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# Computer model of differential-symbolic risk assessment of projects to improve the health of the community population

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## ABSTRACT

The article presents the results of developing a computer model for differential symbolic risk assessment of community health improvement projects. Traditional approaches and methods, such as expert opinions or statistical models, have limitations regarding the accuracy of risk prediction and adaptation to changing conditions of the project environment. The proposed computer model uses a system of differential equations that describe the dynamics of key project indicators, such as public participation in activities, the effectiveness of educational and vaccination measures, budget changes, and their impact on overall risk. This model allows assessing risks taking into account the studied project dynamics, promptly adjusting management decisions, and reducing deviations from the planned indicators. To implement the proposed model, an algorithm has been developed that includes several stages: initialization of variables, construction of a system of differential equations, their numerical solution by the Euler method, risk assessment, and real-time updating of parameters. Based on the developed algorithm, which involves 9 steps, a computer model has been created, which will be further integrated into a decision support system for project managers. The proposed computer model is written in the Python programming language using libraries for solving differential equations, optimization, and visualization of results that implement the proposed mathematical model. This computer model allows project managers to simulate risks, analyze their impact on project performance, and generate recommendations for managing resources and minimizing risks. The developed computer model was tested on the example of real community health improvement projects. For the community vaccination project, the computer model showed a forecasting accuracy of 97.14%, which exceeds the figure for the use of expert estimates (92.86%). In an educational project to promote healthy lifestyles among the community population, the accuracy of the computer model is 90.00% compared to 88.00% when using the method of expert judgment. The risk assessment showed that the use of the differential-symbolic model can reduce the risk level to 2.86% in the community vaccination project and 10.0% in the community health education project. At the same time, traditional methods showed risks of 7.14 % and 12.00 %, respectively. The computer model also proved to be adaptable to the changing project environment, which included an increase in project duration or a decrease in the available budget. The proposed computer model integrates functionality for parameter input, numerical risk calculation, visualization of results, and generation of recommendations. The interface of the computer model is designed in such a way as to provide convenience for project managers, even in conditions of high complexity of input data. The obtained results confirm that the developed computer model for differential symbolic risk assessment of community health improvement projects is an effective tool for project management. The use of the model allows not only to improve the accuracy of risk forecasting but also to ensure efficient resource allocation.

**Keywords:** Computer model; differential symbolic modeling; risk assessment; projects; management; health; population; communities

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## INTRODUCTION

Today, project managers face several scientific and applied tasks that require substantiation and development of tools for their solution when implementing projects in the healthcare sector [1, 2]. One of these tasks is risk assessment in community health improvement projects. It is this urgent task that requires the use of modern approaches to take into account its specifics due to the influence of a changing project environment.

In modern medical project management practice, both traditional methods of risk analysis and automated systems based on mathematical and computational models are used [3, 4]. However, many of these approaches do not take into account the interdependence between time parameters and the dynamics of implementing projects to improve the health status of the community population. In particular, this concerns changes in the time of project components due to the influence of various factors of the project environment.

Theoretical studies by various scholars have already identified the issue of risk assessment. They involve the use of probabilistic methods, fuzzy logic, statistical models, and machine learning algorithms. In addition, some scientific papers on project management emphasize the need to integrate multidisciplinary approaches to take into account complex dynamic processes [5]. However, existing methods are limited in their application to healthcare projects due to insufficient adaptability to specific conditions and dependence on fixed scenarios.

Practical solutions implemented in information systems are mostly based on static models that do not take into account the possibilities of real-time risk prediction [6-9]. This requires management decisions to be made in the complex and rapidly changing conditions of the project environment, which are typical for medical projects. For example, risk monitoring systems are often based on historical data, which does not allow for rapid adaptation to new challenges in terms of changing health status of the community population.

The expediency of developing a computer model based on a differential-symbolic approach is driven by the need to solve the outlined scientific and applied problem. Such a model makes it possible to describe dynamic changes in project parameters, as well as their impact on risks under the influence of a changing project environment. The integration of mathematical differential equations and symbolic computing ensures the development of a more flexible and adaptive solution, which is typical for projects to improve the health of the community. Such a model will reduce subjectivity in risk assessment and improve the accuracy of forecasts.

Thus, the relevance of developing a computer model of differential symbolic risk assessment is driven by the need to improve the efficiency of managing community health improvement projects in conditions of limited resources and high uncertainty.

## LITERATURE ANALYSIS

Risk assessment in community health improvement projects is an important task to ensure their effectiveness and efficiency. The scientific literature presents a variety of approaches to risk modeling and assessment, each with its advantages and disadvantages.

Traditional methods of risk assessment are often based on qualitative analysis, which includes the identification of risks and their classification by the degree of impact and probability of occurrence [10]. Such approaches provide quick identification of the main components of risks, but they are subjective and do not always take into account dynamic changes in the project environment.

Quantitative methods, such as statistical models and economic and mathematical approaches, provide a more objective risk assessment [11]. The use of stochastic models allows determining randomness and uncertainty in processes. However, such methods require significant amounts of data and complex calculations, which makes it difficult for project managers to apply them in practice.

Simulation models have become widespread in project risk analysis in various subject areas [12]. They allow simulating various scenarios and assessing their impact on the project. They mainly ensure that complex relationships between project components are taken into account. However, they have the disadvantage of requiring significant development time and detailed input data, which is often not available for specific health improvement projects in a given community.

Process approaches to risk modelling focus on information management risks through the construction of process models [13, 14], [15]. This allows systematising processes and changes in critical points, but such models are not flexible enough to adapt to rapid changes in the project environment during the implementation of projects to improve the health status of the community population.

The analysis of scientific papers shows that there are various approaches to risk assessment. However, none of them provides full consideration of the dynamic changes in the project environment and their impact on community health improvement projects. This necessitates the development of a computer model for differential symbolic risk assessment. It will compensate for the advantages of existing methods and allow for more accurate


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prediction and management of risks of community health improvement projects.

Thus, developing a computer model for differential symbolic risk assessment of community health improvement projects will ensure an increase in the efficiency of risk management in these projects. This will not only improve the quality of management decision-making but also create a basis for the development of new health information systems.

## FORMULATION OF THE PROBLEM

Effective management of community health improvement projects requires an accurate assessment of the risks that affect the implementation of these projects, taking into account their dynamics due to the influence of factors in the changing project environment. Traditional approaches to risk assessment, including probabilistic and statistical methods, have limitations in adapting to the complex project environment of community health improvement projects. They do not take into account the dynamic nature of risks, their nonlinearity, and mutual influence, which limits their effectiveness in making management decisions.

To solve this problem, it is necessary to develop a model that will take into account the time dynamics, and the dependence of risks on changes in the project environment, and will improve the accuracy of risk forecasting at different stages of the implementation of these projects. One of the approaches to risk assessment is to use mathematical models that allow forecasting and analyzing possible scenarios. The differential-symbolic approach to risk modelling allows taking into account the dynamics of implementation of projects to improve the health of the population, including changes in their components over time and the impact of various factors of the project environment.

We propose a mathematical model for differential symbolic risk assessment of public health improvement projects. This model is based on a system of differential equations that describe the dynamics of basic project indicators, such as the percentage of the population that participated in awareness-raising activities, vaccinations, and educational programs. The model also includes an assessment of changes in the project budget and takes into account the impact of these changes on the overall project risk.

The object of the study is the process of implementing projects to improve the health status of the community population, which are characterized by the impact of risks associated with changes in the main components of projects, such as the level of population involvement, budget constraints, the effectiveness of measures and external factors of the project environment.

The subject of the study is a mathematical model of differential-symbolic risk assessment that describes the dynamics of changes in the state of health of the population, the project budget and risks throughout the entire period of implementation of the project to improve the state of health of the population.

The proposed model provides not only risk analysis but also risk forecasting, which is necessary for timely adjustment of management decisions during the implementation of community health improvement projects and increase of their efficiency.

## THE PURPOSE AND THE OBJECTIVES OF THE STUDY

The purpose of the study is to develop mathematical and computer models for differential symbolic risk assessment of projects to improve the health status of the population of communities. This allows to increase the efficiency of project management, ensure timely risk assessment and reduce their negative impact on the achievement of the goals of these projects.

To achieve this goal, the following tasks should be performed:

– to develop a mathematical model based on a system of differential-symbolic equations describing the dynamics of key project indicators, such as the level of public participation in events, the effectiveness of educational and vaccination measures, budget changes and their impact on the overall risk;

– to develop an algorithm and computer model that implement the proposed mathematical model and allow for prompt risk assessment and generate recommendations to substantiate management decisions by project managers;

– to test the computer model on the example of real community health improvement projects, to analyze its accuracy and adaptability to the changing conditions of the project environment.

## RESEARCH METHODS

The study uses a systematic approach that integrates mathematical modeling, differential-symbolic approach, numerical methods, and computational intelligence tools. The basis of the proposed mathematical model is a system of differential equations that describe the dynamics of key project indicators, such as public participation in events, the effectiveness of educational and vaccination measures, budget changes, and their impact on the overall risk.

The paper applies a mathematical modeling method using a system of differential equations that describe the interaction between budget changes, the level of public participation, and the overall project risk. These equations take into account temporal and nonlinear relationships between project components. Numerical methods were used to solve the system of differential equations. In particular, the numerical solution of the differential equations was performed using the Euler method to predict changes in community health indicators and the budget of the health improvement project. This makes it possible to model complex scenarios with a large amount of input data and high process dynamics.

To develop the computer model, we wrote code in the Python programming language using libraries for solving differential equations, and optimizing and visualizing the results. The NumPy library is used to work with numerical arrays and perform mathematical operations. The matplotlib library is used to visualize modelling results. The Pandas library is used to create and process data tables.

Taken together, these methods provide an effective tool for risk assessment of community health improvement projects, adapted to the conditions of modern health project management.

## MATHEMATICAL MODEL OF DIFFERENTIAL-SYMBOLIC RISK ASSESSMENT OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

Public health improvement projects are an important component of community development and quality of life [16-18]. The products of such projects can be a variety of activities, such as outreach programs, vaccinations, and educational initiatives, which are aimed at improving the overall health status of the community population. However, the implementation of such projects is associated with numerous challenges and risks that affect their success. Assessing and managing these risks are key processes to ensure the effectiveness of these projects.

The main purpose of this model is to provide tools for project managers to quantify risks and support decision-making in the process of managing health improvement projects. This will optimise the use of resources, minimise risks and increase the efficiency of project implementation, which will ultimately contribute to improving the health status of the population in the communities.

To assess changes in the health status of the community population, we use differential equations that describe changes in key project indicators over time. In particular, we consider such indicators as the percentage of healthy people who have participated in awareness-raising activities, vaccinations and received health education.

We assume that the percentage of the population that is healthy is known beforehand $Y_1(t)$, $Y_2(t)$ and $Y_3(t)$, that participated in the relevant activities at a given time $t$. We can write down the dynamics equation for the implementation of educational activities:

$$\frac{dY_1(t)}{dt} = \alpha_1(1 - Y_1(t)) - \beta_1 Y_1(t), \qquad (1)$$

where $\alpha_1$ is the rate of involvement of the healthy population in educational activities; $\beta_1$ – is the rate of decrease in the percentage of the involved population due to various factors (e.g. loss of interest, etc.).

As for the dynamics equation for vaccination, it can be written as follows:

$$\frac{dY_2(t)}{dt} = \alpha_2(1 - Y_2(t)) - \beta_2 Y_2(t), \qquad (2)$$

where $\alpha_2$ is the rate of involvement of the healthy population in vaccination; $\beta_2$ is the rate of decrease in the percentage of the population involved in vaccination.

The equation of dynamics for educational programmes can be written as follows:

$$\frac{dY_3(t)}{dt} = \alpha_3(1 - Y_3(t)) - \beta_3 Y_3(t), \qquad (3)$$

where $\alpha_3$ is the rate of involvement of the healthy population in health education programmes; $\beta_3$ is


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the rate of decrease in the percentage of the population involved in educational programmes.

At the beginning of the simulation, we assume that $t = 0$:

$$\begin{aligned} &Y_1(0) = initial(Y_1), \\ &Y_2(0) = initial(Y_2), , \\ &Y_3(0) = initial(Y_3), \end{aligned} \tag{4}$$

where $initial(Y_1)$ is the initial percentage of the healthy population that participated in educational activities; $initial(Y_2)$ is the initial percentage of the healthy population that participated in vaccination; $initial(Y_1)$ is the initial percentage of the healthy population that received health education.

The total budget of the health promotion project includes $B(t)$ a baseline value and may change over time depending on the costs of the activities:

$$\begin{aligned} &B(t) = initial_B - c_1 \int_0^t Y_1(t)dt - \\ &-c_2 \int_0^t Y_2(t)dt - c_3 \int_0^t Y_3(t)dt \end{aligned} , \tag{5}$$

where $c_1, c_2, c_3$ are respectively, the cost per participant for awareness-raising activities, vaccination, and education.

The risks of a public health improvement project $R(t)$ can be assessed based on the deviation from the planned indicators:

$$\begin{aligned} &R(t) = \gamma_1 \,|\, initial(Y_1) - Y_1(t) \,|\, + \\ &+\gamma_2 \,|\, initial(Y_2) - Y_2(t) \,|\, + \\ &+\gamma_3 \,|\, initial(Y_3) - Y_3(t) \,| \end{aligned} , \tag{6}$$

where $\gamma_i$ are the risk weights for each of the indicators.

The Euler method can be used to solve the differential equations numerically. Let the discrete time points $t_i$ , $i = 0,1,\ldots,n$ , be known, then:

$$\begin{aligned} &Y_1(t_{i+1}) = Y_1(t_i) + h\left(\alpha_1(1 - Y_1(t_i)) - \beta_1 Y_1(t_i)\right), \\ &Y_2(t_{i+1}) = Y_2(t_i) + h\left(\alpha_2(1 - Y_2(t_i)) - \beta_2 Y_2(t_i)\right), \\ &Y_3(t_{i+1}) = Y_3(t_i) + h\left(\alpha_3(1 - Y_3(t_i)) - \beta_3 Y_3(t_i)\right), \end{aligned} \tag{7}$$

where $h$ is the solution step.

The solution step is determined by the formula:

$$h = \frac{e_t - s_t}{n} \tag{8}$$

where $e_t$ is the time of completion of the project status assessment; $s_t$ is the time of the project status assessment; $n$ is the number of stages.

The presented equations (7-8) allow us to assess the dynamics of changes in the state of health of the population in the process of implementing projects to improve the state of health of the population, taking into account the impact of educational activities, vaccination, and educational programs.

The proposed mathematical model allows us to assess the dynamics of changes in the state of health of the population, the project budget, and risks throughout the entire project implementation period to improve the population's state of health.

## RESULTS OF THE DEVELOPMENT OF AN ALGORITHM AND COMPUTER MODEL FOR DIFFERENTIAL SYMBOLIC RISK ASSESSMENT OF PUBLIC HEALTH IMPROVEMENT PROJECTS

We have developed an algorithm for a computer model of differential symbolic risk assessment of projects to improve the health of the population, the flowchart of which is presented in Fig. 1.

The differential symbolic risk assessment of projects to improve the health of the population involves 9 steps, which involve the use of formulas (1-8):

1. Initialisation of variables for performing risk assessment of projects to improve the health of the population. To do this, we set a pre-known value of the percentage of the population that is healthy $Y_1(t)$, $Y_2(t)$ and $Y_3(t)$ then use formulas (1-3) to write down the equations of dynamics for implementing measures to improve the health status of the population. We fix the initial percentage of the healthy population participating in various measures using formula (4). Set the initial budget $B$ and duration $t$ of the project.

2. Determine the solution step using formula (8).

3. Check the condition that all the initial data are consistent. If so, proceed to step 4. If not, go back to step 1 and make changes to the inputs to perform the risk assessment of the health improvement project.

4. Use Euler's method to solve the differential equations numerically using formulas (7).

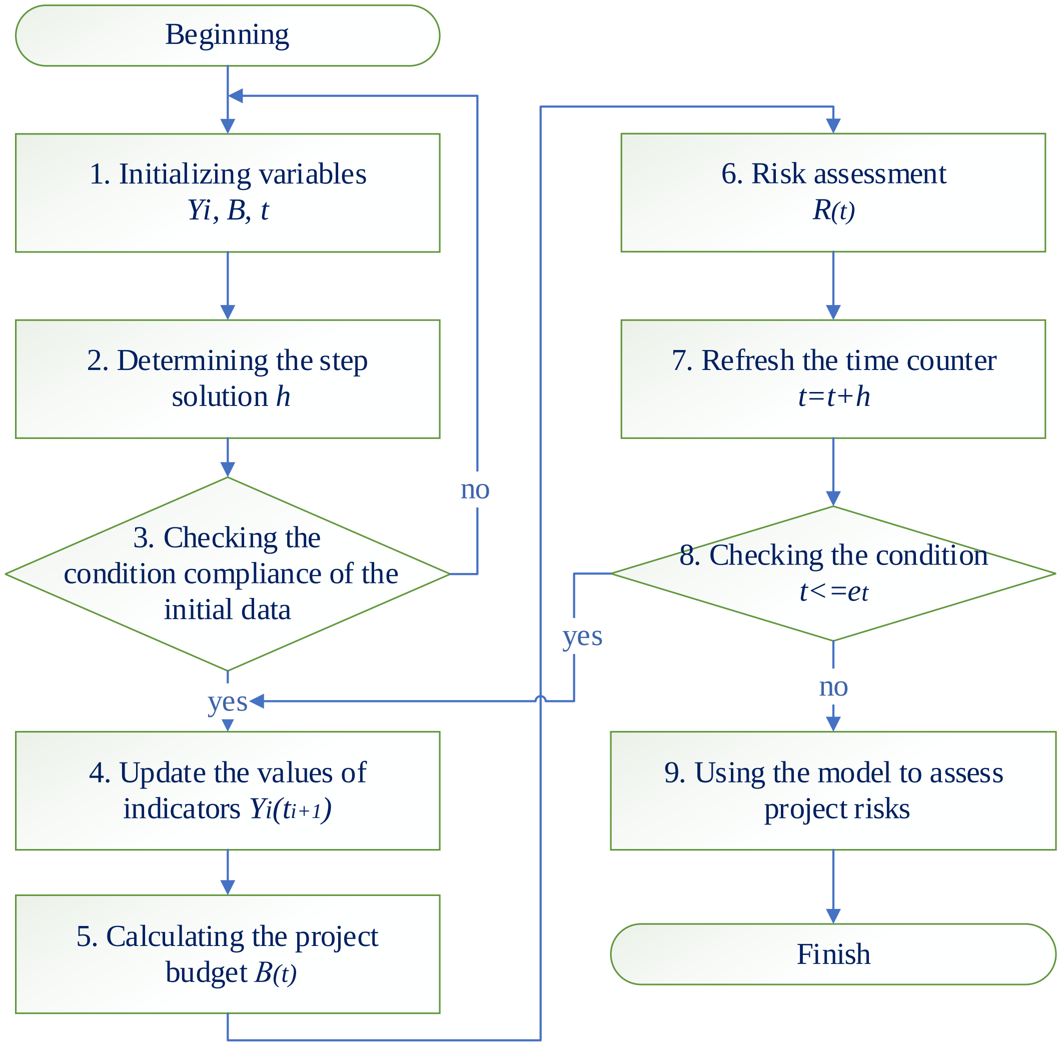


*Fig.1.* **Flowchart of the algorithm of the computer model of differential symbolic risk assessment of projects for improving the health of the population**

***Source*: compiled by the authors**

5. Calculate the budget of the project for improving the health of the population using formula (5) and the following conditions:

$$\int_0^t Y_1(t)dt \approx h\sum_{j=0}^{i} Y_1(t_j)\,, \tag{9}$$

$$\int_0^t Y_2(t)dt \approx h\sum_{j=0}^{i} Y_2(t_j)\,, \tag{10}$$

$$\int_0^t Y_3(t)dt \approx h\sum_{j=0}^{i} Y_3(t_j)\,. \tag{11}$$

In the process of calculating the project budget using formula (5), we use numerical integration to estimate values that change over time, such as population health or other important project indicators. The conditions specified in step 5 imply the use of summation of values at different stages of time, which allows us to approximate the integral. Using summation instead of integration keeps the calculations within the capabilities of numerical methods and allows for fast computations for complex projects where the integration can be replaced by discrete summations at small time intervals (denoted by $h$). Instead of integrating a function $Y(t)$ that describes a change in a quantity (e.g., the level of health of a population), we use a numerical method that approximates the integral by summing the values of the function at certain points in time $t_0, t_1, t_2, ..., t_i$ (according to formulas (9)-(11)). This approximation is correct, provided that the step $h$ is small enough to ensure the accuracy of the results.

6. Risk assessment of the project for improving the health status of the population $R(t)$ based on the


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deviations from the planned indicators using equation (6).

7. Update the time counter for the implementation of the public health improvement project – $t = t + h$ .

8. Check whether the specified modeling stage does not exceed the time for completion of the population health improvement project. If so, go to step 4. In this case, update the values of the indicators for the numerical solution of the differential equations. If not, proceed to step 9.

9. Use the model to assess the risks of public health improvement projects.

Based on the proposed algorithm, we have created a computer model for differential symbolic risk assessment of public health improvement projects. The code is written in Python programming language using libraries for solving differential equations, optimization, and visualisation of results. The NumPy library is used to work with numerical arrays and perform mathematical operations. It is used to implement the numerical solution of differential equations and calculations in the model. Thanks to the Matplotlib library, the modeling results were visualized. This made it possible to create graphs of changes in the percentage of healthy population, budget, and risk throughout the project. It is also used to add a vertical line to the graphs to indicate the optimal risk value. The Pandas library is used to create and process tables with data. It is used to conveniently display initial data, modeling results, and indicators for a given risk level in the form of tables. The code structure of a computer model consists of the following main blocks: 1) initialization of the initial data and model parameters; 2) checking the initial data for correctness; 3) a modeling cycle that performs a numerical solution of differential equations and records the results; 4) outputting and saving the results in the form of graphs and tables; 5) adding analysis and visualization of the optimal risk value.

The computer model of differential symbolic risk assessment of public health improvement projects developed by us will be used by project managers in the process of risk assessment of public health improvement projects. It is based on a mathematical model and algorithm developed by us. The model is implemented in the form of a graphical user interface, which allows you to enter initial data, perform calculations, and display the results in the form of text reports and graphs (Fig. 2).

One of the components of the proposed computer model for differential symbolic risk assessment of these projects is a graphical user interface. It consists of 3 tabs, which are provided for entering initial data, displaying results, and visualising them in the form of graphs.

In the “Initial Data” tab, the user can enter the following initial data for risk assessment of health improvement projects: the existing (initial) percentage of healthy population in a given community, the available (initial) project budget, the planned duration of the project (in months), the time step for modeling the project implementation, the coefficients of the impact of measures on the health of the community, budget expenditures and risk reduction.

In the context of equations (1)-(8), the coefficients α, β, γ are used to adjust and scale the parameters of the equations that describe the dynamics of changes in the project. The coefficient alpha (α) is responsible for the weighting of certain variables on changes in the level of population health or other project parameters. For example, alpha adjusts the magnitude of the impact of changes in the level of public participation or the effectiveness of measures on the overall result. Beta coefficient (β) used to describe the relationship between the budget and project results. It adjusts the effect of the budget on achieving improvements in the health status of the population, taking into account budgetary constraints or other factors related to project financing. Gamma coefficient (γ) used to describe external factors, such as the impact of economic or social conditions on the project. This coefficient allows modeling the project's adaptability to changes in the project environment in which it is implemented. These coefficients allow you to take into account specific aspects of the impact of various factors on the projected results. Thus, α, β, γ act as parameters that regulate the influence of the respective components on the model results, taking into account the specifics of each particular project.

The “Results” tab provides textual data, a text report with modeling results, and identification of optimal risks of health improvement projects (Fig. 3).

At the same time, the “Graphs” tab visualizes the results obtained through a graphical representation of the dynamics of changes in health indicators and risks (Fig. 4).

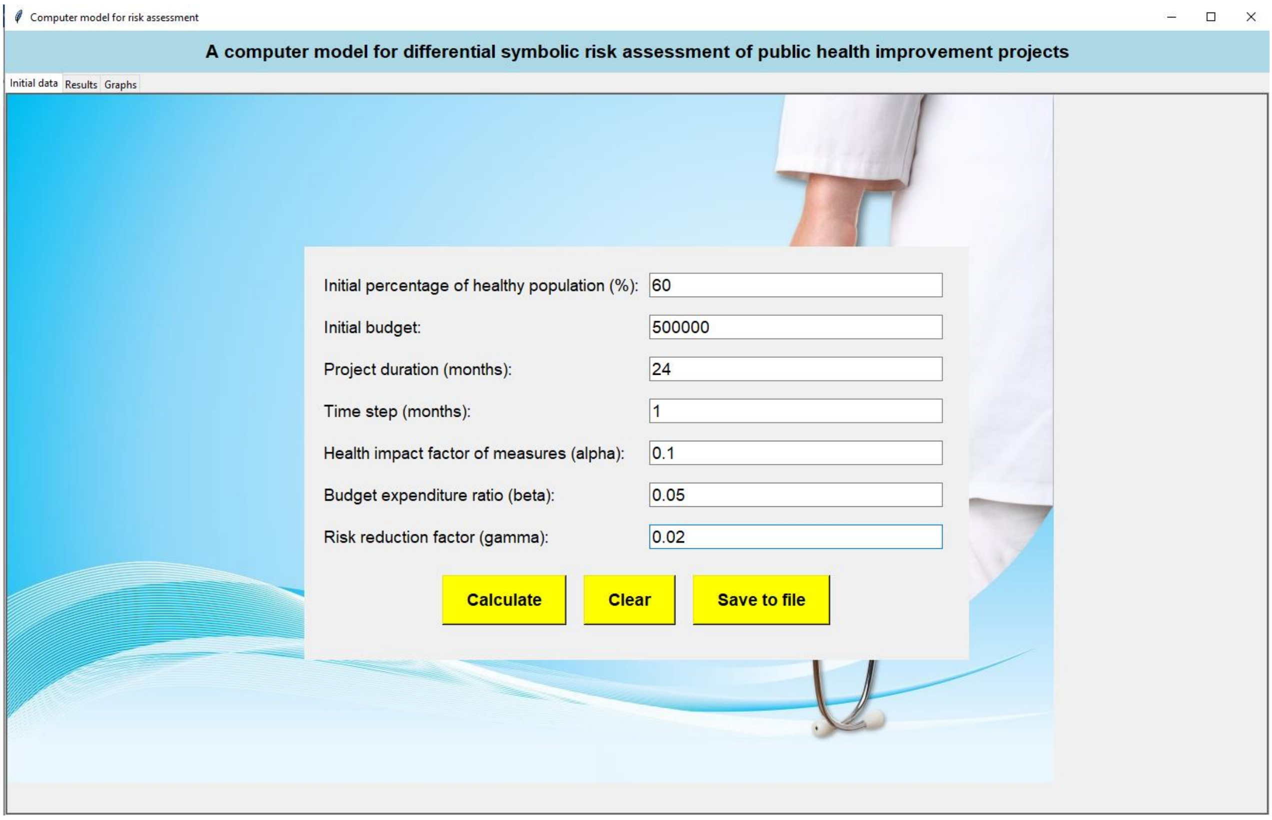


*Fig.2.* **Screen form of the computer model with input data for risk assessment of public health projects**
***Source*: compiled by the authors**

The mathematical basis of the proposed computer model is the numerical solution of differential equations using the Euler method to predict changes in community health indicators and the budget of the project to improve the health status of the population.

As a result of using equations (1-8), projects are modeled and trends in the percentage of healthy population in the community are determined using the specified coefficients of the impact of measures on health and budget expenditures and their impact on the quantitative value of risk.

The process of modeling public health improvement projects is performed as follows. At each modeling step, the percentage of healthy population and budget are updated. Project risk is calculated for each point in time based on the percentage of the community's sick population. The model allows you to find the optimal time to reach a certain level of risk, which is displayed on the graphs as a vertical line.

The proposed visualization of the modeling results (Fig. 4) is presented in the form of graphs of the dynamics of changes in health and risk indicators. The graphs show the dynamics of changes in the percentage of healthy community population and risks during project implementation over a given project duration. The vertical line on the graph shows the optimal risk.

The computer model of differential symbolic risk assessment of community health improvement projects provides for the storage of the results obtained. At the same time, project managers save the modeling results to a file for further analysis and use, if necessary.

Thus, the computer model of differential-symbolic risk assessment of community health improvement projects developed by us allows users (project managers) to assess the risks of community health improvement projects and predict how basic indicators such as health, budget, and risk will change depending on the specified characteristics of the project environment of these projects.

To verify the effectiveness of the proposed computer model, we compare it with the traditional method of risk assessment (expert risk assessment). The comparison was made on real projects implemented in the communities of the Lviv district of Lviv region (Ukraine) and the forecasting accuracy was determined ( $P_a$ ):


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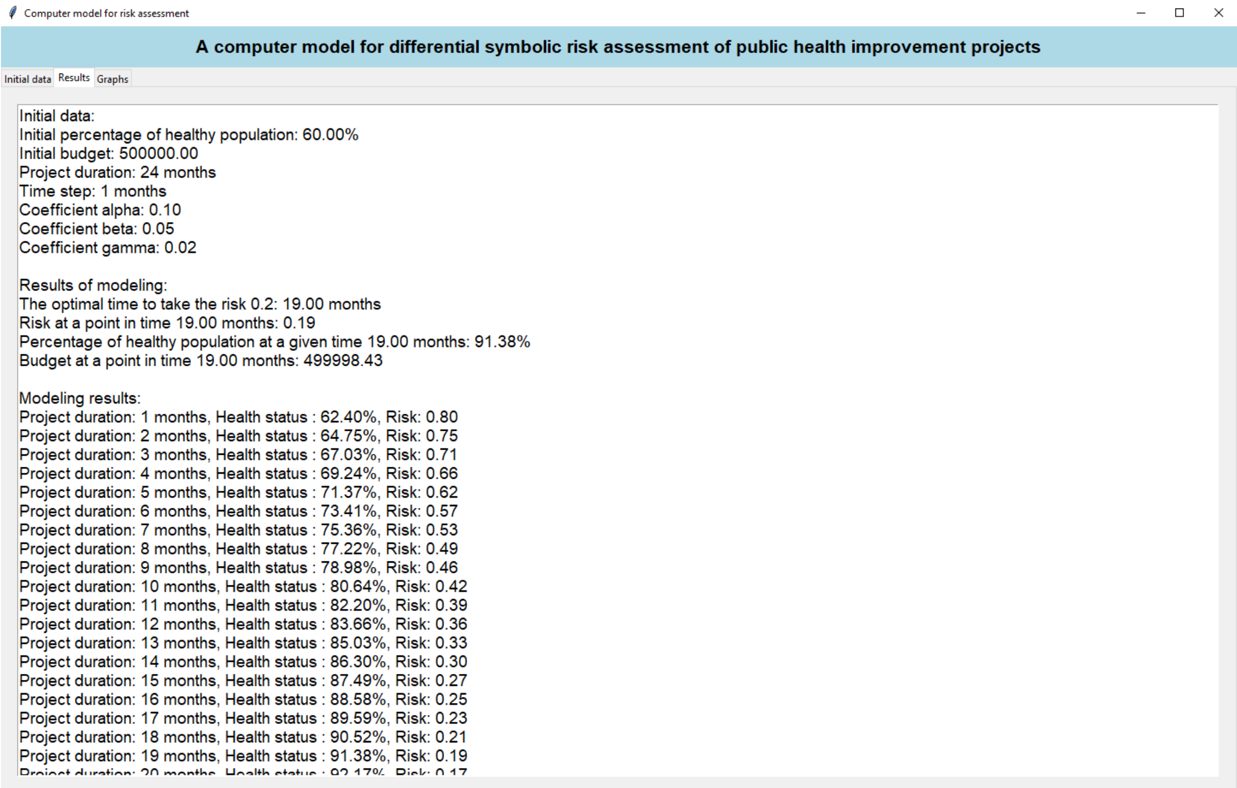


*Fig.3.* **Screen form of the computer model with the results of risk assessment of public health improvement projects**

***Source*: compiled by the authors**

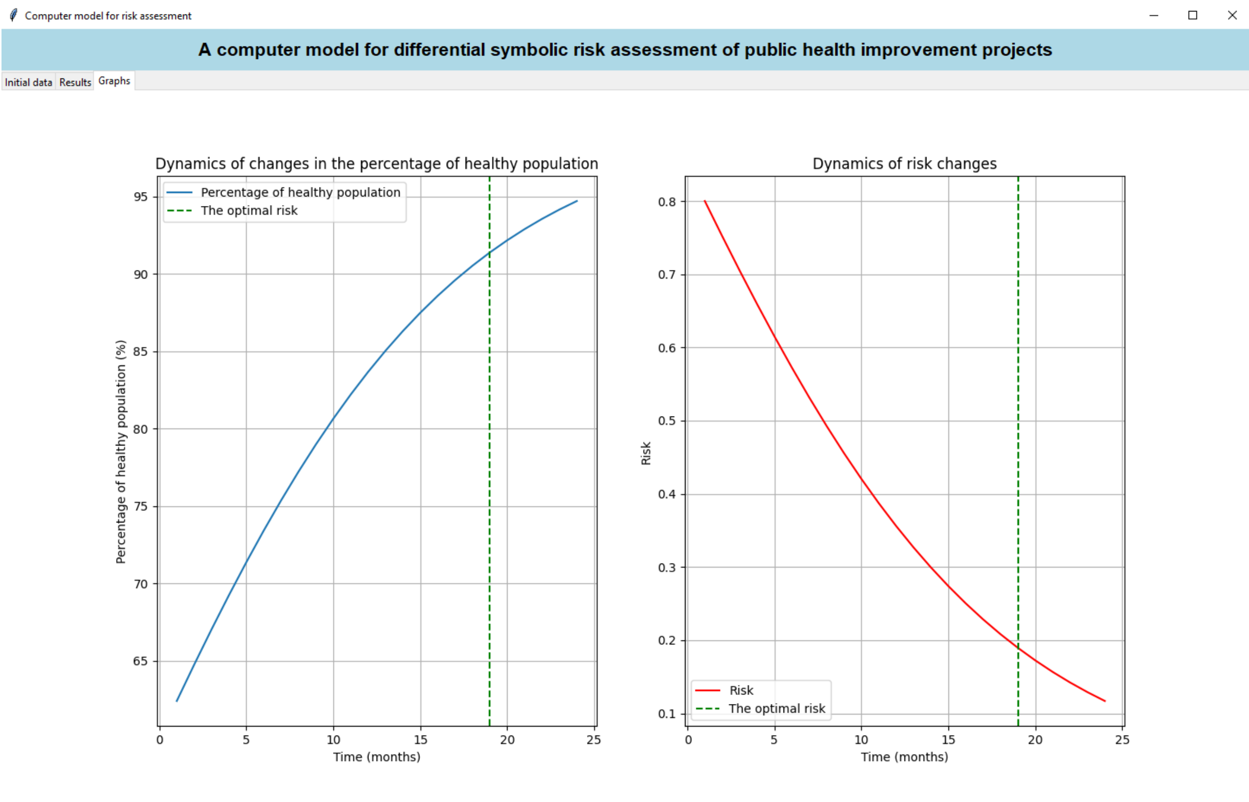


*Fig.4.* **Screen form of the computer model with visualization of the results of risk assessment of public health improvement projects**

***Source*: compiled by the authors**

$$P_a = \frac{1}{N}\sum_{i=1}^{N}\left(1 - \frac{|F_i - A_i|}{A_i}\right) \times 100\%, \qquad (12)$$

where $F_i$ is the predicted value; $A_i$ is the actual value; $N$ is the number of stages.

To test the computer model, two types of projects were considered, information about which was obtained from the archival data of the Department of Health of the Lviv Regional State Administration (Ukraine) [22]:

1) Project A – community vaccination project (planned budget - 500 thousand UAH, duration - 12 months);

2) Project B – an educational project to promote healthy lifestyles among the community population (planned budget - 300 thousand UAH, duration - 8 months).

The results were compared using the proposed computer model of differential symbolic project risk assessment (CM) and the traditional method based on expert opinions (TM) (Fig. 5). Expert opinions were collected from specialists of the Lviv Regional Public Health Center (Ukraine) [23] who have experience in health care, project management, and in the development and implementation of public initiatives. This center monitors and analyzes public health indicators and implements programs to improve the health of the population.

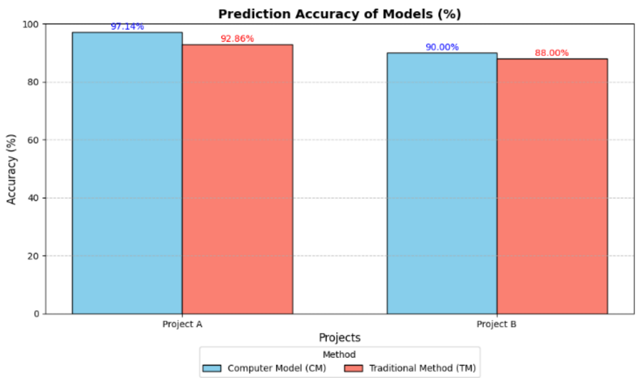


*Fig.5.* **Histogram of risk assessment results for public health projects**

***Source*: compiled by the authors**

Based on the results obtained in terms of forecasting accuracy, it should be noted that the accuracy of the computer model is higher than the traditional method used for the two projects under consideration. For the first project, the accuracy of the CM is 97.14 %, compared to 92.86 % for the TM, showing a difference of 4.28 %. Similarly, for the second project, CM provides an accuracy of 90.00 %, which is an increase of 2.00 % compared to using TM. These results confirm the adequate accuracy of the developed computer model of differential symbolic risk assessment of community health improvement projects. This indicates the feasibility of its implementation in the practice of managing these projects.

## DISCUSSION OF THE RESULTS

The obtained results confirm the need and practical value of the developed computer model for differential symbolic risk assessment of community health improvement projects. Compared to traditional methods, such as expert risk assessments or static probabilistic models, the proposed computer model has advantages. For example, while traditional models often do not take into account dynamic interdependencies and nonlinear factors of the project environment, the differential-symbolic approach provides accurate forecasting and adaptability to the state of the project environment. This is confirmed by the fact that the computer model in the given examples provides forecast accuracy of 97.14% and 90.00% for projects A and B. The corresponding values when using the method of expert estimates are 92.86 % and 88.00 %.

Similar studies have been conducted using probabilistic risk assessment methods in the healthcare sector [19], as well as decision trees for healthcare project management [20]. Their accuracy ranges from 85 % to 91 %. However, these methods do not take into account the variability of the project environment. They are mainly based on historical data, limiting their application to risk assessment of community health improvement projects with a changing project environment [24, 25]. The computer model we developed allows for real-time adjustments to the initial data and the tracking of dynamic projections using differential equations, which was not possible with existing methods.

However, the developed computer model for differential symbolic risk assessment of community health improvement projects has its limitations. Since the model uses numerical methods (Euler's method), the accuracy of the solution depends on the choice of the step $h$ and is limited by the ability of the method to approximate real solutions. Reducing the step can improve the accuracy but increases the computational time. The accuracy of the forecast depends on the accuracy of the input data and the calculation.

The results of the research confirm the effectiveness of the developed computer model, which ensures an increase in the efficiency of management decision-making. Further research should be carried out to improve the scalability of the model and automate the processes of preparing initial data for use in the computer model.

## CONCLUSIONS

The proposed mathematical model, based on a system of differential-symbolic equations that describe the dynamics of key project indicators, such as the level of public participation in activities, the effectiveness of educational and vaccination measures, budget changes and their impact on the overall risk, provides high accuracy in modeling the dynamics of key project indicators.

The developed algorithm, which involves 9 steps, and the computer model written in the Python programming language using libraries for solving differential equations, optimization, and visualization of results that implement the proposed mathematical model, allow for rapid risk assessment and generate recommendations to substantiate management decisions by project managers.

Based on the testing of the computer model on the example of real community health improvement projects, it was found that it increases the accuracy of forecasts by 2.0...4.28 % compared to the method of expert assessments due to its adaptability to changing conditions of the project environment. This confirms that the proposed computer model is an effective tool for supporting decision-making in a dynamic project environment.

## FUTURE WORK

Future research should improve the scalability and usability of the developed computer model for broader applications in health and social projects. This includes the integration of advanced machine learning algorithms to improve data-driven decision-making and the development of automated data preprocessing tools to optimize input data preparation. The user interface of the computer model should also be improved to increase accessibility and usability by project managers for real-world projects.

## REFERENCES

1. Kovalchuk, N., Zachko, O., Kovalchuk, O. & Kobylkin, D. "Project management of the information system for the selection of project teams". *12th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS)*. Dortmund, Germany. 2023. p. 1054–1057, https://www.scopus.com/authid/detail.uri?authorId=57194169062.
DOI: https://doi.org/10.1109/IDAACS58523.2023.10348656.

2. Malanchuk, O., Tryhuba, A., Tryhuba, I. & Bandura, I. "A conceptual model of adaptive value management of project portfolios of creation of hospital districts in Ukraine". *Proceedings of the 4th International Workshop IT Project Management (ITPM). CEUR Workshop Proceedings*. Warsaw, Poland. 2023; 3453: 82–95, https://www.scopus.com/authid/detail.uri?authorId=57205225539.

3. Martínez-Racaj, L., Torreblanca, R., Gutiérrez, I. & Salinas, M. "Clinical decision support system in laboratory medicine". *Clinical Chemistry and Laboratory Medicine*. 2024; 62 (7): 1277–1282, https://www.scopus.com/authid/detail.uri?authorId=8942339000.

4. Quioc, M. A. F., Ambat, S. C., Lagman, A. C., Ramos, R. F. & Maaliw, R. R. "Analysis of exponential smoothing forecasting model of medical cases for resource allocation recommender system". *10th International Conference on Information and Education Technology (ICIET)*. 2022. p. 390–397, https://www.scopus.com/authid/detail.uri?authorId=57211204723.
DOI: https://doi.org/10.1109/ICIET55102.2022.9778987.

5. Hamed, A. F., Salman, R. Y., Mahdi, S. & Khalil, Z. T. "Adaptive complexities and evolutionary paradigms in market dynamics for theoretical exploration". *Journal of Ecohumanism*. 2024; 3 (5): 621–632, https://www.scopus.com/authid/detail.uri?authorId=58613767000.
DOI: https://doi.org/10.62754/joe.v3i5.3927.

6. Tryhuba, A., Tryhuba, I., Ftoma, O. & Boyarchuk, O. “Method of quantitative evaluation of the risk of benefits for investors of fodder-producing cooperatives”. *International Scientific and Technical Conference on Computer Sciences and Information Technologies*. 2019; 3: 55–58, https://www.scopus.com/authid/detail.uri?authorId=57205225539. DOI: https://doi.org/10.1109/STC-CSIT.2019.8929788.

7. Grigorev, A., Saleh, K. & Mihaita, A.-S. “Traffic accident risk forecasting using contextual vision transformers with static map generation and coarse-fine-coarse transformers”. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, 2023. p. 4762–4769, https://www.scopus.com/authid/detail.uri? authorId=57321596200.
DOI: https://doi.org/10.1109/ITSC57777.2023.10421915.

8. Ünsal-Altuncan, I. & Vanhoucke, M. “A hybrid forecasting model to predict the duration and cost performance of projects with Bayesian Networks”. *European Journal of Operational Research*. 2024; 315 (2): 511–527, https://www.scopus.com/authid/detail.uri?authorId=6602303040.
DOI: https://doi.org/10.1016/j.ejor.2023.12.029.

9. Bhatt, J. A., Morris, K. R. & Haware, R. V. “Development of predictive statistical model for gaining valuable insights in pharmaceutical product recalls”. *AAPS PharmSciTech*. 2024; 25 (8): 255, https://www.scopus.com/authid/detail.uri?authorId=57215386967. DOI: https://doi.org/10.1208/s12249-024-02970-z.

10. Tryhuba, A., Koval, N., Tryhuba, I. & Boiarchuk, O. “Application of sarima models in information systems forecasting seasonal volumes of food raw materials of procurement on the territory of communities”. *CEUR Workshop Proceedings*. 2022; 3295: 64–75, https://www.scopus.com/authid/detail.uri? authorId=57205225539.

11. Müller, F., Weber Gössling, T., Santos, S. & Righi, M. “A comparison of Range Value at Risk (RVaR) forecasting models”. *Journal of Forecasting*. 2024; 43 (3): 509–543, https://www.scopus.com/authid/detail.uri?authorId=36781260400. DOI: https://doi.org/10.1002/for.3043.

12. Tryhuba, A., Boyarchuk, V., Tryhuba, I., Pavlikha, N. & Kovalchuk, N. “Study of the impact of the volume of investments in agrarian projects on the risk of their value”. *CEUR Workshop Proceedings*. 2021; 2851: 303–313, https://www.scopus.com/authid/detail.uri?authorId=57205225539.

13. Huang, S., Liang, C. & Liu, J. “Research on neural network prediction model of whole process risk management based on building information model”. *Advances in Civil Engineering*, 2024, https://www.scopus.com/authid/detail.uri?authorId=59352948500.
DOI: https://doi.org/10.1155/2024/5453113.

14. Hu, C., You, L. & Lin, H. “A process-oriented risk monitoring and assessment modeling approach in urban public safety”. *Cehui Xuebao/Acta Geodaetica ET Cartographica Sinica*. 2018; 47 (8): 1062–1071, https://www.scopus.com/authid/detail.uri?authorId=56948126800.
DOI: https://doi.org/10.11947/j.AGCS.2018.20180117.

15. Mahajan, S., Nayyar, A., Raina, A., Vashishtha, A. & Pandit, A. K. “A Gaussian process-based approach toward credit risk modeling using stationary activations”. *Concurrency and Computation: Practice and Experience*. 2021; 34 (5): e6692, https://www.scopus.com/authid/detail.uri?authorId=57209224750. DOI: https://doi.org/ 10.1002/cpe.6692.

16. Horney, J. A. & Wilfert, R. A. “Accelerating preparedness: Leveraging the UNC PERLC to improve other projects related to public health surveillance, assessment, and regionalization”. *Journal of Public Health Management and Practice*. 2014. 20 (Suppl. 5): S76–S78. https://www.scopus.com/authid/detail.uri? authorId=12776884100.

17. David, M., Schwedler, G., Reiber, L., Polcher, A. & Kolossa-Gehring, M. “Learning from previous work and finding synergies in the domains of public and environmental health: EU-funded projects BRIDGE Health and HBM4EU”. *Archives of Public Health*. 2020; 78 (1): 78, https://www.scopus.com/authid/detail.uri?authorId=57202338460. DOI: https://doi.org/10.1186/s13690-020-00460-9.


ISSN 2663-0176 (Print)
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18. Rawther, F., Bondje, S., Rahman, A., Kumaravel, B. & Harris, J. "Community immersion project to enhance medical students understanding of the health needs of the most vulnerable in the community". *BMJ Leader*. 2022; 6 (1): 60–63, https://www.scopus.com/authid/detail.uri?authorId=57195775047. DOI: https://doi.org/10.1136/leader-2020-000382.

19. Padula, W. V., Pronovost, P. J., Makic, M. B. F., Mishra, M. K. & Meltzer, D. O. "Value of hospital resources for effective pressure injury prevention: A cost-effectiveness analysis". *BMJ Quality and Safety*. 2019; 28 (2): 132–141, https://www.scopus.com/authid/detail.uri?authorId=6602464380. DOI: https://doi.org/10.1136/bmjqs-2017-007505.

20. Silva, D. H., Anteneodo, C. & Ferreira, S. C. "Epidemic outbreaks with adaptive prevention on complex networks". *Commun Nonlinear Sci Numer Simul*. 2023; 116: 106877, https://www.scopus.com/authid/detail.uri?authorId=7202480408.
DOI: https://doi.org/10.1016/j.cnsns.2022.106877.

21. Alpysbay, N., Kolesnikova, K., Chinibaeva, T. & Olekh, T. "Using project management tools in the process of modernizing the healthcare system of the Republic of Kazakhstan". *CEUR Workshop Proceedings*. 2022, https://www.scopus.com/authid/detail.uri?authorId=58250322300.

22. "Department of Health of the Lviv Regional State Administration" (in Ukraine). – Available from: https://loda.gov.ua/en/structural-unit/17099.

23. "Lviv Regional Center for Public Health" (in Ukraine). – Available from: https://phc.org.ua/en.

24. Malanchuk, O., Tryhuba, A., Tryhuba, I., Sholudko R. & Pankiv O. "A Neural network model-based decision support system for time management in pediatric diabetes care projects". *18th International Conference on Computer Science and Information Technologies (CSIT)*. 2023. p. 1–4. https://www.scopus.com/authid/detail.uri?authorId=57205225539.

25. Tryhuba, A., Koval, N., Tryhuba, I. & Boiarchuk, O. "Application of sarima models in information systems forecasting seasonal volumes of food raw materials of procurement on the territory of communities". *CEUR Workshop Proceedings*, 2022; 3295: 64–75, https://www.scopus.com/authid/detail.uri?authorId=57205225539.

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# Комп'ютерна модель диференціально-символьного оцінення ризиків проектів покращення стану здоров'я населення громад

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## АНОТАЦІЯ

У статті подано результати розробки комп'ютерної моделі диференційно-символьного оцінювання ризиків проектів покращення стану здоров'я населення громади. Традиційні підходи та методи, такі як експертні оцінки або статистичні моделі, мають обмеження щодо точності прогнозування ризиків та адаптації до мінливих умов проектного середовища. Запропонована комп'ютерна модель використовує систему диференціальних рівнянь, які описують динаміку основних показників проектів, таких як рівень участі населення в заходах, ефективність освітніх і вакцинаційних заходів, зміни бюджету та їх вплив на загальний ризик. Ця модель дозволяє оцінювати ризики із врахуванням досліджуваної динаміки проекту, оперативно коригувати управлінські рішення та зменшувати відхилення від запланованих показників. Для реалізації запропонованої моделі розроблено алгоритм, який включає кілька етапів: ініціалізацію змінних, побудову системи диференціальних рівнянь, чисельний їх розв'язок методом Ейлера, оцінку ризиків та оновлення параметрів у режимі реального часу. На основі розробленого алгоритму, який передбачає 9 кроків, створено комп'ютерну модель, яка у подальшому буде інтегрована в систему підтримки рішень для проекних менеджерів. Запропонована комп'ютерна модель написана на мові програмування Python із використанням бібліотек для розв'язання диференціальних рівнянь, оптимізації та візуалізації результатів, які реалізують запропоновану математичну модель. Ця комп'ютерна модель дозволяє проектним менеджерам моделювати ризики, аналізувати їх вплив на показники проекту та генерувати рекомендації для управління ресурсами та мінімізації ризиків. Тестування розробленої комп'ютерної моделі проведено на прикладі реальних проектів покращення здоров'я населення громади. Для проекту вакцинації населення громад комп'ютерна модель показала точність прогнозування на рівнях 97,14%, що перевищує зазанчений показник від використання експетних оцінок (92.86%). У освітницькому проекті із пропогування здорового способу життя населення громади точність комп'ютерної моделі становить 90.00% порівняно з 88.00% за використання методу експетних оцінок. Оцінка ризиків показала, що використання диференціально-символьної моделі дозволяє знизити рівень ризику до 2.86 % у проекті вакцинації населення громад та 10.0 % у проекті освітницькому проекті із пропогування здорового способу життя населення громади. При цьому традиційні методи продемонстрували ризики відповідно на рівнях 7.14 % та 12.00 %. Комп'ютерна модель також підтвердила свою адаптивність до мінливого проектного середовища, яке стосувалося збільшення тривалості проекту чи зменшення доступного бюджету. Запропонована комп'ютерна модель інтегрує функціонал для введення параметрів, чисельного розрахунку ризиків, візуалізації результатів та формування рекомендацій. Інтерфейс комп'ютерної модель побудовано таким чином, щоб забезпечити зручність для проектних менеджерів, навіть за умов високої складності вхідних даних. Отримані результати підтверджують, що розроблена комп'ютерна модель диференціально-символьного оцінення ризиків проектів покращення стану здоров'я населення громад є ефективним інструментом для управління проектами. Використання моделі дозволяє не лише підвищити точність прогнозування ризиків, але й забезпечити ефективний розподіл ресурсів.

**Keywords:** комп'ютерна модель; диференціально-символьне моделювання; оцінка ризиків, проекти; управління; здоров'я; населення; громади

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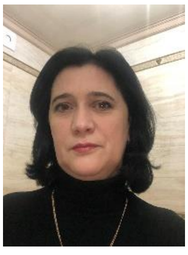

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