Implementation Models Application for IT Project Risk Management

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Abstract. The article considers simulation models of risk analysis for IT projects. An article objective is research of simulation models and their application for risk management of information technology projects. An information system based on simulation models of risk analysis for IT projects is developed. The experimental approbation of the developed system is analyzed. One of the major tasks to address within project management is project risk management or project risk management. This task is not separate from most other project management functions. It projects are characterized by a large number of connected processes. The most expedient method for analyzing and managing IT projects risk, including the risks of observing calendar schedules, is imitation modeling. This method provides both accurate analysis and visual representation of alternatives to management behavior. Considered model allows constructing distributions of probability values for the most important parameters of the progress of the project, which in turn allows you to put and check stochastic hypotheses.

Keywords: Risk, IT Project, Simulation Model.

1 Introduction

One of the major tasks to address within project management is project risk management or project risk management. This task is not separate from most other project management functions. When determining financial needs, calculating budget and budget, preparing and concluding contracts, the task of protecting project participants from various types of risks arises during the control of the project implementation. Risks arise at all stages of the project activity, so the function of managing them is relevant until the project closure. Project risk management permeates all areas of project management activities without exception. This causes various difficulties (organ-

izational, personnel, psychological, etc.) to separate this function into an independent element of the organizational structure of project management.
Within the risk management of IT projects, the following issues are relevant [1-3]:

- Classification of project risks;
- Methods of risk identification and assessment;
- Informational support of risk management;
- Monitoring and forecasting of risks;
- Risk mitigation technologies;
- Organization of risk management;
- Assessing the effectiveness and justification of the optimal level of risk management costs.

Within the theory and practice of project risk management, the most important are, in particular, methods of risk assessment, monitoring and forecasting, risk management information support [5-9]. Risk management activities cover the following main stages: identifying risk, assessing it, choosing a method and means of risk management, preventing, controlling, financing risk, evaluating results. The project is a single process consisting of a set of coordinated and controlled activities with start and end dates, carried out to achieve a specific target that has limitations in terms of time, cost and resources [10-12]. The project operates in a defined environment containing internal and external components that, in turn, take into account economic, political, social, technological, regulatory, and cultural and other factors.

2 Related Works

The project is always focused on the result, the achievement of the set goals, the specific subject area. The authorized project management, project manager and project team working under this management, other project participants who perform specific activities and processes for the project, carry out the implementation of the project. As part of the project, usually on a part-time basis, representatives of the linear and functional divisions of companies responsible for performing their tasks, activities, functions, including planning, management, control, organization, administration, and other system-wide functions, may participate. [1].

The managed parameters of the project are [13-21]:

- Scope of work and types of project work;
- Cost, project expenses;
- Temporary parameters, including terms, duration and reserves of work, stages, phases of the project, as well as parameters of the relationship of works;
- Resources required for the implementation of the project, including: human or labor, financial, logistical, subdivided into building materials, machines, equipment, components and parts, and resource constraints;
- Quality of design decisions, required resources, project components, etc.

Project management is an activity aimed at implementing a project with the highest possible efficiency with given time constraints, resources, and the quality of the project outputs (documented, for example, in the terms of reference) [6]. In order for effectively project management constraints, methods of constructing and controlling work schedules are used. To manage the resource constraints, the methods of forming the financial plan (budget) of the project are used and, as the work is carried out, monitoring is carried out in order to prevent costs from getting out of hand. Appropriate resources are required to perform the work, using specific methods of human and material resource management (for example, the responsibility matrix, resource loading diagrams). Of the three main constraints, the most difficult is to control the constraints on the project results. The problem is that tasks are often difficult to formulate and control. In particular, quality management methods are used to solve these problems. Thus, project managers are responsible for three aspects of project implementation: timing, cost and quality of output. However, effective time management is the key to success by all indicators. Project time constraints are often the most critical. Where project deadlines are severely delayed, cost overruns and poor quality of work are likely consequences. Therefore, in most project management methods focus is on the work scheduling and monitoring of the calendar schedule [22-27].

The main elements of a system of management in situations of uncertainty are: identifying risk in alternatives and keeping it within acceptable levels; development of specific recommendations aimed at eliminating or minimizing the possible negative effects of risk [28-33]. The challenge of managing IT projects is to reduce the impact of unwanted factors on the project lifecycle to produce the results closest to the desired ones. For complex systems, where the problems of research and prediction of states are mostly solved, depending on the chosen management strategies, such as systems of analysis and management of project risks, there are difficulties in the application of analytical models. They are caused by the following factors:

- Large projects have many links between processes;
- Real projects fall under the influence of random external and internal factors, the accounting of which is not possible analytically;
- The possibility of comparison of the original with the model exists only at the beginning and after the application of the mathematical apparatus, since the intermediate results may have no analogues.

In this regard, it is advisable to use a more flexible method, the simulation method.

The model is presented in the form of an algorithm in which all the most essential elements, connections in the system are determined and initial values of the parameters corresponding to the initial moment of time are given.

All further changes occurring in the system by the cause and effect law are calculated by means of logical processing of data when executing this algorithm.

This method does not require equations and does not require their solution, so it is widely used in many areas of human activity without additional special knowledge.

3 Materials and Methods

During the simulation experiment, the computer simulates the functioning of the system, process, or project and calculates the characteristics of the properties manifested by the system. The simulation experiment is similar to a full-scale experiment, but unlike a full-scale experiment, it allows you to experiment with systems that are already missing or to predict the behavior of existing systems in the future, to study their behavior in emergencies. It is cheaper and faster than full-scale experiments.

Simulation modeling in the management of IT projects can be seen as a kind of "simulator" that allows the manager of any level to predict the execution of the project under the influence of various controlled and uncontrolled factors of the external and internal environment [3]. With simple simulation modeling tools, it is possible to calculate the likelihood of a particular result when accounting for the impact of several factors. Efficiency and simplicity of the method allows varying a huge number of situations at many combinations of initial conditions. The constant process of accumulation of simulation results leads to the formation of a sufficiently large but finite array of typical management situations with a finite number of standard behaviors. It gives an opportunity to regulate certain steps in project management and allows increasing efficiency and effectiveness of management activity.

Simulation modeling is a versatile method that provides both accurate analysis and visual display of alternative management behaviors. In addition, because of its versatility, the ability to conduct numerous experiments and plan for various changes, imitation models of complex systems are the most common. In the process of conducting experiments on the simulation model, it is possible to make the following changes:

- In the model structure (add new items and links, remove others)
- Behavior models, model parameters;
- Parameters and laws of distribution of random factors;
- In time of values and external variables.

Simulation models allow us to investigate system-wide properties, system behavior in special situations, to find better values of system parameters that were free before the start of the study, to predict system behavior over time. The algorithmic structure of the simulation models facilitates the implementation of various schemes of hierarchical subordination and coordination between the elements of the model.

We distinguish the following eight stages of simulation.

3.1 Defining the Goals, Objectives and Opportunities of Imitation

The objective is external to the system under consideration, determined by the tactical or strategic interests of the individual or group of persons for whom the study is being conducted. Of particular interest is the situation where the ODA (administrator, manager, and supervisor) solves some practical problem. The purpose of the study (or each set of goals) is specified in the form of a set of tasks, the solution of which is necessary and sufficient to achieve the goal. Usually, many tasks have a hierarchical structure and can conveniently depicted as a tree of goals and tasks.

Another factor that leads to the identification of this problem is the ability of the researcher (theoretical, financial, time and others). Theoretical capabilities are those data and research methods that a researcher can apply to solve a problem based on their professional knowledge and experience. Financial capability limits the use of tools, the volume of experiments and observations, the number of specialists and support staff. Any research should done in specific timeframes, which significantly depend on the scale of the problem and the depth of its study.

In general, the purpose of the study can be decomposed as follows:

- Description of the functioning of the system (description of the system in the framework of an already formulated problem, i.e. some aspect of the functioning of the system);
- Forecast of functioning at different impacts (predicting the state of the system in the future under different variants of internal and external influences (scenarios) on the system);
- Search for the best version of the system.

3.2 Analysis of the System and Construction of its Conceptual Model

The formulation of the research problem allows us to outline the boundaries of the object, distinguishing it from the environment. The result of the systematic approach to the problem is a conceptual model that reflects the concept of the study and is determined by its goals and opportunities. The conceptual model contains:

- Description of the boundaries of the system;
- Set of system elements;
- The set of status indicators for each element;
- A set of links between elements of the system (if necessary, indicate the intensity of resource and information flows);
- A list of processes that take place in the system;
- A list of internal and external influences on the system.

The most common are verbal (verbal) descriptions of the conceptual model; various diagrams, graphs, tables and charts are also used to provide the information in a clear and concise manner. The conceptual model may contain formalized elements (flowcharts, flow models, mathematical relations, etc.), which facilitates subsequent steps of formalization.

3.3 Drawing up and Structuring of the Simulation Model

The next stage of simulation is the formalization of the conceptual model that is obtained, that is, the construction of a formal model. The general appearance of a formal simulation model can defined by the ratios:

$$x(t+\Delta t) = x(t) + (\Delta t) f_t(x(t), u(t), \xi(t)), \quad x(0) = x_0, t = 0, \ldots, T - \Delta t,$$

Where

$x(t) = (x_1(t), \ldots, x_n(t))$ is vector of state;

$x_i(t), (i = 1, \ldots, n)$ is this is the value of the indicators that characterize the state of the system at time t; components of the state vector can take both quantitative (numeric, symbolic, etc.) and qualitative values on some order scale;

$u(t) = (u_1(t), \ldots, u_m(t))$ is vector of controlled effects;

$\xi(t) = (\xi_1(t), \ldots, \xi_p(t))$ is vector of not controlled effects;

$f_1(x(t), u(t), \xi(t))$ is vector-function of the same dimension as x (t), which determines the dynamics of the state vector under conditions of external influence;

$x_0 = (x_{01}, \ldots, x_{0n})$ is the initial value of the state vector that is known;

T is the period during which the dynamics of the system are simulated;

Δt is modeling step (time difference between two consecutive states of the system).

Each of the vectors $x(t)$, $u(t)$ i $\xi(t)$ can take values from some valid range, which is determined accordingly $X(t)$, $U(t)$ i $\Xi(t)$. Area of valid states $X(t)$ is characterizes the range of possible states of the system, the range of acceptable controls, $U(t)$ is characterizes the capabilities of the subject to control the system, and the area $\Xi(t)$ is characterizes the possible values of uncontrollable factors (in the complete absence of information this area coincides with the whole space R^p).

Depending on the purpose of the simulation, a system time is introduced to simulate the course of time in a real system. There are two types of scales of model (system) time: uniform and event (by actions). After setting the system state vector and selecting a time step, the model is decomposed and its block design is determined. The block principle of model building has a number of advantages, especially tangible when creating complex imitation models.

3.4 Software Implementation of the Simulation Model

An integral part of applied systematic research is computer simulation experiments with the model. The constructed formal model should presented in the form of a program that implements the corresponding research algorithm: numerical solution of the system of algebraic and differential equations, optimization problem, and transition of the system from the initial state to the final state.

3.5 Analysis and Correction of the Simulation Model

Before using a built-in simulation model, the following questions must addressed:

- Select the values of structural and numerical parameters of the model;
- Make sure that with these parameter values, the model fits well with the modeled system and describes it adequately (verification, verification of certain adequacy).

3.6 Planning and Conducting Simulation Experiments

In simulation modeling, the computer plays the role of an experimental institution, giving the value of managed variables, uncontrollable factors, and the initial conditions of the system trajectory. Since the number of possible combinations of controlled and unmanaged external factors (even for a finite set of them) per system is large, so is the role of planning simulation experiments.

3.7 Processing and Analysis of Simulation Results

Usually, the immediate results of the simulation are not yet suitable for solving the tasks. They should systematized, submitted in a form that is more favorable for later analysis, submitted to the ODA, and analyzed. Negative results can obtained at this stage, which means that you need to correct the model and return to the previous steps. The statistical methods of processing the simulation results include:

- Data capture and accumulation of modeling statistics;
- Determination of intervals for initial values;
- Identifying functional relationships between variables using regression analysis;
- Identification of the law of distribution on the histogram.

Analysis of simulation results contains:

- Evaluation of the accuracy of the simulation experiment;
- Reducing the number of model parameters;
- Determination of intervals of change of parameters;
- Search for the source of errors;
- Removal of sharply rejected values;
- Selection of coordinate system for presentation of results, etc.

3.8 Management and Support of Simulation Results

The key to simulating systems is to solve practical problems. Therefore, the simulation process does not end even after receiving, processing and interpreting the results of the simulation ODA and experts. It is necessary to ensure the practical application of these results in the management of an appropriate dynamic system. It is necessary that the results can used not only for a single solution of the task, but also for the multiple solution of a complex of problems related to this system [3].

In this way, simulation models allow us to investigate the behavior of large systems, in particular, IT projects, that are not amenable to research by other methods.

4 Experiment

We present information technology project as a certain sequence of $w_i \in W$ processes. The process is a set of interrelated or interrelated activities that converts the inputs to outputs [6]. Each process has its own defined start $t_i^{П} \in T$ and finish $t_i^{З} \in T$ dates. In addition, the beginning of some processes may depend on the end of the others that proceed. Model of the IT project will be as a place in the form of network. Each project will be marked with a network arc, which is focused on project implementation and combines two stages of the project. The stages of the project are designated by network nodes and establish a relationship of retraction among processes of IT project. In other words, the stage is an event of start or end process.

Building a network of project is based on the following rules:

- Each process is fed to one and only one arc;
- Each process is identified by two end nodes (a node of the beginning of the process and its node completion);
- To maintain the correct relationship of transposing additional process, you must specify:
  - Which process is directly preceded by the accompanying process;
  - What process should be performed after the added process is completed;
  - What process competes, that is performed in parallel, with added process.

Fig. 1 will lead to the example of network model of the project, in which there are ten events (knots 1,2,...,10), which define the completed stages of the project. The arcs between the nodes of the network define the processes of the project (14 processes), which are characterized by a certain duration of performance and certain resource constraints.

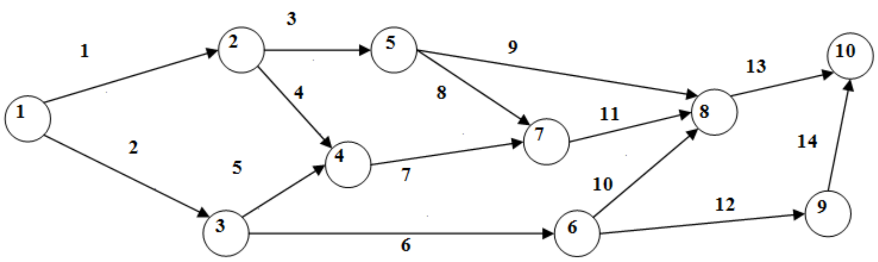


Fig. 1. An example of a network model of IT project.

The analysis of the risk of compliance with the deadlines of the project is to determine the probability of which the project will executed at a certain time and vice versa, how much time is required for successfully complete the project with the given probability. It is obvious that the project will be successful, that is, in a predetermined period, completed in case of completion of all the work of the project. The performance of the project can be calculated by summing the longest by chronological dimension of path (the critical way), which determines the maximum duration of the project overall. The process is critical if it has no "allowance" for the time of its start and completion. So that the entire project is completed immediately, it is necessary that all the critical processes are started and end in a strictly defined time. For a noncritical process, some deviations in its start time, but within certain boundaries – means when the time of its start does not affect the duration of the entire project. To perform the necessary calculations we define an event as a point on the timeline axis where one process ends and another begins. We introduce the following designations:

- t'_j is the earliest possible occurrence of the event *j*;
- t''_j is the latest possible time of occurrence of the event *j*;
- D_{jq} is process Duration (j,q) .

Calculation of the critical path occurs in two passages. During the first pass, the earliest times of occurrence of events are evaluated, and for the second – the earliest times of occurrence of the same events.

I-st pass. The calculations start at node 1 and finish at last node *n*. Let's assume, that $t'_j = 0$, means, projects starts at zero time point. Then for each node *j* we define nodes *p*,*q*...,*v*, which are directly related to node *j* by processes (*p*,*j*) (*q*,*j*)..., (*v*,*j*), for which we already calculated the earliest time of corresponding events. The earliest time of event *j* is calculated by formula: $t'_j = \max\{t'_p + D_{pj}, t'_q + D_{qj}, t'_v + D_{vj}\}$. Moving forward is finished, when value t'_n is calculated for node *n*.

II-nd pass. Calculations start at the last node *n* and end in node 1. Let's assume, that $t''_n = t'_n$, means that earliest and latest time for finishing project are the same. Then for each node *j* we define nodes *p*,*q*...,*v*, directly connected to node *j* by processes (*p*,*j*) (*q*,*j*)..., (*v*,*j*), for which we already calculated latest time of corresponding events. The latest time of event *j* is calculated by formula:

$$t'_j = \min\{t''_p - D_{pj}, t''_q - D_{qj}, t''_v - D_{vj}\}.$$

Moving backward is finished, when value t''_1 is calculated for node 1.

Process (*i*,*j*) will be critical, if following conditions are valid:

1. $t''_i = t'_i$;
2. $t''_j = t'_j$;
3. $t''_j - t''_i = t'_j - t'_i = D_{ij}$.

Critical processes should form a continuous path across the entire network from the initial event to the end. For the implementation of simulation model of IT Projects Risk analysis is developed about a system that decides to determine the probability of successful completion of the project at the specified dates and the time of completion of the project at a specified probability of successful completion.

The project is in the form of a network. An arc oriented in the direction of project implementation marks each process of the project. Each event is set by a network node and establishes a coding relationship among project processes. Its number, title and duration characterize each process of the project.

The duration of the processes can be deterministic, stochastic or probabilistic. In the first case, the Critical Path Method is used, in the second – PERT (Program Evaluation and Review Technique) method.

In the case of probabilistic lifetime's processes, for each of them it is necessary to obtain probabilistic distributions of time of execution of this process. To obtain the kind of law probabilistic distribution and its parameters, you can use several methods. The First is to obtain the type and parameters of the distribution law by questioning experts (subjective probabilities). The second is based on the plural of analogues projects (objective probability). To determine the analogues projects must first classify the simulated project. To do this, we use the database of already executed projects and with the help of fuzzy classification; we divide the projects into classes by certain signs. Later after conducting cluster analysis of a simulated project determine the class to which it belongs and choose the rationing procedure for calculating the parameters of the project.

5 The Results

For example, the developed system is to take the project given by the network in Fig. 1. Input the data in this system to enter the project's network model is the characteristics of the project processes: process numbers and their names, the longest and shortest duration. In order to establish relationships, project processes as input parameter for each process are set numbers of processes without which the process is impossible to start. This data is entered in the dialog box (Fig 2) in the table (Fig 3).

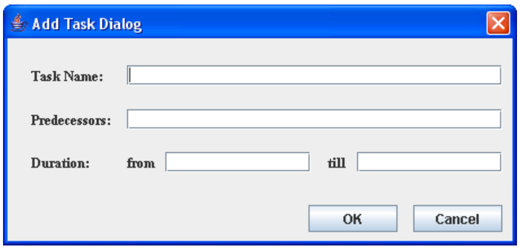
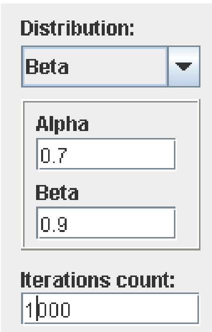


Fig. 2. Custom input window

#	Task Name	Predecessors	From Duration	Till Duration
1	name1		12	15
2	name2		21	23
3	name3	1	7	11
4	name4	1	14	16
5	name5	2	17	20
6	name6	2	11	15
7	name7	4,5	8	11
8	name8	3	7	9
9	name9	3	3	6
10	name10	6	6	9
11	name11	7,8	9	11
12	name12	6	12	14
13	name13	9,11,10	9	11
14	name14	12	23	26

Fig. 3. Able with entered input data for a test project

For all project processes the probabilistic distribution law is specified, which will be used with a random values generator and the distribution parameters are necessary if necessary. The number of settlement iterations is given separately (Fig. 4). To provide random values by the selected distribution law, the generators of random quantities are used.



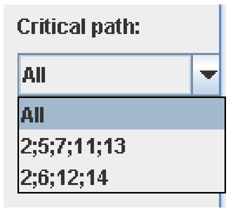


Fig. 4. The Type and Distribution Options window **Fig. 5.** Critical pathways for a test project

In particular, the system provides random value generators to provide random values after we have the law of distribution: Uniform distribution; Normal distribution (D); β- distribution (parameters α and β); Exponential distribution; γ-distribution (parameter α). The system works as follows. After specifying input data is generation of random duration of work with a specified user. Generation occurs according to the selected law distribution. Later passes the process of finding the critical path of the project, in accordance with the given order of following works and their generated lifetimes. The number of such transitions depends on the number of the settlement iterations.

6 Discussions

For the project, the table (Fig. 3) and the distribution parameters (Fig. 4) critical path be the following (Fig. 5). Then the system forms probabilistic distributions for the found critical ways, analyzes them and depicts graphically (Fig. 6). The source data of the system are the formed probabilistic distributions in both separate found critical ways and for the project in general (Fig. 7).
As a result of the system work, we can get an answer to the question:

- How long will the project is performed in advance of the given likelihood?
- What is the probability that the project may executed in a specified period?

For example: For a period of 72 time units, a project that is specified in Fig. 1 will be finalized with a probability of 0.80373, and the completion of this project with the probability of 0.9 is possible in the period not later than 73 time units (Fig. 8).

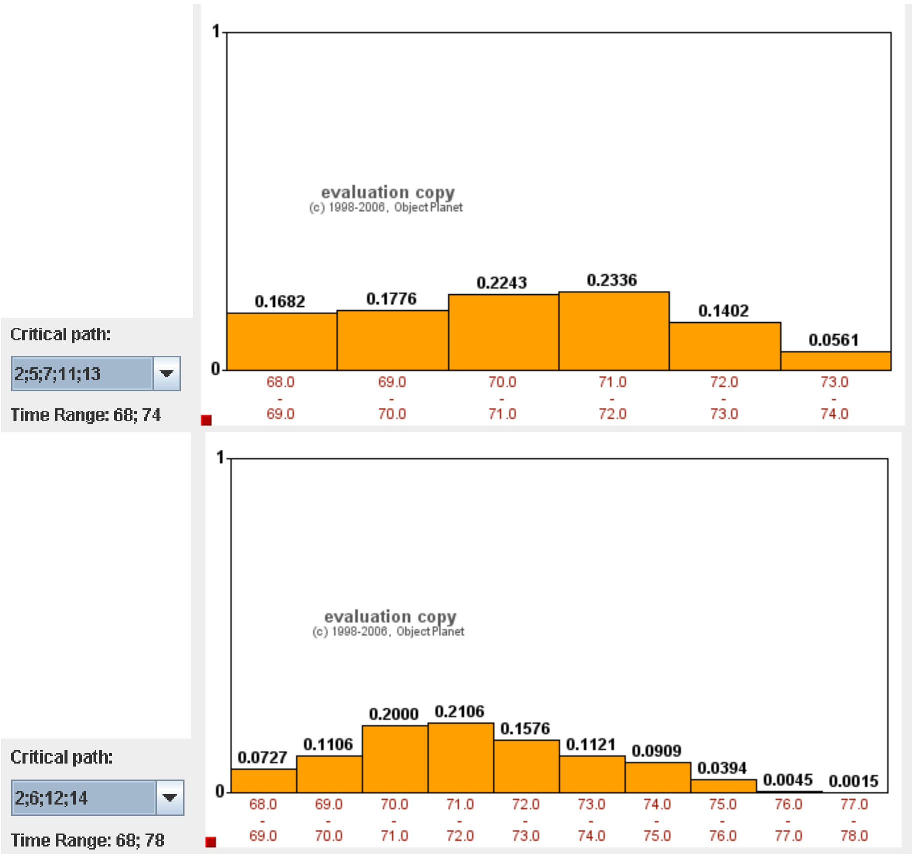


Fig. 6. Probability distributions are in critical ways.

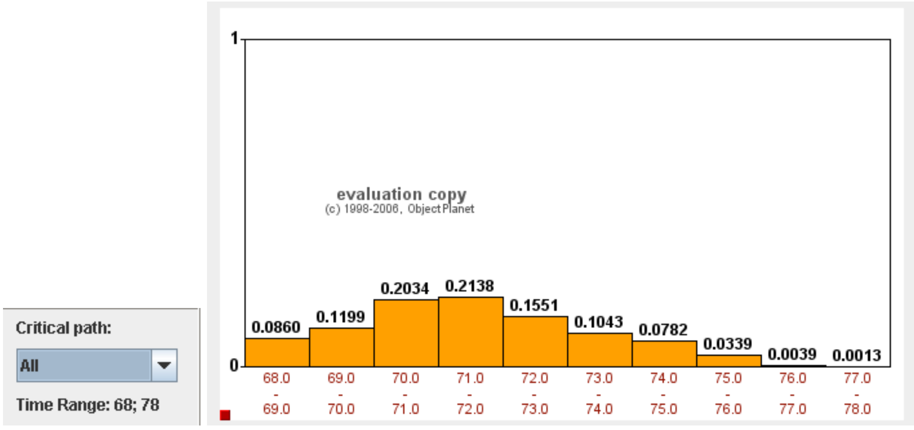


Fig. 7. Probabilistic distribution of the whole project.

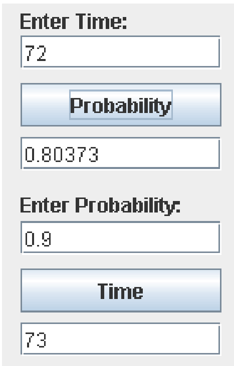


Fig. 8. Duration and probability of successful project completion.

The received information can used to develop specific recommendations for reducing the impact of undesirable factors on the life cycle of the IT project in order to obtain the results closest to the desired ones.

7 Conclusions

It projects are characterized by a large number of connected processes. The most expedient method for analyzing and managing IT projects risk, including the risks of observing calendar schedules, is imitation modeling. This method provides both accurate analysis and visual representation of alternatives to management behavior. Considered model allows constructing distributions of probability values for the most important parameters of the progress of the project, which in turn allows you to put and check stochastic hypotheses. The project is in the form of a network. An arc oriented in the direction of project implementation marks each process of the project.

Each event is set by a network node and establishes a coding relationship among project processes. Its number, title and duration characterize each process of the project. The duration of the processes can be deterministic, stochastic or probabilistic. In the first case, the Critical Path Method is used, in the second – PERT (Program Evaluation and Review Technique) method. In the case of probabilistic lifetime's processes, for each of them it is necessary to obtain probabilistic distributions of time of execution of this process. To obtain the kind of law probabilistic distribution and its parameters, you can use several methods. The First is to obtain the type and parameters of the distribution law by questioning experts (subjective probabilities). The second is based on the plural of analogues projects (objective probability). To determine the analogues projects must first classify the simulated project. To do this, we use the database of already executed projects and with the help of fuzzy classification; we divide the projects into classes by certain signs. Later after conducting cluster analysis of a simulated project determine the class to which it belongs and choose the rationing procedure for calculating the parameters of the project. Further work in this direction will focus on the research of situations in which every particular IT project process may have a different kind of probabilistic runtime distribution.

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