Context of Mobile Application Quality Risk Management Process

Andrei Volkov, Valery Semin
Moscow Technical University of Communications and Informatics
Moscow, Russia
volkov_ai@yandex.ru, semin_valery@mail.ru

Vladimir Semin
Yandex
Moscow, Russia
noric-12@yandex.ru

Abstract—**The article presents the results of the structural-functional modeling of the generalized risk management process of systems based on the design approach. It is shown that the results of the transformation of the content of the main stages in the format of the tasks of managing the risks of the quality of mobile applications (MA) are the methodological basis for building risk management systems for the quality of MAs. The algorithm of risk management of quality of MA based on the principle of guaranteed results is proposed.**

I. Introduction

It is known that in the process of software development (software) the main cause of software quality risk is uncertainty, which is present at all stages of its life cycle (LC), including in the development of mobile applications. In this case, the risks identified and passed through a joint procedure of qualitative and quantitative analysis are usually referred to as known risks. For this category of risks, an action plan is developed to reduce the impact of the risk events. For unknown risks, as well as all known risks for which the development of countermeasures is unacceptable economically, a reserve is set aside for unforeseen circumstances. Depending on the degree to which the risks correlate with threats or chances, they are subjected to further processing with the help of the MA quality risk management processes considered in this paper. Note that in order to successfully solve the problems of ensuring the quality of a mobile application, throughout its life cycle, it is necessary to develop in advance preventive risk management measures. At the same time, despite the fundamental results obtained by domestic and foreign researchers in the field of quality management and the quality risks of complex software systems, these management issues applied to a wide class of MAs require further theoretical and regulatory development [4], [5], [10]. In this regard, the questions of studying the context of the MA risk management process appear relevant.

Characteristics of risks of quality of MA and risks of objects and processes of life cycle of MA are often interrelated, they are influenced by various factors, including environmental factors that directly and indirectly determine certain properties of MA. Quality indicators mainly reflect the positive effect of the use of MA, and the main task of the project developers is to ensure high values of quality. At the same time, the realization of quality risks directly increases the national contribution to the MA as to the product, which ultimately results in the loss of project profits in practice.

For example, according to [15] of the methodology for analyzing and reducing the risks of software system projects, by quality characteristics can be generalized to the following sequence:

- Development of formal methods for analyzing and reducing the risks of software system projects according to quality characteristics.
- Implementation of the stage of preparation of initial data for risk analysis and management.
- Perform a risk analysis step.
- Implementation of the project risk reduction stage.
- Implementing tools to support the stages of analyzing and reducing the quality risks of software system projects.

This paper summarizes the results of solving a wide class of risk management tasks in various application areas based on the project approach [11], [12], [13].

II. Methodology

Currently, there are several definitions of quality concepts that are generally compatible with each other. According to ISO: Quality is the completeness of the properties and characteristics of a product, process or service that provide the ability to satisfy stated or implied needs.

According to the authors, the quality of MA is a relative concept, which makes sense only when taking into account the actual conditions and areas of its application, and is characterized by three basic aspects: the quality of a software product, the quality of life cycle processes and the quality of maintenance or implementation.

Thus, software quality is the degree to which it possesses the desired combination of properties.

The quality risk of a mobile application (MA) is understood as a potential event in the life cycle of an IT product that is associated with damage to the quality of the MA. It is obvious that the solution of the problem of building a quality risk management system for a business enterprise presupposes the existence of a formalized universal model of quality characteristics reflecting the most modern and longterm quality requirements for business companies. According to the authors, the methodological basis for solving the problem of determining the formal quality model of an MA is the system of evaluation characteristics of software quality used in the international standard GOST R ISO IEC 9126 [1], [6]. Note that not all quality attributes enshrined in this standard exhaust the concept of quality in relation to MAs, which necessitates the identification of new attributes and the addition of the existing system of quality assessment characteristics. For example, in the ISO 9126 standard, there are no software mobility attributes in relation to the ability of a program to run under different operating systems. At the same time, in practice, many developers prefer to consider instead of reliability a more general concept of software quality, associated with the main indicators of quality in terms of functionality, performance, usability, with given probabilities of going beyond them, and a certain maximum damage from possible violations [2], [3] . In addition, the concepts of usability, safety and security of MA [2], [3] are being actively investigated. Nevertheless, this international standard served as the basis for the improvement and development of numerous corporate standards for software quality management [2], [3], [7].

In this regard, we consider a generalized risk management algorithm, invariant with respect to subject areas, which is presented in the form of a structural - functional model of the algorithm in the notation of the IDEF0 standard in Fig. 1 [4], [11].

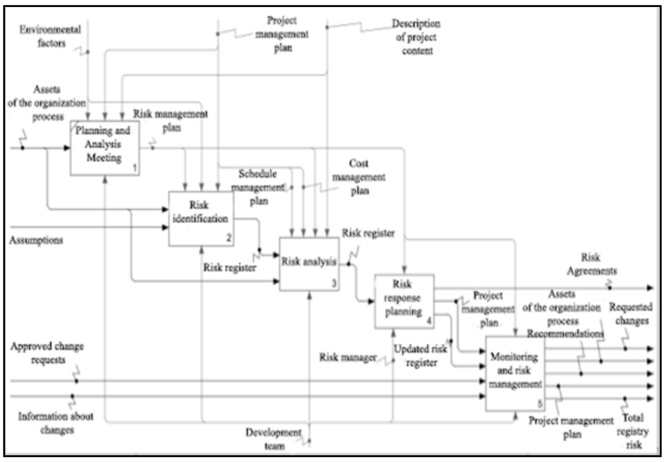

Fig. 1 Structural and functional model of the generalized risk management algorithm of a software project

The model characterizes the continuous nature of the risk management process and the direction of the logical flow of information linking the individual steps of the risk management algorithm. Essentially, the analyzed algorithm is a transformation of the generalized system analysis procedure described in terms and concepts of the domain of the risk management problem. At the same time, the object of risk management is the risk register, which is subjected to successive transformations at the stages of management planning, identification, qualitative and quantitative risk analysis, planning for risk reduction, monitoring and control in order to minimize the consequences of risk. The central stages of the risk management process are the planning and identification stages. The goals and objectives, the content of the organizational support archives, and the contents of the life cycle of an MA make it possible to transform the above process into an objective class of risk management tasks for the quality of MAs and, in particular, to purposefully form a sequence of descriptions of the risk register. In general, the input to the planning stage are the archives of organizational support, which should contain the results of risk management of previous MA projects, as well as a quality management plan, quality results assessments, quality control procedures checklists, a formal MA quality model, and a taxonomy of MA quality risks. The main tools for transformation are the meetings of experts and developers to determine the quality risks of MAs that are taken into consideration during the implementation of this project. The way out is the initial register of risk quality MA. At the identification stage, the initial risk register is supplemented with a list of identified and documented risks with a description of their causes. Within the life cycle of the MA, new risks may arise; therefore, the identification process is iterative in nature with a frequency that depends on the content of a specific MA project. The update of the risk register at the analysis stage occurs according to the results of qualitative and quantitative analysis. Risk registry updates should include a prioritized list of risks; list of priority assessed risks that pose the greatest threat to quality and require maximum funds for unforeseen circumstances, and having a high degree of probability to influence the quality of MA. The risk register at the risk response planning stage should contain the following major updates:

- Coordinated strategies for responding to quality risks of the MA;
- Countermeasures for the chosen strategy indicating the responsible persons for specific risks of the quality of MA.

The stage of monitoring and risk management is a continuous process throughout the life cycle of an MP to identify, analyze new risk events, monitor identified risks, monitor the implementation of risk response measures and evaluate their effectiveness. The risk register formed at this stage includes the following updates:

- The results of the adjustment of probabilistic risk indicators and periodic inspection;
- The actual results of the quality risks of the MA and the results of the response to the risks that are reflected in the archives of the organizational support and can be used to solve the problems of managing the quality risks of new projects of the MA.

The game-theoretic aspect of the context of the risk management process of the quality of MA, based on the principle of guaranteed results, can be algorithmized using the approach proposed in [14], [16].

As criteria, selected as target criteria can be used as separate criteria from the list below and their combination, which will be discussed later in the article:

- The guaranteed result criterion (Maximin Waldo criterion) is initially pessimistic, since only the worst of all possible results of each alternative is taken into account. This approach sets a guaranteed minimum, although the actual result may not be so bad;
- Optimism criterion (maximax criterion) - corresponds to an optimistic offensive strategy. This approach sets only the best option;
- The criterion of pessimism is characterized by the choice of the worst alternative with the worst payback;
- Savage's minimax risk criterion is the criterion of least harm, which determines the worst possible consequences for each alternative and chooses an alternative with the best of the bad values;
- The criterion of generalized maximin (pessimism-optimism) Hurwitz, which allows to take into account the state between extreme pessimism and uncontrollable optimism.

In certain circumstances, each of these methods has its advantages and disadvantages that can help in developing a solution.

In a comparative analysis of performance criteria, it is inappropriate to dwell on the choice of a single criterion, since in some cases this may lead to unjustified decisions leading to significant losses of economic, social and other content. For example, along with the application of the guaranteed result criterion, the Savage criterion can be used, the criterion of optimal behavior can be supplemented by the use of a pessimistic criterion.

Consider a conceptual risk management model that reflects the main elements and semantic concepts of the subject area of research and is presented in Fig. 2 [10], [12], [15].

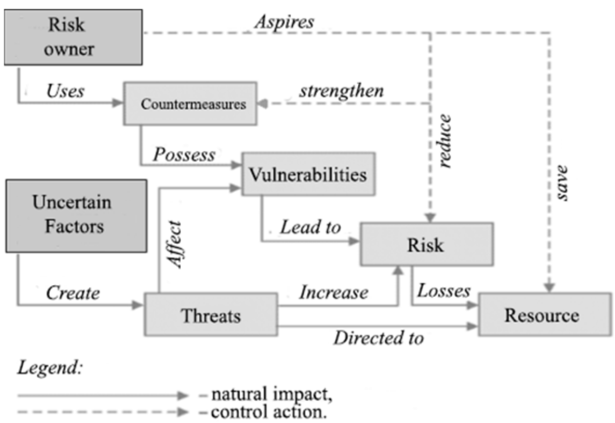

Fig. 2 Conceptual Risk Management Process Model

We introduce the basic definitions:

- The subject as an element of the conceptual model - the risk owner - the person in charge of managing the quality risks of the MA;
- The subject as an element of the conceptual model or uncertainties of the external and internal environment;
- Measures and measures to counter the risks of the quality of MA;
- Threat - a combination of factors and conditions that occur throughout the life cycle of an MA in the process of interaction with other external and internal systems and elements that are potentially capable of having a negative impact on the quality characteristics throughout the life cycle of an MA;
- Vulnerabilities - inherent features of the MA that affect the likelihood of a threat;
- Risk - a potential condition that characterizes the possible damage to the quality of MA, as a result of the realization of the threat, which ultimately reflects the likely financial losses during the life cycle.

In terms of operations research, the presented model is essentially a description of the classical single-side operation (the risk owner is the party conducting the operation) of the risk-resisting strategy in order to save financial resources with minimal costs [8], [9]. However, the effectiveness of such an operation depends not only on the choice of the risk owner, but also on uncertain events during the life cycle of the MA. If there is a lack of knowledge about the probabilistic measure on a set of uncertain factors, the selection operation loses its rational meaning. Therefore, it is believed that the least favorable distribution of uncertain factors may occur. In this case, the party conducting such an operation chooses such a strategy to counter the risks of the quality of the MA, which maximizes the chosen criterion of the effectiveness of the operation with the least favorable behavior of uncertain factors. Let an operation choose a strategy *x* belonging to a set of admissible strategies X, and set an operation efficiency criterion that also depends on Y - uncertain factors of a random nature $y = (y_1, \dots y_m)$. It is necessary to choose such a strategy that will provide the maximum value of the efficiency criterion of operation $K(x_1, \dots x_n, y_1, \dots y_m)$the choice of strategy takes into account the least favorable value of uncertain factors, assuming that any value of uncertain factors can actually be realized. The strategy is chosen as so that with the least favorable value of uncertain factors, the value of the objective function is maximum. This approach leads to the choice of a strategy in accordance with the criterion

$$\min_x \max_y K(X, Y). \tag{1}$$

We call the risk owner and uncertain factors the first and second players, respectively, the function K*(x,y)*- the payment function of the game. Let the first player win be the value of the payment function when the first player chooses a strategy. Let the first player strive to maximize his winnings. The value of K*(x,y)* we determine the winnings of the second player. We believe that in this case a game of persons with opposing interests is given, or an antagonistic game of two persons. Let both vectors n and m-dimensional Euclidean spaces; X and Y are closed bounded sets of n and m-dimensional Euclidean spaces, respectively. In this case, all points of these spaces can be lexicographically ordered and renumbered so that K*(x,y)* goes into the function K*(i, j)*, i = 1, ..., r: j = 1, ..., r, and then we will consider the function of two arguments and the final game with the payment function K*(i, j)*. It is known that for finite games max min K*(i, j)*, ≤ min max K*(i, j)*, the end game has a saddle point when such pure strategies exist. and such a constant w for which

$$K(i,j_0) \leq w \leq K(i_0 \ \ ,j),$$

where w = K(i_0, j_0), and pairs of strategies i_0, j_0 form a saddle point, i.e. K(i_0, j_0)= max min K*(i, j)*, = min max K*(i,j)*. This result is also valid for finite antagonistic games in mixed strategies. Let the task be given:

$$\min_y w; \qquad (2)$$

$$\sum_{j=1}^{m} K(i,j) y_j \leq w, i=1,\ldots,n; y_j \geq 0; \sum_{j=1}^{m} y_j, j=1,\ldots,m.$$

Fix a vector s $y=(y_1,\ldots,y_m)$. satisfying constraints (2), then

$$\min_y w = \max_{1<i<n} \sum_{j=1}^{m} K(i,j) y_j$$

$$\sum_{j=1}^{m} K(i,j) y_j \leq w, i=1,\ldots,n, \text{ or}$$

$$\min_y w; \qquad (3)$$

$$\sum_{j=1}^{m} K(i,j) y_j \leq w; y_j \geq 0; \sum_{j=1}^{m} y_j = 1, j=1,\ldots,m; y=(y_1,\ldots,y_m).$$

As a result of solving the problem (3), we obtain the optimal solution of the game and the optimal mixed strategy of the second player $y^*=(y_1^*,\ldots,y_m^*)$.

The optimal strategy of the second player is obtained from the solution of the problem:

$$\max_x w; \qquad (4)$$

$$\sum_{i=1}^{n} K(i,j) x_i \geq w; x_i \geq 0; \sum_{i=1}^{n} x_i = 1; i=1,\ldots,n, j=1,\ldots,m.$$

Problems (3) and (4) are dual linear programming problems. The general solution of the problem is reduced to a matrix game, which can be reduced to a pair of dual linear programming problems [8], [9]. For the antagonistic game in question, it suffices to consider one of the dual games. Thus, the problem of optimal distribution, in the sense of criterion (1), of a set of counteraction measures for a set of risk events of MA quality, is reduced to solving a linear programming problem, which is a fairly effective method for solving finite antagonistic games. In this regard, we consider the class of final game-theoretic models of the game of two players "risk owner" and "uncertain factors", for solving the problem of analyzing and choosing the optimal variant of the structure of the quality system of MA [10]. When describing the game, we will use the symbols of the players used earlier to simulate both intentional and accidental impacts on the quality of the project. Note that the rationale for choosing the final game-theoretic models in the general case is determined by the following characteristic features of the task of managing the quality of the MA:

- conflict of interests of players;
- the presence of an uncertainty factor;
- lack of reliable statistical information on the effect of uncertain factors;
- a finite set of generalized threats to the quality of MA.

The results of the risk owner's or random factors 'actions can be assessed by a real number (for example, an assessment of damage caused by the loss of quality of the MA) interpreted as a gain to one of the parties.

To build a game, it is necessary to determine the players strategies and the winning function. Let, as before, player I is the owner of risk, player II are indeterminate factors. Player I's strategies are to choose one of the options for the MA quality assurance system. Player II's strategies - the implementation of one of the many threats to the quality of the MA. Assume that the actions of each of the players are one-time or can be reduced to a certain total one-time impact on a specific software project. This assumption allows the use of one-step game models. Consider antagonistic final one-step games. In them, the winning value of the first player is equal in magnitude and opposite in sign to the winning value of the second player. Next, we consider the construction of a set of strategies of the second player, which is formed on the basis of a set of threats to the quality of the MA.

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Next, we consider the construction of the set of strategies of the second player. It is formed on the basis of a variety of threats to the quality of threats to MA. As a result, the set of strategies of player II will be equal. Antagonistic game is defined by the next three

$$\Gamma = < \mathrm{X}, \mathrm{Y}, \mathrm{H} >,$$

Where:

$\mathrm{X} = C \cup \{\tilde{C}\}$ - many first-player strategies;

$Y = U \cup \{\tilde{U}\}$ - a lot of second player strategies:

H - matrix of winnings.

Let the powers of the sets of players' strategies be equal:

$$|\mathrm{X}| = \mathrm{n},$$

$$|\mathrm{У}| = \mathrm{m}.$$

Imagine the matrix of winnings in the following form:

$$H = \begin{array}{c} C_1 \\ \dots \\ C_{(m-1)} \\ \hat{C} \end{array} \begin{bmatrix} U_1 & \dots & U_{(n-1)} & \hat{U} \\ -h_1 - \overline{h_{11}} & \dots & -h_1 - \overline{h}_{1\,(n-1)} & -h_1 \\ \dots & \dots & \dots & \dots \\ -h_{(m-1)} - \overline{h}_{(m-1)1} & \dots & -h_{(m-1)} - \overline{h}_{(m-1)(n-1)} & -h_{(m-1)} \\ -\overline{h}_{m1} & \dots & -\overline{h}_{m(n-1)} & 0 \end{bmatrix}$$

where before the beginning of the rows and columns are the corresponding elements of the sets X and Y. In this matrix, the following notation is used:

- $\overline{h}_{ij}$ - assessment of losses from the second player's implementation of the j-th generalized threat when the i-th version of the quality assurance system is implemented;
- $\overline{h}_i$ - the size of the cost of implementing the i-th version of the system under study.

Estimates of losses can be obtained from the results of risk analysis (as a rule, expert estimation methods are used to obtain them). If the distribution law of the probability of occurrence of random events that pose a security risk is known, then the expected value of losses.

In the case when the second player does nothing = 0 (the last column of the matrix H).

The cost of the implementation of the first player of the last strategy (the refusal of additional events) is also taken to be zero.

Both components of the matrix H are taken with a minus sign, because for the first player this is a negative gain (loss).

The constructed antagonistic game reflects the situation of the most pessimistic forecast, when the real possibilities and goals of the second player are unknown, and it is considered that he is omnipotent and his goal is to cause maximum harm. If it is possible to reliably determine the capabilities of the second player and the "value" in the case of risk realization, then it is possible to use a bimatrix game model, which is given in the form:

$$\Gamma = \langle X, Y, H, H_2 \rangle$$

where:

- X and Y are the sets of strategies of players I and II, H is the matrix of the winners of the risk holder;
- H_2 is the second player's win matrix, which is formed as follows:

$$H_2 = \begin{array}{c} C_1 \\ \dots \\ C_{(m-1)} \\ \hat{C} \end{array} \begin{bmatrix} U_1 & \dots & U_{(n-1)} & \hat{U} \\ \tilde{h}_{11} - \overline{h_{11}} & \dots & \tilde{h}_{1(n-1)} - \overline{h}_{1\,(n-1)} & 0 \\ \dots & \dots & \dots & \dots \\ \tilde{h}_{(m-1)1} - \overline{h}_{(m-1)1} & \dots & \tilde{h}_{(m-1)(n-1)} - \overline{h}_{(m-1)(n-1)} & 0 \\ \tilde{h}_{m1} - \overline{h}_{m1} & \dots & \tilde{h}_{m(n-1)} - \overline{h}_{m(n-1)} & 0 \end{bmatrix}$$

where

- $\tilde{h}_n$ is the evaluation of the second player's gain from the implementation of the j-th threat in relation to the i-th variant of the MA quality assurance system;
- $\overline{h}_{ij}$ - estimation of the second player's costs for the realization of this threat.

For threats that originate from random events, the value is assumed to be zero, and the value is proposed to be taken equal in magnitude and inverse to the value corresponding to the element of the player I. when the second player does nothing.

Compared with the antagonistic gaming model, the bimatrix model reflects a less pessimistic prediction based on the presence of additional knowledge of uncertain factors. Accordingly, the optimal strategies may turn out to be different from the previous model. All the considered game - theoretic models for the implementation of the choice of the optimal quality assurance strategy belong to the class of "games against nature". In this case, the function of winning the first player is unknown to him, since the gain function is "chosen by nature" from some fixed set. Unknown are the probabilities with which a particular function is selected. The task of the first player is to prioritize the available strategies and implement the optimal, in the sense of the quality criterion of choice.

Let the decision-making task be given in the form of a matrix $H_{m\times n}$, with the player choosing a row in the matrix from which his gain is determined. The optimality criterion is the ordering "≥" on the set of alternatives. It is considered that the best alternative in this ordering is considered to be the best.

Note that in decision-making theory, a number of optimality criteria are known, including the Wald criterion, as applied to games against nature [10].

Consider the antagonistic game T = <X, Y, H>, where X, Y are sets of strategies of players I and II, respectively, and H is the winning matrix of player I (player II's loss). In accordance with the maximin principle, player I seeks to choose such a strategy x ° so that with the most unfavorable for him choice of player II, he will get the greatest gain, which is determined by the equality:

$$\min_{y\in Y} \mathrm{H}(\mathrm{x}^0, y) = \max_{x\in X}(\min_{y\in Y} \mathrm{H}(x,y))$$

where H (x, y) is the element of the winnings matrix H, corresponding to the choice of player I of the strategy "x", and player II - of the strategy of "y".

For player II, the gain is equal to the matrix element H with a minus sign. When using the Wald criterion, he will prefer the strategy of y °, which will provide him with the greatest gain with the least favorable choice of player I:

$$\max_{x\in X} H(x, y^0) = \min_{y\in Y}(\max_{x\in X} H(x, y))$$

A situation (x °, y °) is called a situation of equilibrium in pure strategies if for any the saddle point inequality holds. Thus, in the development of risk management systems for the quality of MAs, various game-theoretic models can be used when conducting operations to select the optimal risk response strategy.

III. Conclusion

The experience gained as a result of the implementation of a wide class of software products, including numerous modern MAs, shows their characteristic feature - the presence of uncertainty associated with the non-determinism of future states throughout the LC. At the same time, uncertainty is caused by a variety of external and internal factors affecting the goals and results of the project. Among the most important goals of the project is the quality of the IT product. Issues of risk management quality of MA are an integral part of the overall problem of ensuring the quality of mobile applications. The strict regulation of life-cycle processes for the development of modern IT products, as well as the increasing role of quality, have necessitated the development of methodological foundations for building systems for ensuring and managing the quality of MAs. It is noted that the priorities include the development of a formalized quality model and taxonomy of the quality risks of the MA. This paper presents the results of the simulation of the management process, as well as the algorithm of the risk management system of the quality of MA based on the principle of guaranteed results.

Research into the quality of mobile services allows us to evaluate the consumer characteristics of applications popular among Russians and to identify the weak points and risks of mobile applications.

Note also that the definition of the nomenclature and values of the quality indicator of the MA can be carried out by an expert method by a group of expert specialists competent in solving this problem, based on their experience and intuition. At the same time, most of the criteria are a subset (family) of indicators grouped according to certain characteristics. Such subsets are known as “nested criteria”.

At the same time, the embedded criteria and quality parameters should be understood as those that are part of a higher level criterion and serve to refine it by reducing the dimension of the problem. Thus, the proposed generalized model of the quality structure of the MA preserves the methodological continuity in substantiating the approach to the formation of the concept of the quality profile of the MA and is its key element. According to the basic aspects of the quality of life cycle MA, the definition of the purpose and content of the elements of a generalized structure will introduce quality characteristics depending on the conditions and environment of application of modern MA.

Such an approach naturally allows, under the condition of correctly formulated criteria, to have several game models of continuously risky events covering the entire space. On the other hand, the presence of several models covering various aspects of the quality risk management process complicates the harmonization of criteria at the decision making stage.

Note also that the task of making a decision in real conditions of risk management of the quality of MAs can be reduced to a hierarchical game of a certain number of players, including more than one risk owner.

References

[1] GOST R ISO IEC 9126. Information technology. Evaluation of software products. Quality characteristics and guidelines for their use.

[2] Test methods for mobile applications of the “Personal Finance” category, ANO “Russian Quality System”, 2017

[3] STO 46429990-065-2017, Special requirements for the quality of mobile applications for smartphones, ANO Russian Quality System, 2017

[4] Guide to the Project Management Guidelines (PMBOK® Guide) Third Edition © 2004 Guide to the Body of Knowledge for Project Management. Project Management Institute. Pennsylvania 19073-3299 United States

[5] Lipaev V.V. Analysis and risk reduction of complex software projects. Publishing house: M .: Sinteg, 2005 ..

[6] ISO 25000: 2005. THAT A guide for applying a new series of software quality standards based on a synthesis of ISO9126 standards: 1-4: 2002 and ISO14598: 1-6: 1998-2000.

[7] ISO 15939: 2002. The process of measuring software.

[8] Protasov I.D. Game Theory and Operations Research Occupation: Helios ARV.2006

[9] Hapkin A.S., Mazaeva N.P. Mathematical methods and models for operations research. From: Dashkov and Co. ISBN: 9785394027369 Year: 2017.

[10] V.V. Lipaev. Quality software. Due to "Finance and Statistics 1983

[11] Semin V.G. Risk management of automated systems based on the principle of guaranteed results. Quality Innovation Formation. 2015. № 1 (116). - From .. 58-63.

[12] V.G. Semin. Generalized Risk Management Algorithm of Automated Systems “The 21st CENTURY.– 2012. - vol. 6. No. 4. - pp. 96-98.

[13] Semin V.G. Khakimullt E.R. “In the 15th International Scientific Conference on Economic Development and Social Development, 9-10 June 2016, Varazdin, Croatia, pp.369-374.

[14] Taganov A.I. Technique of analysis and reduction of risks of projects of complex software systems by quality characteristics. ISSN 1995-4565. Bulletin RGRTU. No 1 (release 31). Ryazan, 2010.

[15] Semin V.G. Development of an information model of quality risk management. In Sat: Innovations in the development of information and communication technologies. Materials of the scientific and practical conference. Edited by: V. G. Domracheva, S. U. Uvaisova. 2006. p. 93-97.

[16] Semin V. G., Khakimullin E. R. Game-theoretic algorithmization of the risk management context. In the collection: 2016 IEEE Conference on Quality Management, Transport and Information Security, Information Technologes, INalchik, 04-11 october 2016 . P. 176-180