Mathematical modeling of project management in logistics systems based on two-dimensional random vector

Yu O Glushkova, O Yu Gordashnukova, A V Pahomova, S P Shatohina, D V Filippov

Yuri Gagarin State Technical University of Saratov, 410054 Russia

E-mail: Balomasova@mail.ru

Abstract. The modern markets are characterized by fierce competition, constantly changing demand, increasing demands of consumers, shortening of the life cycle of goods and services in connection with scientific and technological progress. Therefore, for survival, modern logistic systems of industrial enterprises must be constantly improved. Modern economic literature is represented by a large volume of publications on various aspects of the studied issues. They consider the issues of project management in the logistics system that inevitably encounter with triple Limited. It initially describes the balance between project content, cost, and time. Later it was suggested to either replace the content with quality or add a fourth criterion. Therefore it is possible to name such limitation as triple or four-criteria limitation.

1. Introduction

In this paper, these restrictions are defined as product, time, and cost. This link is graphically displayed using the project management triangle, where each side represents a specific constraint, and the quality of the project itself is set within. According to authors Cipes G.L., Tovb A.S., project management is widely used all over the world as a tool to increase the efficiency of business, to ensure its stability, profitability, competitiveness – in general, all that is called success. Challenges of the time, requirements of today’s business are reflected in the practice of project management, but at the same the new opportunities offered by modern project management are known only to a narrow circle of specialists [1].

Changing one side of the triangle will cause others to change. Therefore, the implementation of project management in logistics systems requires knowledge of critical parameters: time to complete the project, budget allocated for the project, a set of actions required to reach the final product project. It is obvious that changing the content of a project usually results in a change in terms (time) and cost. Tight deadlines (time), in turn, involve an increase in cost and reduced content, and a budget restriction can cause an increase in terms and minimization of the product.

The probability of occurrence of a risk event is determined by analyzing and assessing the risk that arises in the project management process. Let us consider how the occurrence of an event is determined by random variables, taking into account that in the same random experiment, it is necessary to consider not one but several - n - numerical functions defined on the same space of elementary events, in this case, the stages of the project in the logistic system [2].

In statistics, the aggregate of such functions is called a multidimensional random value or a random vector and is denoted as $\xi = \{\xi_1, \xi_2, \ldots, \xi_n\}$. The probability space of such project implementation as
Let us put that random values as a set in \( \xi(\omega), \xi_2(\omega), \ldots, \xi_n(\omega) \), determining the risk. Each \( \subseteq \) of these values is put in conformity with n-dimensional vector \( \xi=(\xi_1, \xi_2, \ldots, \xi_n) \), which is called as an n-dimensional random risk vector.

Multidimensional random values are functions of distribution of multidimensional random values. Random vector function distribution \( \xi=(\xi_1, \xi_2, \ldots, \xi_n) \) or joint distribution of random values \( \xi_1, \xi_2, \ldots, \xi_n \) are called as a function defined by equality \( \mathbb{P}(\xi_1 \leq x_1, \xi_2 \leq x_2, \ldots, \xi_n \leq x_n) = P(\xi_1 < x_1, \xi_2 < x_2, \ldots, \xi_n < x_n) \) where \( x=(x_1, x_2, \ldots, x_n) \).

By well-known multidimensional function \( \mathbb{P}(\xi) \), one can find the distribution of each component \( \xi_1, \xi_2, \ldots, \xi_n \).

For example, if \( \xi=(\xi_1, \xi_2) \) - a dimensional random value that has joint distribution \( \mathbb{P}(\xi_1, \xi_2) \), component distribution \( \xi_1 \) and \( \xi_2 \) are calculated according to the formulas:

\[
\mathbb{P}(\xi_1 < x_1, \xi_2 > x_2) = \int_{x_1}^{x_2} f_{\xi_1, \xi_2}(x_1, x_2) \, dx_1 \, dx_2.
\]

In this case, function \( f_{\xi_1, \xi_2} \) is called the joint distribution density. Obviously, \( \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f_{\xi_1, \xi_2} \, dx_1 \, dx_2 = 1 \).

If \( f_{\xi_1, \xi_2} \) - joint distribution density of 2D random vector \( \xi=(\xi_1, \xi_2) \), the density of distribution of its component is determined by equality:

\[
p_{\xi_1}(x) = \int_{-\infty}^{\infty} f_{\xi_1, \xi_2}(x, y) \, dy \quad \text{and} \quad p_{\xi_2}(x) = \int_{-\infty}^{\infty} f_{\xi_1, \xi_2}(x, y) \, dx.
\]

Conditional density distribution of random value \( \xi \), provided that the random value of \( \eta \) takes the value of \( \eta = y_0 \), called the function of variable \( x \), defined by formula

\[
p_{\xi}(x|\eta = y_0) = \frac{f_{\xi, \eta}(x, y_0)}{p_{\eta}(y_0)}.
\]

Similarly, the conditional density of the distribution of a random value, provided that the random value of the \( \xi \) takes the value of \( \xi = x_0 \), is called the function of variable \( y \), defined by formula

\[
p_{\eta}(y|\xi = x_0) = \frac{f_{\xi, \eta}(x_0, y)}{p_{\xi}(x_0)}.
\]

However, let us deviate from this reasoning and try to determine how to minimize the risk at the stage of choosing a project implementation strategy in the logistics system.

On the basis of the described triplicity influence, it is suggested to take into account risk and to reduce it by choice of a strategy, priority for the customer. The introduction of this proposal is proposed to conduct according to figure 1.
Figure 1. Author's chart of planning strategy of project development at first stage

To develop the management strategy taking into account the minimization of the risk of execution of the project, implemented within the logistics system, the authors propose taking the base of the scheme, based on the model "Delta", shown in Figure 2.
The model "Delta" integrates the system of additive processes, which implies a systematic approach to the development of the project management strategy, realised within the logistics systems and implementation. During practical realization of the considered model into the decision-maker, by results of negotiations with the customer, it is necessary to reveal priorities of the customer and sizes of proportions of correlation of three allocated factors (quality, terms and cost) [3]. The "Customer Questionnaire", which is shown in table 1, has been developed for the formation.

| Factor    | Relative value assessment (from 100%) | D-deviations, scoring (from 1 to 5) |
|-----------|--------------------------------------|-----------------------------------|
| Quality   |                                      |                                   |
| Time      |                                      |                                   |
| Budget    |                                      |                                   |

The next step is to manage the project implementation in the logistics system, giving preference to one of the three directions from the scheme shown in Figure 2. It is designated by the customer as a priority. Further in the context, the direction is the same as the manager of the priority resource.

2. Materials and methods
The work was based on the methods of vector algebra, in particular, the functions of the multidimensional random variable (random vector). Risk vectors within the probabilistic space of the project implementation are determined by means of multidimensional random variable distribution functions [7].

The Macquarie Dictionary (2010) was initially consulted for the definition of the separate components of this term. Project: something that is contemplated, devised, or planned; a plan; a
scheme; an undertaking. Management: the act or manner of managing; handling, direction, or control [8].

The PMBOK (PMI 2008, p. 6) expands on this topic further with a definition of project management: project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.[9]

Managing the development of the logistics system on the basis of the identified priority resources, the composition of which was specified above (budget or cost, the time of final product quality), taking into account their ratio on the basis of proportion, for example, total impact. The force of control influences on all three directions of allocation of resources equals one. Figure 3 shows the direction of control influences on resources. According to the direction of control, let us call axes as Cartesian coordinate system. On the axes, let us postpone permissible deviations D with the number corresponding to the name of one of the three resources. There is the description of the implementation of the project evaluation method [1]. They were named as:

D1 – time deviations;
D2 – variances in value;
D3 – quality deviations.

They have developed point scale [1] estimates of possible losses: "1-unacceptable, 2-unwanted, 3-permissible, 4-planned, 5-without loss." The received points are proposed to be adjusted by multiplying the weights of the selected direction of control by one of the three allocated resources.

As noted above, the priority direction of management can be chosen only one-strategic.

First, the management strategy that is developed in case the customer is focused on a strictly planned level of quality. It is obvious that the main vector of management is aimed at improving the quality of the "final product". At the same time, the indicators on the two remaining areas are worsening, as it implies the growth of the budget and the increase of terms. Thus, the sum of deviations can be calculated with a plus on a priority and with a minus on two others, if to adhere to the hypothesis that "the total influence of force of control on all three directions of distribution of resources equals one".

The graphic realization of the given direction is presented in Figure 3.

Secondly, let us consider a strategy, which will be called as "limited budget". This strategy of logistics system management is proposed to be developed when the customer's priority is to minimize the cost of implementation, which reduces the project budget. It is obvious that along with this, it is necessary to sacrifice the directions: timing and quality. This implies the growth of terms of implementation and deterioration of quality. This calculates the initial proportion. The tolerances are determined by the results.
Figure 3. Strategy "stubborn customer"; black shows the ideal strategy

When quality decreases, the employees of the logistics system, implementing the project should ensure that the final content and quality is not worse than the required state standard and other normative documentation. The strategy diagram is shown in Figure 4.

For example, when compiling a specification, it is proposed to replace expensive equipment with cheaper equipment, which simultaneously leads to a deviation of the quality of execution.
Thirdly, let us consider a strategy, which will be called as "tight deadlines". It is planned to limit and shorten the project implementation time. Obviously, it reduces the quality and plans the level of decline and the permissible deviation of the increase in the budget amount.

**Figure 4.** Strategy "Limited budget"; black shows the ideal strategy
Figure 5. Strategy "tight deadlines"; black shows the ideal strategy

When planning the selected project management strategy in the logistics system, according to the selected priorities, the permissible deviations are calculated according to the specified or reference terms. In this case, as a rule, the permissible savings are calculated. Material resources take into account its negative impact of this economy on the axis of project quality [5]. During preservation or growth of quality of material resources, it is necessary to count on negative influence on a budget axis; the maximal shift in the direction of its growth is shown in Figure 5.

3. Conclusion
After choosing the management strategy of priority for the customer and preliminary estimation of the proportions of influence in three directions of the Delta model, the deviations of $D$ on the three basis are placed. As stated above, it is possible to calculate the weights of the $K_1$, $K_2$, $K_3$, which in sum should make the unit. At the same time, let us consider that each of the coefficients should strive to the maximum, when planning one of the three strategies mentioned: 1 is a "stubborn customer", "limited budget" is the second coefficient and "hard time" assumes the maximization of the third factor.

After that the system of base points which should be reached during realization of each stage of control; influence on the project within the framework of the logistical system is built, on the basis of which PD-complex estimation of admissible risks or variances in project implementation is made:

$$PD = \frac{\sum_{i=1}^{3} (K_i \times D_i)}{\sum K_i}$$

where $D_1$, $D_2$, $D_3$ - evaluation of deviations; $K_1$, $K_2$, $K_3$ - weight coefficients.
The selection of criteria for evaluating the effectiveness of the project and their accounting should be taken into account at the earliest stages of the selection of management strategies, otherwise one will face imminent losses, which is belated, will indicate errors in management. Of course, none of the strategies is found in practice in pure form in the real management of the enterprise as a logistics system meets only mixed-type strategies.

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