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# CHAPTER 4

# DIFFERENTIAL-SYMBOLIC APPROACH AND TOOLS FOR MANAGEMENT OF MEDICAL SUPPORT PROJECTS FOR THE POPULATION OF COMMUNITIES

## ABSTRACT

The aim of the study is to propose a differential-symbolic approach to managing community health support projects, to develop algorithms and computer models on its basis, and to use them to conduct a study of the impact of project environment components on the choice of the optimal project implementation scenario and risk assessment.

The work uses project management methodology, system and differential-symbolic approaches, which underlie the developed algorithms and computer models for planning community health improvement projects and assessing their risks. To implement the proposed models, code was written in the Python programming language using libraries for solving differential equations, optimizing and visualizing results. NumPy libraries were used to work with numerical data and vectors, SciPy for numerically solving differential equations and optimizing the objective function, and Matplotlib for visualizing the results.

The main stages of the proposed differential-symbolic approach to managing community health support projects are presented. Mathematical models of differential-symbolic planning of projects for planning projects for improving the health of the community population and risk assessment of projects for medical support of the community population have been developed. They involve the use of differential equations to describe the dynamics of projects as a separate system and the use of symbolic expressions to represent individual parameters and their description. Algorithms of differential-symbolic management of projects for improving the health of the community population and risk assessment of projects for medical support of the community population have been developed, the block diagram of which involves the implementation of 16 and 9 interconnected steps, respectively. Based on the proposed algorithms, computer models of differential-symbolic planning of projects for improving the health of the community population and risk assessment of projects for medical support of the community population have been developed. Based on the use of computer models for given conditions of the project environment, the results of optimizing the configuration of projects for improving the health of the community population and risk assessment of projects for medical support of the community population have been obtained.

The prospect of further research is to expand the functionality of computer models, adding modules for the analysis of other component projects.

For the first time, a differential-symbolic approach to managing projects for medical support of the population of communities has been proposed, which is based on methods of mathematical modeling, numerical analysis and optimization, which ensure the determination of a rational configuration of these projects and the assessment of risks for the given characteristics of the project environment. Based on the substantiated stages of the differential-symbolic approach, mathematical models, algorithms and computer models have been developed. The use of the proposed computer models makes it possible to obtain the dependence of the growth rate of the percentage of the healthy population participating in educational activities on the configuration of projects for improving the health of the population of communities, as well as to determine the optimal scenarios for the implementation of these projects in the community and the risks of projects for medical support of the population of communities.

The proposed computer models are a tool for project managers, which allows to perform labor-intensive calculations to form possible scenarios for the implementation of projects to improve the health of the population in the community, determine the optimal one among them, as well as assess the risks of projects for medical support of the population of communities.

## KEYWORDS

Differential-symbolic approach, computer models, modeling, planning, projects, medicine, population of communities.



Currently, the development of various industries is taking place thanks to project-oriented management, which from year to year is becoming an increasingly effective tool for management activities [1, 2]. At the same time, changes are observed in the project environment of organizations in various industries, which significantly affect the implementation of their development projects and, accordingly, their efficiency [3]. Without the use of tools that take into account dynamic changes in the components of the project environment, it is impossible to successfully implement the relevant projects [4]. One of the industries in Ukraine that is undergoing reform is the medical industry. Today, medicine faces challenges that require effective project management to ensure optimal development and the provision of high-quality medical services. However, medical project management is a complex task due to the need to take into account not only technical aspects, but also the organizational structure, the supply chain of resources and services, regulatory and stringent requirements, as well as flexibility in making management decisions to resolve unforeseen situations during project implementation [5, 6]. Projects of medical support of the population of communities deserve attention, which ensure the promotion of a healthy lifestyle and activity among the population [7]. During their implementation, a number of scientific and applied tasks arise, among which effective planning and risk assessment are significant.

In this context, computer models of differential-symbolic planning for improving the psychological state and health of the population of communities and risk assessment of projects of medical support of the population of communities are an important tool that allows to systematize and optimize the process of managing these projects, contributing to their successful implementation and adaptation to a changing project environment. Our work reveals the features of the development and use of computer models of differential-symbolic planning and risk assessment of projects of medical support of the population of communities, which underlies the increase in the efficiency of management of these projects and, accordingly, the reduction of morbidity and increase in the activity of the population of communities.

Substantiation of effective scenarios and risk assessment are important processes that determine the effectiveness of project management [8]. Changes in the components of the project environment can occur at any time during the life cycle of projects, and they can have a significant impact on the outcome of the project [9, 10]. Effective project planning can help minimize the negative impact of changes on the project and ensure its successful completion [11].

In well-known scientific works, their authors identify separate scientific and applied tasks regarding project risk management [12] and management of medical development projects [13, 14]. These include the opacity of relationships between project participants and ineffective communication between them. There is also a lack of adaptation of each of the participants to changes in the project environment, as they do not have a reasoned justification for such changes. In addition, some of the participants do not perceive the appropriateness of changes, as they do not have a sufficient quantitative assessment of the impact of changes on the effectiveness of project implementation.

Some authors of scientific papers [15, 16] justify the feasibility of creating computer models, which are the basis for accelerating and making accurate management decisions. Computer models allow to quantitatively assess the impact of various decision alternatives on target indicators [17]. This can be especially useful in conditions of variability of the components of the project environment, when expert assessments are inaccurate. Computer models provide the generation of alternative project implementation scenarios and the assessment of their risks, which cannot be described intuitively. This allows project managers to consider a wide range of factors in the project environment and find a rational solution. Nevertheless, computer models provide automation of the process of making management decisions and its acceleration.

The development and use of computer models for managerial decision-making encounters certain difficulties [18, 19]. In particular, it is necessary to select a simple and sufficiently accurate mathematical apparatus that will underlie the developed computer model [20]. In particular, the creation of computer models that are too complex leads to the fact that users are unable to understand and use them in practice [21]. In addition, computer models with incorrect knowledge distort the result, lead to errors in the justification of management decisions or software operation [22]. Despite these shortcomings, computer models have significant potential to improve the efficiency and quality of management decision-making in projects [23]. They can be particularly useful in complex or uncertain situations where manual decision-making may be impossible or inefficient [24, 25].

Existing studies [26] on community projects confirm the possibility of benefiting clinics, patients and communities. The differential-symbolic approach to the management of community health support projects is noteworthy [27, 28]. Differential-symbolic equations allow modeling complex dependencies between variables, which can be useful for assessing the impact of changes on performance indicators, such as cost, timing and quality of project implementation [29]. In addition, differential-symbolic equations can be used to develop algorithms that automatically assess the impact of changes on the project and generate alternative solutions [30]. Therefore, there is a need to develop a differential-symbolic approach to the management of community health support projects, and to develop algorithms and computer models based on it. Such models will make it possible to substantiate the optimal scenario for the implementation of community health improvement projects and assess their risks, as well as visualize the impact of changes in the project environment on the performance indicators of these projects. The availability of such tools for project managers will increase the accuracy of determining an effective project implementation scenario, qualitatively assess risks, and establish communication between stakeholders [31]. The results of computer modeling increase the effectiveness of developing plans for responding to changes in the project environment.

The aim of research is to propose a differential-symbolic approach to managing community health support projects, develop algorithms and computer models on its basis, and also use them to conduct a study of the influence of project environment components on the choice of the optimal project implementation scenario and risk assessment.

In accordance with the aim, the following objectives should be solved in the work:

1. Substantiate the main components and stages of the differential-symbolic approach to managing community health support projects.

2. Propose and describe mathematical models and, on their basis, develop algorithms for differential-symbolic planning of community health support projects and assessment of their risks.

3. Develop computer models of differential-symbolic planning of community health support projects and assessment of their risks.

4. Based on the developed computer models, determine the optimal scenario for the implementation of the project to improve the health of the community for the given conditions of the project environment and assess the risks.



## 4.1 DIFFERENTIAL-SYMBOLIC APPROACH TO MANAGING COMMUNITY HEALTH SUPPORT PROJECTS

Community health support projects are understood as temporary actions aimed at implementing preventive measures related to the promotion of a safe and healthy lifestyle, as well as activities to prevent diseases among the community population and increase its activity. To increase the accuracy and quality of management of community health support projects, it is proposed to use a differential-symbolic approach, which ensures the consideration of a number of necessary components, as presented in **Fig. 4.1**.

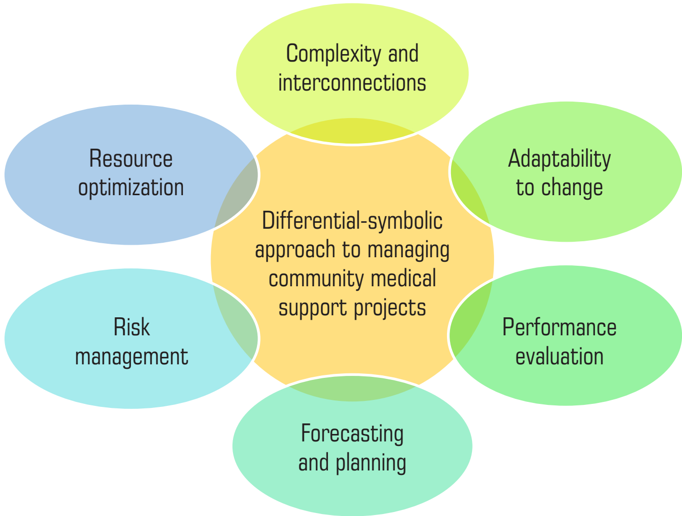


**Fig. 4.1** Components of project management of medical support for the population of communities using the differential-symbolic approach

The proposed differential-symbolic approach makes it possible to take into account the complexity and interrelationships between both the components of the project environment and the components of community health support projects. In particular, health support projects often have a complex structure and include numerous relationships between different components. These components include medical services, resources, patients and their health status, medical personnel, and finances. The differential-symbolic approach allows to model these relationships, track the impact of changes in the project environment on various aspects of the project, and conduct a comprehensive analysis of their implementation scenarios.

Community health support projects can be subject to numerous changes caused by a changing project environment (changes in the health of the population, the emergence of new medical technologies, political and economic factors, etc.). The differential-symbolic approach allows to effectively manage these changes by modeling their impact on the implementation of the community health support project and quickly adapt already developed strategies to these changes.

By using the differential-symbolic approach, it is possible to analyze in detail the effectiveness of various aspects of a community health support project, such as resource allocation, costs and results. This allows for a more accurate assessment of costs and benefits (value for stakeholders), as well as to determine the most effective management decisions.

Community health support projects are often long-term in nature, which requires accurate forecasting and planning. The differential-symbolic approach helps to create models that take into account various factors and their interaction, which provides more accurate forecasts and plans for the future development of community health security.

The implementation of community health support projects is accompanied by the emergence of risks that belong to their financial, technical and social components. The differential-symbolic approach allows to identify, analyze and assess these risks, as well as develop strategies to minimize them.

Resource management is a very important component of managing community health support projects, since resources are in most cases limited. The use of the differential-symbolic approach allows for effective planning and allocation of resources, ensuring their rational use and optimization.

In general, the use of the differential-symbolic approach to the management of community health support projects provides a comprehensive analysis and optimization of these projects, which allows for increasing their efficiency and achieving better results in providing medical care.

To present the features of the proposed differential-symbolic approach to the management of community health support projects, its scheme was constructed (**Fig. 4.2**). It illustrates the main stages and components of the proposed approach, which involves the use of differential equations to describe the dynamics of community health support projects as a separate system and the use of symbolic expressions to represent parameters and their description.

The scheme of the proposed differential-symbolic approach to the management of community health support projects displays eight main blocks. First of all, there is a block (Data input) that provides for the collection and input of the necessary initial data about the community, the medical needs of the population, resources and factors affecting the health of the population. The next block (Symbolic expressions for project parameters) provides for the formation of symbolic expressions that describe the components of community health support projects and their impact on the population. After this, there is a block (Differential equations for dynamics modeling), which uses differential equations for mathematical modeling of the dynamics of changes in the health of the community and their well-being.

The block (Numerical solution of differential equations (SciPy)) provides for the numerical solution of differential equations using the open SciPy library with high-quality scientific tools in the Python programming language. The block (Optimization (SciPy)) is also based on the SciPy library, which provides for the use of optimization methods to determine the optimal configuration of community health support projects.

The next block (Results analysis and visualization (Matplotlib)) involves analyzing the obtained results and visualizing them using the Matplotlib library in the Python programming language. The block (Selection of optimal scenario) ensures the establishment of the optimal scenario for project implementation based on the analysis of the obtained results, forecasting their indicators and taking into account the conditions of the project environment and constraints.

The last block (Report generation and recommendations) provides for the preparation of reports and analysis of the results of community health support projects, as well as the development of recommendations for their implementation and further implementation in the community.

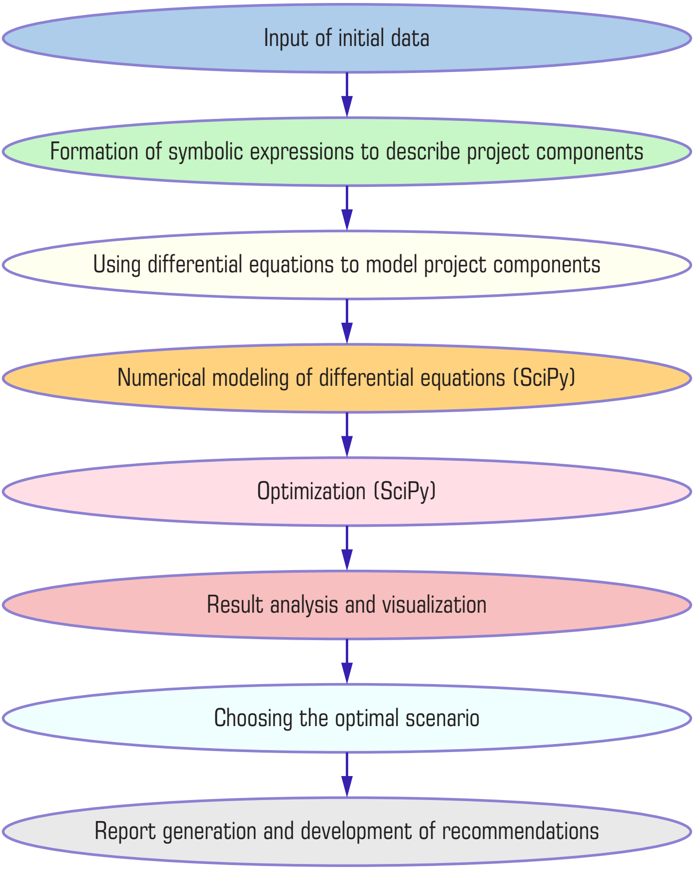


**Fig. 4.2** Scheme of the proposed differential-symbolic approach to managing projects of medical support for the population of communities

The presented scheme (**Fig. 4.2**) makes it possible to outline the stages of the process of the differential-symbolic approach to the management of community health support projects, and also demonstrates the need to use mathematical modeling, numerical analysis and optimization to assess risks and determine the rational configuration of these projects. Based on the proposed scheme for using the differential-symbolic approach to the management of community health support projects, appropriate mathematical models have been developed to solve scientific and applied problems of planning and assessing the risks of these projects.

To implement the proposed approach, our work uses the project management methodology, system and differential-symbolic approaches, which are the basis of the developed algorithms and computer models for planning projects to improve the health of the community population and assessing their risk. To implement the proposed models, code was written in the Python programming language using libraries for solving differential equations, optimizing, and visualizing results. NumPy libraries were used to work with numerical data and vectors, SciPy for numerically solving differential equations and optimizing the objective function, Matplotlib for data visualization, in particular for creating a 3D graph displaying the optimal scenario for implementing community health improvement projects and their quantitative risk assessment.

## 4.2 MATHEMATICAL MODEL OF DIFFERENTIAL-SYMBOLIC PLANNING OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

The mathematical model of differential-symbolic planning of projects to improve the health of the population involves the use of differential equations to describe the dynamics of projects as a separate system and the use of symbolic expressions to represent individual parameters and their description. Let's consider a general description of this mathematical model. Let's define differential equations that describe the implementation of medical projects to support the population of communities as a separate system.

Let $Y(t)$ – the vector of the state of project implementation in a given community; $P(t)$ – the vector of project configuration (system parameters); $U(t)$ – the vector of project management; $F(Y, P, U, t)$ – the function that determines the dynamics of the implementation of medical projects to support the population of communities. Then the mathematical expression of the differential equation has the form:

$$\frac{dY}{dt}=F\left(Y,P,U,t\right), \tag{4.1}$$

Let's introduce symbolic expressions for the existing state of the population in a given community and its changes. Let $P_0$ – the initial value of the share of morbidity in the population of the community, and $\Delta P$ changes in morbidity in the population of the community. Then the symbolic representation of changes in the population status in a given community looks like this:

$$P\left(t\right)=P_0+\Delta P\left(t\right). \tag{4.2}$$

Here $P(t)$ represents a vector that characterizes the formation of the product of medical projects supporting the population of communities, which changes over time. It is determined by the budget spent $B(t)$, resources spent $E(t)$, project implementation duration $T(t)$, etc.:

$$P(t)=\begin{bmatrix} B(t) \\ E(t) \\ T(t) \end{bmatrix}. \tag{4.3}$$

Project management for improving the condition of the population of communities is determined by the influence of the project environment on its configuration (system parameters). In particular, an insufficient project budget over time $B(t)$ leads to a transition to another project implementation scenario with a change in the configuration of the desired product. The lack of available resources $E(t)$ at a particular point in time $t$ leads to a change in the implementation scenario for medical projects to support the population of communities. Deviation from the work plan $T(t)$at a particular point in time $t$ leads to changes in the project implementation scenario.

Let $Y(t)$ determine the state of the project at time $t$. Project implementation can be described by the differential equation:

$$\frac{dY}{dt}=F\big(Y,P(t),U(t),t\big), \tag{4.4}$$

where $F$ – a function that determines the dynamics of the project depending on its current state $Y$, configuration $P(t)$, change management $U(t)$ and time $t$.

The project management vector $U(t)$ includes individual possible scenarios for its implementation. It concerns changes in the resources used, the work schedule or other important components of the project:

$$U(t)=\begin{bmatrix} U_1(t) \\ U_2(t) \\ \dots \\ U_?(t) \end{bmatrix}. \tag{4.5}$$

So, the vector $U(t)$ defines the processes of managing medical and social projects of community support in the form of justified scenarios of actions. Thus, the product of the project (system parameters) changes based on the ratio:

$$\Delta P(t)=U(t). \tag{4.6}$$

The objective function $J$ can be defined to assess the effectiveness of management decisions and justify scenarios of actions in medical and social projects of community support:

$$J\left(Y,P\left(t\right),U\left(t\right),t\right). \tag{4.7}$$

Optimal management solutions can be found by maximizing or minimizing the objective function taking into account the constraints and conditions of the problem. To introduce constraints in the community support project regarding the budget $B(t)$, available resources $E(t)$, duration of work $T(t)$, let's use conditions that take into account the maximum values of these parameters. Let $B_{max}$, $E_{max}$, and $T_{max}$ represent the maximum allowable values for the budget, resources involved and duration of work in the project, respectively. Then the constraints can be expressed as follows:

$$\begin{aligned} &B\left(t\right) \le B_{max};\\ &\left(t\right) \le {}_{\max};\\ &T\left(t\right) \le T_{max}. \end{aligned} \tag{4.8}$$

The objective function $J$ is the minimum cost of funds for the implementation of the project with the maximum increase in the percentage of healthy population. Minimizing the objective function $J$, let's search for the optimal scenario for the implementation of the public health improvement project, which will ensure high-quality management:

$$min_{U(t)} J\left(Y,P_0+U,t\right). \tag{4.9}$$

Solving the optimization problem, the objective function $J$, taking into account the specified restrictions in expression (4.8), is written as follows:

$$min_{U(t)} J\left(Y,P_0+U,t\right),$$

$$\text{provided } B\left(t\right) \le B_{max}, E\left(t\right) \le E_{\max}, T\left(t\right) \le T_{max}, \tag{4.10}$$

where $J$ – the objective function for optimizing the scenario for the implementation of the medical project for supporting the population of communities; $U(t)$ – the management vector (implementation scenario) of the medical project for supporting the population of communities; $Y$ – the vector of the state of the medical project implementation for supporting the population of communities in a given community; $P_0$ – the initial value of the share of morbidity in the community population; $t$ – time.

If there is a need to provide for other conditions or restrictions in the medical project for supporting the population of communities, they can be added to the described system, taking into account all aspects of the task of managing the specified projects.

## 4.3 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. The products of such projects can be various activities, such as educational programs, vaccinations and educational initiatives, which are aimed at improving the overall health of the community population. However, the implementation of such projects is associated with numerous challenges and risks that can affect their success. Assessing and managing these risks is key to ensuring the effectiveness and sustainability of projects.

One approach to risk assessment is the use of mathematical models that allow predicting and analyzing possible scenarios. The differential-symbolic approach to risk modeling allows taking into account the dynamic implementation of public health improvement projects, which include changes in their components over time and the impact of various factors of the project environment.

Let's 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 educational 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 risk of the project.

The main goal of creating this model is to provide project managers with tools for quantifying risks and supporting decision-making in the process of managing projects to improve the health of the population. This will optimize the use of resources, minimize risks, and increase the efficiency of project implementation, which will ultimately contribute to improving the health of the population in communities.

To assess changes in the health of the population in communities, let's use differential equations that describe the change in key project indicators over time. In particular, let's consider indicators such as the percentage of the healthy population that participated in educational activities, vaccinations, and received health education.

It is possible to assume that the percentage of the healthy population $Y_1(t)$, $Y_2(t)$ and $Y_3(t)$, that participated in the relevant activities at time $t$, is known in advance. It is possible to write the dynamics equation for the implementation of educational activities:

$$\frac{dY_1(t)}{dt} = \alpha_1(1 - Y_1(t)) - \beta_1 Y_1(t), \tag{4.11}$$

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

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

$$\frac{dY_2(t)}{dt} = \alpha_2(1 - Y_2(t)) - \beta_2 Y_2(t), \tag{4.12}$$

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

The dynamics equation for educational programs can be written as follows:

$$\frac{dY_3(t)}{dt} = \alpha_3(1 - Y_3(t)) - \beta_3 Y_3(t), \tag{4.13}$$

where $\alpha_3$ – the rate of involvement of the healthy population in health educational programs; $\beta_3$ – the rate of decrease in the percentage of the involved population in educational programs.

At the beginning of the simulation, the condition is assumed that $t=0$:

$$\begin{aligned} Y_1(0) &= initial(Y_1); \\ Y_2(0) &= initial(Y_2); \\ Y_3(0) &= initial(Y_3), \end{aligned} \tag{4.14}$$

where $initial(Y_1)$ – the initial percentage of the healthy population that participated in educational activities; $initial(Y_2)$ – the initial percentage of the healthy population that participated in vaccination; $initial(Y_3)$ – the initial percentage of the healthy population that received health education.

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

$$B(t) = initial_B - c_1\int_0^t Y_1(\tau)d\tau - c_2\int_0^t Y_2(\tau)d\tau - c_3\int_0^t Y_3(\tau)d\tau, \tag{4.15}$$

where $c_1$, $c_2$, $c_3$ – the costs per participant for educational activities, vaccination and education, respectively.

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

$$R(t) = \gamma_1 \,|\, initial(Y_1) - Y_1(t) \,|\, + \gamma_2 \,|\, iinitial(Y_2) - Y_2(t) \,|\, + \gamma_3 \,|\, initial(Y_3) - Y_3(t) \,|\,, \tag{4.16}$$

where $\gamma_i$ – the risk weighting coefficients for each of the indicators.

For the numerical solution of differential equations, the Euler method can be used. Let the discrete time points $t_i$, $i=0, 1,\ldots, n$, be known, then:

$$Y_1(t_{i+1}) = Y_1(t_i) + h\left(\alpha_1(1 - Y_1(t_i)) - \beta_1 Y_1(t_i)\right);$$
$$Y_2(t_{i+1}) = Y_2(t_i) + h\left(\alpha_2(1 - Y_2(t_i)) - \beta_2 Y_2(t_i)\right); \qquad (4.17)$$
$$Y_3(t_{i+1}) = Y_3(t_i) + h\left(\alpha_3(1 - Y_3(t_i)) - \beta_3 Y_3(t_i)\right),$$

where $h$ – the solution step.

The solution step is determined by the formula:

$$h = \frac{e_t - s_t}{n}, \qquad (4.18)$$

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

The presented equations (4.17) and (4.18) allow to assess the dynamics of changes in the health status of the population during the implementation of projects to improve the health status of the population, taking into account the impact of educational activities, vaccination and educational programs.

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

## 4.4 ALGORITHM AND COMPUTER MODEL OF DIFFERENTIAL-SYMBOLIC PLANNING OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

We have developed an algorithm for creating a computer model of differential-symbolic planning of projects to improve the health of the population, the block diagram of which is presented in **Fig. 4.3**.

Differential-symbolic planning of projects to improve the health of the population involves the implementation of 16 steps, which involve the use of formulas (4.1)–(4.10):

1. Data collection for planning medical projects to support the population of communities.

2. Determination of the main parameters, which include the current health and activity of the community population, the project budget, available resources, the duration of the project implementation and other important characteristics.

3. Formation of differential equations involves writing the differential equation (4.1) based on the function $F(Y, P, U, t)$, which determines the dynamics of project implementation.

4. Symbolic definition of the project configuration, which provides a representation of the project configuration $P(t)$ using equation (4.3).

5. Formation of the project management vector $U(t)$ using equation (4.5) and conditions (4.6).

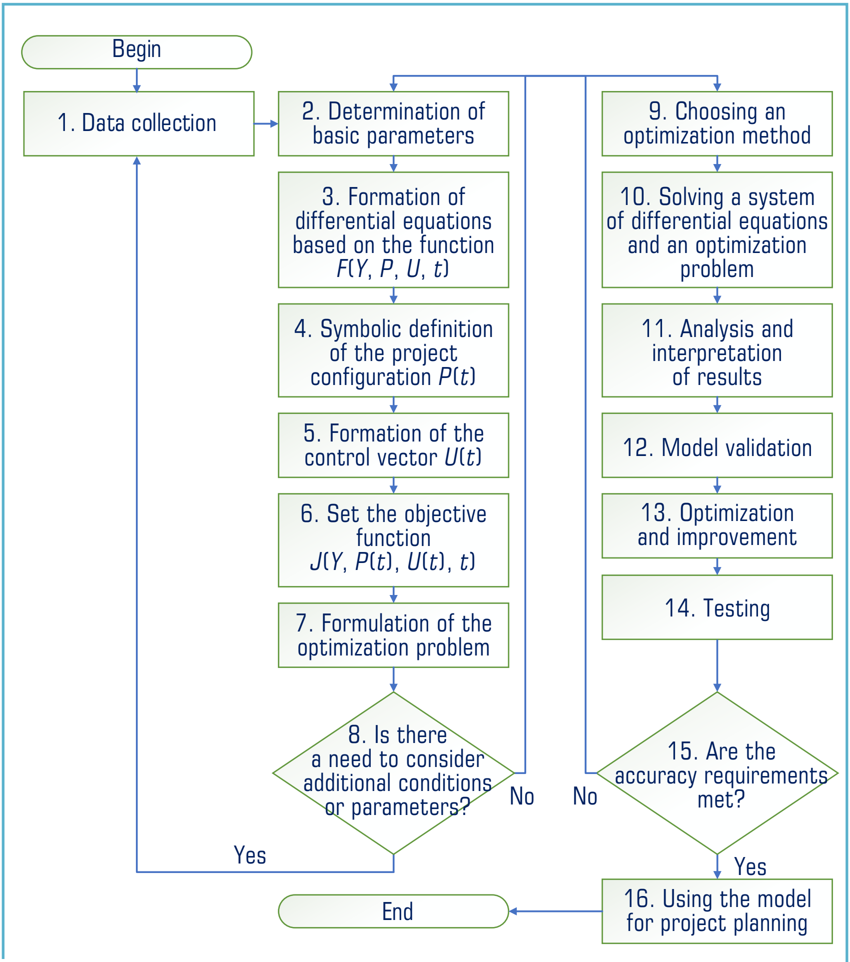


**Fig. 4.3** Block diagram of the algorithm for creating a computer model of differential-symbolic planning of projects to improve the health of the population

6. Set the objective function $J(Y, P(t), U(t), t)$ in accordance with the defined goals and constraints.

7. Formulation of the optimization problem using equation (4.10) and condition (4.8).

8. Checking the condition whether there is a need to take into account additional conditions or parameters. If yes, then go to Step 1. In this case, additional conditions or parameters should

be added that may affect the dynamics of the project (for example, restrictions on the maximum values of the budget, resources and duration). If not, then go to Step 9.

9. Select an optimization method to solve the optimization problem. This can be a numerical method, metaheuristics or analytical method, depending on the complexity of the project and the model.

10. Solving the system of differential equations and the optimization problem. In this case, the selected method is used to solve the system of differential equations and the optimization problem.

11. Analysis and interpretation of the results, which provides an assessment of the results obtained, an analysis of the impact of various parameters and the quality of management decisions on the implementation of the project.

12. Model validation ensures verification of the correctness and adequacy of the model, its results are compared with empirical data or literature sources.

13. Optimization and improvement ensures the implementation of necessary adjustments and, if necessary, optimization of the model. The model is documented, including the introduced assumptions, mathematical equations, optimization methods and other important aspects.

14. Testing the model with various input parameters and checking its stability and reliability.

15. Checking the condition whether the accuracy requirements are met. If yes, then go to Step 16. If not, go to Step 2.

15. Using the model for planning medical projects to support the population of communities.

Based on the proposed algorithm, we created a computer model of differential-symbolic planning of medical projects to support the population of communities. The code is written in the Python programming language using libraries for solving differential equations, optimizing and visualizing results. In particular, NumPy was used to work with numerical data and vectors. SciPy for numerical solution of differential equations and optimization of the objective function, Matplotlib for data visualization, in particular for creating 3D graphs. The SLSQP optimization method was used to find the optimal values of control parameters that minimize the objective function under given constraints.



## 4.5 ALGORITHM AND COMPUTER MODEL FOR DIFFERENTIAL-SYMBOLIC RISK ASSESSMENT OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

We have developed an algorithm for creating a computer model for differential-symbolic risk assessment of projects to improve the health of the population, the block diagram of which is presented in **Fig. 4.4**.

Differential-symbolic risk assessment of projects to improve the health of the population involves the implementation of 9 steps, which involve the use of formulas (4.11)–(4.18):

1. Initialization of variables to perform risk assessment of projects to improve the health of the population. To do this, let's assume that the percentage of the healthy population is previously

known, and then, based on formulas (4.11)–(4.13), write the dynamics equation for the implementation of measures to improve the health of the population. Let's fix the initial percentage of the healthy population that participated in various measures using formula (4.14). Let's set the initial value of the budget and duration of the project implementation.

2. Determination of the solution step using formula (4.18).

3. Checking the compliance condition of all initial data. If yes, then go to Step 4. If no, then go to Step 1 and make changes to the initial data to perform risk assessment of projects to improve the health of the population.

4. For numerical solution of differential equations use Euler's method using formulas (4.17).

5. Calculate the budget of the project to improve the health of the population using formula (4.15) and conditions: $\int_0^t Y_1(\tau)d\tau \approx h\sum_{j=0}^{i} Y_1(t_j)$, $\int_0^t Y_2(\tau)d\tau \approx h\sum_{j=0}^{i} Y_2(t_j)$ and $\int_0^t Y_3(\tau)d\tau \approx h\sum_{j=0}^{i} Y_3(t_j)$.

6. Assess the risks of the project to improve the health of the population $R(t)$ based on the deviations found from the planned indicators using equation (4.16).

7. Update the counter of the time of implementation of the project to improve the health of the population – $t=t+h$.

8. Check the condition whether the specified stage of modeling does not exceed the completion time of the project to improve the health of the population. If yes, then go to Step 4. In this case, it is possible to update the values of the indicators for the numerical solution of differential equations. If not, then go to Step 9.

9. Using the model to assess the risks of projects to improve the health of the population.

Based on the proposed algorithm, we created a computer model for differential-symbolic risk assessment of population health improvement projects. The code is written in the Python programming language using libraries for solving differential equations, optimizing and visualizing results. The NumPy library is used to work with numerical arrays and perform mathematical operations. It is used to implement numerical solutions of differential equations and calculations in the model. The Matplotlib library was used to visualize the modeling results. This allowed to create graphs of changes in the percentage of healthy population, budget and risk during the project. It is also used to add a vertical line to the graphs, indicating the optimal risk value. The Pandas library is used to create and process data tables. It is used to conveniently display the initial data, modeling results and indicators for a given risk level in the form of tables.

The structure of the computer model code consists of the following main blocks:

1) initialization of the initial data and model parameters;

2) checking the initial data for correctness;

3) simulation cycle that performs numerical solution of differential equations and records the results;

4) output and storage of results in the form of graphs and tables;

5) addition of analysis and visualization of the optimal risk value.

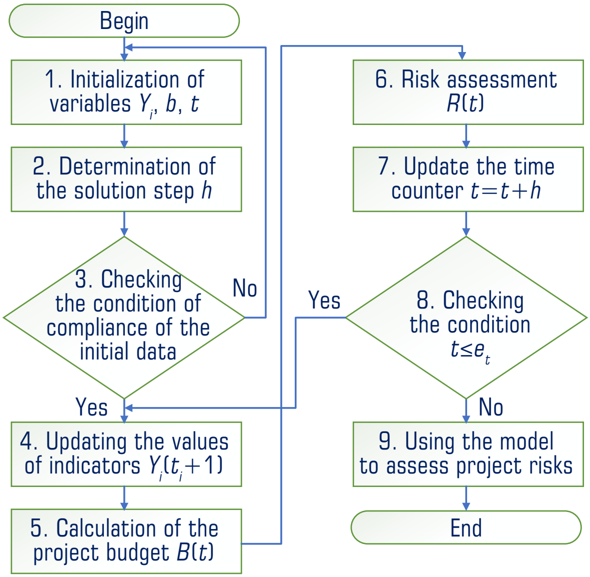


**Fig. 4.4** Block diagram of the algorithm for creating a computer model for differential-symbolic risk assessment of projects to improve the health of the population

## 4.6 RESULTS OF DIFFERENTIAL-SYMBOLIC PLANNING OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

The developed computer model of differential-symbolic planning was tested on the example of projects to improve the health of the population of communities. The initial data for optimizing the implementation scenario of the project to improve the health of the population of communities are presented in **Table 4.1**.

The constraints are set taking into account expression (4.8) in the form of a vector as the maximum values of the project budget $B_{max}$ = 100000 USD, available resources $E_{max}$ =30000 USD (part of the budget allocated for information campaigns, training and educational activities, purchase of necessary equipment and resources to ensure the successful implementation of population activities in the project) and the duration of the project $T_{max}$ = 24 months.

Based on the conducted research, we have constructed dependences of the growth rate of the percentage of the healthy population who participated in educational activities during the implementation of the project in different configurations (**Fig. 4.5**).

**Table 4.1** Initial data for optimizing the implementation scenario of the project to improve the health of the population of communities

| Indicator | Designation | Unit of measurement | Value |
|---|---|---|---|
| Percentage of healthy population that participated in educational activities | initial_Y1 | % | 41 |
| Percentage of healthy population that participated in vaccination | initial_Y2 | % | 55 |
| Percentage of healthy population that received health education | initial_Y3 | % | 65 |
| Baseline value of project budget | initial_B | USD | 50000 |
| Baseline value of available human resources allocated to implement activities in the community | initial_E | USD | 15000 |
| Initial duration of work in the project | initial_T | month | 12 |
| Initial simulation time | start_time | month | 0 |
| Final simulation time | end_time | month | 24 |
| Number of points for numerical solution of differential equations | num_points | pcs | 20 |

It was found that regardless of the basic value of the project budget and available human resources allocated for the implementation of activities in the community, the percentage of the healthy population who participated in educational activities begins to increase only after 18 months of implementation of the specified projects.

Subsequently, using the developed computer model of differential-symbolic project planning, which provides mathematical modeling of the dynamics of changes in the health status of the community population, a numerical solution of differential equations was performed using the open library SciPy. The results of the numerical solution of differential equations are presented in **Table 4.2**.

We conducted a study of the impact of changing parameters on the model results – on the percentage of healthy population in the community (initial_Y1). To do this, we constructed sensitivity graphs for each of the considered parameters (initial_Y1, initial_Y2, initial_Y3, initial_B, initial_E, initial_T) (**Fig. 4.6**). This graph presents a sensitivity analysis of each of the considered parameters to the parameter initial_Y1, which corresponds to the percentage of the healthy population participating in educational activities. The curves in the graph show changes in the values of the models when the parameter initial_Y1 is increased and decreased by 10 %. The blue line reflects the baseline value of the parameter. The green line represents the parameter value increased by 10 % from the baseline value. The red line shows the parameter value decreased by 10 % from the baseline value. It was found that the greatest impact on the percentage of the healthy population participating in educational activities initial_Y1 is the initial value of the project budget initial_B and the initial amount of financial and human resources initial_E, which are intended for the implementation of activities in the community. They have the largest deviation between the baseline values and the changed values. This indicates a significant impact on the parameter initial_Y1 of the model result.

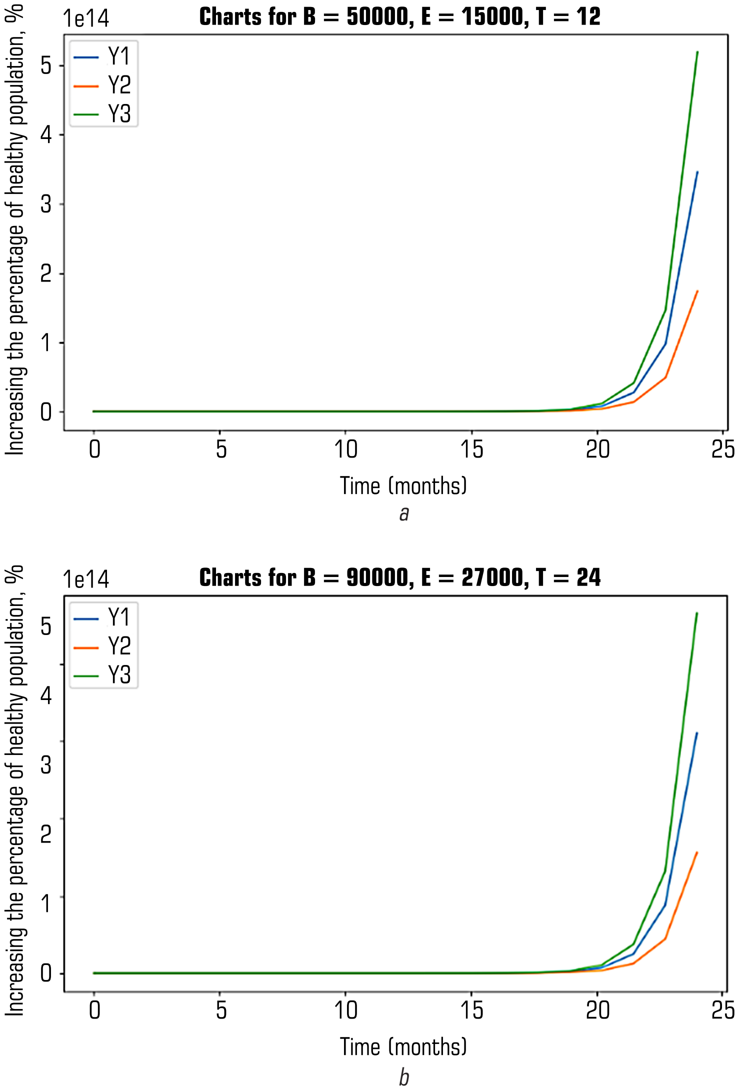


**Fig. 4.5** Dependences of the increasing the percentage of healthy population who participated in educational activities during the project implementation for the following configurations: *a* – B = 50000 USD, E = 15000 USD, T = 12 months; *b* – B = 90000 USD, E = 27000 USD, T = 24 months

**Table 4.2** Results of the numerical solution of differential equations

| Point number for numerical solution | Time (months) | initial_Y1 | initial_Y2 | initial_Y3 | Point number for numerical solution | Time (months) | initial_Y1 | initial_Y2 | initial_Y3 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.000000 | 4.100000e+01 | 5.500000e+01 | 6.500000e+01 | 10 | 12.631579 | 3.992236e+09 | 2.006697e+09 | 5.989414e+09 |
| 1 | 1.263158 | 3.312665e+04 | 1.668550e+04 | 4.970227e+04 | 11 | 13.894737 | 1.411886e+10 | 7.096846e+09 | 2.118204e+10 |
| 2 | 2.526316 | 1.501364e+05 | 7.550047e+04 | 2.252480e+05 | 12 | 15.157895 | 4.993241e+10 | 2.509852e+10 | 7.491187e+10 |
| 3 | 3.789474 | 5.639500e+05 | 2.835038e+05 | 8.460783e+05 | 13 | 16.421053 | 1.765896e+11 | 8.876275e+10 | 2.649313e+11 |
| 4 | 5.052632 | 2.027431e+06 | 1.019123e+06 | 3.041689e+06 | 14 | 17.684211 | 6.245218e+11 | 3.139159e+11 | 9.369487e+11 |
| 5 | 6.315789 | 7.203139e+06 | 3.620692e+06 | 1.080663e+07 | 15 | 18.947368 | 2.208666e+12 | 1.110186e+12 | 3.313586e+12 |
| 6 | 7.578947 | 2.550740e+07 | 1.282133e+07 | 3.826788e+07 | 16 | 20.210526 | 7.811108e+12 | 3.926253e+12 | 1.171874e+13 |
| 7 | 8.842105 | 9.024174e+07 | 4.536005e+07 | 1.353866e+08 | 17 | 21.473684 | 2.762455e+13 | 1.388548e+13 | 4.144416e+13 |
| 8 | 10.105263 | 3.191794e+08 | 1.604356e+08 | 4.788539e+08 | 18 | 22.736842 | 9.769620e+13 | 4.910699e+13 | 1.465703e+14 |
| 9 | 11.368421 | 1.128834e+09 | 5.674084e+08 | 1.693551e+09 | 19 | 24.000000 | 3.455097e+14 | 1.736704e+14 | 5.183563e+14 |



The created model allowed to identify possible scenarios (**Fig. 4.7**) for the implementation of projects to improve the health of the community population, as well as to choose the optimal scenario from among a set of alternative ones (**Table 4.3**).

The obtained optimization results show that the values of the objective function ($J$), which concerns the minimization of the cost of funds for the implementation of the project with the maximum increase in the percentage of healthy population, fall on the scenario that assumes the following optimal values of parameters:

1) project budget $B^{opt} = 45000$ USD;

2) part of the project budget, which is provided for the purchase of necessary equipment and resources to ensure the successful implementation of population measures in the project $E^{opt} = 14250$ USD;

3) duration of the project after its initiation $T^{opt} = 9.6$ months.

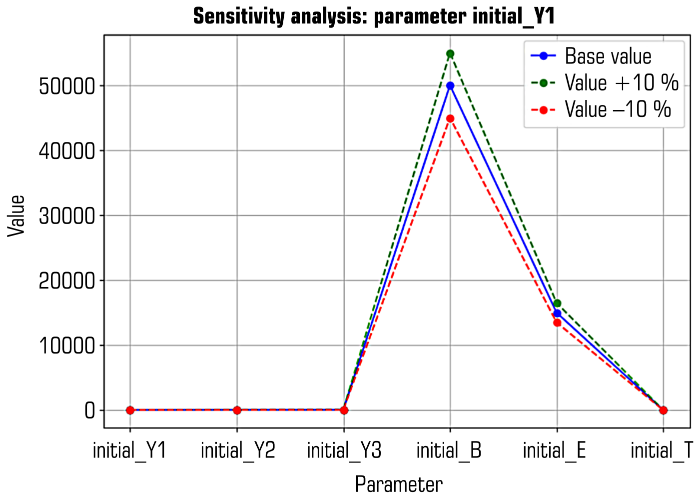


**Fig. 4.6** Sensitivity graphs of each of the considered parameters relative to the percentage of healthy population in the community

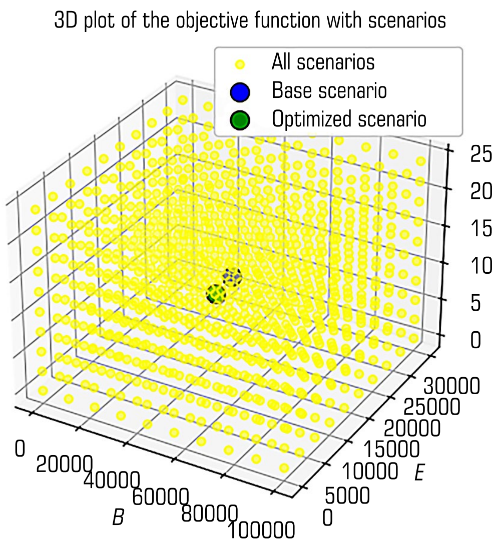


**Fig. 4.7** Results of determining the optimal scenario for implementing a project to improve the health of the population in the community

**Table 4.3** Results of optimizing the scenario for implementing a project to improve the health of the population in the community

| **Scenario** | **Y1** | **Y2** | **Y3** | **Budget used** | **Resources used** | **Duration (months)** |
|---|---|---|---|---|---|---|
| Basic | 41 | 55 | 65 | 50000.0 | 15000.0 | 12.0 |
| Optimal | 51 | 67 | 80 | 45000.0 | 14250.0 | 9.6 |

## 4.7 RESULTS OF DIFFERENTIAL-SYMBOLIC RISK ASSESSMENT OF PROJECTS TO IMPROVE THE HEALTH OF THE POPULATION

The developed computer model for differential-symbolic risk assessment of community health improvement projects was tested on the example of community health improvement projects. The initial data for risk assessment of community health improvement projects are presented in **Table 4.4**.

**Table 4.4** Initial data for risk assessment of community health improvement projects

| **Initial percentage of healthy population, %** | **Initial budget, UAH** | **Project duration, months** | **Time step, months** | **Coefficient of impact of measures on health, α** | **Coefficient of budget expenditure on health improvement, β** | **Coefficient of risk reduction, γ** |
|---|---|---|---|---|---|---|
| 60 | 1000000 | 24 | 1 | 0.1 | 0.05 | 0.02 |

It is assumed that the initial percentage of healthy population is 60 %. This value indicates that 60 % of the community population is healthy at the beginning of the project. The available budget of the community health improvement project is 1 million UAH. This is the main resource that will be spent on the implementation of the health improvement project. The project is planned to be implemented within 24 months. This determines the total time during which measures to improve the health of the population will be implemented. The selected time step for modeling and assessing the project is 1 month. This means that the model will be updated monthly.

Further, using the developed computer model of differential-symbolic risk assessment of health improvement projects, which provides mathematical modeling of the dynamics of changes in the health of the community population, a numerical solution of differential equations was performed. The results of the simulation based on the numerical solution of differential equations are presented in **Table 4.5**.

We conducted a study of the impact of the project implementation period and the duration of its life cycle on risk. For this purpose, let's develop the dependencies (**Fig. 4.8–4.10**).

It was found that the percentage of healthy population gradually increases with the duration of the project to improve the health of the population (**Fig. 4.8**). This indicates the effectiveness of the measures implemented within the project [32]. The increase in the percentage of healthy population of the community by 21.2 % during the 24 months of project implementation demonstrates the positive impact of the implemented measures on improving the health of the population.

**Table 4.5** Results of risk simulation based on the numerical solution of differential equations

| Time, months | Percentage of healthy population, % | Project budget, UAH | Risk |
|---|---|---|---|
| 1 | 60.0 | 1000000 | 0.80 |
| 2 | 60.6 | 998600 | 0.79 |
| 3 | 61.1 | 997200 | 0.78 |
| 4 | 61.7 | 995800 | 0.77 |
| 5 | 62.2 | 994400 | 0.76 |
| … | … | … | … |
| 22 | 80.5 | 978600 | 0.39 |
| 23 | 80.9 | 977200 | 0.38 |
| 24 | 81.2 | 975800 | 0.37 |

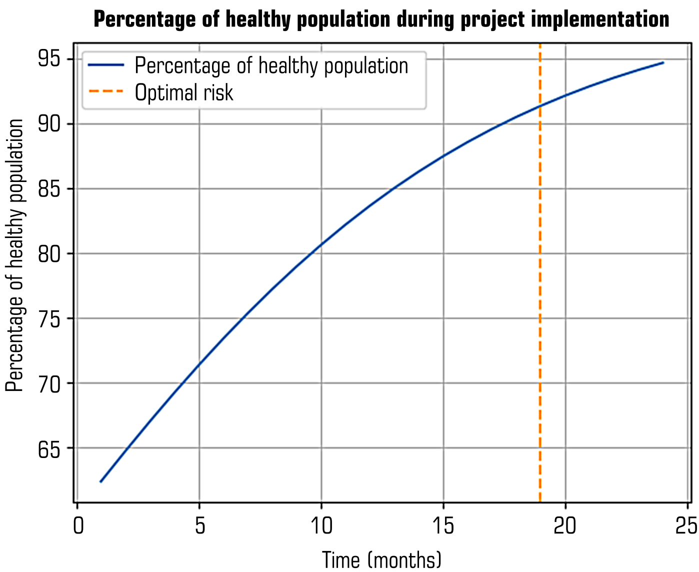


**Fig. 4.8** Dependence of the percentage of healthy population of the community on the duration of the project implementation to improve the health of the population

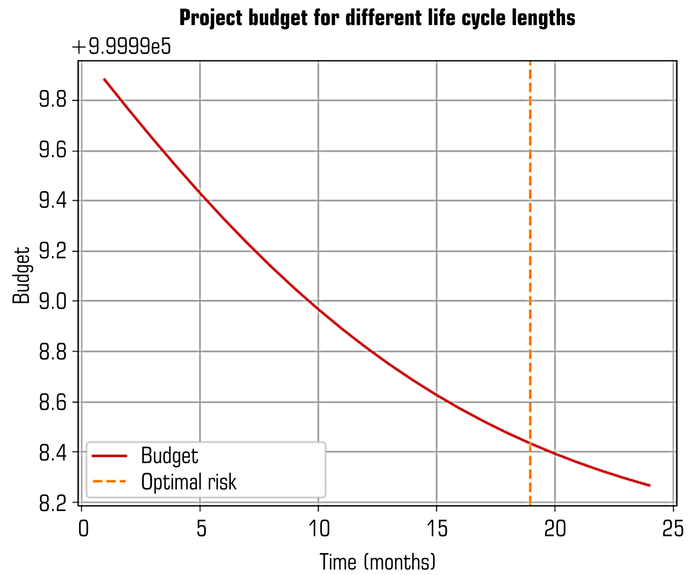


**Fig. 4.9** Dependence of the change in the budget requirement of the project to improve the health of the population on the duration of its implementation

The required budget of the project to improve the health of the population decreases over time (**Fig. 4.9**), which may be the result of the costs of implementing the measures or less funding due to the achievement of the set goals [33]. It was found that the risk decreases during the project implementation (**Fig. 4.10**), which indicates the successful reduction of risks associated with the health of the population. A risk reduction of 0.43 (or 53.75 %) over 24 months is a significant achievement and confirms the positive impact of the project implementation on the health of the population of the community.

Overall, the implementation of the project to improve the health of the population demonstrates positive results, as the percentage of healthy population increases and the risk decreases [34]. This indicates that the implemented measures have a significant impact on improving the health of the population [35].

The created model allowed to identify possible risks (**Fig. 4.4**) for different durations and budgets of the implementation of projects to improve the health of the community population, as well as determine the optimal risk from a set of alternative project implementation options (**Table 4.6**).

It was established that the optimal risk of the project to improve the health of the community population is at the level of 0.20. At the same time, the project requires 16 months to implement, which confirms its high effectiveness in controlling and reducing risks [36]. This also shows the effectiveness of management measures and the economic benefit from implementing the project according to the proposed scenario with the minimum possible risk and maximum benefits [37].

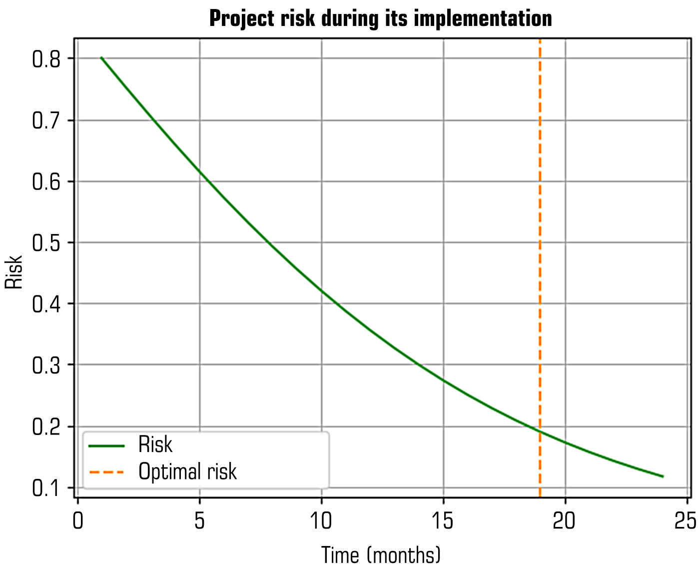


**Fig. 4.10** Dependence of the risk of the project to improve the health of the population on the duration of its implementation

**Table 4.6** Results of risk optimization during the implementation of the project to improve the health of the community population

| Duration of project implementation, months | Percentage of healthy population, % | Project budget, UAH | Risk |
|---|---|---|---|
| 16 | 75.0 | 987000 | 0.20 |

Thus, the proposed differential-symbolic approach, which is implemented in the presented algorithms and computer models, is a fairly simple and effective tool for project managers [38], which ensures accurate planning of community health improvement projects and risk assessment of these projects [39]. This is confirmed by the results obtained based on the conducted study of the influence of project environment components on the choice of the optimal scenario for the implementation of community health improvement projects and the quantitative value of the risks of these projects. For further research, all possible constraints, the function of the object and internal optimization parameters should be reviewed. The optimization method can also be changed, which will ensure the formation of real constraints and take into account additional factors to improve the stability of optimization [40]. Based on computer models of differential-symbolic planning of community health improvement projects and risk assessment, management plans for these projects can be developed [41]. Quantitative assessment of the effectiveness of the models has shown that it can be an effective tool for project managers. Models allow to effectively manage the configuration and risks of projects and minimize the cost of their implementation while maximizing the percentage of healthy population.

## CONCLUSIONS

Analysis of recent studies and publications shows that planning of medical projects for community support is an important aspect of managing these projects. Given the growth of medical data, rapid technological changes and expansion of the capabilities of analytical tools, computer models are becoming an integral part of planning the implementation of these projects.

The main stages of the differential-symbolic approach to managing community medical support projects involve the use of mathematical modeling, numerical analysis and optimization to determine the rational configuration of these projects. Based on the scheme of the proposed differential-symbolic approach to managing community medical support projects, appropriate mathematical models have been developed, which made it possible to develop algorithms for differential-symbolic planning of community medical support projects and risk assessment of these projects.

Based on the proposed algorithms, computer models for differential-symbolic planning of medical projects to support the population of communities and risk assessment of these projects have been developed. They are based on the mathematical models we have proposed, written in the Python programming language using libraries for solving differential equations, optimizing and visualizing results. The models allow to perform labor-intensive calculations to form possible scenarios for the implementation of medical projects to support the population of communities and assess the risk of these projects, as well as visualize possible configurations of projects and determine their optimal scenario.

Using the proposed computer models on the example of planning a project to improve the health of the population in a community made it possible to obtain the dependence of the growth rate of the percentage of the healthy population who participated in educational activities on the configuration of projects to improve the health of the population of communities. In addition, it made it possible to determine the optimal scenario for the implementation of a project to improve the health of the population in a community, which demonstrates its effectiveness and practical use.

The prospect of further research is to expand the functionality of computer models, adding modules for analyzing other components of medical projects to support the population of communities. Based on the use of computer models, it is possible to conduct research on the effectiveness of the implementation of various types of medical projects, taking into account the real conditions of the project environment.

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