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Production capacity optimization in cases of a new business line launching in a company

Optimización de la capacidad de producción en casos de lanzamiento de una nueva línea de negocio en una empresa

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ABSTRACT:
Situation of the country in the modern world depends not only on the possession of scientific knowledge; reflect the latest achievements of scientific and technological progress, but also on the ability to apply this knowledge in practice. High technologies play a huge role in the development of the economy and society. Formation and execution of the production program of high-tech enterprises should be carried out in accordance with established expertise, available production capacity and portfolio on high technology in general. This work analyses approaches to optimizing production capacity in cases of a new business line launching in a company. The idea of optimization is the effective involvement of production capacity with free effective time fund. Production capacity planning is based on factors, which affects its value. Improve the use of existing production capacity allow improving the organization of production, labor and management, as well as the intensification of production. In this paper the optimization model that takes into account the characteristics of high-tech enterprises, is created.
Keywords: Production capacity; optimization; high-tech companies; technical “rearmament”; production diversification; KPI.

RESUMEN:
1245/5000 La situación del país en el mundo moderno depende no solo de la posesión del conocimiento científico; reflejar los últimos logros del progreso científico y tecnológico, pero también sobre la capacidad de aplicar este conocimiento en la práctica. Las altas tecnologías juegan un papel muy importante en el desarrollo de la economía y la sociedad. La formación y ejecución del programa de producción de empresas de alta tecnología debe llevarse a cabo de acuerdo con la experiencia establecida, la capacidad de producción disponible y la cartera de alta tecnología en general. Este trabajo analiza los enfoques para optimizar la capacidad de producción en casos de lanzamiento de una nueva línea comercial en una empresa. La idea de la optimización es la participación efectiva de la capacidad de producción con un fondo de tiempo efectivo libre. La planificación de la capacidad de producción se basa en factores que afectan su valor. Mejorar el uso de la capacidad de producción existente permite mejorar la organización de la producción, el trabajo y la gestión, así como la intensificación de la producción. En este trabajo se crea el modelo de optimización que toma en cuenta las características de las empresas de alta tecnología.
Palabras clave: capacidad de producción; mejoramiento; empresas de alta tecnología; "rearme" técnico; diversificación de la producción; KPI.

1. Introduction

In current market conditions businesses are forced to conduct continuous work, connected to development and mastering new production technologies, implementation of new production activity organization schemes, security of new production release. Main aim of conducting these processes is company and product competitiveness increase to secure current market position and expand to new markets (Kolmakov et al, 2014). Matters of competitive product creation and perspective markets penetration is a key point of interest among economists, entrepreneurs and managers of all grades (Cantwell and Santagelo, 2000). Research on competitiveness management is connected to theoretical justification of different approaches to evaluate product, company or industry branch competitiveness, with background and mathematical proof of competitiveness management laws and with development and approbation of appropriate economic-mathematical models (Bhattacharya and Van den Bergh 2014; Bird 2011; Siedel and Haapio 2011). According to Chursin and Makarov (2015) creation and development of competitive advantages allows stable economic development of manufacturer by creating healthy conditions for goods and services, having fundamentally new consumer parameters, production, and also creating additional sales markets for such goods and services.

It is natural to assume, that companies do not always have the financial capability and economic justification to build a new manufacture. Certainly, in some cases (automobile factory, for example) new production line can be organized by ramping up production capacity. On the other hand, in case of need for new types of machinery production, optimization of product capacity becomes a key factor of competitiveness increase. Performance of a manufacturing company is not infrequently linked to the need of special, high-tech, and highly specialized equipment usage (Mensch, 1975; Schumpeter, 1926). Such equipment is often just partly used in production cycle of a company, but costs of production infrastructure maintenance (room heating, for example) and specialists' salary (the one who operates the machinery) are permanent for the company. On the other hand, production area can be occupied by equipment, which remained in working condition after production modernization. Effective time fund of such equipment could be also used just partially. In such case, company also has to conduct huge financial expenses, connected to production infrastructure and proper working conditions maintenance. Finally, manufacturers' production structure change, application of modern production technologies, increasing automation of manufacturing operations currently allow to complete production program using less volume of production capacity (Aydın and Takay, 2012).

Based on stated background to increase effectiveness of manufacturing capabilities of an enterprise usage we get a problem of optimal usage of liberated production capacity and need of fixed costs share decrease in operating profit structure of a company. One of the methods of such optimization is production diversification, which implies using companies' free production area, funds, workforce and other resources to create new types of product or carry out orders from other companies. Thereby a task to evaluate manufacturing capabilities of these area and resources (taking into account probable plan of their involvement) occurs. Solving the matter helps to develop effective scheme of production diversification. Resolution of this issue will be based on optimization model of manufacturing capabilities calculation, taking into account specific characteristics of production, modeling different scenarios of diversification using methods of imitational modeling and evaluation of diversifications' market effectiveness with the help of economic KPI of a company.

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2. Economic-mathematical model of production capacity optimization in a company

Manufacturing capabilities of a company (its' technological conversion) are expressed in maximum possible volume of production output in case of certain production target taking into account optimal companies' resource usage during considered period (Goedhuys and Srholec 2015).

It's natural to assume, that manufacturing capabilities' indicators are under influence of different factors, which can both decrease and increase their values. For instance, they can increase in case of technical "rearmament" and decrease in case of qualified staff lack.

Methods of manufacturing capabilities evaluation of a company or its' divisions can be based on data on staff, list of equipment, laboriousness of product manufacturing (reference examples, for instance) and following imitational modeling of production program with a possibility of a differentiated assortment structure review. Data specification can be different (depending on quantitative indicators available), so that modeling can be implemented by some enlarged product groups.

Based on data on equipment and cadre, limits of effective working time fund are assessed. Then a model is formed, that should have maximum possible volume of production under stated limits on effective working time fund during a certain period as a result. Maximization of equipment working time can be the objective function of this model. Ergo, initial data for optimal usage of production capacity model will be as follows:

$$S_i = d \cdot t \cdot k \cdot n$$

Where

d – working days in considered period

t – working mode (duration of shift considering quantity of shifts)

k – correction on equipment adjustment, service

n – quantity of equipment units

S_i – effective equipment working fund type .

Specialists' compound should match the types of equipment. Planned effective working time fund equals total duration of workers' shifts in considered period. Planned effective fund is decreased by correctional coefficient, which considers time loss, connected to workers' activity. Thus, we acquire

$$T_i \text{ ,}$$

that expresses planned working time fund considering losses.

Based on limits on equipment and staff the value of manufacturing operation effective time fund is acquired, using the formula below:

$$b_i = \min(S_i, T_i) \cdot$$

Values a_{ij} (i - equipment type, j - product type) of each manufacturing operation duration are also preassigned. Values a_{ij} constitute matrix A, where number of rows – quantity of equipment types, number of columns – quantity of products.

Let manufacturing capabilities of a factory (workshop, line) be evaluated based on calculation of maximum production volume possible, where assortment is represented by products, that match $Q_1, Q_2, ..., Q_N$, where Q_i - unit quantity of each type of product. Laboriousness of production is a known value for each type of product.

Objective function of a task is maximization of equipment (staff) working time, namely available effective working time funds involvement maximization:

$$a'Q \to \max,$$
$$\begin{cases} AQ = b, \\ Q \in \mathbb{Z}_+ \end{cases}$$

where Q - column vector, that matches sought-for values of optimal output of each type of product,

a - column vector, that matches total laboriousness of product manufacturing,

b - column vector, that matches effective time fund by each manufacturing operation.

Optimization model presented is of theoretical type, and its' usage in production is conjugated with a number of difficulties. Thus an adaptation of this model to high-tech product, whose mission is to provide competitiveness increase of a company, is needed. Thereby, let us describe the specifics of production and approaches to improve economic-mathematical model.

An objective of current interest in cases of manufacturing capabilities of high-tech production optimization is technical "rearmament" factors (which, as a rule, happen simultaneously to production program realization), assortment change, untimely hardware arrival, postponed production, equipment break and need in intensive fulfillment of a certain manufacturing operation factors registration. Moreover, to define correct value of each product type manufacture laboriousness (with division into all necessary manufacturing operations) it is often needed to conduct extra research, that can be of continuous nature.

Considering this, in case of optimal production capacity model usage it is convenient to use interval marks of production laboriousness values, and also interval marks of effective time funds. Thus, these marks can take any value from a certain preassigned interval. Herewith density of values distribution inside these intervals is unknown due to random nature of mentioned factors manifestation. That's why using averaging procedures, accepted in stochastic programming, and transfer to determined models seems challenging. Solving interval task in our case can be found as acceptable determined solution for the whole totality of linear programming tasks, acquired by using different combinations of model parameters, taken from appropriate intervals.

Ergo, interval task of linear programming for model of production capacity optimization looks as follows:

$$a'Q \to \max,$$
$$\begin{cases} AQ = b, \\ |A - A_0| \le \Delta A, \\ |b - b_0| \le \Delta b, \\ |a - a_0| \le \Delta a, \\ Q \in \mathbb{Z}_+ \end{cases}$$

Values $A_0,\ \Delta A,\ b_0,\ \Delta b,\ a_0,\ \Delta a$ are preassigned and determine intervals, where parameters of the models can be.

Let us justify the existence of solution for optimization interval task.

Let ε - be the vector of negative residual. Solution Q of interval task is its' ε - plan, if $|AQ - b| \le \varepsilon$ for all possible values of laboriousness and effective time. In Azshepkov and Davydov (2006) shows, that such vector Q will be ε - plan of optimization task solution, if it complies to following conditions:

$$\begin{cases} -\underline{A}Q + \overline{b} \le \varepsilon, \\ \overline{A}Q - \underline{b} \le \varepsilon, \\ Q \in \mathbb{Z}_+, \end{cases}$$

where $\overline{A}, \overline{b}, \underline{A}, \underline{b}$ - highest and lowest grades of corresponding parameters.

Interval task of linear programming looks as follows:

$$a'Q \to \max,$$
$$\begin{cases} -\underline{A}Q + \overline{b} \le \varepsilon, \\ \overline{A}Q - \underline{b} \le \varepsilon, \\ Q \in \mathbb{Z}_+, \end{cases} \qquad (*)$$

Discrepancy of ε task is an unknown value, and its' rough evaluation can lead to optimal solution loss or to incompatibility of inequality-constraints. To avoid such situation an auxiliary linear programming task should be formed, that could help determine minimum discrepancy. Minimum discrepancy (norm) can be found assuming the conditions $\varepsilon_{\min} \to \min,\ e'\varepsilon - \varepsilon_{\min} \le 0$, where e - is a single vector. After finding minimum discrepancy $\tilde{\varepsilon}_{\min}$ it becomes possible to find optimal solution for basic optimization task, as of below:

$$
a'Q \to \max,
\begin{cases}
-\underline{A}Q + \overline{b} \le \varepsilon, \\
\overline{A}Q - \underline{b} \le \varepsilon, \\
e'\varepsilon - \tilde{\varepsilon}_{\min} \le 0, \\
\varepsilon \ge 0, \\
Q \in \mathbb{Z}_+,
\end{cases}
$$

Limitation of plurality of optimal task solution comes from its' conditions (effective time funds on each manufacturing operation are limited). Solution existence for optimization tasks as mentioned is justified in (Vasilyev and Ivanitskiy 1998), and it could be found using standard M - method of linear programming tasks solution.

Maximum possible output volume $Q_1, Q_2, \ldots, Q_N$ (fully using effective time funds during considered period) will be the calculation result for proposed model. **N.B.** It is possible to supplement optimization task by limits for certain product type output volume.

Using imitational modeling makes it possible to evaluate production capacity for different product assortments in conditions of laboriousness value change and limits on effective time funds. It is also possible to superposition conditions (equalities and inequalities) to produced quantity of a certain type of product. Let us show, how to consider factors of technical "rearmament" of production, using current model. To do that we need to form an imitational modeling task as follows below. Let us consider, that to increase production effectiveness we raise a question of equipment change (the one that is needed to complete the operation B_i). We need to calculate effective and actual working time fund for this operation in case of using new equipment. Thus, we determine new operation laboriousness values (the ones, conducted on this equipment) and prepare optimal output calculation considering new effective working time fund values for this operation. Manufacturing capability evaluation of free area allows optimization stages planning for production capacity optimization in a company, and also helps estimate the need for new equipment and extra workforce.

Diversification measures effectiveness with consideration of planned product assortment structure choice can be estimated using standard operating profit indicator, which is calculated as follows:

$$
EBIT = \sum_{i=1}^{N} (p_i - v_i) Q_i - FC,
$$

where N –product type quantity, p_i – unit cost of a certain product type, i, v_i – variable costs of production per unit of i product, FC – fixed production costs.

3. Example of high-tech company production capacity optimization

Let us suppose that a company has free effective equipment and workforce working time funds. We need to provide optimal charge for free production capacity to increase operating profit. Period of calculation for current example – 1 month.

Management of the company set up 7 types of product, which can be manufactured using free production capacity. Let us fix output volume, matching these product types, through $Q_1, Q_2, \ldots, Q_7$. Let us suppose, that using production area we can complete 10 different types of manufacturing operations, and effective working type for these operations is marked by $b_1, \ldots, b_{10}$.

Let us assume, that management of the company determined 2 satisfactory production assortment types (in their point of view), that could provide charge of free production capacity:

$$\Theta_1 = \{Q_1, Q_2, Q_3, Q_4, Q_5\},$$
$$\Theta_2 = \{Q_1, Q_3, Q_4, Q_6, Q_7\}.$$

Then let us show interval manufacturing operations completion time and effective time funds assessment per each type of manufacturing operation. We present our assessment in form of matrix (Tab. 1; Tab. 2) and vectors (Tab. 3), describing interval limits below and above.

Table 1. Matrix $\underline{A}$

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
Q_1	2	0.9	0.7	0.5	3	0	0	0	0.4	1
Q_2	1	1.2	1.4	2	1.1	1.5	1.2	1.4	1	1
Q_3	1.8	1.7	1.4	1.3	2.2	2.7	2.4	2.0	1.1	3
Q_4	2.5	3.1	2.1	0	0	0	1.2	2.4	1.2	1.1
Q_5	1.1	2.4	0	1.3	0	1.1	0	0	2.1	2.1
Q_6	2.1	2.2	2.1	1	1	2.1	0	2.1	2.4	1.1
Q_7	3.2	3.2	2.3	1.4	1.7	3	3.1	2.2	1.7	2.4

Table 2. Matrix $\overline{A}$

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
Q_1	2.7	1.9	1.3	1.5	3.4	0	0	0	0.7	1.3
Q_2	1.5	1.8	1.9	2.2	1.7	1.8	1.9	1.4	1.6	1.4
Q_3	2.5	2.7	1.9	1.8	2.5	2.7	2.5	2.6	1.4	3.8
Q_4	2.9	3.6	2.7	0	0	0	1.8	2.8	1.5	1.8
Q_5	1.4	2.7	0	1.6	0	1.7	0	0	2.8	2.5
Q_6	2.4	2.7	2.5	1.4	1.2	2.4	0	2.3	2.7	1.7
Q_7	3.8	3.7	2.6	1.7	1.9	3.3	3.2	2.7	1.9	2.9

Table 3. Vectors $\underline{b}, \overline{b}$

	$\underline{b}$	$\overline{b}$
b_1	125	156
b_2	89	132
b_3	117	124
b_4	132	176
b_5	107	134
b_6	115	143
b_7	120	155
b_8	136	160
[illegible]	[illegible]	[illegible]

b_9	117	135
b_{10}	96	109

Cost p and variable costs v of 1 unit of each product type are presented in Table 4 below. There we can also see aggregated laboriousness estimation a for each product type preparation.

Table 4. Cost p and variable costs v of 1 unit of each product type (conventional units)

	p_i	v_i	$\underline{a}$	$\overline{a}$
Q_1	100	45	8.5	12.8
Q_2	85	34	12.8	17.2
Q_3	115	45	19.6	24.4
Q_4	87	20	13.6	17.1
Q_5	145	75	10.1	12.7
Q_6	112	60	16.1	19.3
Q_7	95	44	24.2	27.7

Finally, fixed costs value for considered production equals $FC = 2350$.

Linear programming interval task is marked as (*) for each assortment Θ_1, Θ_2.. Further, let us present solutions, acquired using method, described above. Ergo, optimization function for first assortment reaches maximum of 1138.2 in case of reaching the following output volume:

$$Q_1 = 11, Q_2 = 35, Q_3 = 18, Q_4 = 8, Q_5 = 3.$$

Optimization function for second assortment reaches maximum of 1291.6 in case of reaching the following output volume:

$$Q_1 = 9, Q_3 = 13, Q_4 = 11, Q_6 = 22, Q_7 = 14.$$

After that, we need to calculate operating profit of the company (the one, that occurs due to new product types output) to make conclusions on market effectiveness of production capacity optimization.

Ergo, first product assortment allows to provide significant operating profit and its' usage is more effective in case of production area optimization.

4. Conclusion

Current research reviews approaches to production capacity optimization in cases of a new business line launching in a company. The idea of optimization was to use production capacity, which has free effective time fund, effectively. An optimization task was formed; solution to this task is set as optimal output volume, which allows providing maximum operating profit. Outstanding characteristics of high-tech companies were considered in process of optimization model creation.

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