FORMATION OF THE ENTERPRISE PRODUCTION PROGRAM ON THE BASIS OF ECONOMIC-MATHEMATICAL MODELING

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Abstract. The article generalizes theoretical and methodical approaches to the formation of the enterprise's production program. The article generalizes theoretical and methodical approaches to the formation of the enterprise's production program, namely model of optimal batch volume (wilson's model); model of multicriteria optimization of the enterprise's production capacity; model of optimal use of resources in production planning with maximizing the result; model of combinatorial minimization of losses; model of optimal resource allocation (equipment limitations, several periods); model for producing a calendar product release plan.

Keyword: economic-mathematical modeling, production program, enterprise, models of production.

Introduction

In today's economic conditions, which are characterized by a high level of risk and uncertainty and increased competition, the formation of an effective industrial program of an industrial enterprise is one of the means of increasing competitiveness, a guarantee of obtaining high economic results and a prerequisite for market success.

As the age-old practice of economic relations shows, the effectiveness of production planning is determined primarily by the level of understanding of the market situation, the degree of study of the main market problems and opportunities, the ability to avoid direct and indirect losses associated with risks and uncertainty, and success is achieved by enterprises that the process of economic activity is guided by market priorities.

Basic Material

When developing the budget, the purchase of materials, the disappearance of their needs in order to support the continuous process of production, economic and mathematical models that can optimize the volume and timing of purchasing materials can be applied.

One of the most common is the «Economic Ordering Quantity» (EOQ-model), better known as Wilson's Model (Formula).

In this case it is also relevant when optimizing the production program.

Products are delivered to the warehouse regularly with identical batches of Q-size (in each batch of goods), and from the warehouse it goes out on 1 kg (sold or launched in production).

It is assumed that the quantity of products in the composition decreases evenly from Q to 0, and then there is an instantaneous replenishment of the composition of the new batch (by Q) and so several times during the period where D is the demand for the product. Accordingly, replenishment occurs D / Q times over the period.

In this model, 2 sources of expenditure:

– costs associated with the procurement procedure for the batch of goods;

– costs of storing raw materials in the warehouse.

The cost of the purchase of one lot is fixed and equal to K, it includes the costs of loading, unloading, delivery, etc. Then, the total cost of all parties during the period:

$$\textit{The total cost of all parties during the period} = K \cdot \frac{D}{Q} \tag{1}$$

The cost of storing one product for a certain period = h (including holding of the warehouse, insurance, etc.). The average number of items stored in the warehouse = Q / 2 (because the number is evenly diminished from Q to 0). Hence, the cost of storing products:

$$\textit{The cost of storing products} = h \cdot \frac{Q}{2} \tag{2}$$

Total Storage and Purchase Costs (TC):

$$TC = K \cdot \frac{D}{Q} + h \cdot \frac{Q}{2} \tag{3}$$

After the differentiation by Q, we define Q * - the size of the lot in which TC is minimal.

$$Q^* = \sqrt{2 \cdot D \cdot \frac{K}{h}} \text{ – Wilson's formula} \tag{4}$$

In fig. 1 − 4 calculations and graphs of cost of production, cost of storage and total costs are presented.

The larger the party's production of material resources, the less operational costs of placing goods in a given period. That is, the more we manufacture, the less is the import of materials, the lower the cost of transportation, acceptance, and so on. Thus, on the basis of the EOQ model, it is grounded that the optimal batch size at which TC is minimal is 4 tons of finished products. The optimal number of deliveries per unit time is 25.

	K×D/G	h×Q/2	TC
Q	cost of production	storage cost	general expenses
1	2000	125	2125
2	1000	250	1250
3	666,7	375	1041,7
4	500	500	1000
5	400	625	1025
6	333,3	750	1083,3
7	285,7	875	1160,7
8	250	1000	1250
9	222,2	1125	1347,2
10	200	1250	1450
11	181,8	1375	1556,8
12	166,7	1500	1666,7
13	153,8	1625	1778,8
14	142,9	1750	1892,9
15	133,3	1875	2008,3
16	125	2000	2125
17	117,6	2125	2242,6
18	111,1	2250	2361,1
19	105,3	2375	2480,3
20	100	2500	2600

Given	
D	100
K	20
h	250
Q *	4
TC min	1000

Fig. 1 – EOQ model

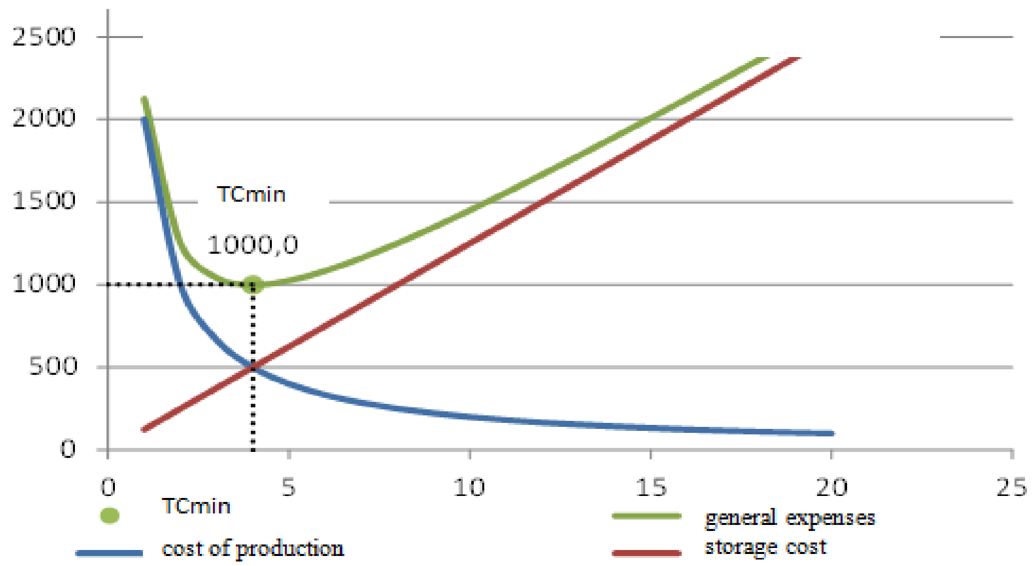
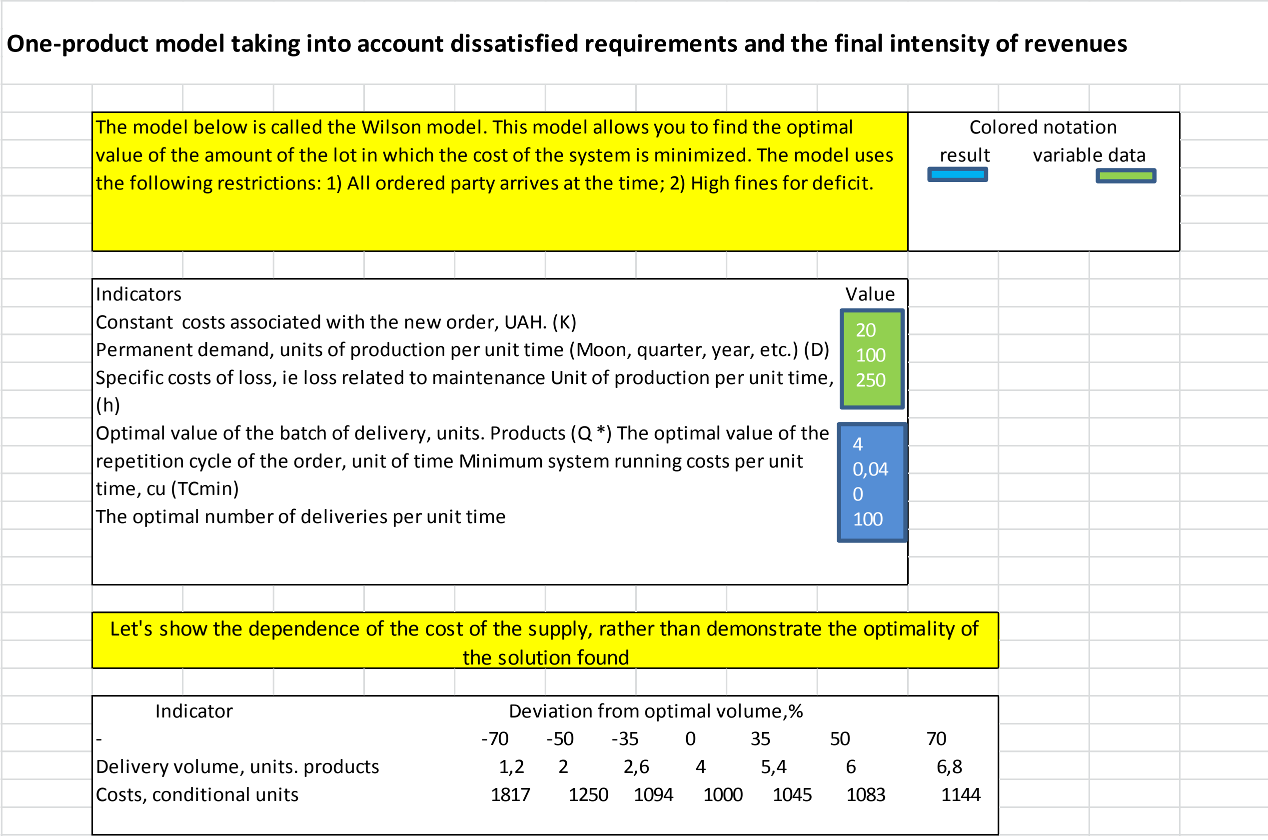


Fig.2 – Graph of the EOQ model



One-product model taking into account dissatisfied requirements and the final intensity of revenues

The model below is called the Wilson model. This model allows you to find the optimal value of the amount of the lot in which the cost of the system is minimized. The model uses the following restrictions: 1) All ordered party arrives at the time; 2) High fines for deficit.

Colored notation: result | variable data

Indicators	Value
Constant costs associated with the new order, UAH. (K)	20
Permanent demand, units of production per unit time (Moon, quarter, year, etc.) (D)	100
Specific costs of loss, ie loss related to maintenance Unit of production per unit time, (h)	250
Optimal value of the batch of delivery, units. Products (Q *) The optimal value of the repetition cycle of the order, unit of time Minimum system running costs per unit time, cu (TCmin)	4 0,04 0
The optimal number of deliveries per unit time	100

Let's show the dependence of the cost of the supply, rather than demonstrate the optimality of the solution found

Indicator	Deviation from optimal volume,%						
-	-70	-50	-35	0	35	50	70
Delivery volume, units. products	1,2	2	2,6	4	5,4	6	6,8
Costs, conditional units	1817	1250	1094	1000	1045	1083	1144

Fig.3 – Wilson Model

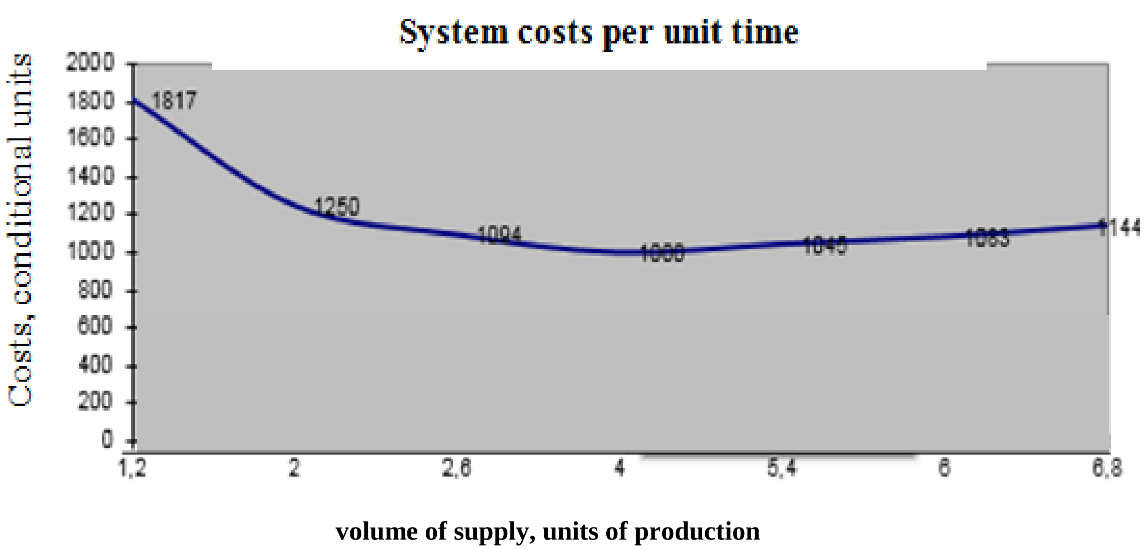


Fig.4 – Graph of the Wilson model

Planning of production and sales is the main part of the plan, on the basis of which is the production program of the enterprise. One of the tasks of effective planning is to optimize the production capacity of the enterprise. In the calculation of the production capacity of the enterprise included all available equipment of the main production (in particular, ineffective due to repair, malfunction and modernization), with the exception (within the limits of the standard) of the reserve equipment and equipment of pilot experimental and specialized areas for vocational training [1].

Grain-cleaning machines, the work of which is based on the use of different properties of grain and impurities, is essential in the technological process of flour-mill production.

In the modern market there are many types of this equipment. Therefore, one of the priority tasks of forming a production program is the calculation of the capacity of grain processing.

Thus, based on the method of multi-criteria optimization, an optimal type of grain cleaning machine was determined based on performance and cost criteria with an optimization orientation to the maximum and minimum, respectively, for each of the criterion indicators.

Let, type 1 − SIPMA ZZ4020, 2 type − ISM-40, type 3 − OVU-25, type 4 − ACM-10 and type 5 − ACM-5.

Table 1 − Data on types of equipment

Type of grain cleaning machine	1	2	3	4	5
Productivity, t / h	20,000	15,000	10,000	7,000	4,000
Cost, thousand UAH	260,00	215,00	170,00	150,00	125,00

A generalized additive value function has the form:

$$u = \frac{\text{Productivity}, \text{t / h } (x)}{16} - \frac{\text{Cost}, \text{thousand UAH } (x)}{135\,000} \to \max \qquad (5)$$

At the next stage, the values of each of the types of equipment are calculated and the admissible plan x1, which corresponds to the maximum (5), is determined. The results of calculations are given in Table. 2.

The best value function is the third type of equipment: x1 = 3, y1 = f (x1) = [10 t / h; 170 thousand UAH]. The results received were sent to ODA (the decision maker).

Table 2 − Values of equipment types

Type of grain cleaning machine	1	2	3	4	5
Productivity, t / h	1,25	0,9375	0,625	0,4375	0,25
Cost, thousand UAH	1,926	1,593	1,259	1,111	0,926
Value (u)	**-0,676**	**-0,655**	**-0,634**	**-0,674**	**-0,676**

Since the plan x1 is not agreed upon by the ODA, it introduces acceptable levels for each target function that it considers to be satisfactory: But equipment with such parameters is absent, therefore the reality of the admissible levels introduced in the previous step was determined.

As a result, the search for an effective plan x2 satisfies the real levels of the criterion indicators: x2 = 2, its estimate y2 = f (x2) = [15 t / year; 215 thousand UAH], which the ODA receives.

Therefore, in order to ensure the efficiency of the production program at the expense of the equipment's capacity, the grain-cleaning machine ISM-40 should be used on the grain cleaning line.

The success of the overwhelming majority of managerial tasks depends on the best, most profitable way of using resources such as money, goods, raw materials, equipment, labor, etc. After all, the resources required to perform a certain work, almost always limited. And from what decision will be made regarding the quantitative distribution of these limited resources, the final result of the organization depends on.

LLC «Firm DIAMANT LTD» uses four types of raw materials: cereals, dried fruits, walnuts and chocolate to produce three types of oat flakes «Fitnes» (A1), «Extra» (A2) and «Premium» (A3). The rates of use of raw materials of each species for the production of one ton of flakes of each type, the total amount of raw materials of each type is also known and the profit from the sale of 1 ton of finished product of this type.

To determine the production plan, which provides maximum profit, an economic-mathematical model has been constructed, which has the form:

Known parameters:

m – number of types of raw materials;;

n – number of types of flakes;

a_{ij} – norms of consumption of the i-th raw material for the production of the j-th type of flakes;

c_j – profit from the sale of 1 t of products;

b_i – stock of and-th raw materials.

Managed Options:

x_j – is the optimal quantity of products.

Computational quantities:

$$\sum_{j=1}^{n} a_{ij} x_j, \left(i = \overline{1, m}\right) \tag{6}$$

– costs i-th raw materials for the manufacture of each type of product.

Target function:

$$f(x) = \sum_{j=1}^{n} c_j x_j \rightarrow max \tag{7}$$

– total profit from the sale of all manufactured products.

Limitation:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \left(i = \overline{1, m}\right) \tag{8}$$

– the cost of raw materials for the production of optimal quantities of products should not exceed the stock of raw materials:

$$x_j \geq 0 \quad \left(j = \overline{1, n}\right) \tag{9}$$

– the quantity of produced products should be greater than 0.

The best plan that you received during the calculations can be seen in Fig. 5.

Type of raw material	Norms of raw material consumption per 1 ton of products			Stock of raw materials
	A1	A2	A3	
Cereals	0,8	0,7	0,65	570
Dried fruit	0,02	0,07	0,1	350
Nuts	0,1	0,12	0,9	500
Sunflower seeds	0,08	0,09	0,12	400
Chocolate	0	0,02	0,04	230
Profit from the sale of 1 ton of products (ths. UAH)	2,6	2,7	2,35	
Optimal quantity of products	0	814,27	0	
Earnings from sales of products	0	2198,6	0	

Consumption of raw materials for the production of optimal quantities of products	Percentage ratio	Reserve (t)
570	100,00%	0
57	16,29%	293
97,71	19,54%	402,28571
73,29	18,32%	326,71429
16,29	7,08%	213,71429

Total profit from sales - max	2199

Fig.5 − Optimal output

Thus, a plan for the production of flakes has been defined, which will ensure maximum profits. With the help of «Search for the solution» it was determined that the optimum variant for the confectionery factory is the production of flakes of the species A2. For this kind of products per 1 ton of flakes, the average amount of raw materials is used in almost all types, and the profit from the sale of 1 t of production is the highest. Therefore, for the enterprise it is optimal for the production of flakes of the type A2 – 814,29 tons, from which the company analyzed and will have its total profit from sales in the amount of 2 198,57 thousand UAH.

LTD «Firm DIAMANT LTD» has at its production capacity 4 lines of processing of varieties of different volumes. An enterprise must complete an order: to process a certain number of breeds of three different types. Unfortunately, the total volume of lines is less than the volume of the order. An unpaid order is subject to a fine, the amount of which is proportional to the amount of the non-executed order.

It is necessary to minimize the size of the fine by filling the machine-and-hardware conveyors in the optimal way.

The economic-mathematical model of the task is as follows::

Known parameters:

m – the number of production lines that are involved in production;

n – number of species of cereals;

b_i – orders of i-th groats;

c_j – capacity of the j-th line of processing;

Managed Options:

We introduce the logical variables xij - a sign of the availability of processing of the i-th groats on the j-th production line.

$$x_{ij} = \{1\ if\ grower\ i\ is\ converted\ to\ j-th\ equipment\ 0, otherwise\} \quad (10)$$

As variables of the model was taken and loading of processing lines of various types of cereals – d_{ij}.

Computational quantities:

$$k_i = (b_i - \sum_{i=1}^{m} d_{ij}) \left(i = \overline{1,n}\right) \quad (11)$$

– the size of the fine for the short supply of the i-th type of cereals.

Target function:

$$f(x) = \sum_{i=1}^{\mathrm{m}} k_i \rightarrow min \quad (12)$$

– the amount of the fine must be minimal.

Limitation:

$$\sum_{i=1}^{m} d_{ij} \leq c_j \quad \left(j = \overline{1,n}\right) \quad (13)$$

– the volume of processed cereals should not exceed the volume of the capacity of the processing line;

$$x_{ij} - binary\ number.$$

– the sign of the presence of the processing of the i-th groats on the j-th production line can take values of 1 or 0.

$$\sum_{i=1}^{m} x_{ij} \leq 1 \quad \left(j = \overline{1,n}\right) \quad (14)$$

– the amount of line load selection must be less than or equal to 1.

$$\sum_{i=1}^{m} d_{ij} \leq b_i \quad \left(j = \overline{1,n}\right) \quad (15)$$

– the volume of processed cereals should be as close as possible to the number of orders.

The best plan that you received during the calculations can be seen in Fig. 6.

Capacity of processing lines

	Line 1	Line 2	Line 3	Line 4
Capacity	1050	800	1200	700

Loading lines (1 - yes; 2 - no)

	Line 1	Line 2	Line 3	Line 4
Buckwheat	1	0	0	1
Rice	0	0	1	0
Millet	0	1	0	0
	1	1	1	1

Loading Lines (Capacity)

	Line 1	Line 2	Line 3	Line 4	Totally redone	Orders	Losses, UAH
Buckwheat	1050	0	0	700	1750	1800	50
Rice	0	0	1200	0	1200	1500	300
Millet	0	800	0	0	800	1000	200
							550

Loading lines (by type of cereals)

	Line 1	Line 2	Line 3	Line 4
Buckwheat	1050	0	0	700
Rice	0		1200	0
Millet	0	800	0	0

Fig.6 − Optimal loading of processing lines of the enterprise

Consequently, as a result of the calculations, the size of the fine was minimized, filling the processing lines in the best way, taking into account the orders of the buyers. With the help of «Solution Search» it was determined that the best option for the enterprise is the processing of buckwheat on line 1 and line 4, the amount of fine in this warehouse − 50 UAH. The rice should be processed on line 3, with the minimum costs at the same time − 300 UAH. And the wheat must be loaded on line 2, which will be 200 UAH. fine due to lack of supply of products to customers. Hence, the total amount of a fine is minimized − 550 UAH.

In practice, many-stage operations are commonly associated with a reasonable distribution of resources. The task of optimal resource allocation is to find the best distribution of resources, in which either maximizes the result, or minimizes costs.

LLC «Firm DIAMANT LTD» produces flour and it is necessary to fulfill the customer's order. The enterprise has 3 types of equipment. All types of equipment produce the same product. The productivity of each type of equipment is different. Each type of equipment has a constant and variable part of the cost. The variable part of expenses is proportional to the quantity of manufactured products. There is a limited number of units of equipment of each type (but the total amount of equipment is redundant to execute the order).

It is necessary to minimize the cost of equipment upon fulfillment of the order.

The enterprise costs according to the type of equipment: use of the equipment of type Alpha-3000 is the most expensive in operation, but it is also the most productive.

Equipment of the type Alpha-1000 is cheapest in operation, but it is also less productive. The task is to select the cheapest equipment so that the order is executed (Alpha-1000 capacity is not enough to fulfill the order). It should be borne in mind that because of the low productivity of cheap cars, they have to take more, carrying substantial constant costs.

Known parameters:

m – number of types of equipment;

a_i – constant costs of the same type of equipment;

b_i – variable costs of the same type of equipment;

c_i – maximum productivity of the type of equipment;

d_i – number of the type of equipment available;

k – quantity of product order.

Managed Options:

The variables of the model are the number of units of equipment of each type involved and the total quantity of products issued for each type of equipment (productivity is given not for each unit, but for the type as a whole).

x_i – the number of units involved in each type.

y_i – the quantity of products issued for each type of equipment.

Computational quantities:

$$\sum_{i=1}^{m} c_i \cdot \sum_{i=1}^{m} x_i, \tag{16}$$

– maximum capacity of the enterprise for the period;

$$a_i / c_i, \tag{17}$$

– constant cost per unit of performance;

$$\sum_{i=1}^{m} c_i \cdot x_i \tag{18}$$

– constant cost per unit of performance;

Target function:

$$f(x) = \sum_{i=1}^{m} y_i \cdot b_i + \sum_{i=1}^{m} x_i \cdot a_i \to min \tag{19}$$

– total operating expenses should be minimized.

Limitation:

$$\sum_{i=1}^{m} x_i \le \sum_{i=1}^{m} d_i, \tag{20}$$

– the number of machines involved in each type should be no more than is available;

$$x_i \text{ – whole} \quad (21)$$

– the number of machines involved should be an integer number;

$$\sum_{i=1}^{m} x_i \leq k, \quad (22)$$

In general, products must be produced at least as much as the order size.

$$y_i \leq \sum_{i=1}^{m} c_i \cdot x_i, \quad (23)$$

– the quantity of output is not less than the productivity of the equipment involved.

With the help of «Finding Solutions», an optimal set of equipment units by type and performance was found, in which the operating costs would be minimal, and the order was executed.

In fig. 7. The given model, created for the decision of the given task.

Equipment data / For reference

Type of equipment	Constant expenses for the period, UAH	Variable costs UAH / kg	Maximum productivity, kg per period	Number of machines available	Maximum capacity of the enterprise for the period	Constant costs per unit of performance
Alpha - 1000	50	0,5	400	6	7350	0,1
Alpha - 2000	75	0,8	600	4		0,1
Alpha - 3000	125	0,9	850	3		0,1

Cars are used to execute the order

Type of equipment	Number
Alpha - 1000	6
Alpha - 2000	4
Alpha - 3000	2

Number of products issued for order fulfillment

Type of equipment	Number	Maximum performance of the machines involved
Alpha - 1000	2400	2400
Alpha - 2000	2400	2400
Alpha - 3000	1700	1700
Totally made	6500	

The order for the product to be executed	6500	The order is complete

Total Operating Expenses, UAH	5 500,00

Fig. 7 − Optimal allocation of enterprise resources

Consequently, 6 500 Alpha-1000 machines (out of 6 possible), 4 Alpha-2000 machines (out of 4 possible) and 2 Alpha-3000 machines (out of 3 possible) will be used to secure the order of 6,500 kg buyers. Thus, the order is executed, and the minimum expenses at this amount are 5 500 UAH.

In the condition of the task, it is assumed that production is carried out only during one period. For ease of planning of production activity, the best distribution of resources was determined in case of several periods.

From the operational data, production is carried out within 5 days. Shipment order is daily. Moreover, on the day it is possible to produce more products than required on the day of order, the surplus is carried over to the next day.

With the help of «Finding Solutions», an optimal set of equipment units by type and performance was found, in which the operating costs would be minimal, and the order was executed.

In fig. 8. The given model, created for the decision of the given task.

As a result of calculations, the optimal set of equipment units for several periods by type and their performance was obtained, in which the operating expenses would be minimal, and the order was executed.

Thus, the optimal allocation of resources for 5 days, when ordering buyers in the amount of 33 500 kg, has the following structure: on Monday, 6 Alpha-1000 machines (out of 6 possible), 4 Alpha-2000 machines (out of 4 possible) and 3 cars should be used on Monday Alpha-3000 (out of 3 possible). On this day, production will be produced in the quantity of 7 350 kg - the maximum productivity of equipment per day, with an order of 5,500 kg.

On Tuesday, 6 Alpha-1000 machines (out of 6 possible), 4 Alpha-2000 machines (out of 4 possible) and 2 Alpha-3000 machines (out of 3 possible) should be used. On this day, production will be produced in the quantity of 6 450 kg, at the order of 6 500 kg. And on this day there is a remnant of produced products for the previous period in the amount of 1 850 kg.

On Wednesday, 6 Alpha-1000 machines (out of 6 possible), 4 Alpha-2000 machines (out of 4 possible) and 3 Alpha-3000 machines (out of 3 possible) should be used. On this day, production will be produced in the quantity of 7 350 kg, at the order of 9 000 kg. And on this day there is a remnant of produced products for previous periods in the amount of 1 800 kg.

On Thursday, 6 Alpha-1000 machines (out of 6 possible), 4 Alpha-2000 machines (out of 4 possible) and 3 Alpha-3000 machines (out of 3 possible) should be used.

Equipment data

Type of equipment	Constant costs, UAH / kg	Variable costs, UAH / kg	Maximum productivity, kg per period	Number of machines available
Alpha - 1000	50	0,5	400	6
Alpha - 2000	75	0,8	600	4
Alpha - 3000	125	0,9	850	3

For reference

The maximum capacity of the enterprise for the period	Maximum power of the company for 5 periods
7350	36750
Order	33500

Cars are used to execute the order

Type of equipment	Monday	Tuesday	Wednesday	Thursday	Friday
Alpha - 1000	6	6	6	6	6
Alpha - 2000	4	4	4	4	3
Aipha - 3000	3	2	3	3	1

Number of products issued by days

Type of equipment	Monday	Tuesday	Wednesday	Thursday	Friday	
Alpha - 1000	2400	2400	2400	2400	2400	
Alpha - 2000	2400	2400	2400	2400	1800	
Alpha - 3000	2550	1650	2550	2550	800	
Total released	7350	6450	7350	7350	5000	
Moved	0	1850	1800	150	0	
Together	7350	8350	9150	7500	5000	
An order that needs to be executed	5500	6500	9000	7500	5000	The order is complete

Maximum performance of the machines involved

Type of equipment	Monday	Tuesday	Wednesday	Thursday	Friday	Total Operating Expenses, UAH	Average transaction costs per day, UAH
Alpha - 1000	2400	2400	2400	2400	2400		
Alpha - 2000	2400	2400	2400	2400	1800		
Alpha - 3000	2550	1700	2550	2550	850		
Total operating expenses for the period, UAH	6 390,00	5 455,00	6 390,00	6 390,00	4 010,00	28 635,00	5 727,00

Fig. 8 − Optimal allocation of enterprise resources

On this day, production will be produced in the quantity of 7 350 kg, at the order of 7 500 kg. And on this day there is a remnant of produced products for previous periods in the amount of 150 kg, which covers the underproduction.

On Friday, 6 Alpha-1000 machines (out of 6 possible), 3 Alpha-2000 machines (out of 4 possible) and 1 Alpha-3000 (out of 3 possible) machines should be used. On this day, products will be produced in quantities of 5,000 kg, with order of 5,000 kg. Moreover, the balance of produced products in previous periods is not, which shows the effectiveness of the developed program.

Thus, the order is executed, and the minimal expenses for 5 periods make 28 635 UAH.

One of the most difficult tasks of economic management is the preparation of a calendar plan of production in the conditions of a deficit of production capacities. Calculation algorithms of production programs or ERP-systems in most cases form plans only by the nomenclature and enlarged scheduled periods. In the future, these plans are hand-crafted by the scheduler manager, creating daily variable tasks. It is obvious that the quality and optimality of such a plan entirely depends on the experience of the specialist-planner.

The difficulty in finding an optimal work plan is due to many unknowns, which is why it is very difficult to write an algorithm even for a particular customer − in real work there are constantly situations, predict and formalize which in advance was impossible. These complexities increase many times when writing universal programs focused on a particular industry or type of production.

Setting up a task: In the firm «DIAMANT LTD» there is a plan of release for the range of products for a certain period (5 days), the company works in 2 changes. Production can be carried out simultaneously on 3 production lines. The re-adjustment of the line for release from one product to another requires some time, as indicated in the directory.

It is necessary to draw up a timetable for the issue of products by date-changes and lines, so that the total release was no less than the established nomenclature plan for the period.

It is understood that for algorithmic calculation only those products are used, the preparation of the forecast plan for which presents certain difficulties.

To calculate, we use an overview of the options implemented with the VBA program. Verification of conditions occurs using formulas of the worksheet.

We draw attention to the problem of restrictions on the selection of options. It is necessary to achieve the minimum number of unknowns in the task, and only then run the algorithm.

Thus, search restrictions are:

- Number of days and changes.
- Number of types of products manufactured (nomenclature).
- Number of production lines (sites).
- Possibility of producing certain products in certain areas.
- Time of work and time for equipment re-adjusting.
- Predefined task variables for specific dates and lines.

Guides and restrictions are set up in special tables − the cells are highlighted in green. When setting the time for redirection, you must specify all possible options for products manufactured for each production line.

Parameters

Days in plan	5
Change at the bottom	2
	10
Duration of change, h	8
Max duration of adjustment in changes, year	5
Lines	3

Legend:

Flour is oatmeal	A
Oatmeal flakes	B
Wheat flour	C
Macaroni	D
Croup is oatmeal	E
Oat bran	F

Product

	Line 1, kg / h	Line 2, kg / h	Line 3, kg / h
A	3	1	0
B	0	2	3
C	8	10	0
D	2	2	2
E	0	0	5
F	0	0	10
	ACD	ABCD	BDEF

ACCESSORY

Line 1

hour	A	B	C	D	E	F
A			3	3		
B						
C	2			3		
D	1		1			
E						
F						

Line 2

hour	A	B	C	D	E	F
A		2	2	2		
B	2		1,5	2,5		
C	2	2		3,5		
D	1	1	2			
E						
F						

Line 3

hour	A	B	C	D	E	F
A						
B				2	2	3
C						
D		3			4	3
E		2,5		3,5		1
F		4		1	2	

Fig.9 – Formation of a product release calendar

To launch the solution search algorithm, a special «Start» button is assigned.

PLAN

A	180
B	100
C	60
D	80
E	
F	100

PREVIOUSLY INSTALLED PLANS

Date	Change	Line 1	Line 2	Line 3
last state		C	B	B
13.11.18	1		B	
13.11.18	2	A		
14.11.18	1		B	
14.11.18	2	A	B	F
15.11.18	1	A		
15.11.18	2			
16.11.18	1			
16.11.18	2			
17.11.18	1	A		
17.11.18	2			

CALCULATION

Fig.10 − Generating a schedule for product release

The results of calculations are shown in the tables «Proposed release plan» and «Issue of products».

PROPOSED EXPANSION PLAN

Date	Change	Line 1	Line 2	Line 3	Changeover, year	
The last condition		C	B	B		
13.11.18	1		B	F		
13.11.18	2	A		D	3,0	3,0
14.11.18	1	D	B	D		
14.11.18	2	A	B	F	3,0	4,0
15.11.18	1	A		D	1,0	
15.11.18	2	D	C	D	4,5	
16.11.18	1	A	A			
16.11.18	2	A	A	B	3,0	3,0
17.11.18	1	A	A	B		
17.11.18	2	A	A	B	0,0	0,0

RELEASE ON PRODUCTS

	Issue, kg	Excess, kg	Control
A	**186**	6	0
B	**111**	11	0
C	**65**	5	0
D	**80**	0	0
E	**0**	0	0
F	**100**	0	0

Fig.11− Formation of a product release calendar

As a result of calculations, the following optimal production plan was obtained:

- On 13.11.18 for change I planned to use Line 2 for production of products B and line 3 for products F. The total time for adjustment is 3 hours. For the second change, it is planned to use Line 1 for production of products A and line 3 for products D. The total adjustment time is 3 hours.
- On November 14, 17th, for change I planned to use Line 1 for manufacturing products D, line 2 for production of products B and line 3 for products D. The total time for adjustment is 3 hours. For the second change, it is planned to use Line 1 for manufacturing products A, line 2 for the production of products B and line 3 for products F. The total time for adjustment is 4 hours.
- On 15.11.18 for change I planned to use Line 1 for the production of products A and line 3 for products D. The total time for adjustment is 1 hour. For the second change, it is planned to use Line 1 for the production of products D, line 2 for the production of products C and line 3 for products D. The total time for adjustment is 4.5 hours.
- On 16.11.18 for change I planned to use Line 1 and Line 2 for manufacturing products A. The total time for adjustment is 3 hours. For the second change, it is planned to use Line 1 and Line 2 for production of products A and line 3 for products B. The total time for adjustment is 3 hours.
- On 17.11.18 for changes I and II planned to use Line 1 and Line 2 for production of products A and line 3 for products B. The total time for reconfiguring for each change is 0 hours.

The quantity of products released for a period of (5 days) is: for products A - 186 kg, B - 111 kg, C - 65 kg, D - 80 kg, E - 0 kg and F - 100 kg. Consequently, the production plan is completed.

For the economist of the planning department, the use of this algorithm can increase understanding of the problems when compiling the production schedule and will allow replacing or facilitating the work of managers of production sites.

But there are significant drawbacks of the algorithm:

- Mandatory one-character encoding of the nomenclature. Moreover, it is necessary to use the English letters «A-Z».
- The search for the nomenclature only in one direction.
- There is no possibility to search alternative variants without specifying new restrictions.
- Lack of search time prediction. Approximately imagine the speed of work can only be visually, looking at changing options.
- The formulas used in the example with standard iterative calculations are very difficult to understand.

Conclusions and suggestions

On the basis of the data of the company LLC «Firm DIAMANT LTD» the models of the formation of the production program at the expense of economic-mathematical modeling were developed, namely:

1. Model of the optimal volume of a party (Wilson's model).
2. Model of multicriteria optimization of production capacity of the enterprise.
3. Model of optimal use of resources in production planning with maximizing the result.
4. Model of combinatorial minimization of losses.
5. Model of optimal allocation of resources (restrictions on the number of equipment, several periods).
6. Model of the formation of the calendar plan for the release of products.

Thus, the optimal decision regarding the choice of a particular version of the enterprise's production program is based on a system of interconnected criteria, among which: demand for products, level and dynamics of prices, own capabilities, that is, availability of production capacity and space, labor and material resources, and also, investment resources.

It is not necessary to speak about the definition of any particular model for planning a production program, since each of the analyzed models considers each segment of the planning of the production plan.

Implementation of this module will reduce the cost of time for recording, monitoring, searching and entering data, analyzing the flow of documentation. However, the need for the constant input of initial and operational information in a non-Microsoft Office Excel, an infinite search for the necessary data to fill out or view among a large number of files that store the information needed to work, will facilitate the work of employees of the planning and production departments.

The proposed configuration increases the growth rate of productivity and efficiency of the department as a whole.

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