Synthesis of Group Incentive Systems on the Basis of
Heuristic Algorithms

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Abstract. The task of synthesizing the system of incentives for executives is considered with the aim of ensuring the project implementation deadlines. This problem occurs when, with the accepted method of organizing the execution of work on a project, the period for its implementation exceeds the allowable one. In this case, a list of organizational and technological measures is being developed, aimed at reducing the duration of the work that constitutes the project. The cost of reducing the duration of work is linearly dependent on the magnitude of this reduction. The incentive system is designed to offset these costs performers. In the system of group incentives, all projects are divided into several groups, and each group has its own incentive system. It is shown that the most preferable will be a group incentive system that combines the advantages of both individual and collective incentive systems. A task is considered when the number of groups is set into which it is necessary to divide the whole set of project works, and the number of works in groups is assumed to be two. This formulation of the problem can be represented as a graph. It is shown that in this case the problem reduces to determining the maximum matching of the minimum weight. A heuristic algorithm for solving this problem is given.

Keywords: project, incentive models, individual incentive systems, unified incentive systems, group incentive systems, maximum matching minimum weight, heuristic algorithm.

1 Introduction

One of the key tasks of management theory is the problem of encouraging the active work of members of labor collectives, that is, the task of organizing incentives. This presupposes the formulation of a certain rule, according to which the remuneration of performers is carried out, for actions beneficial to the center. This rule is called the incentive mechanism. The presence of the incentive mechanism ensures the same approach to all performers involved in the project. There is a significant number of incentive mechanisms, which are conventionally divided into several groups [1-6].

The first group consists of individual incentive systems, which are characterized by the fact that the volume of incentives is individual for each actor. In this regard, from the standpoint of additional costs, these incentive systems are the most economical, since they require minimal additional costs. On the other hand, the stimulation is carried out according to the results of the activity of a specific performer, but, as a rule, the results of the activities become known from the words of the performer who can consciously distort information in their own interests. Another disadvantage of this incentive system is the lack of interest of performers in reducing costs. Thus, individual incentive systems are...
the most economical, but they are also the most vulnerable from the point of view of the manipulability of information on the part of the performers [1, 3, 7-11].

Another class of incentive systems are unified systems that provide a unified approach to stimulating all performers. The advantages of these systems include: significantly less opportunities for manipulating information; great interest in reducing costs, and the disadvantages - a high level of costs for organizing incentives [2, 4, 12-15].

Intermediate position between these two classes of incentive mechanisms is occupied by collective incentive systems, when the whole team of performers is divided into groups and a single unified incentive system is used within each group. Thus, strictly speaking, in each group there can be a different system of incentives. Such an incentive mechanism retains the main advantages of an individual and unified system, while at the same time weakening their inherent flaws.

Group modeling systems, as well as information modeling in project management, are considered in the works of Bakhareva O.V., Romanova A.I., Afanasyeva A.N. and others [16-20]. It can be argued that the synthesis of inventory systems is relevant in the framework of a sustainable economy.

2 Methods

Consider the following problem situation. A project consisting of an arbitrary number of works must be completed by the contractual date, but in the process of detailed design of the project implementation process, it turned out that it is not possible to meet the specified period under the analyzed conditions. There is a problem of shortening the project timeframe. One way to reduce the duration of the project is to reduce the duration of the implementation of individual, leading works on the project. And for this purpose it is necessary to stimulate the performers of these works accordingly.

Consider a project consisting of an arbitrary number of jobs, denoted by \( n \). As a result of the development of organizational and technological measures, ways of reducing the overall duration of the project to the directive value were determined \( \Delta t_i, i = 1, n \). Expenditures of performers to reduce the duration are linear functions of \( \Delta t_i \), i.e.

\[
Z_i = k_i \Delta t_i, \quad i = 1, n, \tag{1}
\]

where \( k_i > 0 \).

If a linear incentive system is chosen for group \( j \) then, obviously, to compensate for the costs of all the performers in this group, the minimum incentive fund will be:

\[
S_j = \lambda_j T_j, \tag{2}
\]

where \( \lambda_j = \max_{i \in j} k_i, \quad T_j = \sum_{i \in j} \Delta t_i \).

If for group \( j \) a jump incentive system is chosen, then the minimum incentive fund for the compensation of the performers’ costs will be:

\[
S_j = n_j \max_{i \in j} k_i \Delta t_i, \tag{3}
\]

where \( n_j \) – number of jobs in a group \( j \).

In this case, the following task arises: to determine the splitting \( Q_j, j = 1, m \) and choose the incentive system for each group so that the incentive fund is minimal.

Consider the task of building a system of group incentives, provided that in each group the same number of jobs. Tasks of this class, as a rule, are related to complex (NP-hard) discrete optimization problems. Therefore, we consider one particular case when the number of jobs in each group is 2, and the number of groups is \( m = n/2 \) (\( n \) – is an even number).

We define a complete \( n \)-vertex graph \( G \). The lengths of the arcs of the graph are equal:

\[
l_{ij} = (\Delta t_i + \Delta t_j) \max(k_i, k_j), \tag{4}
\]

if a linear incentive system is used, equal:

\[
l_{ij} = 2 \max(k_i \Delta t_i, k_j \Delta t_j), \tag{5}
\]

if an intermittent stimulation system is used, and equal:

\[
l_{ij} = \min[(\Delta t_i + \Delta t_j) \max(k_i, k_j), 2 \max(k_i \Delta t_i, k_j \Delta t_j)], \tag{6}
\]

if a mixed incentive system is used.
Definition 1. A matching of a graph is a set of mutually non-adjacent edges [6, 13, 14].

The matching with the maximum number of edges is called the maximum. Note that any division of work into m groups, two jobs in each group, corresponds to the maximum matching and, conversely, any maximum matching corresponds to the division of work into groups of two jobs in each group. Thus, the task was reduced to the definition of matching with the minimum sum of edge lengths [5, 7, 8].

3 Results and Discussion
Thus, there is a problem of finding the maximum matching of the minimum weight [9, 10, 12] in a graph of the following form, figure 1.

To solve the problem, consider the following heuristic algorithm.

Preparatory step. We build a matrix, an arbitrary element of which \((i, j)\), in the numerator contains the value of the cost of incentives in the event that work \(i\) and \(j\) will be combined into one group, and in the denominator will be the value of losses in this case compared to the individual incentive system.

\(k\)-th step. We choose among the uncrossed lines, the one in which all elements are the same and are the largest. This means that this work needs to be combined into a group with some other. We select the work from the elements of the found row with the lowest denominator. Cross out the relevant rows and columns. At each step, 2 lines and two columns are deleted. The number of the crossed-out row and column is fixed.

\(k+1\) step. If there are still lines and columns not crossed out, then go to step \(k\). If not, the decision is complete. The groups should be combined work that crossed out at every step.

Analysis of examples and results of a computational experiment led to the conclusion: the greater the scope of variation in the cost of organizing group incentives, the higher the efficiency of group incentives.

But the considered heuristic algorithm is applicable only in case of fulfillment of sufficiently strict restrictions: a fixed number of groups and in each group should be no more than two papers. Let's try to generalize this algorithm to a more general case. Let the number of groups into which performers are divided is, as before, fixed, but in each group three works can be combined.

A further solution is based on assertion 1.

Statement 1. In any grouping, one of the groups containing the work with the highest level of costs will determine the highest share of the cost of organizing group incentives. This share of costs is determined by the ratio \(q/n\), where \(q\) – is the number of jobs placed in this group.

This statement provides the basis for applying a very simple heuristic rule.

Heuristic rule: arrange the works in order of increasing costs and group them according to this criterion.

Statement 2. In cases where performers are divided into a given number of groups and in each group the number of performers is the same, this rule gives the optimal solution.

The proof is by contradiction. Assume that this condition is not satisfied, that is, there is a division into groups, the total costs of which for stimulation will be smaller than the division in order of decreasing costs. Consider two such groups having the numbers \(p\) and \(q\) while the condition \(p < q\) is fulfilled, that is, the group of works \(p\) has higher costs than \(q\). Recall that all works are sorted in
descending order of costs. Consider the last work $i$ of the group $p$ and the first work $i+1$ of the group $q$. We change these jobs in places, that is, work with number $i+1$ will be included in group $p$, and work with number $i$ in group $q$. From this, taking into account the accepted incentive rule, the amount of costs for encouraging workers who belong to group $p$ will not change, since the amount of costs for incentives will be determined by the first job in this group, but the costs for encouraging workers of group $q$ will increase, since the first job in this group was work with number $i$, the costs of which exceed the costs of doing work $i+1$ and, therefore, the costs of stimulation in this group will increase, and therefore the total costs of organizing will also increase incentive. Thus, we have come to a contradiction, which means that our assumption that the solution obtained by the heuristic rule is not optimal is wrong.

4 Conclusions

Thus, the issue of organizing group incentives with a view to shortening the project implementation time has been considered. The results can be formulated as follows:

Statement 3. Reducing the number of groups increases the cost of group incentives, approaching the cost of unified incentive systems, and an increase in the number of groups leads to their reduction, approaching the systems of individual incentives.

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