MATHEMATICAL MODELING AND COMPUTING, Vol. 8, No. 1, pp. 78–88 (2021)

Modeling of production processes with regeneration for ensuring enterprise competitiveness

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(Received 4 May 2020; Revised 17 December 2020; Accepted 12 January 2021)

The article presents the research and rationale of theoretical issues and applied decisions regarding the influence of enterprises and the mechanism of managing production processes with regeneration (renovation) on the competitiveness. Mathematical tools were developed and methods for calculating basic economic indicators were suggested, namely, the starting factors and direct regulatory costs for materials; the economic and mathematical model of production processes with regeneration was designed, which allows comparing the output of production with the cost of its manufacturing and the improvements of the competitiveness of strategically important enterprises.

Keywords: *production processes with regeneration, enterprise competitiveness, modeling, mathematical tools, starting factor, material costs.*

2010 MSC: 49K10, 93B15 **DOI:** 10.23939/mmc2021.01.078

1. Introduction

In the current competitive environment and in the global industrial market the effectiveness of domestic enterprises depends on their ability to take full advantage of their competitors. Therefore, in the implementation of competition policy, the production and management activities of Ukrainian enterprises should, first and foremost, be subordinated to the production of quality goods with specified technical and economic characteristics in the required quantity, when the manufacturer decides on such a level of goods quality which would strengthen its position in the target market.

In such circumstances, it is necessary to identify sound ways of forming and improving the competitiveness of domestic enterprises for their further development, which will allow them to become more attractive for investments and, as a consequence, to compete with foreign firms in the European market.

Studies of the essence of enterprise competitiveness, the methods of its definition, and the ways of its improvement have been reflected in the works of many well-known foreign and Ukrainian scientists, whose large number and variety of publications testify to the complexity of these issues (Lamben, 2004; Porter, 2000; Azoev & Chelenkov, 2000; Vovchak & Kamyshnikov, 2005) [1–4].

Thus, Jean-Jacques Lamben (2004) [1] distinguishes competitiveness of the enterprise as the opportunity to meet the needs of customers better than competitors. Analysing this type of competitiveness, the most important thing is to determine the type of competitive advantage which is provided by three groups of factors:

- excellent quality of goods, which is of highest value to customers;
- low costs for their production;
- key "competences" that create unique value for consumers.

It is common that the competitiveness of an enterprise is both its ability to achieve certain goals of activity in all alternative strategic directions formed on the basis of the same type of groups of available and potential consumer needs which the enterprise satisfies with the results of its activity, and the technologies that provide the necessary level of competitive advantages in products and resources markets. One can assume from the definition that the competitiveness of an enterprise is ensured by the competitive products produced by the enterprise.

Competitiveness of goods and services is a set of consumer properties of products, which provides the ability of an enterprise to compete with analogues in a competitive market in a certain period of time (Moroz & Chukhray, 2005) [5]. If it is necessary to increase the competitiveness of an enterprise, it is necessary to increase the competitiveness of its products, which can be done by developing a fundamentally new type of products that has no analogues, that is, to develop innovative products.

Thus, today the competitiveness of an enterprise is a complex indicator because it is influenced not only by the factor of product competitiveness but also by other factors (Moroz & Adelshinova, 2008) [6]. The competitiveness indicator of an enterprise includes the following indicators: product competitiveness, competitiveness of communications of the enterprise and competitiveness of personnel. This is due to the fact that in order to determine the competitiveness of the enterprise by and large, one needs to examine the enterprise from all sides.

Therefore, the choice of effective management decisions in the enterprise is impossible without a thorough detailed analysis of the complex of interdependent components, as well as the identification and comparative assessment of possible alternatives and plausible action plans. Consequently, mathematical methods have been widely used in managerial decision-making. In this aspect a range of researchers should be mentioned, namely, Johann von Neumann, George Dantzig, Wasily Leontief, Leonid Kantorovich, Viktor Glushkov, Serhiy Zhdanov, Aleksandr Golikov. They made a significant contribution into the development of economic and mathematical models and the development of mathematical tools in the adoption of economic decisions in the production activity of enterprises.

The mathematical model of any production process is a system of relations that determine the dependence of the characteristics of passing processes on their parameters and time. For the mathematical model to satisfy the necessary requirements of production and maintain the permissible state of competitiveness of the studied enterprise, it should be built on the basis of economic theory, the existing process of organizing production and appropriate mathematical tools. Thus, the economic and mathematical model of the production process is a theoretical rationale for the mathematical reflection of the processes under consideration. It is obvious that mathematical model cannot give a complete reflection of the studied phenomena and patterns since it helps to establish only the most significant relationships that affect the efficiency of production. Modeling can solve complex issues that are not practically solved by traditional methods. On the other hand, the construction of the economic and mathematical model inevitably evolves the issue of its complexity degree, the structural features, in particular the factors and the nature of the relationship between them, the availability of reliable background information, as well as the requirements for the level of accuracy of the calculated parameters.

The search for the opportunities and ways to save resources and reduce production costs in times of economic crisis are at the forefront of many businesses. Therefore, cost accounting for production occupies a special place in the management system of any enterprise.

In the conditions of electronic, radio engineering, mechanical engineering and other industries, where the use of regeneration (renewable) processes is expedient and possible, there is the task of determining increasing regulatory costs of production taking into account the coefficients of technological losses and regeneration at each technological operation of the main production process with differentiation between "total", "suitable for products" and "non-renewable technological losses".

Nowadays a large number of theoretical works and results of practical logistics activities have been accumulated, which consider the issues of planning, management and control of material flows of production activity of enterprises. The development of the calculation of needs for material resources and the normalization of their costs, as well as the normalization and management of inventory are considered to be the most effective (Moroz, 2017; Greshchak, Gordienko & Kotsyuba, 2008; Krushelnytska, 2007; Turylo, Kravchuk & Turylo, 2006; Johnson, Wood, Wardlow & Murphy, 2002; Oklander & Khromov, 2004; Pokropivny, 2006; Trydid & Tankov, 2005) [7–14].

2. Theoretical background

In the overall set of measures to improve the efficiency of social production and the state of its competitiveness, the rational and economical use of material and labor resources are to be given due attention. In today's conditions of management it is necessary to establish a constant work to identify the available reserves of material and labor resources economy. This can be achieved by:

- further implementation of innovative technological processes;
- continuous improvement of the manufacturability of the designed and manufactured products as a basis for increasing the percentage of suitable products output;
- achievement of a single percentage of the output of suitable products for duplicate products;
- use of production wastes and regeneration processes (product recovery) as sources of additional resources;
- improvement of normalization processes.

To fulfill this condition, the production process at the enterprise should be characterized by the following:

- some technological processes should have an inherent lack of controllability, resulting in significant technological losses;
- techniques for regeneration of a significant part of technological losses should be known.

3. Research objective and methodology

One of the important conditions for researching any production process and solving its practical problems is building a model of this process. To create a model of production processes with regeneration, as well as to obtain a model of any production, it is necessary to develop a model of the whole system and its individual subsystems with the output parameters characteristic of the production, that is, to obtain a set of indicators that allow to compare production results with the cost of resources.

3.1. Modeling of production processes with regeneration

The purpose of this study is to build a model of the production process with regeneration on the example of assembly production which can formally be represented as a series of sequential and parallel circuits reflecting the operations of the main production and regeneration processes (Fig. 1).

Semi-finished products that come in every technological operation of the main production process, being conditioned at its output, are transferred to the next operation or otherwise, (i.e. in the event of loss of conditioning) are further considered as technological losses that may be restored or not. The recycled semi-finished products are subjected to the operations of a regeneration process, which in its turn represents a series of sequential operations, at the output of each of which there can be obtained conditioning (recovered) or sub-standard (non-recovered) semi-finished products.

Recycled semi-finished products are transferred to the further operations of the regeneration process until the final completion of the regeneration and their relocation for the operations of the main technological process. Sub-standard semi-finished products, which are subjected to regeneration operations, are treated as technological losses, which are also differentiated into final and recoverable in terms of regeneration. The latter come back to the first operation of the regeneration process for restoration. With respect to each regeneration process, its initial and final points of the main production process are recorded, i.e. the semi-finished products to be recovered (from where) and the semi-finished product having been recovered (where to). Usually technological losses are recorded either at each operation of the basic production process, or at the control operations of sites. The recycled semi-finished product is returned to a specific technological operation to be included in the main production process. There may be several (where) positions regarding the same regeneration process; there is one position into which the returned semi-finished products go.

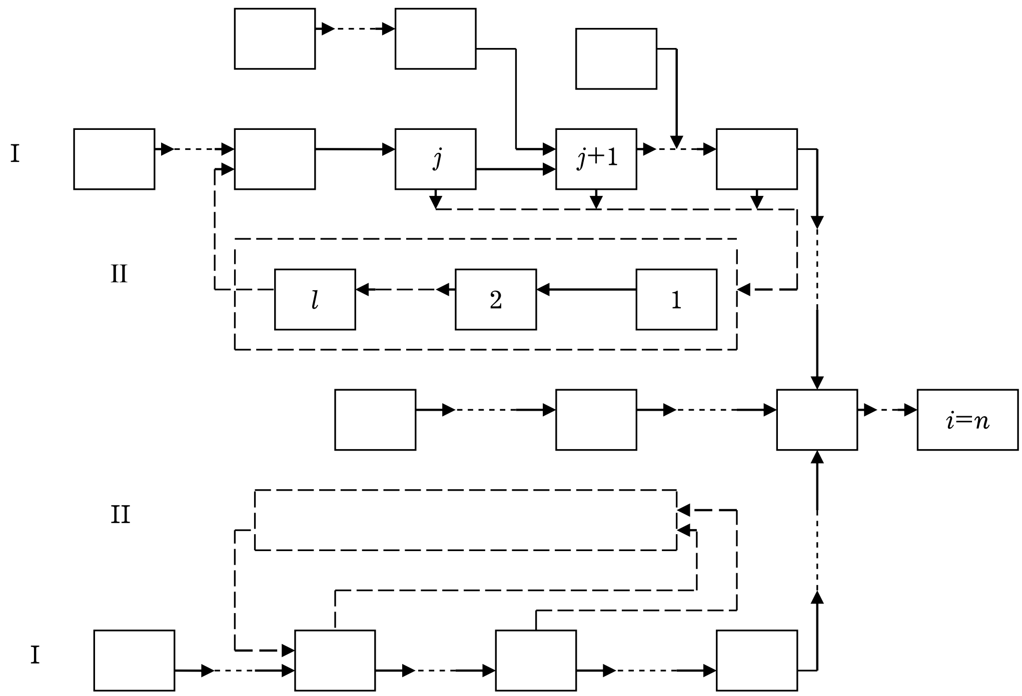

Fig. 1. Formalized model of production process with regeneration: I are fragments of the main production process: $(0, \ldots, j-1, j, j+1, \ldots, i=n)$ technological operations of the main production process; II is regeneration process: $(1, 2, \ldots, l)$ technological operations of the regeneration process; □ are operations of the basic production and regeneration processes; ⟶ is the trajectory of the conditioned semi-finished products movement; --→ is the trajectory of the semi-finished products, namely those which are being regenerated and those having been regenerated.

3.2. Determination of direct regulatory material costs of production processes with regeneration

In the management system of any enterprise the accounting of production costs occupies a certain place, as the operational information on production costs reflects the production and economic activities of the enterprise and serves to perform various managerial functions. Therefore, before taking into account production costs and calculating the cost of production, one should set the task to increase the efficiency of the information presented and to improve its quality.

Timely provision of the enterprise management bodies with complete and accurate information on the regulatory costs of production at all technological operations is an important prerequisite for production and economic activity of the enterprise. Herewith, the data on regulatory costs should reflect the value of costs not only for each individual technological operation, but also for all previous ones. Not knowing the cost of implementation of individual technological processes and the cost of parts and components, it is impossible to accurately determine the cost of finished products. It is the localization of information, the reflection of the stage manner of production in it and the nature of rising costs which contribute to the conditions for quality information. The availability of information of this kind is necessary for proper assessment of the economic efficiency for various organizational and technical decisions and for the construction of an effective system of internal enterprise control.

Information on regulatory costs of production is characterized by a large volume of raw data, close interrelation and interconnection of most indicators, as well as their frequent updating. In any production the regulatory costs for the manufacture of parts, semi-finished products and articles consist of the costs that occurred in the operation (local) and the costs that occurred in all previous operations (attached). In the manufacture of assembly joints (semi-finished products, products), in addition to the costs incurred in previous operations and the costs of acceding ones, also the cost of manufacturing of all input parts and semi-finished products is included. The order of increasing regulatory costs is determined by the sequence of entry of the relevant parts and semi-finished products into the assembly connections up to finished products according to technological routes.

Thus, for the preparation of qualitative regulatory calculations it is necessary and sufficient to know the amount of local costs for each operation, to find out the order of arrangement of all links of the production process chain, the items that are included and formed; to determine the size of the associated costs and the incremental costs attributable to each item, bearing in mind that they represent the sum of the corresponding local and attached costs.

Finding the values of the considered indicators is further complicated by the fact that the calculation of direct regulatory costs for different calculation items is carried out on a fundamentally different basis. In particular, direct material costs are determined by the standards of costs for all products, and direct labor costs are based on the eligible products of each workplace since only eligible products are payable.

On the basis of the standards of material and labor costs being developed, regulatory calculations are made for parts, components and products in general. In the conditions of application of regeneration processes, the organization of regulatory accounting of costs and costing of production is significantly different from simple approaches and requires some development.

4. Results and discussion

Production costs are generated in the process of formation and use of resources to achieve a specific goal of the enterprise. They are known to have different purposes and are reproduced in natural and cost form. If the planning and cost accounting in natural kind (quantity, mass, volume, etc.) are important for the organization of the enterprise, the cost form is crucial for evaluating the results of the enterprise, because the monetary cost estimate reflects the cost of production of the enterprise. Moreover, an important aspect of cost management in quantifying their savings is the comparison of actual costs with the norms, the difference between which forms deviations and their analysis allows to evaluate each cause or factor that led to these deviations.

But it should be noted that all the experience in the management of material costs do not consider the specifics of industries (such as electronic, radio), where the technological losses and output of suitable products are planned and the possibility of using regeneration (renewable) processes are not taken into account.

4.1. Formation of innovative approaches and models of material cost management of production processes with regeneration

Studies of theoretical and applied problems of material and financial flows of in-house logistics systems movement (Moroz, 2009) [15] determine the following aims and objectives:

- to investigate the behavior of specific logistic systems that use regeneration (renewable) processes;
- to establish dependencies that allow to determine the normative material costs of each semi-finished product per unit of (final) production or per unit of higher-grade semi-finished product in logistics systems, taking into account technological loss coefficients and regeneration coefficients.

On this basis, we consider the in-house logistics system, both loss-free and loss-adjusted, with a view to regeneration (renewable) processes, which is designed to manage and optimize material and related financial flows in the production, supply and marketing process and which is detailed to production units of the enterprise, namely, to workshops, working sections and workplaces (Fig. 1) (Moroz, 2016) [16].

The initial data to the quantitative solution of the task are: k_j is the normative coefficient of technological losses (on the input) on the j operation of the main production process, which expresses the ratio of the difference between the corresponding quantities of output and conditioned semi-finished products of this operation to the number of output semi-finished products ($j = 0, 1, 2, \ldots, n$); k'_j is the normative coefficient of technological losses (at the input) on the j operation of the regeneration process ($j = 1, 2, \ldots, l$); r_j is the normative coefficient of regeneration of the j operation of the main production process ($j = 0, 1, 2, \ldots, n$); r'_j is the normative coefficient of regeneration of the j operation of regeneration process ($j = 1, 2, \ldots, l$); λ_{j-1}, λ_j represent local regulatory material costs per unit of the $(j-1)$, j items in monetary terms, $n_{j-1,j}$ is the cost rate of the $(j-1)$ of the item that is included in the unit of the j formed item (the cost per unit of regulation based on waste); $\lambda_j = \sum_{i(j)} n_{i(j)} c_i$, where $n_{i(j)}$ is the rate of cost of a position included in the unit of the j formed item without taking into account technological losses; $c_i$is the price of the i material resource.

It is necessary to determine increasing regulatory material costs, taking into account technological losses coefficients (k_j) and the regeneration ratios (r_j) per unit of the j formed item (Q_i) on the differentiation of materials, namely, for "the suitable products", "total" and "the non-renewable materials in technological losses".

The condition for obtaining full information on the regulatory costs of production presupposes the availability of information about the nomenclature and the order of placement of individual semi-finished products, parts and units in the assembly connection before completion of assembly of finished products, as well as calculated coefficients of startup with regard to regeneration (Moroz, 2017) [7]:

$$m_0 = \frac{1 - q_2}{q_0}, \tag{1}$$

where

$$q_2 = \frac{q_1 q'_0}{1 - q'_1}, \tag{2}$$

$$q_0 = \prod_{\alpha=j}^{n} (1 - k_\alpha), \tag{3}$$

$$q_1 = \sum_{\beta=j}^{n} k_\beta r_\beta \prod_{\alpha=j}^{\beta-1} (1 - k_\alpha), \tag{4}$$

$$q'_1 = \sum_{\beta=1}^{l} k'_\beta r'_\beta \prod_{\alpha=1}^{\beta-1} (1 - k'_\alpha), \tag{5}$$

$$q'_0 = \prod_{\alpha=1}^{l} (1 - k'_\alpha), \tag{6}$$

where m_0 is the initial factor of the original semi-finished product; q_2 is the coefficient of complete regeneration of the main production and regeneration processes; q_0 is the output coefficient of suitable products in the main production chain; q_1 is the coefficient of recovery of technological losses in the main production chain; q'_1 is the coefficient of recovery of technological losses in the regeneration chain; q'_0 is the coefficient of output of suitable products in the regeneration chain.

If the regeneration process operates without losses, then:

$$m_0 = \frac{1 - q_1}{q_0}. \tag{7}$$

For such systems, incremental regulatory costs for non-regenerative materials Q_j are the sum of local (λ_j) and adjusted costs ($\sum_{j-1}^{j} \lambda_{j-1} n_{j-1,j}$), which are equal to the sum of the product of incremental costs of the $(j-1)$ items directly included in the j's formed item, by the corresponding unit cost of the ($n_{j-1,j}$) waste-based valuation where the sum extends to all previous items.

Therefore, for the initial position ($j = 1$), which has no associated material costs, we have:

$$Q_1^{\text{good}} = \lambda_1;$$

for the second item ($j = 2$)

$$Q_2^{\text{good}} = Q_1^{\text{good}} \cdot n_{1,2} + \lambda_2; \tag{8}$$

for third item ($j = 3$)

$$Q_3^{\text{good}} = Q_2^{\text{good}} \cdot n_{2,3} + \lambda_3. \tag{9}$$

In this case, for any j formed item that is not affected by regeneration (e.g., auxiliary materials), we have:

$$Q_j^{\text{good}} = Q_{j-1}^{\text{good}} \cdot n_{j-1,j} + \lambda_j = \sum_{j-1}^{j} \lambda_{j-1} n_{j-1,j} + \lambda_j, \tag{10}$$

where Q_j^{good} is the increasing regulatory costs for materials per unit of the j formed item (for eligible products); Q_{j-1}^{good} is the increasing regulatory costs for materials per unit of the $(j-1)$ initial item; λ_{j-1}, λ_j is the local regulatory material costs, respectively, per unit of $(j-1)$, j item in value terms, $n_{j-1,j}$ is the rate of cost of the $(j-1)$ input item per unit of the j generated item (unit cost of waste).

If the entry is an assembly unit, a part, a semi-finished product or a product, where $n_{j-1,j} = 1$, then $Q_j^{\text{good}} = Q_{j-1}^{\text{good}} + \lambda_j$. Increasing regulatory material costs with regeneration per unit of the j formed item (total) (Q_j) are calculated by the formula:

$$Q_j = \left(S_{j,0} + \sum_{j+1}^{n} S_{j+1,1} \right) \frac{1}{m_{j,n}}, \tag{11}$$

where $m_{j,n}$ is the starting coefficient of the input unregenerated item (by the output); $m_{j,n} = \frac{1}{\prod_{\alpha=j+1}^{n}(1-k_\alpha)}$; $S_{j,0}$ is the increasing regulatory material costs that are included in the material costs of $m_{j,n}$ units of the j item

$$\begin{aligned} S_{j,0} &= \sum_{\alpha=2}^{j} \lambda_{\alpha-1} m_{\alpha-1,n} + \lambda_j m_{j-1,n} + \sum_{\beta} (m_{\text{reg}})_\beta (\lambda_{\text{reg}})_\beta \\ &= S_{j-1,0} + \sum_{\alpha=j-1}^{j} \lambda_\alpha m_\alpha + \lambda_j m_{j-1,n} + \sum_{\beta} (m_{\text{reg}})_\beta (\lambda_{\text{reg}})_\beta. \end{aligned} \tag{12}$$

The sum $\sum_{\alpha=2}^{j} \lambda_{\alpha-1} m_{\alpha-1,n}$ extends to the input items that preceded the formed j item, and the amount $\lambda_j m_{j-1,n}$ is the local regulatory material costs of the j formed item; $m_{j-1,n}$ is for the starting input coefficient of the $(j-1)$ non-regenerated positions (by input). The sum $\sum_\beta (m_{\text{reg}})_\beta (\lambda_{\text{reg}})_\beta$ relates to the regeneration chains (β) from which the regenerated semi-finished products are returned for specific operations of the main production process.

In the absence of data on the site of regeneration the amount

$$\sum_{\beta} (m_{\text{reg}})_\beta (\lambda_{\text{reg}})_\beta = 0. \tag{13}$$

Then

$$S_{j,0} = \sum_{2}^{j} \lambda_{j-1} m_{j-1,n} + \lambda_j m_{j-1,n} = S_{j-1,0} + \sum_{\alpha-j-1}^{j} \lambda_\alpha m_\alpha + \lambda_j m_{j-1,n}. \tag{14}$$

The item under consideration is influenced not only by the entry and by-products, but also by the subsequent ones, because after exiting for the regeneration and returning from it, the recovered semi-finished products contain material and labor costs of the $(j+1)$, $(j+2)$ and other subsequent positions.

We determine the contribution of the cost of the j item to the succeeding one $(j+1)$. Due to technological losses and regeneration at the $(j+1)$ item, the contribution to the j item from the sum $(S_{j+1,0}-S_{j,0})$ of local regulatory material costs of the $(j+1)$ item and the side chain passing through the $(j+1)$ item will be

$$\frac{(S_{j+1,0}-S_{j,0})k_{j+1}r_{j+1}}{1-k_{j+1}+k_{j+1}r_{j+1}}, \tag{15}$$

and some of the costs transferred to the $(j+2)$ item will equal

$$(S_{j+1,0}-S_{j,0})\frac{1-k_{j+1}}{1-k_{j+1}+k_{j+1}r_{j+1}}. \tag{16}$$

Due to losses and regeneration on the $(j+2)$ item the additional contribution to the expenses of the j item will be

$$(S_{j+1,0}-S_{j,0})\frac{1-k_{j+1}}{1-k_{j+1}+k_{j+1}r_{j+1}}\cdot\frac{k_{j+2}r_{j+2}}{1-k_{J+2}+k_{j+2}r_{j+2}}. \tag{17}$$

As we continue the process, we find that the total contribution of the $(j+1)$ and all incoming side items to the material costs of the j item $(S_{j+1,1})$ is equal to

$$S_{j+1,1}=(S_{j+1,0}-S_{j,0})\cdot t_{j+1}, \tag{18}$$

where $(S_{j+1,0}-S_{j,0})$ is the sum of local material costs of the $(j+1)$ item and the side chain going through the $(j+1)$ item; t_{j+1} is the estimated coefficient of a particular chain, taking into account the coefficients of technological losses and regeneration on it:

$$\begin{aligned} t_{j+1} = {} & \frac{k_{j+1}r_{j+1}}{1-k_{j+1}+k_{j+1}r_{j+1}}+\frac{(1-k_{j+1})k_{j+2}r_{j+2}}{(1-k_{j+1}+k_{j+1}r_{j+1})(1-k_{j+2}+k_{j+2}r_{j+2})}+\ldots \\ & +\frac{1}{1-k_{j+1}+k_{j+1}r_{j+1}}\sum_{\alpha=j+1}^{n}k_\alpha r_\alpha\prod_{\beta=\alpha-1}^{\alpha}\frac{1-k_\beta}{1-k_{\beta+1}+k_{\beta+1}r_{\beta+1}}, \end{aligned} \tag{19}$$

where α corresponds the items, that follow the j item and those that are regenerated (restored). Then, on the basis of the dependencies obtained, the increasing regulatory material costs, taking into account the regeneration per unit of the j formed item (total) will be equal to (Q_j), look (11).

Based on the obtained dependencies (Q_j, Q_j^{good}) the incremental regulatory costs for materials in technological losses (total) (U_j^Q) per unit of the j formed item will be equal $U_j^Q=Q_j-Q_j^{\text{good}}$, where Q_j is the increasing regulatory material costs with the account of the regeneration per unit of the j formed item (total); Q_j^{good} is the increasing regulatory material costs per unit of the j formed item (for finished product).

In the conditions of real assembly production (radio engineering, electronic industry) not only products, semi-finished products, but also raw materials, materials (technological air, water, phosphorus suspension, colloidal graphite suspension, coagulants, etc.) are involved in process for which to $k_j=0; r_j=0$, and calculations of intermediate and final results are not carried out, therefore in the table there is a sign "–". The results of calculations by formulas (10)–(19) are given in Table 1.

Table 1. Intermediate and final results of assessments of direct increasing standard material costs.

Number position j	k_j	r_j	λ_j	$n_{j-1,j}$	$\lambda_{j-1}n_{j-1,j}$	Q_j^{good}
1	*2*	*3*	*4*	*5*	*6*	*7*
1	0.00	0.00	27.40	1.00	27.40	2330.74
2	0.00	0.00	0.00	1.00	0.00	2330.74
3	0.00	0.00	0.25	0.10	0.025	0.025
4	0.00	0.00	0.00	1.00	0.00	2330.77
5	0.21	0.62	0.63	1.00	0.63	2331.40
6	0.01	1.00	6.26	1.00	6.26	2760.79
7	0.00	0.00	17.00	1.00	0.00	2777.79
8	0.04	0.62	0.03	1.00	0.03	2777.82
9	0.00	0.00	6.50	1.00	6.50	2784.32
10	0.10	0.87	11.55	1.00	11.55	2795.87
11	0.00	0.00	0.00	1.00	0.00	2795.87
12	0.00	0.00	39.22	1.00	39.22	3189.64
13	0.00	0.00	11,68	1.00	11,68	3201,32
14	0.03	0.90	19.08	1.00	19.08	3220.40
15	0.00	0.00	672,42	1.00	672,42	3892,82

Number position j	$m_{j-1,n}$	$m_{j,n}$	t_{j+1}	$S_{j,0}$	$S_{j+1,0} - S_{j,0}$	$S_{j,1}$	Q_j	U_j^Q
1	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	1.517	1.517	0.26497	3750.096	41.5658	11.0137	2543.83	213.09
2	1.517	1.517	0.26497	3750.096	0.00	0.00	2543.83	213.09
3	1.517	1.517	—	0.025	—	—	0.025	0.00
4	1.517	1.517	0.26497	3750.1339	0.03792	0.01004	2543.84	213.07
5	1.517	1.198	0.26497	3751.0896	0.9557	0.25323	3221.80	890.40
6	1.198	1.186	0.14383	4381.3694	630.2797	90.6531	3709.39	948.60
7	1.186	1.186	0.13518	4401.5314	20.1620	2.72552	3724.10	946.31
8	1.186	1.145	0.13518	4401.5670	0.03558	0.00481	3857.47	1078.92
9	1.145	1.145	0.11284	4409.0095	7.4425	0.83981	3863.24	1505.92
10	1.145	1.031	0.11284	4422.2342	13.2248	1.49228	4301.79	1505.92
11	1.031	1.031	0.02708	4422.2342	0.00	0.00	4301.79	1532.06
12	1.031	1.031	0.02708	4867.2138	409.8769	120.0505	4721.70	1532.06
13	1.031	1.031	0.02708	4879.2559	12.0408	0.326112	4733.06	1531.74
14	1.031	1.000	0.02708	4898.9677	19.7118	0.533816	4898.97	1678.57
15	1.000	1.000	0.00	5571.3877	72.4200	0.00	5571.39	1678.57

5. Conclusion

The economic and mathematical model for production processes with regeneration has been created and its dependencies allow the operating managers involved in the system of ensuring the enterprise competitiveness to determine the normative material costs of each semi-finished product per unit of (final) production or per unit of semi-finished products with a higher cost of refinement and their possible use for in-house logistics systems that use a regeneration processes.

A cost accounting analysis and material cost management studies have shown that in today's conditions, the use of raw materials will be more effective if the following requirements are met:

- technological losses at the production site should be negligible; for this purpose, it would be advisable to use organizational measures to strengthen the control of technological losses;
- it is optimal to use raw materials with the possible use of regeneration (recovery) processes, which allows to save resources and gain additional profit;
- to improve the organization of discharging and optimization of logistics chains it is necessary to carry out the standardization and typing of semi-finished and finished products;

- in terms of developing innovative technologies and products, it is crucial to take into account the peculiarities of the materials used.

The proposed methods for determining the material costs of in-house logistics systems with regeneration allow:

- to more accurately plan and regulate the launch of materials and semi-finished products and production;
- to obtain more reliable data on the regulatory material costs of production in any operation of a process that uses regeneration;
- to conduct cost estimation of regulatory technological losses;

in order to save resources more precisely and reasonably to plan production needs for a given production program.

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Моделювання виробничих процесів з регенерацією для забезпечення конкурентоспроможності підприємства

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У статті представлені дослідження та обґрунтування теоретичних питань і прикладних рішень щодо впливу на стан конкурентоспроможності підприємств та механізм управління виробничими процесами з регенерацією (відновленням). Розроблено математичний інструментарій та запропоновано методи розрахунку основних економічних показників, таких як коефіцієнти запуску і прямі нормативні витрати на матеріали, та побудовано на цій основі економіко-математичну модель виробничих процесів з регенерацією, що дає можливість порівняти результати виробництва продукції з витратами ресурсів на її виготовлення та покращення стану конкурентоспроможності стратегічно важливих підприємств.

Ключові слова: *виробничі процеси з регенерацією, конкурентоспроможність підприємства, моделювання, математичний інструментарій, коефіцієнт запуску, матеріальні витрати.*