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Optimal resources allocation for independent and joint test of it service releases

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Abstract. The problem of resources allocation for testing IT service releases, which are built into the operational environment for reducing information risks, is considered. Testing can be either independent or system (joint). The problem was formulated, for which the method of network (dichotomous) programming was used allowing the solution of the optimization problem to be considerably simplified. The scheme for changing the current baseline of IT environment when embedding releases into it is introduced, which is necessary to prevent the destruction of the operating environment. The scheme of the network representation of cost functions and incidents probability function, which are structurally similar, is shown. Specific examples of this problem solution for four releases are given, in which the specific values of incidents probability, costs and quality of testing were assigned.

1. Introduction

IT service is a complex of interacting IT assets, the purpose of which is to produce value for consumers, determined by usefulness, availability, capacity, continuity and security of service, or a combination of assets.

The life cycle of any IT service consists of stages of strategy, design, implementation and operation. At the stage of implementation into the operational environment, the IT service is exposed to the risk of full or partial loss, in addition, the destruction of the operational environment itself is possible [1 - 4]. To reduce the probability of such risk, it is proposed to break the implemented IT service into releases, integrate them into a specially created test environment and conduct pre-test. Releases can be built in and tested sequentially one by one and such test is called independent. If the releases are tested in parallel, then it is a system test. The higher the quality of a conducted test, the less likely the occurrence of any incident during the operation of the IT service.

2. Methods

To create a test environment and conduct the test itself, it is necessary to provide the organization with additional resources, and the important task is to minimize the costs required for IT service releases implementation into the operational environment.

Below in figure 1 there is a diagram of the change of the current base states of operation environment into new states as a result of embedding IT service releases into the environment, that update the technological assets (release A_1), application assets (release A_2), service portfolio assets (release A_3) and business assets (release A_4).

Let us denote the probability of occurrence of IT incidents in the operational environment when embedding the appropriate release after testing by $P(A_i), i = \overline{1,4}$. Test quality K is assessed on a



three-point scale: 1 –“poor”, which corresponds to a large risk of IT incidents, 2 –“satisfactory”, which corresponds to an average risk, 3 –“good”, which corresponds to low risk.

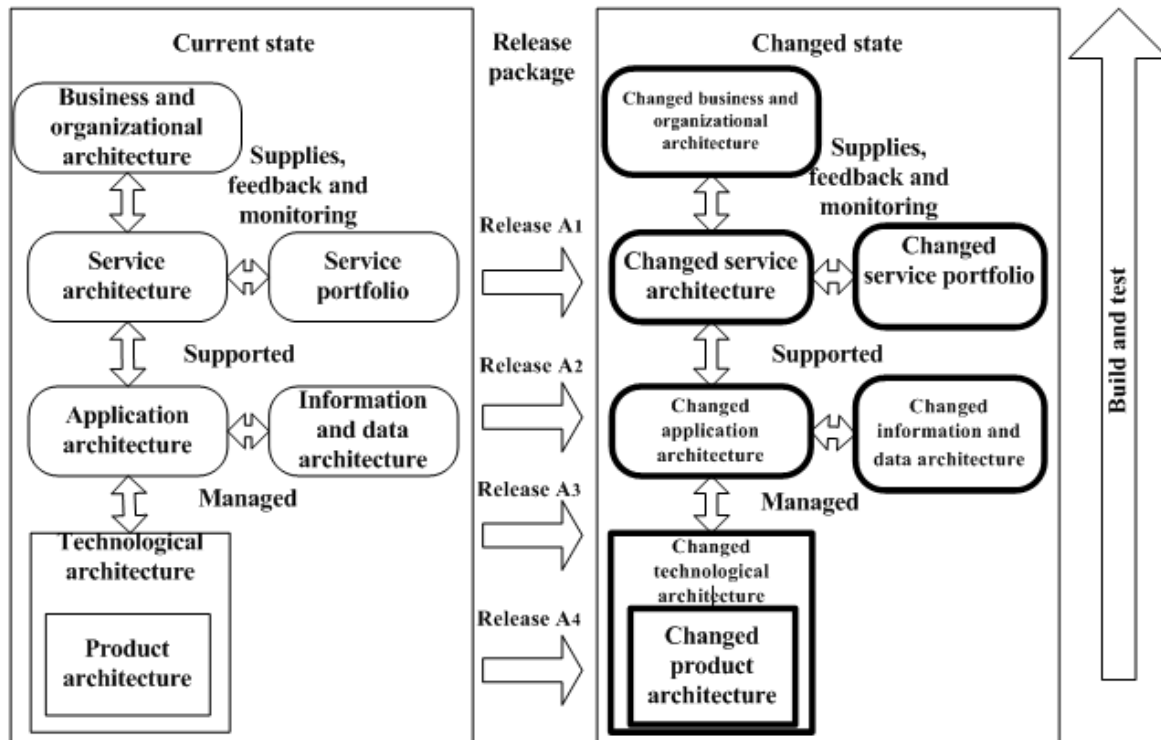


Figure 1. Changes of the current states of IT environment into new base states.

Let us denote the costs for release testing by $z(A_i), i = \overline{1,4}$. The cost functions from the release of test quality $z_K(A_i), K = \overline{1,3}, i = \overline{1,4}$ are specified, it is shown in table 1.

Table 1. Cost functions depending on the release of test quality.

$K(A_i)$	3	2	1
$z_K(A_i)$	$z_3(A_i)$	$z_2(A_i)$	$z_1(A_i)$

Let us state the problem of optimal resources allocation for independent and system test of IT services releases.

Given:

1. Operating environment, the composition of which is shown in figure 1.
2. Package of releases $A_i = 1, 2, 3, 4$.
3. Quality of releases testing $K(A_i)$.
4. Incidents probability $P(A_i), i = \overline{1,4}$.
5. Costs of releases testing: $z_K(A_i), K = \overline{1,3}, i = \overline{1, n}$.
6. Limitation: $K(A_1 \cup A_2 \cup A_3 \cup A_4) \geq K^*$ for independent test of IT service and $K(A_i | A_1, A_2, \dots, A_{i-1}) \geq K^*$ for system test of IT services.
7. Criterion: total costs for releases testing: $\sum_{i=1}^4 z_K(A_i)$.

Required:

To optimize the resources allocation for testing, follow restrictions and minimization of the criterion, i.e. $\sum_{i=1}^4 z_K(A_i) \rightarrow \min$.

Otherwise, it is required to determine such minimum costs $z_K(A_i), i = \overline{1, n}$, which provide quality $K(A_1 \cup A_2 \cup A_3 \cup A_4) \geq K^*$ for independent test of IT service and $K(A_i | A_1, A_2, \dots, A_{i-1}) \geq K^*$ for system test of IT services, i.e. not lower than the given level K^* .

To simplify the procedure of problems solution, it is proposed to use the method of network programming [5 - 7]. Complex functions are represented in the form of a composition of simpler ones, and the function representation itself is convenient to use in the form of a network (network representation), where the inputs are function variables, the outputs are the functions themselves, the intermediate vertices – functions included in the composition. Two functions are structurally similar if their network representations coincide, which is a prerequisite for using the network programming method.

Consider the solution of the problem of optimal allocation of resources first for the case of system test of releases of IT services when they are introduced into the operational environment [8].

Figure 2 shows the network representation of costs functions for a test and the incidents probability during testing. Obviously, that they coincide, i. e. these functions are structurally similar, therefore, it is possible to use the network programming method.

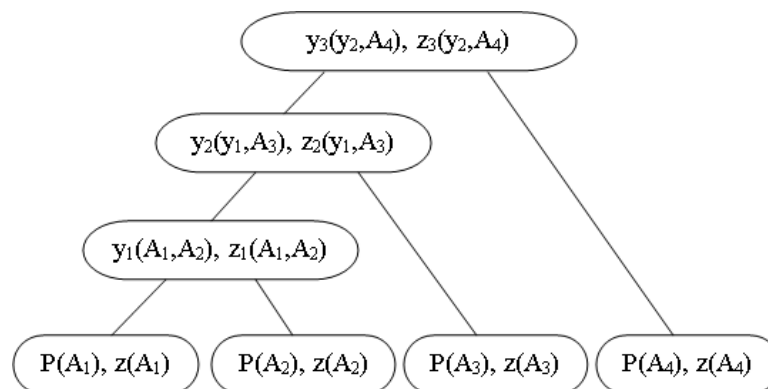


Figure 2. Network representation of functions $P(A_i)$ and $z(A_i)$.

The implemented IT service S consists in the general case of n releases A_i , i.e. $S = (A_1, A_2, \dots, A_n)$. The incidents probability $P(S) = P(A_1, A_2, \dots, A_n)$ during the service implementation is related to the number of service links between each other and with the environment. According to the theorem of multiplication of probabilities, the probability of incidents occurrence will be calculated by the formula:

$$P(A_1, A_2, \dots, A_n) = P(A_1)P(A_2 | A_1) \dots P(A_n | A_1, A_2, \dots, A_{n-1}). \quad (1)$$

In figure 3, for example, a graph is given that describes the relations between four releases with the components of the environment itself, and the numbers on the graph branches are the numbers of releases between each other and the environment.

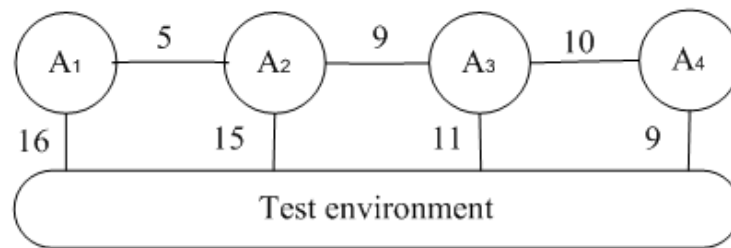


Figure 3. Mutual relations of services and their relations with the operational environment.

Table 2 shows the numerical values of mutual relations of services and relations with the operational environment.

Table 2. Numerical values of service relations

	A ₁	A ₂	A ₃	A ₄
A ₁	16	5	0	0
A ₂	5	15	9	0
A ₃	0	9	11	10
A ₄	0	0	10	9

Suppose that:

$$P(A_i | A_1, A_2, \dots, A_{i-1}) = \frac{A_{ii} + A_{i(i-1)}}{\sum_{i=1}^n (A_{ii} + A_{i(i-1)})}, \quad (2)$$

where $A_{10}=0$.

Then:

$$P(A_1, A_2, \dots, A_n) = \prod_{i=1}^n \left(\frac{A_{ii} + A_{i(i-1)}}{\sum_{i=1}^n (A_{ii} + A_{i(i-1)})} \right). \quad (3)$$

The interval $(0 \div P(A_i | A_1, A_2, \dots, A_{i-1}))$ is divided into three equal subintervals, after which the test quality is evaluated depending on the probability value of a test. The costs functions $z_K(A_1, A_2, \dots, A_{i-1}), K = \overline{1,3}, i = \overline{1,n}$ from the quality of releases testing are known.

Then there are following relations for the costs function:

$$z_1 = \sum_{i=1}^2 z(A_i); z_2 = z_1 + z(A_3); z_3 = z_2 + z(A_4). \quad (4)$$

For probabilities the following relations are valid:

$$y_1 = P(A_1); y_2 = P(A_1)P(A_2 | A_1); \dots; y_{n-1} = P(A_1)P(A_2 | A_1) \dots P(A_n | A_1, \dots, A_{n-1}). \quad (5)$$

To solve the initial problem by the method of network programming it is necessary to solve successively (n-1) problems:

The task of the first level:

$$z_1 = \sum_{i=1}^2 z(A_i) \rightarrow \min; K(y_1) = K(P(A_1)P(A_2 | A_1)) \geq K^*. \quad (6)$$

The task of the second level:

$$z_2 = z_1 + z(A_3) \rightarrow \min; K(y_2) = K(P(A_1)P(A_2 | A_1)P(A_3 | A_1, A_2)) \geq K^*. \quad (7)$$

...

The task (n-1), which corresponds to the output from the network, is solved the last:

$$z_{n-1} = z_{n-2} + z(A_n); K(y_{n-1}) = K(P(A_1)P(A_2 | A_1)...P(A_n | A_1, ..., A_{n-1})) \geq K^*. \quad (8)$$

The solution of (n-1) problem is the solution of the original problem.

In case with testing four releases, the links of which are shown in Fig. 3 and in Table 2, according to the formula 2 we obtain [9]:

$$\begin{aligned} P(A_1) &= \frac{16}{75} = 0.21; P(A_2|A_1) = \frac{20}{75} = 0.7; \\ P(A_3|A_1, A_2) &= \frac{20}{75} = 0.27; P(A_4|A_1, A_2, A_3) = \frac{19}{75} = 0.25. \end{aligned} \quad (9)$$

Suppose the costs for testing releases A_1 and A_2 , depending on the testing quality, are described by functions $z_K(A_i)$, their values are specified and given in tables 3 and 4. The calculated intervals $P(A_i)$ are divided into three equal subintervals.

Table 3. Values of costs $z_K(A_1)$ for different intervals of probabilities and test quality indicators.

$K(P(A_1))$	3	2	1
$P(A_1)$	$(0 \div 0.07)$	$(0.07 \div 0.14)$	$(0.14 \div 0.21)$
$z_K(A_1)$	15	12	8

Table 4. Cost values $z_K(A_2|A_1)$ for different intervals of probabilities and test quality indicators.

$K(P(A_2 A_1))$	3	2	1
$P(A_2 A_1)$	$(0 \div 0.09)$	$(0.09 \div 0.18)$	$(0.18 \div 0.27)$
$z_K(A_2 A_1)$	21	17	9

Multiplying the mean values of each obtained intervals $P(A_1)$ and $P(A_2|A_1)$ with the corresponding quality values, we obtain the probability values y_1 . The costs required for a test are calculated by summing the costs $z_K(A_1)$ and $z_K(A_2|A_1)$. These results are shown in table 5.

Table 5. Values of probabilities y_1 and costs $z(y_1)$ depending on the quality of releases testing.

$K(P(A_1))$	3	3	3	2	2	2	1	1	1
$K(P(A_2 A_1))$	3	2	1	3	2	1	3	2	1
y_1	0.0016	0.0047	0.079	0.0047	0.0141	0.0236	0.0079	0.0236	0.0394

$z(y_1)$	36	32	24	33	29	21	29	25	17
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Then the interval $(0 \div \max(y_1))$ is divided into three equal subintervals, the inclusion of each obtained probability value y into these intervals is checked. From each interval such probability value is chosen, at which the costs will be minimal, thus, we obtain the solution of the problem of the first level, given in table 6.

Table 6. Final values of probabilities and costs for testing releases (A_1) and $(A_2|A_1)$.

$K(y_1)$	3	2	1
y_1	0.0079	0.0141	0.0394
$z_K(y_1)$	24	29	17

Next, we calculate the probability of incidents occurrence and costs for testing releases A_1 and $(A_2|A_1)$ with release of A_3 . y_1 and $z(y_1)$ are computed at the previous stage, values of $P(A_3|A_2, A_1)$ and $z_K(A_3|A_2, A_1)$ are shown in table 7.

Table 7. Cost values $z_K(A_3|A_2, A_1)$ for different intervals of probabilities and quality indicators of the test.

$K(P(A_3 A_2, A_1))$	3	2	1
$P(A_3 A_2, A_1)$	$(0 \div 0.09)$	$(0.09 \div 0.18)$	$(0.18 \div 0.27)$
$z_K(A_3 A_2, A_1)$	22	19	11

The calculation of the values of probability y_2 and costs $z(y_2)$ is carried out as before, that is, the second level problem is solved, its result is given in tables 8 and 9.

Table 8. Values of costs $z(y_2)$ and the probability y_2 for different quality of the test.

$K(y_1)$	3	3	3	2	2	2	1	1	1
$K(P(A_3 A_2, A_1))$	3	2	1	3	2	1	3	2	1
y_2	0.0004	0.0011	0.0018	0.0006	0.0019	0.0032	0.0014	0.0041	0.0068
$z(y_2)$	46	43	35	51	48	40	39	36	28

Table 9. Final values of incidents probability for release $(A_3|A_2, A_1)$ testing and the costs required for that.

$K(y_2)$	3	2	1
y_2	0.0014	0.0041	0.0068
$z_K(y_2)$	39	36	28

The probability values and costs for testing release A_4 release are calculated in the same way. The probabilities and costs for testing A_4 release are described by functions $P(A_4|A_3, A_2, A_1)$ and $z_K(A_4|A_3, A_2, A_1)$, their values are given in table 10, they are also specified in advance.

By analogy with the above calculations, we calculate the probability and costs required for system testing of releases with A_4 release. All results obtained are given in tables 11 and 12.

Table 10. Value of costs $z_K(A_4|A_3, A_2, A_1)$.

$P(A_4 A_3, A_2, A_1)$	$(0 \div 0.08)$	$(0.08 \div 0.16)$	$(0.16 \div 0.25)$
$K(P(A_4 A_3, A_2, A_1))$	3	2	1
$z_K(A_4 A_3, A_2, A_1)$	15	10	8

Table 11. The probability of incidents occurrence y_3 and costs $z(y_3)$.

$K(y_2)$	3	3	3	2	2	2	1	1	1
$K(P(A_4 A_3, A_2, A_1))$	3	2	1	3	2	1	3	2	1
y_3	0.00006	0.00020	0.00029	0.00016	0.00049	0.00086	0.00027	0.00081	0.001394
$z_K(y_3)$	54	49	47	51	46	44	43	38	36

Table 12. Total values of incidents probability and costs for release testing ($A_4|A_3, A_2, A_1$).

$K(y_3)$	3	2	1
y_3	0.00027	0.00086	0.001394
$z_K(y_3)$	43	44	36

Therefore, the minimum costs for testing IT services with the best evaluation of testing quality corresponding to 3 (“good”) are 43 units of resources, and the probability of incidents during IT services implementation is negligible and equals to 0.00027.

In the case of independent testing of IT service releases, the probability of IT incidents is calculated differently [9, 10].

Network representations of cost functions and occurrence probabilities for this type of a test are similar to the network representations discussed above (figure 2). The costs in this case are also calculated by the formula (4).

The probability of the sum of two joint events A and B is determined by the formula:

$$P(A + B) = P(A) + P(B) - P(AB). \quad (10)$$

Then probability y_1 of IT incidents is calculated by the formulas:

$$y_1(A_1, A_2) = P(A_1 + A_2) = P(A_1) + P(A_2) - P(A_1 \cap A_2), \quad (11)$$

$$y_2 = (y_1, A_3) = y_1 + P(A_3) - y_1 P(A_3), \quad (12)$$

$$y_3 = (y_2, A_4) = P(A_1 + A_2 + A_3 + A_4) = y_2 + P(A_4) - y_2 P(A_4). \quad (13)$$

To solve the problem of optimal resources allocation for releases testing, as in the previous task, it should be divided into several sub-tasks. First, the values $y_1(A_1, A_2)$ and $z_1(A_1, A_2)$ are calculated. Wherein

$$z_1 = \sum_{i=1}^2 z(A_i) \rightarrow \min; K(y_1) = K(A_1 + A_2) \geq K^*. \quad (14)$$

Further, using the obtained values, $y_2(y_1, A_3)$, $z_2(y_1, A_3)$ are calculated under the following conditions:

$$z_2 = z_1 + z(A_3) \rightarrow \min; K(y_2) = K(A_1 + A_2 + A_3) \geq K^*. \quad (15)$$

After that, the values $y_3(y_2, A_4)$; $z_3(y_2, A_4)$ are calculated in a similar way under the following conditions:

$$z_3 = z_2 + z(A_4) \rightarrow \min; K(y_3) = K(A_1 + A_2 + A_3 + A_4) \geq K^*. \quad (16)$$

This is the solution of the original problem.

3. Results and discussion

Let us explain the above stated ideas on the example of the four releases from the previous example. As the initial values of the incidents probabilities, we use values $P(A_i)$, calculated from formula (2). Similarly, the obtained intervals $(0 \div P(A_i))$ are divided into three equal subintervals. The values of the cost functions $z(A_i)$ are given. The quality of testing, depending on the values of incidents probabilities, is evaluated in the same way as in the previous example. The specified values of costs, probabilities and quality of testing during implementation of A_1 and A_2 releases are given in tables 13 and 14. Depending on the quality of A_1 and A_2 releases testing and the incidents probabilities during implementation of these releases, probabilities y_1 are calculated (according to formula 11)) and costs $z(y_1)$ (according to formula (4)), besides, probabilities $P(A_i)$ of occurrence of IT incidents in the course of release implementation in each interval are taken as maximum, the final calculations are shown in table 15.

Table 13. Cost values of $z_K(A_1)$ for different intervals of probabilities and indicators of testing quality.

$K(P(A_1))$	3	2	1
$P(A_1)$	$(0 \div 0.07)$	$(0.07 \div 0.14)$	$(0.14 \div 0.21)$
$z_K(A_1)$	15	12	8

Table 14. Cost values $z_K(A_2)$ for different probability intervals and indicators of testing quality.

$K(P(A_2))$	3	2	1
$P(A_2)$	$(0 \div 0.09)$	$(0.09 \div 0.18)$	$(0.18 \div 0.27)$
$z_K(A_2)$	21	17	9

Table 15. Values of incidents probability during releases testing A_1 , A_2 and costs required for that.

$K(P(A_1))$	3	3	3	2	2	2	1	1	1
$K(P(A_2))$	3	2	1	3	2	1	3	2	1
y_1	0.154	0.237	0.321	0.217	0.295	0.372	0.281	0.352	0.423
$z(y_1)$	36	32	24	33	29	21	29	25	17

Thus, an interval of probabilities $y_1 = (0.154 \div 0.423)$ was obtained, which in turn is divided into three equal sub-intervals, and the quality of testing A_1 and A_2 releases is reduced to a three-point scale. For each sub-interval, the probability value y_1 is chosen, at which the costs of testing are minimal. If there are several such probability values, then the minimal value of y_1 is chosen. The final solution of the first level problem is given in table 16.

Table 16. Total values of y_1 and $z(y_1)$.

$K(y_1)$	3	2	1
y_1	0.237	0.321	0.423
$z(y_1)$	32	24	17

Next, the task of the second level is solved, the values of costs, probabilities and quality of a test during the implementation of A_3 release are specified and given in table 17. The values of incidents probabilities y_2 during A_3 release implementation and costs of $z(y_2)$, necessary to ensure the appropriate quality, are determined. The results of these calculations are presented in table 18.

Table 17. Cost values $z_K(A_3)$ for different intervals of probabilities and indicators of the test quality.

$K(P(A_3))$	3	2	1
$P(A_3)$	$(0 \div 0.09)$	$(0.09 \div 0.18)$	$(0.18 \div 0.27)$
$z_K(A_3)$	22	19	11

Table 18. Values of probabilities y_2 and costs $z(y_2)$.

$K(y_1)$	3	3	3	2	2	2	1	1	1
$K(P(A_3))$	3	2	1	3	2	1	3	2	1
y_2	0.306	0.375	0.443	0.382	0.443	0.504	0.475	0.527	0.579
$z(y_2)$	54	51	43	46	43	35	39	36	28

The defined interval $y_2=(0.306 \div 0.579)$ is divided into three equal sub-intervals, in each of them such probability value is chosen, so that the value of cost function would be minimal. The solution obtained is given in table 19.

In the example above, the third-level task is the last one, it is solved with the values of probabilities y_2 and costs $z(y_2)$, as well as the pre-set cost values z_4 for A_4 release testing and estimated incidents probabilities $P(A_4)$. The initial data for the solution of the problem of the third level are given in table 20, the intermediate results – in table 21.

Table 19. Total values y_2 and $z(y_2)$.

$K(y_2)$	3	2	1
y_2	0.382	0.443	0.579
$z(y_2)$	46	43	28

Table 20. Cost values $z_K(A_4)$.

$P(A_4)$	$(0 \div 0.08)$	$(0.08 \div 0.16)$	$(0.16 \div 0.25)$
$K(P(A_4))$	3	2	1
$z_K(A_4)$	15	10	8

Table 21. Values of probabilities y_3 and costs $z(y_3)$.

$K(y_2)$	3	3	3	2	2	2	1	1	1
$K(P(A_4))$	3	2	1	3	2	1	3	2	1
y_3	0.438	0.493	0.549	0.493	0.543	0.594	0.617	0.655	0.693
$z(y_3)$	61	56	54	58	53	51	43	38	36

Similar to the previous steps, the obtained interval $y_3=(y_{\min} \div y_{\max})$ is divided into three sub-intervals, from each such value y_3 is selected, at which costs would be minimal. This is the final result presented in table 22.

Table 22. Final values y_3 and $z(y_3)$.

$K(y_3)$	3	2	1
y_3	0.493	0.594	0.693
$z(y_3)$	56	51	36

4. Conclusion

Thus, the minimal costs for testing of an IT release with a “good” grade are 56 units of resources. At the same time, the probability of occurrence of IT incidents when implementing IT services is 0.493.

When comparing the results obtained in solving the optimal resources allocation for independent and system testing, it was found that performance of a system testing is more efficient, since with its best quality and lower costs required for this, the probability of occurrence of IT incidents is significantly lower than in the case with independent testing.

References

- [1] Zimin V V, Kulakov S M, Purgina M V and Koinov R S 2013 *Steel in Translation* **43(12)** 793–7
- [2] Zimin V V, Kulakov S M and Purgina M V 2013 *Steel in Translation* **43(4)** 176–9
- [3] Zimin V V, Kulakov S M and Zimin A V 2011 *Steel in Translation* **41(2)** 109–16
- [4] Zimin V V and Kulakov S M 2010 *Steel in Translation* **40(6)** 539–48
- [5] Burkov V N and Burkova I V 2014 *Automation and Remote Control* **75(3)** 470–80
- [6] Burkov V N and Burkova I V 2012 *Automation and Remote Control* **73(7)** 1242–55
- [7] Burkova I V 2009 *Automation and Remote Control* **70(10)** 1606–12
- [8] Kiseleva T V and Maslova E V 2016 *Proc. Int. Conf. on Technologies for the Development of Information Systems TRIS-2016* (Taganrog: SFU) pp 40–4
- [9] Avdeev V P, Burkov V N and Kiseleva T V 2001 *Automation and Remote Control* **62(10)** 1645–50
- [10] Zimin V V, Kiseleva TV and Maslova E V 2016 *Proc. IVth Int. Conf. on Modeling and Science-intensive Technologies in Technical and Socio-economic Systems* (Novokuznetsk: SibSIU) pp 220–5