Stochastic Models of Project Time Management

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Abstract. The importance of the project time management process is noted. It is shown that the main factor affecting the temporal characteristics of the project is the composition of the project team. The process of forming a project team is considered taking into account the fact that the main characteristics of the performers, in particular their labor productivity, will be stochastic values. We consider the design process of the organization of the project, which is reduced to a stochastic programming problem, which reduces to a deterministic problem and can be solved by numerical methods. For a random variable with a normal distribution law, the problem statement is given in an analytical form. Concrete recommendations are given for determining the distribution law and solving the problems of managing construction production.

1. Introduction

Analysis of failures in the process of project implementation showed that the main reasons for the negative result was a lack of resources. Moreover, given the specifics of the current state of economic relations, it should be recognized that, as a rule, there is a lack of financial resources, which should be recognized as a fairly universal type of resource. Indeed, in the conditions of free economic relations, financial resources are quite simply transformed into almost any type of resource.

In this case, it should be remembered that usually two groups of resources are distinguished: renewable (stored) or material-technical type resources and non-renewable (non-stored) or resource type resources. It is quite clear that the resources of the first type can very easily be learned in the project from the financial resources that make up its budget, but the resources of the second type are far from always. But there is one flaw in such a classification, which lies in the fact that it does not cover such an important factor as time. Rather, it is assumed that the resources of the second type also include time, but, as a rule, designers use more specific concepts such as labor input, machine shifts, headcount, etc. But the time factor itself is often ignored.

Meanwhile, it should be noted that the time factor is quite important, if only because it is often impossible to compensate for an insufficient time resource for any financial means. For some industries, the time factor is quite secondary: for example, calendar plans for the implementation of construction projects are very often developed up to a quarter, that is, 3 months. But for high-tech industries, this factor is key to ensuring competitive advantages in the market. Statistics show that a delay in entering the market for a new software product for six months leads to less than 30% of revenue.

Thus, in many cases, loss of control over the project’s lead time leads to significant financial losses and, very often, is the main reason for failure in the process of project implementation, which is
explained by the fact that such a situation is very difficult to diagnose and, when detected, has practically no adjustment tools. This is due to the fact that a reduction in the timing of work due to an increase in the number of employees is not always possible, even for ordinary industries having a flow character. This is explained by the fact that the saturation of the fronts of work by performers has limitations, both under the conditions of safe performance of work and restrictions on the available set of operating equipment. For example, when carrying out finishing work in an apartment building, you can use a significant number of finishing workers, putting from 2 to 6 people in each room, but there is a problem of providing these workers with the appropriate materials and their supply to the workplace. As a rule, in this case, the company’s capabilities are limited to a few dozen people, although it’s possible to put a few hundred.

On the other hand, if we consider high-tech production, for example, associated with design and construction work, we have to admit that in this case the possible compensation for temporary losses from financial resources is even more limited. On the one hand, it should be recognized that in these sectors the simplest rule applies: even twenty cats will not replace one tiger. This means that a specialist with unique knowledge and experience cannot be replaced by a large number of specialists without such experience and knowledge. This inevitably leads to yet another not very optimistic conclusion: the time to solve intellectual problems does not have a direct proportion to the number of specialists involved in its solution [1 – 7].

Therefore, the task of managing the project implementation time is quite relevant, and in the areas of design and construction work and simply necessary. In this regard, we consider the main reasons that affect the duration of projects. In this case, we will focus on the design and construction sector.

2. The relevance of research

The analysis of factors affecting the duration of the work allows us to identify the following "bottlenecks", which are often overlooked in the planning process. Firstly, the planning often does not take into account the real balance of working time that develops during the implementation of the project. In this case, it is not only about taking into account weekends and holidays, but also about regular vacations and other cases of absenteeism of specialists for a good reason, for example, illness, fulfillment of state duties, vacation without pay for family reasons, etc., characterized by such a generalizing parameter of statistical reporting as the coefficient of absenteeism. Accounting for this coefficient helps to determine more or less accurately the number of employees involved in the implementation of the project being developed.

When calculating, it is possible, guided by the statistics of personnel records for a specific specialist, to calculate the individual absenteeism rates for all employees involved, which will certainly increase the objectivity and reliability of the plans developed. In the event that such information is not available, for example, the project team is formed from newly recruited employees, you can use the information provided in the industry methodological recommendations for individual sectors of the economy, which contain the required data.

Moreover, such information must be taken into account not only for the direct developers of the project, but also the most important thing for specialists participating in the development of the project by the customer. This is due to the fact that if we take into account the specifics of developing projects in the construction industry, we should note a general trend: the direct development of the project itself, of a building or a complex of buildings, takes about ⅓ of the whole time, and the rest ⅔ are related to direct work with the customer, aimed at identifying his needs and agreeing on a common vision of the problem being developed. A tool for solving these problems is a series of meetings held in various forms, the results of which are recorded in relevant documents. Naturally, the customer’s representatives, ensuring the fixation of the agreements reached and giving them the force of a document that is a guide to action, although they are not formally participants in the project, but their work will significantly affect the overall duration of the project [8 – 11].

Another feature requiring accounting in the planning process is the stochastic nature of the labor productivity of each of the participants in the project. Usually, in this case, some normative correction
factors are used to take this specific feature into account. For example, in construction, when calculating the execution time, an overfulfillment rate is used, which depends on the type of work performed. But it is possible to directly take into account the stochastic nature of the considered parameter in the process of designing options for the formation of the project team.

3. Formulation of the problem

The considered task of forming a project team can be assigned to the class of the well-known assignment problem [11 - 17], which can be divided into several meaningful statements: forming a project team, distributing functions in heterogeneous teams and distributing the volume of work between team members. In the general case, it is natural that all three problem statements should be implemented in practice during the creation of the project team. Indeed, before forming the composition of the project team, it is necessary to formulate general requirements for its composition, possible functions performed by team members, as well as the amount of work to be performed.

The whole variety of possible methods for solving the problem of forming the composition of the project team can be conditionally divided into three groups.

The first group includes methods based on a simple purposeful enumeration of possible options for forming a team. This approach is based on the fact that the set of possible solutions is finite and amounts to only $2^n$ possible options for $n$-applicants. Given the power of modern computing technology, this computing task now no longer seems insurmountable. The advantage of this group of methods is the guaranteed obtaining of the optimal solution, but the main disadvantage, nevertheless, is their high computational complexity.

The second group of methods includes local optimization methods associated with finding a solution in the vicinity of the expected optimum. The main disadvantages of this group of methods include the difficulty of finding a neighborhood in which a solution is supposed to be found. Finding such a neighborhood is an independent and rather complicated task, which is not always possible to simply solve. Moreover, in this case, the resulting solution may not be optimal and additional studies are required to prove the effectiveness of the obtained solution.

The third group of methods consists of methods based on some a priori known heuristic rules that allow you to get some solution that may not be optimal, but will be quite “good”. The most striking example of the formation of such a “decisive” rule is the location of applicants for inclusion in the project team in decreasing order of effectiveness, that is, in our case, the effectiveness of each potential member of the project team is calculated as the ratio of his labor productivity to the cost of attracting him to the project.

Consider the task of forming the composition of the project team. Let the project consist of $n$ work to be completed. To perform the $i$-th work, it is necessary to involve a specialist, and specialists have different qualifications, and, therefore, different labor productivity. Denote the labor productivity of the $j$-th specialist at the $i$-th job by $w_{ij}$. In total there are $m$ of specialists. The work of the $j$-th specialist performing the $i$-th work is paid in the amount of $c_{ij}$. The problem arises of forming a project team with minimal costs with restrictions on the timing of the project. Suppose that the labor productivity of the $j$-th specialist at the $i$-th job is a random variable, that is, the quantities $w_{ij}$ are random, distributed according to a certain law $f(w)$. Thus, the task is formulated as follows: it is necessary to form a project team in such a way that the total cost of paying specialists is minimal, and the implementation time of the entire project would ensure the fulfillment of contractual obligations on time. In this case, the formal statement of the problem takes the form:

$$
\sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \rightarrow \max
$$

$$
P \left( \sum_{i=1}^{n} \sum_{j=1}^{m} w_{ij} x_{ij} \geq W \right) \geq p
$$
Here $x_{ij}$ is a binary variable taking the value equal to 1 if the specialist with the $j$-th labor productivity is assigned to the $i$-th job and 0 otherwise; $W = Q/T$ – minimum required level of labor productivity to fulfill contractual obligations; $P$ – probability of occurrence of the event in parentheses; $p$ – specified level of probability of fulfillment of the constraint; $Q$ – scope of work carried out under the project; $T$ – contractual deadline.

4. Theoretical part
The obtained problem relates to the problem of stochastic programming with probability constraints. In that case, if all the coefficients of the problem were deterministic quantities, then this problem would belong to the class of combinatorial programming problems and would be solved using standard algorithms. But constraints (2) contain random variables $w_{ij}$, which complicates the matter. Using the properties of a random variable and the laws of their distribution, the probability constraint (2) can be transformed to

$$
\sum_{i=1}^{m} \sum_{j=1}^{n} \bar{w}_{ij} x_{ij} + t_p \sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} \sigma_{ij}^2} x_{ij} \geq W,
$$

where $\bar{w}_{ij}$ – average value of productivity of the $j$-th specialist at the $i$-th job; $\sigma_{ij}^2$ – standard deviation of a random variable; $t_p$ – confidence coefficient (tabular value).

The obtained problem (1) and (3) will already refer to deterministic problems and can be solved by numerical methods.

Relation (1), (3) was obtained under the assumption that the random variable has a normal distribution law. In the event that this is not so, the question arises of determining this basic characteristic of the random variable in question.

For this purpose, statistical information on previous similar projects is usually used. But, unfortunately, this method is likely to be unavailable, due to the fact that it is very difficult to select a sufficient number of completed projects with similar implementation conditions in order to construct the distribution law of the random variable under study from such a sample.

5. Practical significance
First of all, a legitimate question arises about the form of the theoretical distribution law that we have to deal with in this case. And in this case, it would be most preferable to use the well-studied normal distribution law, which is often used in scientific research, which occurs when many random independent or weakly dependent factors act on the studied quantity, each of which generally plays a relatively an insignificant role, that is, there is no dominant factor. The general position for describing the productivity of an employee will be consistent with this assumption. But here the other features of the random variable under study clearly do not fit this distribution law.

Reveal these features:
  - the distribution law must be determined on a finite interval, since the studied value varies in a strictly limited range;
  - the distribution law should be asymmetric, since the probability of the highest labor productivity will still be less than the probability of a lower one;
  - the distribution law should have left-side asymmetry, which characterizes the fact that the probability of the lowest level of labor productivity will be higher.

The use of these empirical features of the studied problem is unambiguously displayed on a beta distribution that well describes random variables limited on both sides, for example, the size of the daily production, the distribution of time remaining until the work is completed, etc., i.e., a change in the random variable occurs on some known interval and is defined by the function

$$
f(x) = \begin{cases} A \cdot (x-a)^p \cdot (b-x)^q ; & a \leq x \leq b; \\ 0 ; & x < a, \ x > b. \end{cases}
$$

(4)
Studies have shown that in the problems of managing construction production, the values of the distribution parameters are \( p = 1 \) and \( q = 2 \). In this case, the probability distribution density will take the following form
\[
f(x) = \frac{12}{(b-a)^4} \cdot (x-a) \cdot (b-x)^2,
\]
using relation (5) and the main properties of the laws of distribution of random variables, we can proceed to a deterministic version of the problem.

6. Conclusion
Thus, the article considers a model that allows to obtain optimal (or close to optimal) options for the efficient use of labor resources for the project, taking into account individual differences in labor productivity of various members of the project team.

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