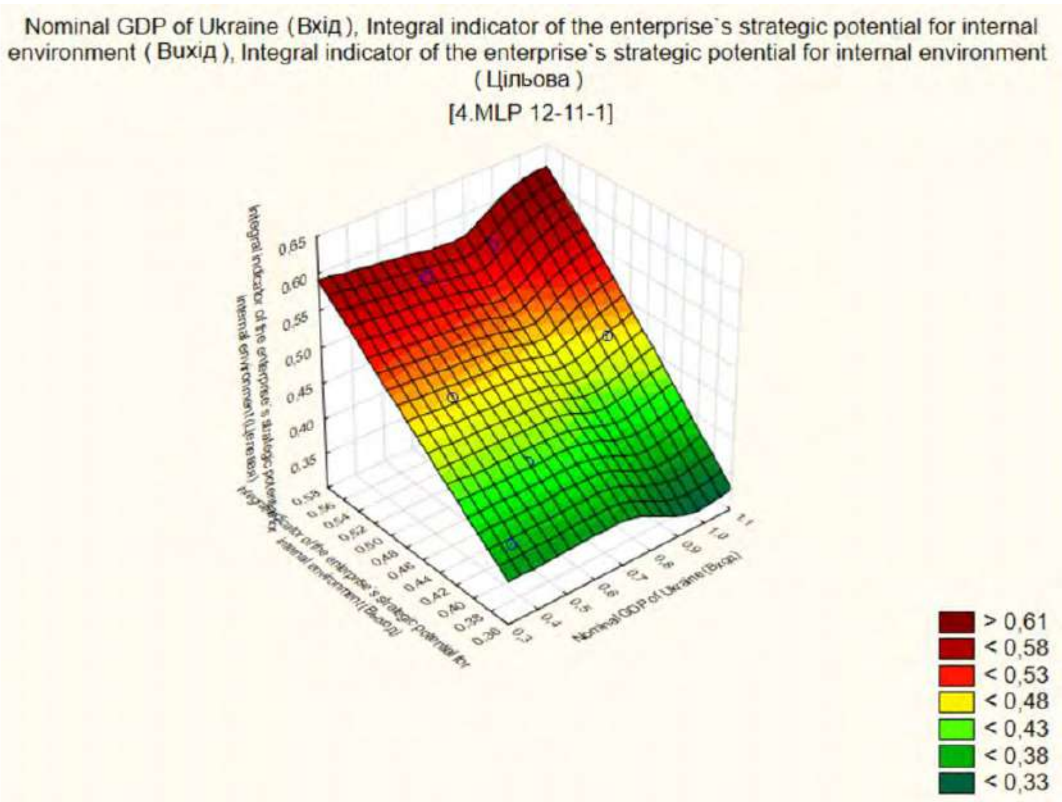

Fig. 2.25. Graphical visualization of the values of nominal GDP of Ukraine relative to the integrated indicator of the internal environment (baseline) and the integrated indicator of the internal environment (target)

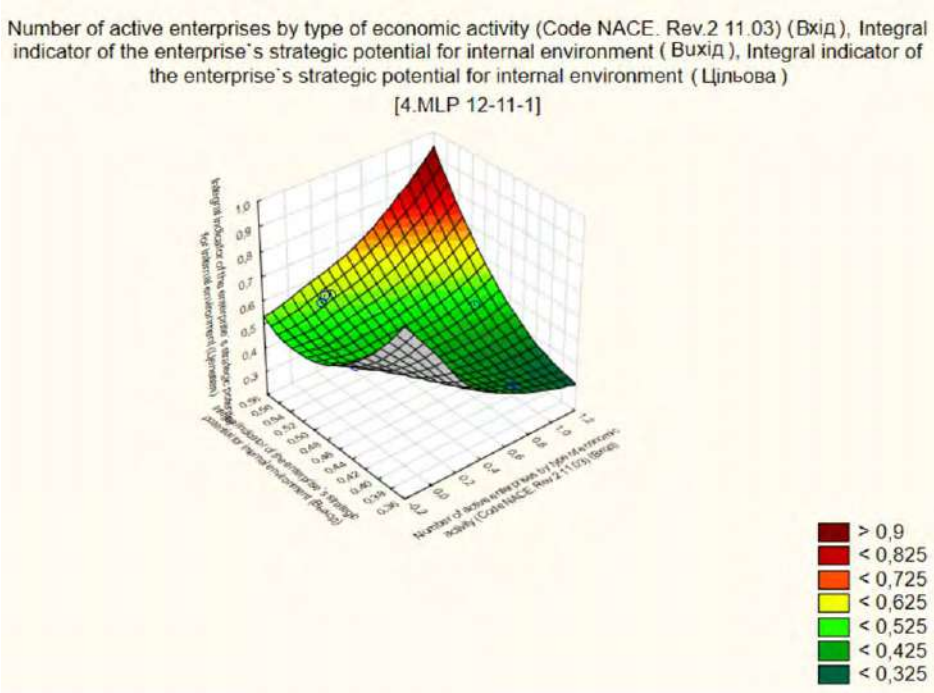

Fig. 2.26. Graphical visualization of the number of operating enterprises by type of economic activity (NACE 2010: 11.03) relative to the integrated indicator of the internal environment (output) and the integrated indicator of the internal environment (target)

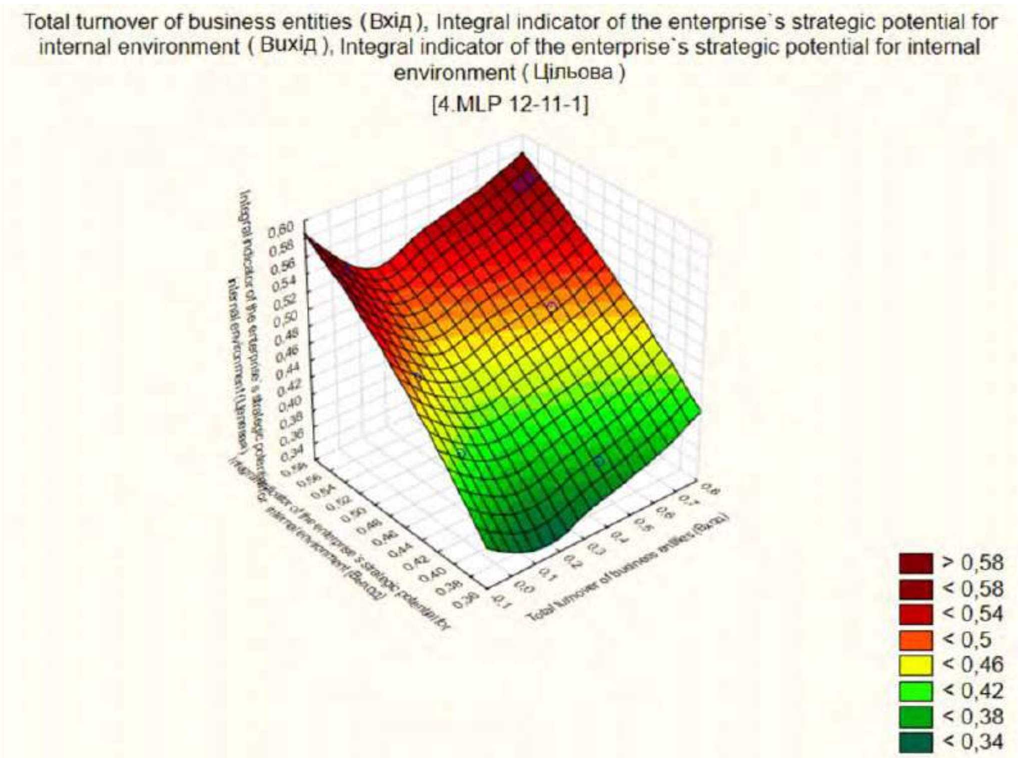

Fig. 2.27. Graphical visualization of the values of the indicator of the volume of products (goods, services) sold by business entities:
11.03 relative to the integrated indicator of the internal environment (output) and the integrated indicator of the internal environment (target)

Having proved the existence of influence and relationships between the indicators of the external environment and the integral indicator of the internal environment of enterprises, it is advisable to analyze the opposite situation, where the integral indicator of the external environment is taken as a continuous objective function, and the indicators of the internal environment are taken as a continuous input function. The results of modeling by the neural network method are shown in Fig. 2.28.

Підсумки моделей (Таблиця даних у Робоча книга1)

N	Архітектура	Продуктивність навчання	Помилка навчання	Контрольна помилка	Тестова помилка	Алгоритм навчання	Функція помилки	Ф-я актив. прихованих нейр.	Ф-я актив. вихідних нейр.
1	MLP 15-11-1	0,538244	0,010621	0,003064	0,009379	BFGS 1	Сум. квадр.	Логістична	Тотожна
2	RBF 15-3-1	-0,891610	0,010678	0,001960	0,009252	RBFT	Сум. квадр.	Гауссіан	Тотожна
3	MLP 15-16-1	0,999502	0,000032	0,000250	0,000105	BFGS 12	Сум. квадр.	Експонента	Експонента
4	RBF 15-3-1	0,528844	0,007692	0,001008	0,004395	RBFT	Сум. квадр.	Гауссіан	Тотожна
5	MLP 15-13-1	0,962726	0,009835	0,002725	0,009068	BFGS 1	Сум. квадр.	Гіперболічна	Гіперболічна

Fig. 2.28. Models of interrelation between the integral indicator of the external environment of enterprises and indicators of their internal environment

In accordance with Fig. 2.28, according to the values of the training performance criteria of 0.999502 and the training error of 0.000032, the best is the third model of the multilevel perceptron (MLP 15-16-1) with the number of hidden neurons greater than the number of input indicators, which confirms the hypothesis of the nonlinearity of the economic world. The results of the predicted values of the integral indicator of the external environment according to this model are shown in Fig. 2.29.

Таблиця передбачених значень Integral indicator of the enterprise`s strategic potential for external environment (Таблиця даних у Робоча книга1)
Вибірки: Навчальна

Спостереж номер #	Integral indicator of the enterprise`s strategic potential for external environment Цільова	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 1. MLP 15-11-1	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 2. RBF 15-3-1	**Integral indicator of the enterprise`s strategic potential for external environment - Вихід 3. MLP 15-16-1**	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 4. RBF 15-3-1	Integral indicator of the enterprise`s strategic potential for external environment - Вихід 5. MLP 15-13-1
2016	0,657254	0,603606	0,602861	0,657391	0,554947	0,602911
2017	0,714808	0,604368	0,602861	0,718214	0,724830	0,605974
2018	0,651741	0,603584	0,602861	0,661434	0,718046	0,606493
2019	0,709768	0,603827	0,602861	0,721953	0,582574	0,606844
2021	0,733214	0,602509	0,602861	0,744378	0,573330	0,604206
2022	0,396875	0,602079	0,602861	0,389261	0,527207	0,591905
2023	0,356371	0,603105	0,602861	0,358598	0,540738	0,592096

Fig. 2.29. Predicted values of the integral indicator of the external environment according to the built models

Analyzing the values of the integrated indicator of the external environment in accordance with Fig. 2.29 according to the MLP 15-16-1 model and comparing them with the actual values of the integral indicator, it can be noted that they do not differ significantly. However, according to the results of the analysis of the external environment alone, there were significant deviations in the values of the integral indicator in 2022 and 2023. This means that the activities of enterprises with regard to the internal environment can help to stabilize the fragility of the external environment to some extent, but both the actual values of the integral indicator and those predicted in 2022 and 2023 showed a significant decrease compared to previous years. Thus, the full-scale military invasion has indeed increased the unpredictability of the BANI-world's impact on the activities of enterprises in terms of the use of domestic economic resources.

The sensitivity analysis of the indicators of the best multilevel perceptron model is presented in Fig. 2.30.

	Чутливість (Таблиця даних у Робоча книга1) Вибірки: Навчальна															
Мережі	**Share of employees employed full-time**	Net profitability of sales	Share of innovative products (flavour) in the total volume of products shipped	Share of employees with university degrees	Capital equipment	Share of employees performing R&D work	Fixed asset serviceability ratio	Financial stability ratio	Return on total equity	Return on assets	Share of employees aged 29 to 50 years	Average annual output per employee	Share of trade mark expenses in total expenses	Share of employees trained in new professions	Share of employees who improved their skills in the reporting year
1.MLP 15-11-1	0,9995	0,99865	1,00122	1,001197	0,999627	1,002927	1,000064	0,999660	1,000870	1,002393	0,999847	1,001454	1,000377	0,999419	0,998169
2.RBF 15-3-1	1,0000	1,00000	1,00000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000
3.MLP 15-16-1	328,6469	43,96422	26,51991	8,431454	8,109295	5,904246	4,928814	4,822136	4,447472	3,618059	2,789187	2,322627	1,549948	0,908658	0,880823
4.RBF 15-3-1	1,1023	1,01296	1,02376	1,038294	1,006784	0,996511	0,970804	0,948079	0,912775	0,981976	0,976330	0,974773	0,969149	0,969205	0,985206
5.MLP 15-13-1	1,0436	0,99557	1,00334	1,018971	1,002275	1,012067	1,002605	0,997918	1,000902	1,005684	0,998542	0,997143	1,000849	1,007249	0,999632
Середнє	66,5585	9,59428	6,10965	2,497983	2,423596	1,983150	1,780457	1,753559	1,672404	1,521622	1,352781	1,259199	1,104065	0,976906	0,972766

Fig. 2.30. Sensitivity of indicators of the internal environment of enterprises to changes in the integrated indicator of the external environment according to the built models

The ranking of sensitivity values of the internal environment indicators by rationality coefficients according to the best multilevel perceptron model is presented in Table 2.3.

Table 2.3

Ranking of sensitivity of indicators of the internal environment of enterprises according to the best model of the multilevel perceptron model (MLP 15-16-1)

Rank	Indicator name	Value
1	Share of employees employed full-time	328,65
2	Net profitability of sales	43,96
3	Share of innovative products (flavour) in the total volume of products shipped	26,52
4	Share of employees with university degrees	8,43
5	Capital equipment	8,11
6	Share of employees performing R&D work	5,90
7	Fixed asset serviceability ratio	4,93
8	Financial stability ratio	4,82
9	Return on total equity	4,45
10	Return on assets	3,62
11	Share of employees aged 29 to 50 years	2,79
12	Average annual output per employee	2,32
13	Share of trade mark expenses in total expenses	1,55
14	Share of employees trained in new professions	0,91
15	Share of employees who improved their skills in the reporting year	0,88

According to Table 2.3, the top 3 most sensitive indicators of the internal environment to changes in the values of the integrated indicator of the external environment include the following: the share of full-time employees; net profitability of sales; and the share of innovative products in the total volume of shipped products. As in the previous separate analysis of the internal environment of enterprises, the share of full-time employees remained one of the most important indicators. This indicates that managers and owners of enterprises should create conditions for full-time employment. It is positive that the external environment encourages enterprises to intensify their innovation activities, as the third indicator in the top 3 is the share of innovative products in the total volume of shipped products. In the previous separate analysis of the internal environment of enterprises, this indicator was the fourth, i.e., not in the top 3. This indicates that one of the preferred ways to improve the economic condition of enterprises and counteract the uncertainty of the external environment is through innovation, which should be focused on the effective demand of consumers who have a positive impression of the capabilities of enterprises.

Graphical visualizations of the scatter points of the values of the internal environment indicators with the highest sensitivity to the integrated indicator of the external environment (baseline) and the integrated indicator of the external environment (target) according to the selected model (MLP 15-16-1) are shown in Figures 2.31 – 2.33.

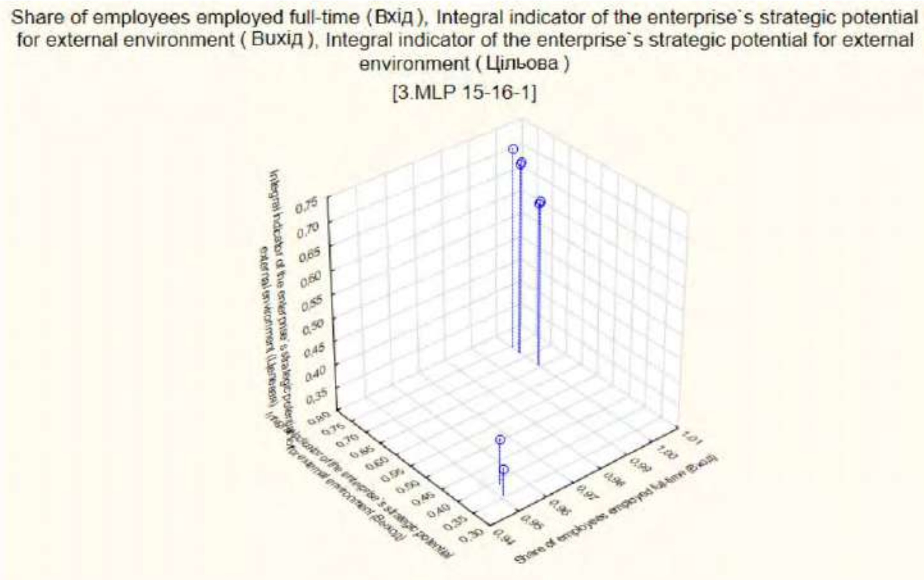

Fig. 2.31. Graphical visualization of the values of the share of full-time employees relative to the integrated environmental indicator (Output) and the integrated environmental indicator (Target)

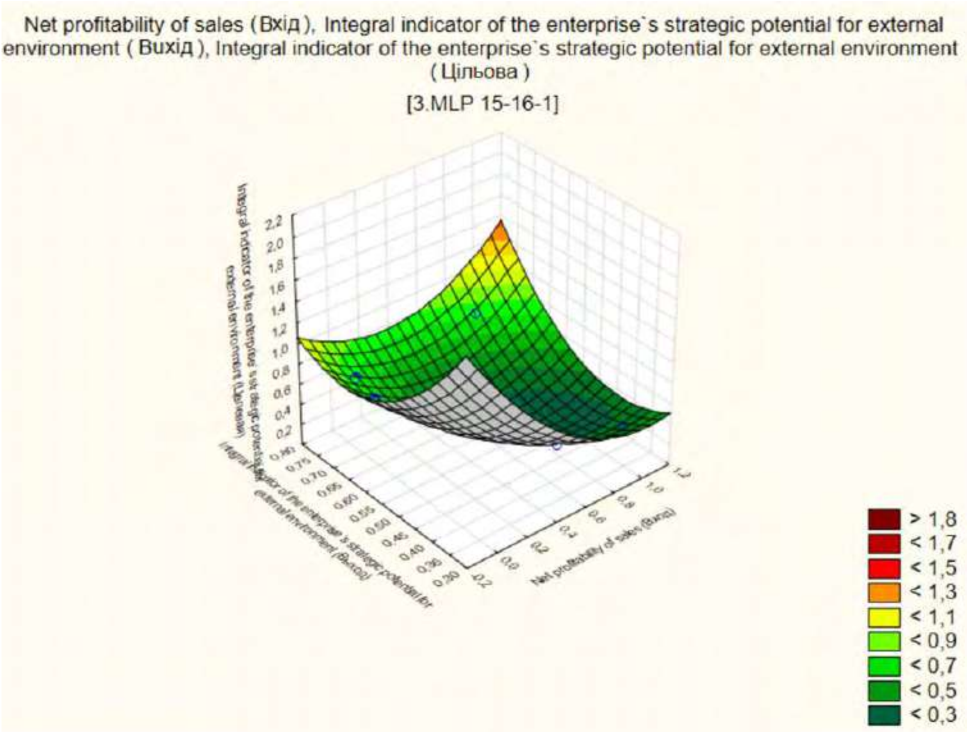

Fig. 2.32. Graphical visualization of the values of the net profitability of sales indicator relative to the integrated indicator of the external environment (Output) and the integrated indicator of the external environment (Target)

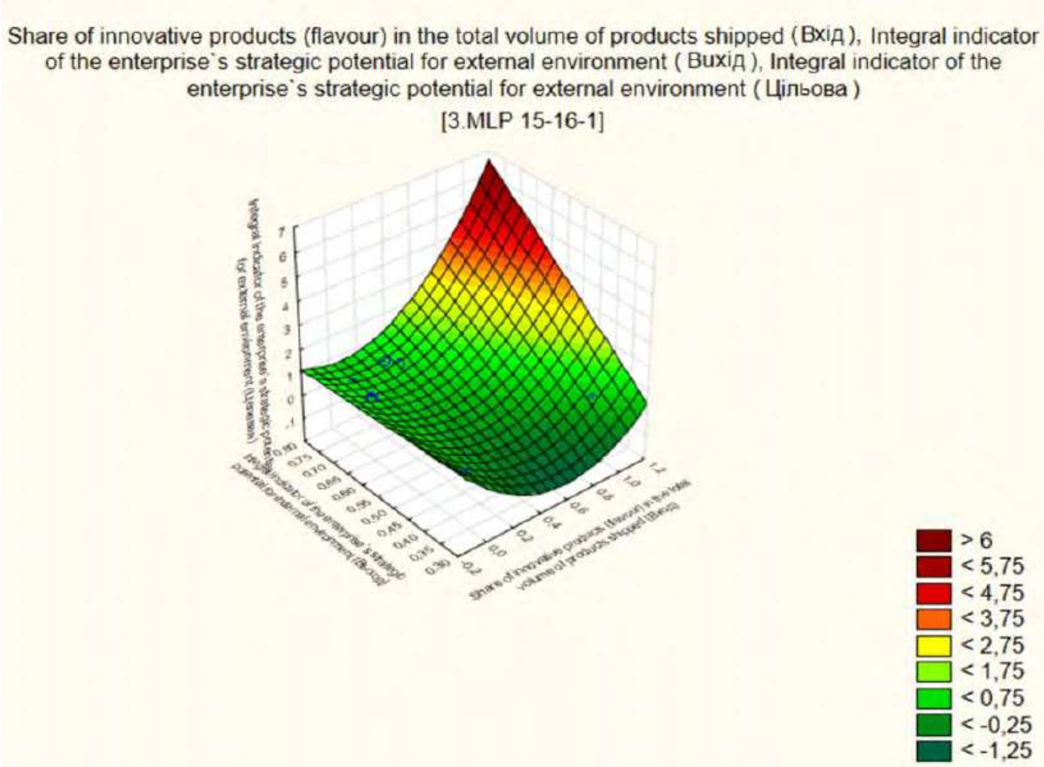

Fig. 2.33. Graphical visualization of the values of the indicator of the share of innovative products in the total volume of shipped products in relation to the integrated indicator of the external environment (Output) and the integrated indicator of the external environment (Target)

Based on the results of the analysis of the relationship and influence of the indicators of the internal environment of enterprises on the integrated indicator of the external environment, the following conclusions can be drawn. The internal environment of enterprises has a non-linear effect on the state of the external environment. The most sensitive indicators to the impact are: the share of full-time employees; net profitability of sales; the share of innovative products in the total volume of shipped products. By changing the values of these indicators, companies can adapt to the complex BANI world and smooth out its negative effects. It is important that management decisions encourage consumers and partners to cooperate with enterprises, based on their positive impressions of the company’s products, their new innovative advantages, price competitiveness in the market by increasing the productivity of full-time employees, increasing the profitability of sales of attractive products for consumers that can provide new types of pleasure, which is in line with the model of the experience economy.

Conclusions

In the current conditions of economic relations, the external environment of enterprises functions as unstable, nonlinear, fragile, and risky, which corresponds to the main characteristics of the VUCA world and the BANI world. The VUCA (Volatility, Uncertainty, Complexity, Ambiguity) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) worlds are characterized by a high level of instability and uncertainty, which directly affects all sectors of the economy, including the food industry. Studying the impact of the VUCA and BANI worlds helps to improve enterprise management systems, which will increase their resilience to external shocks and ensure sustainable development.

For Ukraine, under martial law, the BANI world is more inherent, so studying the peculiarities of the functioning of business entities in its conditions is an urgent need. It is possible to smooth out the difficulties and challenges of the external environment and the complexities of life in the internal environment using the latest progressive model of economic relations – the economy of impressions, which is aimed at forming positive impressions among enterprise stakeholders that promote close cooperation, increase in the volume of contracts, their signing on favorable terms, increase in sales, and, above all, innovation, which can enhance the positivity of impressions and satisfaction from cooperation. However, an important and still unresolved issue is the substantiation of indicators of the internal and external environment of enterprises, on which it is advisable to exercise managerial influence, models of interaction and management measures. Therefore, this study presents the proposed methodology for determining the interrelationships and managerial influence on the factors and indicators of the internal and external environment of enterprises on the example of the food industry. The main stages of the methodology are as follows:

– analysis of external and internal environment factors, determination of the most relevant factors of priority importance, for this purpose it is advisable to use the method of modeling by multivariate factor analysis;

– determination of adequate models of the relationship between these factors; as a method of determining the relationship, it is advisable to use neural networks that are close in their algorithm to the process of human thinking, it is possible to hypothesize that such models and relationships between the factors of the internal and external environments of enterprises will be non-linear;

– in accordance with the selected and substantiated models, to forecast the values of indicators of the internal and external environment and to determine the most sensitive indicators characterizing the factors of the internal and external environment by rating;

– to make management decisions on changing the values of selected sensitive indicators, the impact of which will allow enterprises to adapt to the relevant changing world as soon as possible in the process of functioning of the impression economy model;

– to use change-sensitive indicators as the basis for forming positive impressions of the enterprise (according to the impression economy model), which are characteristic and necessary for the growth of their added value and profit at a faster rate compared to other models of economic relations development to start and continue productive cooperation with partners and relationships with consumers.

The proposed methodology has been tested, and the results of the testing are presented in this study separately for the factors of the internal environment, the external environment of enterprises, as well as in their direct and inverse relationship. The obtained models of interrelation and influence of these factors in the form of multilevel perceptrons confirm the hypothesis of their nonlinearity and compliance of the Ukrainian economy with the characteristics of the BANI world. The practical use of the modeling results, the identified sensitive indicators on which managers and owners should exert managerial influence, will allow enterprises to maintain competitiveness in difficult modern operating conditions and form positive impressions of the results and capabilities of their activities for rapid growth of added value and profit, to withstand the challenges of the external environment of the BANI-world in wartime. In general, the proposed methodology can be applied to both the BANI world and the VUCA world, which proves its versatility and practical significance.

Directions for further research are the application of Agile management technologies to achieve the required level of adaptability to rapidly changing environmental conditions by enterprises.

References

1. After VUCA, the transformation to a BANI world. URL: https://ideasen.llorenteycuenca.com/2021/03/16/aftervuca-the-transformation-to-a-bani-world/
2. BANI: A new framework to make sense of a chaotic world. URL: https://thinkinsights.net/leadership/bani/
3. Koshchii O., Koretska N., & Vasylyk N. (2023) Management of the organization in the conditions of VUCA. Economic Journal of Lesya Ukrainka Volyn European National University. Vol. 3. – №35. – С. 129–135. https://doi.org/10.29038/2786-4618-2023-03-129-135 https://echas.vnu.edu.ua/index.php/echas/article/view/846/691

4. Chalyuk Y. O. (2022) Global socio-economic development in VUCA, SPOD, DEST AND BANI conditions of the world. Economy and society. Issue 36. http://dx.doi.org/10.32782/2524-0072/2022-36-21
5. Cascio J. Facing the age of chaos. [Electronic resource] // Medium. – https://medium.com/@cascio/facing-the-age-of-chaos-b00687b1f51d
6. Baran B. E. Managing VUCA: The human dynamics of agility / B. E. Baran, H. M. Woznyj // Organizational dynamics. – 2021. –. Vol. 50. – №2, 100787. https://www.sciencedirect.com/science/article/pii/S0090261620300395
7. Halina, V. Yu. Challenges of the BANI of the world and new opportunities for the development of Soft Skills. / V.Yu. Khalina // Emotional intelligence in finance: micro-level aspect. – Odesa: Publishing house "Helvetika", 2023. – P. 424-427
8. A.V. Chmut Modern management challenges in the VUCA world / A.V. Chmut, O.O. Chmut // Scientific Bulletin of the Kherson State University. Series "Economic Sciences". – 2023. – No. 47. – P. 47–52. DOI: 10.32999/ksu2307-8030/2023-47-7
9. Sagaidak M.P., Merzlyakova O.L., Simshag I.O. Study of modern trends in the functioning of business organizations in the context of the challenges of the VUCA world. Transformation of the management of business organizations: modern trends and challenges: monograph / by General. ed. Sagaidak M.P., Soboleva T.O. Kyiv: KNEU after name V. Hetmana, 2021. P.31–53.
10. Motuzka O. Strategic guidelines for the development of foreign economic activity of enterprises in the environment of BANI / O. Motuzka, N. Hrynchak // Bulletin of the Khmelnytskyi National University. Series "Economic Sciences". – 2023. – No. 1. – P. 133–138. https://doi.org/10.31891/2307-5740-2023-314-1-19
11. Ostrikova T. Six models of economic development after the coronavirus pandemic and their development potential / T. Ostrikova // Economic truth 2020.– https://www.epravda.com.ua/columns/2020/08/26/664360/.
12. Iastremska O. M., Demchenko G. V. Activation of innovative activity of enterprises: monograph. Kharkiv: FOP Liburkina L.M., 2018. 232 p. http://www.repository.hneu.edu.ua/jspui/bitstream/123456789/20633/1/%D0%9C%D0%BE%D0%BD%D0%BE%D0%B3%D1%80%D0%B0%D1%84%D0%B8%D1%8F.pdf
13. State of development of innovative infrastructure. [Electronic resource] // Me.gov. – URL: https://www.me.gov.ua/Documents/Detail?lang=uk-UA&id=022cfe7f-2c18-4545-ab69-1a3a39aea3f8&title=StanRozvitkuInnovatsiinoiInfrastrukturi
14. Kobelev V.M. Innovative activity of an industrial enterprise / V.M. Kobelev, K.O. Vasylyuk // Bulletin of the National Technical University "Kharkiv Polytechnic Institute" (Economic Sciences): coll. of science pr. – Kharkiv: NTU "KhPI", 2018. – No. 47 (1323). – P. 67–72. URL: https://repository.kpi.kharkov.ua/handle/KhPI-Press/39770
15 Savina, H.G., Skibina, T.I. Factors of external and internal influence on the level of efficiency of enterprise management of a complex of communal services. Effective Economy 2016. No. 12. http://www.economy.nayka.com.ua/?op=1&z=5300
16. Epifanova I.Yu., Hladka D.O. Innovative potential of the enterprise: essence, components and factors of influence Economics and management of enterprises. 2018. Issue 14. S. S. 354 – 360. URL: https://chmnu.edu.ua/wp-content/uploads/2019/06/Ekonomika-i-suspilstvo-14-2018.pdf#page=354

17. Huk O.V.; Melnyk A. V. Factors influencing the innovative activity of enterprises. International scientific and practical conference "Business, innovations, management: problems and prospects". K. NTU KPI named after I. Sikorskyi. 2020. P. 164–165. URL: https://confmanagement-proc.kpi.ua/article/view/201200
18. Melnyk Yu. M., Savchenko O. S. Problems of using a balanced system of indicators at domestic enterprises. Marketing and innovation management. 2011. No. 1. P. 192–203. URL: https://mmi.sumdu.edu.ua/wp-content/uploads/mmi/volume-2-issue-1/mmi2011_1_192_203.pdf
19. Kuznetsova K.O. Factors influencing the formation of enterprise competitiveness https://ela.kpi.ua/server/api/core/bitstreams/2348ab89-5cc4-4ebf-8122-720982532ba6/content
20. Gerasimova V. O., Rezanov E. O. Enterprise competitiveness: essence and influencing factors in modern conditions. Economic space. 2020 #154. P. 93–97. DOI: https://doi.org/10.32782/2224-6282/154-17. http://prostir.pdaba.dp.ua/index.php/journal/article/view/482/470
21. What Is the Knowledge Economy? Definition, Criteria, and Example [Electronic resource] // Investopedia. – Access mode: https://www.investopedia.com/terms/k/knowledge-economy.asp#citation-1
22. Khaminich, S. Yu. Knowledge economy as a driving force of progress / S. Yu. Khaminich, O.V. Khaminich // National economy and infrastructure projects. – 2023. – P. 35–37. https://er.dduvs.in.ua/xmlui/handle/123456789/12510?show=full
23. O. Bondar-Pidgurska. Development of innovative activity of strategically important branches of industry during the war and post-war development of the economy of Ukraine / O. Bondar-Pidgurska, V. Koshman // Collection of materials int. scientific and practical conference. – 2023. – No. VI. – pp. 98–99. https://knute.edu.ua/file/MzEyMQ==/ed3426146432ea2f6837c04fe0c85b86.pdf
24. Piletska S. T. Formation of the strategy of innovative development of the enterprise / S. T. Piletska, E. V. Tkachenko // Scientific and practical journal "Economic Studies". – 2020. – Issue No. 1 (27). – P. 146-150.
25. Komandrovska V. Conceptual bases of the Investment Mechanism of the Innovative Activity of Enterprises in the Context of Achieving the Tasks of Strategic Development / V. Komandrovska, M. Kolesnyk, K. Barkova, S. Vasylyk, D. Dorofieiev // International Journal of Computer Science and Network Security. – 2021. – Vol. 21. – No.11. – P. 111–118 URL: http://paper.ijcsns.org/07_book/202111/20211115.pdf
26. Cirera X. The innovation paradox : developing–country capabilities and the unrealized promise of technological catch-up: World Bank Publications / X. Cirera, W. F. Maloney. – Washington, DC: World Bank, 2017. – 186 p. URL: https://openknowledge.worldbank.org/server/api/core/bitstreams/b0b06101-6fa4-5ea8-9b5b-1f4f2b170c1f/content
27. Derya Öztürk, and Hancıoğlu Yasemin. "Evaluation of Innovation Performance With AHP and TOPSIS Integrated Approach: An Application in Hazelnut Sector." Handbook of Research on Recent Perspectives on Management, International Trade, and Logistics. IGI Global, 2021. 294-315. URL: https://www.igi-global.com/dictionary/evaluation-of-innovation-performance-with-ahp-and-topsis-integrated-approach/49873

28. Đuričin, Sonja. "The Impact of the Covid-19 Pandemic on the Financial Performance of Innovative Enterprises in Serbia." (2022): 235-247. URL: http://ebooks.ien.bg.ac.rs/1799/1/sonja%20djuricin.pdf
29. What is Innovation? Definition, Types, Examples and Process. [Electronic resource] // Ideascale. – Access mode: https://ideascale.com/blog/what-is-innovation/
30. Zaliznyuk V. P. Modern trends of innovative activity of Ukrainian enterprises in the international economic space / V. P. Zaliznyuk, N. P. Safonik, A. S. Kaya // Economic Bulletin of the Dnipro Polytechnic. – 2021. – Issue No. 4. – P. 183–189. URL: https://ev.nmu.org.ua/docs/2021/4/EV20214_183-189.pdf
31. Multivariate analysis https://studfile.net/preview/5775952/page:19/
32. Malyarets L. M. Measurement of signs of objects in the economy: methodology and practice: scientific publication. Kharkov: Ed. KhNEU, 2006. 384 p.
33. Khlaiboroda M. What is a neural network? https://incrypted.com/ua/shcho-take-nejromerezhi/
34. Kyzim N.A., Iastremska O.M., Senchukov V.F. Neural networks: theory and practice of application. Monograph. – Kh.: Publishing House "INZHEK", 2006. – 240 p.
35. Zaliznyuk V. P. Modern trends of innovative activity of Ukrainian enterprises in the international economic space / V. P. Zaliznyuk, N. P. Safonik, A. S. Kaya // Economic Bulletin of the Dnipro Polytechnic. – 2021. – Issue No. 4. – P. 183–189. URL: https://ev.nmu.org.ua/docs/2021/4/EV20214_183-189.pdf
36. Didur K. M. Essence, classification and structure of investment and innovation activity of the enterprise / K. M. Didur // Investments: practice and experience. – 2022. – No. 9–10. – pp. 30–38. – http://www.investplan.com.ua/pdf/9-10_2022/7.pdf
37. Iastremska O.M. Application of the theory of fuzzy sets for the qualitative demarcation of the characteristics of enterprises (on the example of enterprises of machine-building, food and light industry). Development economics. – 2006. – No. 3 (39). – P. 95 – 101.
38. Nguyen M.H. UK economic policy uncertainty and innovation activities: A firm-level analysis/ M.H. Nguyen, V.Q. Trinh // Journal of Economics and Business. – 2023. – Vol. 123, 106093 https://www.sciencedirect.com/science/article/pii/S0148619522000492#sec0095
39. Konfo T. R. C. Recent climate-smart innovations in agrifood to enhance producer incomes through sustainable solutions / T.R. C. Konfo, A.B.P. Chabi, A.A. Gero, C. Lagnika, F. Avlessi, G. Biaou, C.K.D. Sohounhloue // Journal of Agriculture and Food Research. – 2024. –. Vol. 15, 100985. https://www.sciencedirect.com/science/article/pii/S266615432400022X#sec4
40. Jelonek D. Environmental uncertainty and changes in digital innovation strategy / D. Jelonek // Procedia Computer Science. – 2023. – Vol. 225. – P. 1468–1477. https://www.sciencedirect.com/science/article/pii/S1877050923012930

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