The Model for Justification of the Structure of Special Purpose Telecommunications System

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Abstract:
A verbal-formal model for the justification of an optimal structure of special purpose telecommunications systems presented, basing on the condition of ensuring the maximum level of possibilities within the allocated budget. The purpose of the article is to develop a scientific and methodological approach to the formation of program and model based framework and determination of the rational options to equip aviation with telecommunication unit of the special purpose telecommunications system by the years of the planning period, taking into account the possible risks of weapons and military equipment development programs.

Keywords:
Telecommunication unit, possibilities, optimization, structure

1. Introduction

The basis of technical equipment (TE) of special purpose telecommunications system are program activities (PA) aimed at repair, serial modernization of telecommunication unit in operation, and purchase (lease) of new modern telecommunication unit, including virtual (VTU). A certain number of repaired, upgraded and purchased (leased) telecommunication units are a separate version of PA for TE of the special purpose telecommunications system. In this case, the effectiveness of aviation TE of the special purpose telecommunications system is determined by the degree of required possibilities level achievement by each telecommunication unit type by the years of the planning period [1]. It is possible to solve this task by determining the optimal PA options for TE of special purpose telecommunications system, i.e. the rational ratio of repaired, upgraded and purchased (leased) telecommunication unit by the years of the planning period. Today, such a task is solved by heuristic methods in the military administration, which causes a high probability of making wrong decisions and irrational spending of financial resources of the military department. Therefore, the development of formalized models in the system of planning and implementation of measures for TE of telecommunication unit in the special purpose telecommunications system on the basis of modern scientific and methodological apparatus of decision-making theory is an urgent scientific and applied problem.

2. The main part of the research

If we accept the assumption that the control and support means in the core of the special purpose telecommunications system meet the specified requirements, the possibilities of a particular telecommunication unit type (P) will be unambiguously determined by the number of i-type telecommunication unit (N_i) and their quality, which is a coefficient of technical level of i-type telecommunication unit (K_i)

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$$P = \sum_{i=1}^{I} K_i N_i \,. \tag{1}$$

Thus, in terms of its physical content, the indicator of the possibilities of a particular telecommunication unit type of the special purpose telecommunications system is the number of conventional telecommunication unit, calculated in relation to the sample of telecommunication unit, taken as the basic, which coefficient of technical level is equal to one (K_{bas}= 1,0).

The task of maximizing the possibilities of the telecommunication unit within the allocated budget can be solved by forming the optimal PA options for TE of special purpose telecommunications system with telecommunication unit samples, i.e. by determining the optimal ratio of repaired, upgraded and purchased / leased telecommunication unit by the years of the planning period. Today, in real-world context such a problem is solved by heuristic methods, which causes a high probability of making wrong decisions and, as a result, irrational spending of budget allocations of the military department. Therefore, the development of formalized models in the system of planning and implementation of measures aimed at equipping special purpose telecommunications system with telecommunication unit samples on the basis of modern scientific and methodological framework for decision making theory is an urgent scientific and applied problem. The verbal formulation of the research task is the following: to determine the optimal variant of PA aimed at equipping the special purpose telecommunications system with telecommunication unit by each year of the planning period, which provides the maximum possibilities level of a certain type provided that the allocated budget was not exceeded, taking into the account the feasibility of PA and restrictions on telecommunication unit fleet strength of a certain type, their serviceability level, terms and pace of equipping the special purpose telecommunications system with telecommunication unit samples.

The formalized formulation of the research problem is the following

$$P(n_{11}, n_{12}, ..., n_{21}, n_{22}, ..., n_{ij}, ..., n_{IJ}) = \sum_{i=1}^{I}\sum_{j=1}^{J}(K_{ij} n_{ij})\Omega_{ij} \to \max \tag{2}$$

under such conditions

$$\sum_{i=1}^{I}\sum_{j=1}^{J} c_{ij} n_{ij} \le \hat{C} \,, \tag{3}$$

$$n_{ij} \ge 0, \text{aim} \tag{4}$$

$$i = 1,2,...,I \,, \tag{5}$$

$$j = 1,2,...,J \,, \tag{6}$$

$$K_{ij} > 0 \,;\ 0 < \Omega_{ij} \le 1 \,,\ 0 < c_{ij} \le \hat{C} \,, \tag{7}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} n_{ij} + \sum_{i=1}^{l} N_i^0 - \sum_{i=1}^{k} N_{DIS_i} = \hat{N}_{FT} \,, \tag{8}$$

$$n_{i1} = \min\left[\hat{N}_{i1}; N_{PC_i}\right], \tag{9}$$

$$n_{i2} \le N_{PC_i} - n_{i1}, \tag{10}$$

$$n_{ij} \ge \hat{N}_{TU} \text{ for } j = 3,4,5 \,, \tag{11}$$

where P is a possibilities level of a particular type of the special purpose telecommunications system; n_{ij} is a number of i type telecommunication unit, obtained during the implementation of j PA; K_{ij} is a coefficient of technical level of i type telecommunication unit, obtained during the implementation of j PA; Ω_{ij} is the implementation of j PA for i type telecommunication unit; c_{ij} are expenditures, connected with the implementation of j PA relating to i type telecommunication unit; $\hat{C}$ is an allocated budget; N_{i0} is a number of *i* type telecommunication unit, not involved in PA; N_{DISi} is a number of *i* type telecommunication unit disposed; $\hat{N}_{FT}$ is an telecommunication unit fleet number; $\hat{N}_{i1}$ is a number of i type telecommunication unit requiring repair; N_{PC_i} is an (upgrade) repair productive capacity of *i* type telecommunication unit; $\hat{N}_{TU}$ is a number of telecommunication unit in a full amount.

The activities mentioned below should be considered as *j* PA in the problem description (2) … (11): 1 – maintenance of the current connection units, 2 – upgrade of the current connection units, 3 – purchase of the modern national equipment, 4 – purchase of the modern foreign equipment, 5 – leasing the modern foreign equipment.

Condition (8) reflects the requirement to maintain the regular (directive) number of telecommunication unit of a particular type. Condition (9) determines that the number of repaired telecommunication unit is determined by the relevant need and may not exceed the production capacity of the telecommunication unit repair company. Condition (10) stipulates that the number of upgraded telecommunication unit may not exceed the production capacity of the telecommunication unit repair company, taking into account the current number of telecommunication unit being repaired at the enterprise. Condition (11) stipulates that a certain number of telecommunication units must be purchased / leased at the same time, as a rule, at least one tactical unit - squadron (12 … 14 telecommunication units). The authors propose a model (presented in Figure 1) for the formation of the optimal version of the PA aimed at equipping the special purpose telecommunications system with telecommunication unit samples.

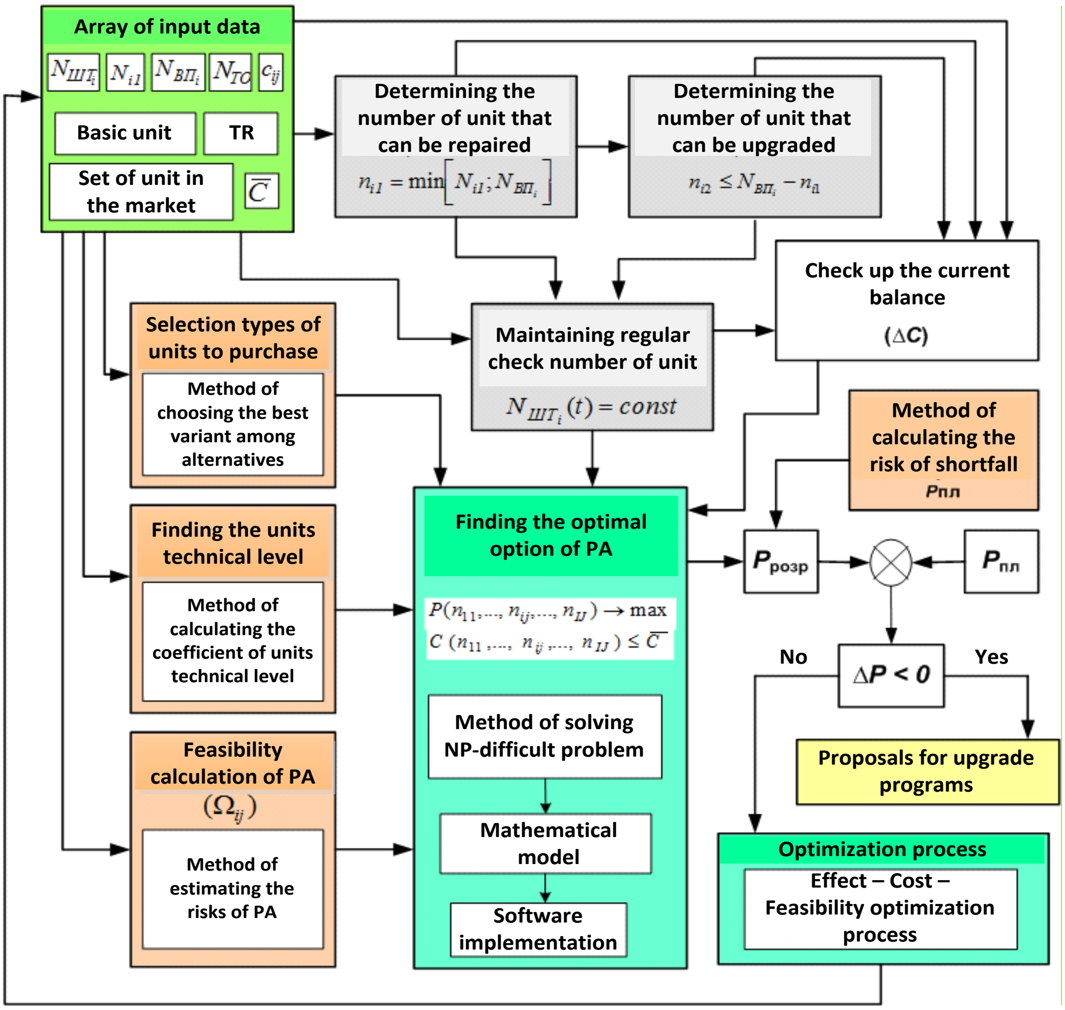

Figure 1: A block diagram of the model for forming the optimal version of PA aimed at equipping the special purpose telecommunications system with telecommunication units

The array of initial data includes a set of telecommunication unit in the arms market, a sample of telecommunication unit, taken as a basic, options for telecommunication unit upgrade, specified (required) number of telecommunication unit strength, tactical and technical characteristics of telecommunication unit, data on the certain PA cost, data on the number of telecommunication unit requiring repair and upgrade, production capacity of enterprises for telecommunication unit repair and upgrade, data on allocated funds, expanded lists of possible PA implementation risks, etc.

In accordance with the presented model (Figure 1), the solution of the problem (2) … (11) is preceded by: determining the number of telecommunication unit that can be repaired, upon the demand, production capacity of enterprises and the funds availability; determining the number of telecommunication unit that can be upgraded, based on the production capacity of enterprises and the funds availability; checking the condition of authorized operational telecommunication unit maintenance; checking the current funds balance after the implementation of regular activities; selection of a foreign telecommunication unit model for purchase / lease; calculation of telecommunication units technical level; calculation of each PA implementation.

Assessment of the technical level of telecommunication unit, including VTU, is carried out using the method [2], which is based on the methodological apparatus of qualimetry – a science that deals with the issue of quantitative assessments of the quality of objects (products, processes).

The technical level of the telecommunication unit is a relative indicator of its quality (technical perfection) as a complex technical system. As an indicator of the technical level of the telecommunication unit is used the coefficient of the technical level, which determines the degree (level) of quality of the telecommunication unit, as a complex special-technical system, in relation to the base / reference sample (analogue). The method of calculating the coefficient of technical level is based on the analogy between the concepts of technical level of a complex technical system (as a relative quality characteristic based on comparing the values of technical perfection of the assessed and basic systems) and the coefficient of technical level of special telecommunication units (as a relative characteristic its possibilities, which is based on the comparison of the defining tactical and technical characteristics of the assessed and base telecommunication unit). Under the determinants understand the tactical and technical characteristics that have the greatest (decisive) impact on the effectiveness of the telecommunication unit for its intended purpose. The calculation of the coefficient of technical level of telecommunication units (K) is based on the mathematical apparatus of estimation of technical level (quality) of complex technical system on a ratio of defining indicators of technical perfection (tactical and technical characteristics) of the estimated and base / reference telecommunication unit considering relative importance of these indicators

$$K = \sum_{k=1}^{M} \sum_{ki=1}^{N_k} \delta_k \gamma_{ki} \frac{\overline{\chi}_{ki}}{\overline{\chi}_{ki}^{b}}, \tag{12}$$

where δ_k – coefficient of weight of the *k*-th functional subsystem of the telecommunication unit, which is estimated, such as $\sum_{k=1}^{M} \delta_k = 1$; γ_{ki} – coefficient of weight of the *i*-th indicators of technical excellence / tactical and technical characteristics of the *k*-th functional subsystem of the telecommunication unit, which is estimated, such as $\sum_{ki=1}^{N_k} \gamma_{ki} = 1$; M – the number of functional subsystems of the evaluated telecommunication unit; *Nk* – the number of determining indicators of technical excellence / tactical and technical characteristics of the *k*-th functional subsystem of the evaluated telecommunication unit; $\overline{\chi}_{ki}, \overline{\chi}_{ki}^{b}$ – the values of the *i*-th indicators of technical perfection / tactical and technical characteristics of the *k*-th functional subsystem of the assessed and basic telecommunication unit, respectively, are as follows:

$$\overline{\chi}_{ki}(\overline{\chi}_{ki}^{b}) = \begin{cases} X_{ki}(X_{ki}^{b}), & \text{if the increase of the i-th indicators of technical perfection / tactical and technical characteristics of the } k\text{-th functional subsystem of the telecommunication unit corresponds to the increase of its technical perfection;} \\ \dfrac{1}{X_{ki}}\left(\dfrac{1}{X_{ki}^{b}}\right), & \text{if the increase of the i-th indicators of technical perfection / tactical and technical characteristics of the } k\text{-th functional subsystem of the telecommunication unit corresponds to the decrease of its technical perfection;} \end{cases}$$

X_{ki}, X_{ki}^{b} – natural values of the *i*-th indicators of technical perfection / tactical and technical characteristics of the *k*-th functional subsystem of the assessed and basic telecommunication unit, respectively. The procedure for estimating the coefficient of the technical level of a telecommunication unit begins with an analysis of its purpose and a set of tasks to be solved by organizational and staff formations, which are armed or planned to deliver a sample telecommunication unit. In this case, the telecommunication unit sample is presented in the form of a complex technical system, which is formed from a functionally connected set of subsystems. Each of these functional subsystems is characterized by a set of sets of its own parameters (tactical and technical characteristics), which summarize the full range of capabilities of the telecommunication unit to perform tasks for their intended purpose. The method of calculating the coefficient of the technical level of special telecommunication units is based on the principle of functional decomposition and fine-grained comparative analysis of the defining tactical and technical characteristics of such telecommunication units. Carrying out this analysis involves the construction of a multilevel hierarchical structure of indicators of technical excellence (tactical and technical characteristics) of telecommunication units and the selection of their determinants.

For special telecommunication units, it is advisable to distinguish three levels of hierarchy:

Level 1 – the level of the purpose of the structural decomposition of the telecommunication unit;

Level 2 – the level of functional subsystems of the telecommunication unit, corresponding to its intended purpose;

Level 3 – the level of tactical and technical characteristics (parameters) of the functional subsystems of the telecommunication unit.

At the first level of the hierarchy, the purpose of the structural decomposition of the telecommunication unit is determined - to assess the technical perfection of the telecommunication unit in accordance with its intended purpose. At the second level of the hierarchy, the main functional subsystems of the telecommunication unit are determined, which determine its structure as a complex technical system and correspond to its purpose. At the third level of the hierarchy consider the tactical and technical characteristics (parameters) of each individual functional subsystem of the telecommunication unit (their quantitative values or qualitative gradations), which have a decisive influence on the level of technical perfection of the telecommunication unit in accordance with its intended purpose. In the general case, the process of solving the problem of assessing the level of technical perfection of telecommunication unit samples involves the following stages:

1. Formation of an array of initial data required for calculations of the coefficient of the technical level. At this stage, the purpose of the sample and the tasks it solves are analyzed, the telecommunication unit sample is determined, which will be taken as the base, and, if necessary, the mathematical apparatus of quasimetric quality assessment of complex technical systems is adapted to a specific assessment object.
2. Formation of the structure of the evaluated indicators (tactical and technical characteristics, parameters). At this stage, the construction of a multilevel hierarchical structure of telecommunication unit technical excellence is performed: the main functional subsystems of telecommunication units and their defining tactical and technical characteristics, the direction of influence of tactical and technical characteristics on the technical perfection of the sample, the value (quantitative or qualitative) of tactical and technical characteristics samples.
3. Determination of weights of functional subsystems of units and their tactical and technical characteristics. At this stage, the relative importance of each of the functional subsystems of

the unit and the relative importance of each tactical and technical characteristic in the functional subsystem of the unit in terms of its intended purpose is defined.

4. Calculation of the coefficient of the technical level of the telecommunication unit. At this stage, a direct calculation of the coefficient of the technical level of the estimated telecommunication unit is performed and the analysis of the obtained results is performed.

It should be noted that in the case of multi-purpose telecommunication units, it has specific values of the coefficient of the technical level for each of the options for use (use). For example, a modern light telecommunication unit in the form of a multifunctional (multi-role) fighter, which can perform tasks to defeat both air and ground / surface targets, has for each of the options of its coefficient of technical level, the value of which is mainly due to weapons and characteristics of aiming equipment. And the modern telecommunication unit will be additionally characterized by the coefficient of the technical level for the implementation of training tasks, due to the capabilities of the telecommunication unit to perform exercises for the training. Thus, the generalized (total) coefficient of the technical level (K^{Σ}) of telecommunication unit provided that the equal importance of options for its application, can be determined by the formula

$$K^{\Sigma} = \frac{1}{M}\sum_{m=1}^{M} K^{(m)} , \tag{13}$$

where M is the total number of telecommunication unit applications; $K^{(m)}$- the coefficient of the technical level of the telecommunication unit in the m-th variant of the telecommunication unit.

Quantitative assessment of the implementation of program activities is carried out by determining the probability of determining the risks of implementing the relevant program activities using the methodological apparatus of risk theory [3]. The project evaluation procedure includes risk analysis, formation of a group of unacceptable risks, identification of the defining risk (risk from the group of unacceptable with the maximum probability of occurrence) inherent in a particular project, and calculation of the actual level of implementation as the probability of non-overall risk. Risk analysis includes the identification of possible risks and their assessment.

The purpose of identification is to identify the risks specific to a particular project, their causes and forms of manifestation. The main result of the identification is a detailed list of possible risks inherent in the project. Risk assessment is about measuring the actual level of risk of each individual risk and determining the extent of its impact on the project. This assessment involves determining the parameters of each risk (probability of occurrence and the amount of possible losses / losses) and the calculation of the risk index. The risk index is an indicator that allows you to judge the level of risk threat. To calculate the risk index, an expert method of estimating risk parameters using the probability-loss matrix with a dimension of 5 × 5 is used.

That is, a matrix that includes five numerical intervals on the scale of probability of occurrence of risks and five intervals on the scale of possible losses (Figure 2). At the same time, it is convenient to estimate the values of the probability of risk occurrence and damage from its occurrence on expert scales of scores depending on the possible frequency of risks and consequences of their occurrence (see Tables 1 and 2).

The estimate that links the amount of damage with the probability of occurrence of a negative event that leads to this loss is the risk index, calculated by the formula

$$I_r = U_r p_r , \tag{14}$$

where I_r – the r-th risk index; U_r – the amount of damage from the onset of the r-th risk; p_r – probability of r-th risk.

The procedure for calculating the value of the risk index is performed using the matrix "probability – loss", which is based on expert scores of the amount of damage from the occurrence of risk (minimum, low, medium, high, maximum) and the probability of its occurrence (unlikely, unlikely, probable, sufficient probable, almost possible) and in accordance with which the level of risk threat to the project is determined (Figure 2).

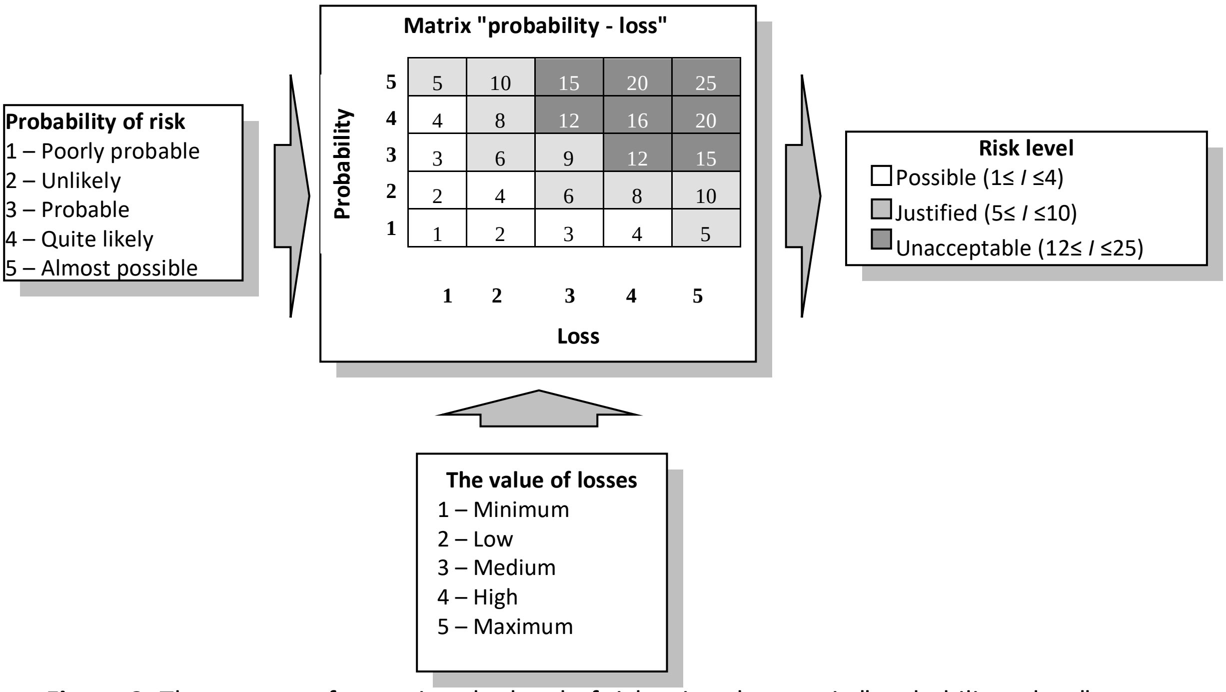

Figure 2: The process of assessing the level of risk using the matrix "probability – loss"

Table 1
Estimation of the probability of occurrence of the major risk

Types of events	The value of the likelihood	
	Quantitative description (points)	Qualitative description
Poorly Probable	1	The event could happen in exceptional cases
Unlikely	2	A rare event, but one that has already taken place
Probable	3	There is enough information to suggest the possibility of an event
Quite likely	4	The event can occur
Almost possible	5	The event is expected to take place

At the intersection of the corresponding row and column of the matrix, we obtain a cell with the value of the value of the *r*-th risk index (I_r) according to formula (14), which determines the level of risk threat. According to their level of threat, risks are divided into acceptable (or acceptable), justified and unacceptable (see Figure 2). To assess the feasibility of the project, a group of unacceptable risks is selected, the occurrence of which is critical for the successful implementation of the project and may lead to its non-implementation (failure, failure) in general.

The group of unacceptable risks is formed on the basis of the calculation of the index I_r of each *r*-th risk, which connects the amount of damage with the probability of occurrence of a negative event that leads to this loss, which is determined by formula (14). The value of the index *k*-th unacceptable risk ranged from 12 to 25 units ($12 \leq I_k \leq 25$). The level of project implementation (Ω) is defined as the inverse of the total risk of project implementation, which is the ratio of the sum of indices of unacceptable risks to the sum of indices of all identified risks of project implementation, according to the formula

$$\Omega = 1 - \frac{\sum_{k=1}^{K} I_k}{\sum_{r=1}^{R} I_r}, \tag{15}$$

Table 2
Estimation of the amount of damage from the occurrence of risk

Types of damage	The value of losses	
	Quantitative description (points)	Qualitative description
Minimum	1	The consequence of the occurrence of risk is an increase in the cost of the project or a decrease in quality*, or an increase in the time for project implementation
Low	2	The consequence of the occurrence of risk is an increase in the cost of the project and an increase in the time for project implementation
Medium	3	The consequence of the occurrence of risk is a decrease in quality* and increase in the cost of the project (or decrease in quality and increase in time for project implementation)
High	4	The consequence of the occurrence of risk is an increase in the cost of the project, a decrease in quality* and an increase in the time for project implementation
Maximum	5	The consequence of the risk is a failure to achieve the goals (failure to implement the project as a whole)

* – by reducing the quality means obtaining a telecommunication unit with worse technical characteristics than provided by the terms of the contract (agreement) in the implementation of the project

where *R*, *K* – the number of identified risks and unacceptable risks from among those identified, respectively; I_r, I_k – indexes identified *r*-th and *k*-th unacceptable risks, respectively.

The value of the level of project implementation Ω presented by expression (15) in terms of its physical content is considered as the expected degree (probability) of successful project implementation as a whole. The values Ω range from "0" to "1", where "0" corresponds to the expected failure (failure, fail) project and "1" – the expected success of the project.

Thus, according to recommendations of the theory of risks the project is considered expedient to realization (opening) at the expected probability of its successful performance not less than 0,8.

According to the results of identification of risks inherent in certain alternative projects to equip the special purpose telecommunications system with promising telecommunication unit, we can distinguish three main classes of risks:

- risks that accompany the purchase projects for import / lease telecommunication unit;
- risks that accompany the draft license / cooperation in production of telecommunication unit;
- risks accompanying the project of development and production of telecommunication unit by national enterprises with the involvement of foreign companies to obtain components that are not manufactured in Ukraine.

Actually, the research tasks in statement (2) … (11) belong to the class of integer linear programming tasks ("backpack" type). This type of problem refers to the so-called NP-difficult, which can not be solved in polynomial time. The most accurate method of solving such problems is a complete search for possible solutions, which, with a large problem (as in the case presented above), makes such an approach impossible on a practical level [4, 10, 12, 13].

Known methods of an approximate solution of the problem of linear programming of the "backpack" type, as practice shows, give solutions that are sometimes significantly different from the optimal ones [5]. The authors propose to use a combination of Newton's method and a genetic-type model [6, 7, 11] to solve the research problem in the statement (2) … (11). Previous research shows that this approach allows to solve the problem in polynomial time, and the results obtained almost coincide with the optimal solutions.

As a result of solving this problem, the calculated level of telecommunication unit possibilities (P_{calc}) by each year of the planning period is compared with the planned level (P_{pl}), which is determined by the program documents on the development and maintenance special equipment of the special purpose telecommunications system. Compliance of the calculated level of possibilities with the planned one ($\Delta P = P_{pl} - P_{calc} \leq 0$) is the basis for the inclusion of the calculated optimal PA options in the program documents concerning the upgrade of telecommunication unit of the special purpose telecommunications system. If the estimated level of possibilities does not correspond to the planned one ($\Delta P = P_{pl} - P_{calc} \leq 0$), the initial data is corrected, including through the optimization of technical and economic characteristics of the telecommunication unit proposed for the upgrade, in order to increase their special and technical level. Program implementation of the presented model is performed in the Excel spreadsheet editor of Microsoft Office software package.

3. Acknowledgement

Basing on the results of approbation of the presented model in relation to the special purpose telecommunications system, the optimal PA options by the years of the current planning period have been determined. Comparison of the calculated PA options with the measures adopted by the program documents for the specified period shows that the funds allocated for PA implementation can be used more efficiently if they are redistributed in accordance with the calculated optimal PA options: increase the possibilities of telecommunication system of the Air Force of Ukraine may equal to 8…15% in accordance with the years of the planning period – this is in addition to the current telecommunication capabilites.

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