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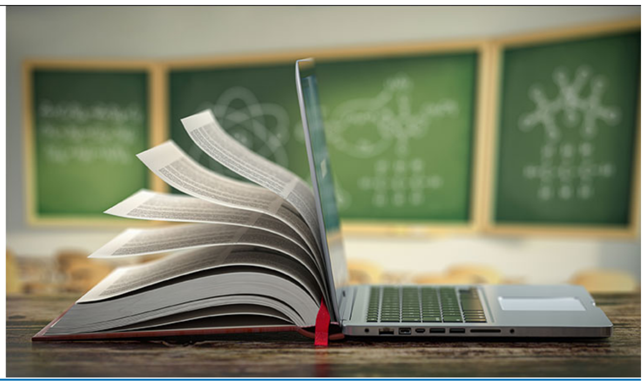

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Optimization of the production plan taking according to the customers' strategic importance

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Abstract. The article is devoted to the management of the production plan of the industrial enterprise. Existing approaches to optimization of the production plan are focused mainly on stochastic demand and consider the process of production plan formation. At the same time, many modern industrial enterprises often deal with rush orders in the course of their work. They have to solve the task of changing the formed production plan. If resources are limited, the decision to include an urgent order may result in a failure or a change in the due date of the orders included in the plan. In this regard, it becomes important to take into account the strategic importance of clients to the enterprise. The article proposes a methodological approach to the issue of inclusion or non-inclusion of rush order in the already formed and accepted production plan. The authors have developed a mathematical model of optimization of the formed production plan with the participation of rush order. The model uses Boolean variables to decide whether to include or refuse an order and an additional factor to increase margin income from the order for strategic customers.

1. Introduction

The production plan (PP) of the industrial enterprise is traditionally considered as established tasks on the volume and assortment of produced products with established quality requirements [1,2,3]. The formation of the PP involves the search for the optimal combination of types and volumes of products taking into account the resource capabilities of the enterprise and market demand.

Existing approaches to PP optimization are based on the use of different mathematical methods. They are typically based on one or more target functions that characterize some of the resulting performance indicators of a particular PP. These functions have a number of variables that characterize possible variants of PP composition. The whole task of optimization is to define such a combination of designated variables (PP composition) in which all target functions best achieve the required values.

The models proposed by researchers differ in the resource constraints taken into account, the peculiarities of setting the target functions and taking into account the uncertainty factor.

The resource constraints are those on the production capacity, labour resources and other parameters of the production system. This is a traditional approach used by almost all researchers. The model considering the degree of consumer reliability is considered in [4]. The model adapted for vertically integrated corporate structures is presented in [5]. The model taking into account transport and financial support is considered in [6]. Models with uncertain demand are considered in [7,8,9,10,11].

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The proposed target functions have the greatest variety. They may be single-criteria [4,6,7,10,11,12,13,14] and multi-criteria [8,9,15,16]. There are models that include customer satisfaction rating [8.9]. Some authors propose complex optimization conditions that take into account not only production costs, but also related costs. For example, product storage costs [7.12], product quality costs [12], market demand investment [10], transportation costs [13].

Most models consider the number of products as an optimizable parameter. The order integrity task remains unresolved. In part, it is considered in [17] as part of the formation of the production program for enterprises of the defense-industrial complex, using the model of integer programming. But the issue of including or refusing an additional order remains unresolved.

The purpose of this work is to develop a methodological approach to the issue of including or not including a rush order in an already formed and accepted PP.

2. Materials and methods

The research base is the PP of the medium machine-building enterprise. The main methods of a research were the financial and economic analysis, statistical methods, methods of group expert assessment.

The hypothesis of the study is that when adjusting the production program in case of a new order, it is necessary to take into account the strategic importance of the customer, rather than the current financial and economic results of the order.

The task of optimizing PP in the context of deterministic demand requires a completely new approach to the formulation of the optimization task itself. Since market needs are defined, the main focus of production enterprises should not be on individual products targeted at the intended groups of consumers, but on specific orders, each of which is targeted at a specific consumer. The optimization task can be formulated as follows.

The enterprise has a set of manufacturing resources that ranges from 1 to E.

$$e = 1, \dots, E, \tag{1}$$

where E – number of different groups of production resources.

The enterprise has a formed PP consisting of i orders, where i takes values from 1 to I.

$$i = 1, \dots, I, \tag{2}$$

where I – number of orders included in the enterprise PP.

For each order its labor capacity of T_i manufacturing is determined in hours of direct work on its execution, which consists of separate labor capacity for each group of production assets used in its manufacturing.

$$T_i = \sum_{e=1}^{E} t_{ei}, \tag{3}$$

t_{ei} – work capacity of order i by group of production assets e.

Each production resource group has its own F_e working time limit, which the group can no longer be loaded.

$$\sum_{i=1}^{I} t_{ei} \le F_e \tag{4}$$

For each order, based on the agreed price and the estimate of direct costs, the amount of margin income m_i is calculated, which can be obtained if it is included in PP and then executed. Including or not including an order in the PP in our task will be reflected by the p_i variable, which is a boolean variable.

$$p_i = \{0,1\} \tag{5}$$

The target function and the constraints are as follows:

$$M(p) = p_1 m_1 + \dots + p_i m_i \to max$$

$$\begin{cases} \sum_{i=1}^{i} t_{1i} \leq F_1 \\ \dots \\ \sum_{i=1}^{i} t_{Ei} \leq F_E \end{cases} \tag{6}$$

Now enter rush order in this task. Let it have index i+1. Then the following indicators will appear in the task: its labor capacity T_{i+1}, its variable p_{i+1} and its value of possible margin income m_{i+1}.

Placing this order in PP potentially means suspending one of the current orders, which can cause some losses for the manufacturer. In a simple case, it can be the payment of a certain compensation for the delay. In a difficult case, this could be a total loss of this order with a substantial penalty for violating the delivery deadlines. Obviously, the objective function will now depend not on one, but on two boolean variables. The first p_i remains the same. The second variable, c_i, will reflect the existence or absence of losses due to cancellation of the relevant order. The value of this variable will be determined as follows:

$$c_i = \begin{cases} 0, & p_i = 1 \\ 1, & p_i = 0 \end{cases} \tag{7}$$

At the same time, the possible losses l_i are entered individually for each order. These two key figures generally give the following function L of possible cumulative losses:

$$L(c) = c_1 l_1 + \dots + c_i l_i \tag{8}$$

It should also be noted that among all orders in question there may be one or more of the strategically significant customers. These are the same orders that will result in additional orders in the following periods. To take this into account, we will introduce a special k_i factor, which will reflect the degree of growth of possible margin income in future periods from the amount of margin income that can be obtained from the fulfillment of the current order placed by a strategically significant client. Note that for ordinary orders from ordinary "disposable" customers k_i will always be 1. When we get it together, we get the following:

$$\begin{gathered} R = M(p) - L(c) \to max \\ M(p) = k_1 p_1 m_1 + \dots + k_i p_i m_i + k_{i+1} p_{i+1} m_{i+1} \\ p_i = \{0,1\} \\ L(c) = c_1 l_1 + \dots + c_i l_i \\ c_i = \begin{cases} 1, & p_i = 0 \\ 0, & p_i = 1 \end{cases} \\ \begin{cases} \sum_{i=1}^{i+1} t_{1i} \leq F_1 \\ \dots \\ \sum_{i=1}^{i+1} t_{Ei} \leq F_E \end{cases} \end{gathered} \tag{9}$$

Variables:

p_i – boolean variable reflecting inclusion (1) or not inclusion (0) of i-th order in PP,

c_i – boolean variable, reverse p_i, indicating presence (1) of losses due to cancellation of i-th order or their absence (0).

Parameters:

m_i – margin income of the i-th order,

l_i – possible losses from cancellation of i-th order,

k_i – coefficient reflecting the degree of growth of possible margin income in future periods from the value of margin income that can be obtained from fulfillment of the current i-th order placed by a strategically significant customer,

t_{ei} – labor input of the i-th order per group of production assets e,

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T_i – labor input of the i-th order,
F_e – production assets working time limit.

3. Results

Here is an example of how to use the resulting model. The raw data for example are shown in table 1.

Table 1. Raw data.

orders	labor input, work hours				m_i, rubles	l_i, rubles
	T_i	t_{1i}	t_{2i}	t_{3i}		
CO 1	542	217	271	54	205 960	111 140
CO 2	634	285	292	57	259 940	57 160
CO 3	635	191	286	158	241 300	75 800
CO 4	823	247	370	206	181 060	136 040
CO 5	625	156	375	94	256 250	60 850
CO 6	906	281	390	235	317 100	0
CO 7	738	258	332	148	162 360	154 740
CO 8	806	339	347	120	290 160	26 940
RO	230	138	69	23	82 800	0
F_e		2 016	2 688	1 344		

There is a PP accepted for execution, which includes eight current orders (CO). At a certain point in time, an rush order (RO) appears, the inclusion of which in PP will lead to exceeding the limit funds of working time of production assets. K_i for all CO is 1, for RO it is 4.

Solving this task without taking k_i into account showed that there is no order in the current PP that could be cancelled for the sake of including an RO. The solution of this task taking into account k_i showed that in order to include an RO in the current PP it is possible to cancel the CO 5.

The methodological approach tested at the enterprise showed the following results. In June 2015, the company receives and successfully executes an order from a new customer. The margin income from this order amounted to 120,000 rubles. This leads to the fact that in 2017 the company receives four more orders from the same customer with a total margin income of 3,430,000 rubles. This amount exceeds the amount from the original order by more than 28 times. In August 2015, the company also receives and successfully executes another order from another new customer. The margin income from it amounted to only 25,000 rubles. The total margin income from subsequent orders of the same customer in 2017 amounted to 5,905,000 rubles, which exceeds the amount under the original order by more than 236 times.

In these examples, k_i was determined by expert means. A further development of the methodical approach is to determine the method of calculating the coefficient based on the ranking of clients and their score.

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