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Competitive-resource information model of the machine building manufacturing system

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Abstract. The article discusses the method of creation a competitive-resource information model of the manufacturing system on the example of producing batch of parts, which allows expanding the field of determining the information links acting in the manufacturing process. It makes possible to determine the relationship of machining operations with elements of the manufacturing system. List of input data is selected for assessing of parts machining effectiveness for productivity parameters. A conceptual description of the competitive resource model with data groups of the information model is presented. The results of practical implementation of the methodology tested at one of Russian machine-building enterprises are presented.

1. Introduction

The modern period of machine-building enterprises development is characterized by the transition to digital production, which in turn involves the replacement of the output of a relatively constant range of products for the manufacturing of customized products [1]. Changing the paradigm leads to the need to ensure the flexibility of the manufacturing system, which are implemented as part of the production process planning. This requires a comprehensive study of technological and organizational problems.

Thus, the technological system must be developed in conjunction with control, maintenance and repair systems, forming a single design object.

The development of new approaches to the design of engineering enterprises includes the definition of a object complex design, its information model and its support processes at all stages of the manufacturing system life cycle[2].

As such a design object, the manufacturing system (MS) of the enterprise is proposed, which includes the main blocks shown in figure 1.

The efficiency of the manufacturing system at different stages of the life cycle is largely determined by the quality of information support.

The MS is regarded as a complex of organizational and technical systems intended for the manufacturing of products. Stages of the MS life cycle differ from the stages of manufactured products life cycle (aircraft, cars, etc.).

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The manufacturing system of the enterprise is part of the Smart Manufacturing Ecosystem. The Smart Manufacturing Ecosystem encompasses a broad scope of systems in the manufacturing business including production, management, design, and engineering functions. The product life cycle is concerned with the information flows and controls beginning at the early product design stage and continuing through to the end-of-life of the product. The manufacturing system life cycle focuses on the design, deployment, operation and decommissioning of an entire production facility including its systems [3].

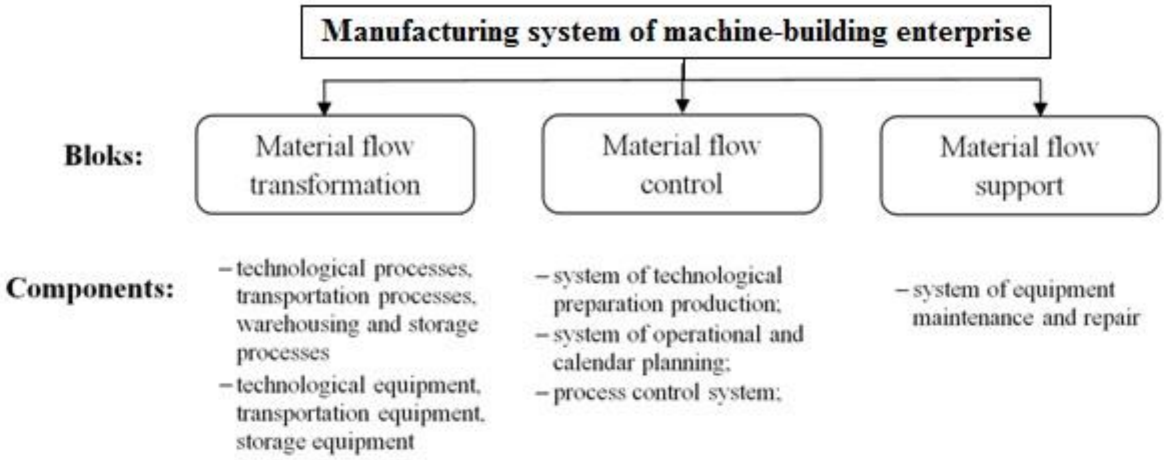

Figure 1. The main blocks and components of the manufacturing system.

The main difference is that the MS at the stage "Operation of the substation" includes the following stages: "Design of the configuration of the substation", "Utilization / Construction of the configuration of the substation" and "Operation of the configuration of the substation" (figure 2.) This is due to the need for its technical re-equipment when changing the products and / or the release program [4].

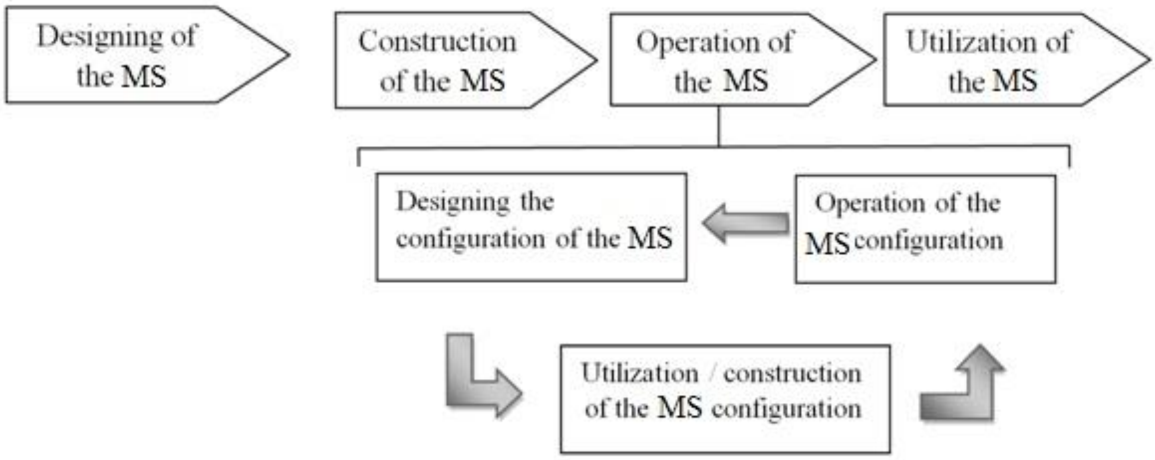

Figure 2. Content of the stage "Operation of MS" of the life cycle of the production system.

Thus, the simulation model (SM) of the manufacturing system undergoes periodic significant changes at the stage of "Operation of the substation".

The SM of the *i*-th configuration of the MS includes information blocks that are formed at different stages of the "Operation of the MS" phase.

At the stages "Design of the configuration of the substation" and "Construction / Utilization of the configuration of the substation", a project data block is formed, at the stage "Operation of the configuration of the substation" - a block of operational data.

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2. Initial data for creating a competitive-resource information model

The primary sources of input data for the developed method are designing and technological documentation.

To perform the evaluation according to the developed method, only a certain part of the information that is contained in this documentation is needed. And for its choice requires considerable preparatory work.

One of the ways to reduce the preparatory work is to present the initial information in the form of a formal model of a limited set of facts, concepts or instructions that are necessary and sufficient to inform the developed method.

The availability of an information model will allow further automating the process of preparing the initial data and, thereby, significantly reducing its laboriousness.

The information model is an intermediate link in the information interaction of structural divisions that are suppliers of designing and technological documentation and users of the developed method (figure 3).

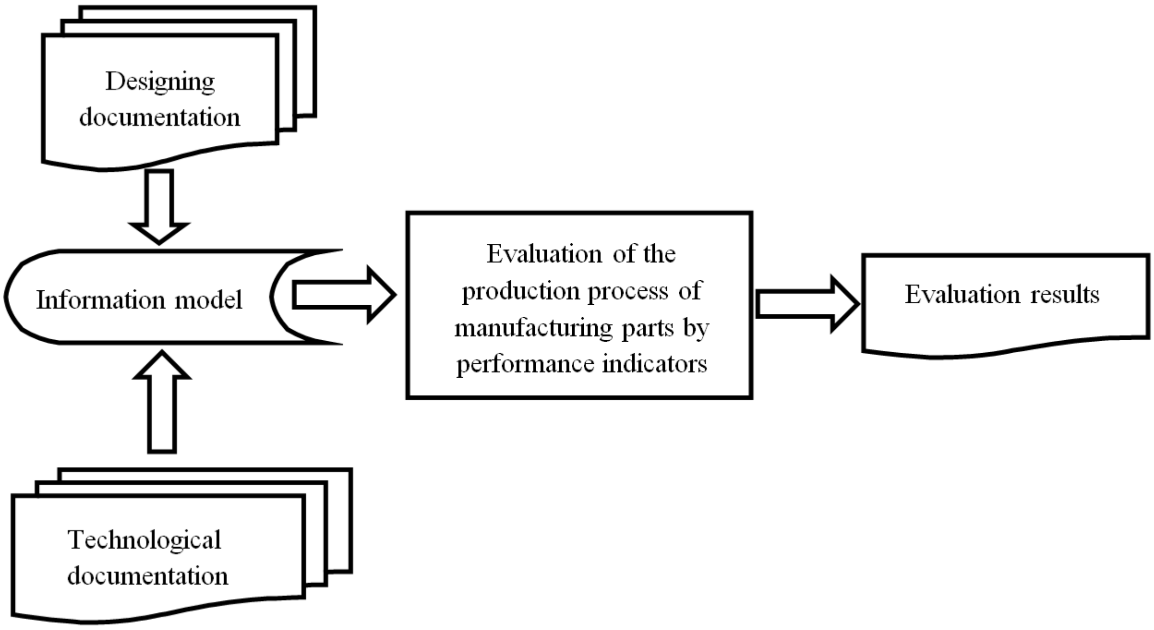

Figure 3. Diagram of the information links of the developed method with the primary source information.

In accordance with the conceptual model for assessing the production process of manufacturing part for performance indicators (figure 4), the information model should contain the following data groups [5]:

- general information about the parts produced,
- data on available resources of the technological subsystem $Tech_i^a$,
- data on the required resources of the technological subsystem $Tech(n)_i^{req}$,
- data on the available resources of the transport subsystem Tr_i^a ,
- data on the required resources of the transport subsystem $Tr(n)_i^{req}$,
- data on the duration of storage (accumulation) and the laboriousness of the storage processes of blanks $Lab_{St}(n)_i$.

Analysis of designing documentation showed that for each unit of technological and transport equipment, the number of hours per year involved in performing operations to manufacture all parts is a complex and time-consuming task. Often such information is not available [6].

Therefore, in the present paper, it is suggested that the available time for each unit of technological and transport equipment will be determined through the factor of consolidation of operations.

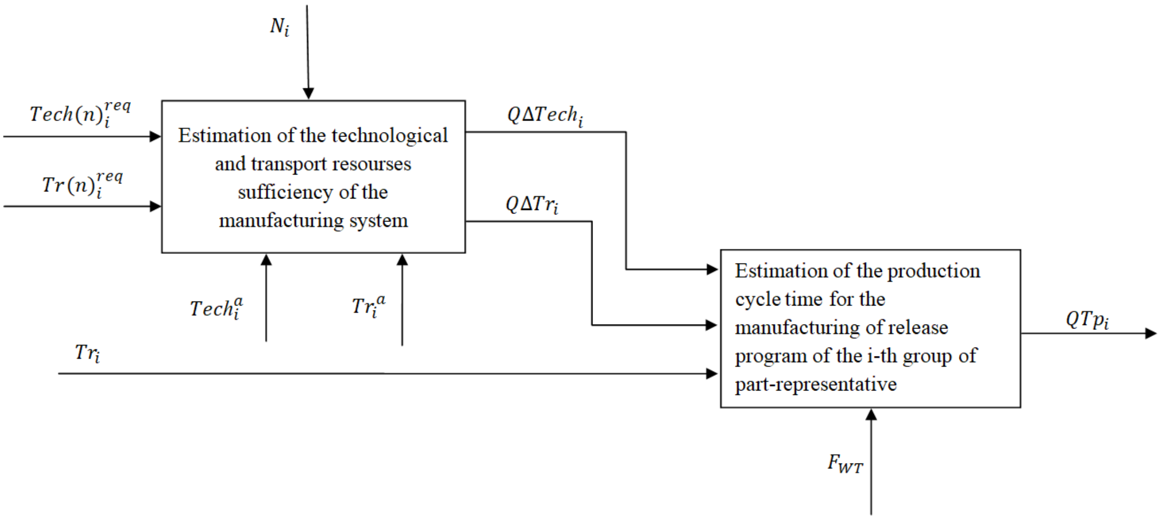

Figure 4. A conceptual model for evaluating the production process of manufacturing part of the *i*-th group in terms of performance indicators in the manufacturing system.

Then the available resources of the technological subsystem for each unit of equipment can be determined from the following relation:

$$Tech_{Mj,gi}^{a} = F_{WT\,gi} \cdot k_{fo\,gi} \tag{1}$$

where $F_{WT\,gi}$ is the year working time of the technological equipment performing the *g*-th technological operation of the *Mj*-th method of transformation of the *i*-th group part material flow;

$k_{fo\,gi}$- the coefficient of fixing the operation of the technological equipment performing the *g*-th technological operation of the *Mj* -th method of transformation of the *i*-th group part material flow.

The available resources of the transport subsystem are determined by the following relation:

$$Tr_{Mj,si}^{a} = F_{WT\,si} \cdot k_{fo\,si} \tag{2}$$

$F_{WT\,si}$ - is the year working time for the transport equipment performing the *s*-th transport operation of the *Mj*-th method of transformation of the of the *i*-th group part material flow,

$k_{fo\,si}$ - the factor of the operation fastening for transport equipment performing the *s*-th transport operation of the *Mj*-th method of transformation of the of the *i*-th group part material flow.

Thus, the formal model determines the manufacturing system of the production process of the installed batch of the part.

One of the features of this information model is the description of available resources for performing technological and transport operations of the corresponding subsystems elements, taking into account the existing competition for them in the operations of other parts producing.

In accordance with the above, the proposed information model was called a competitive-resource information model of the manufacturing system of a batch parts production process.

3. Practical implementation of the competitive-resource model in one of the shops of the Russian machine-building enterprise

Let's consider an example of the project of the manufacturing system of the shop for producing some unit.

At the first stage of the workshop project, a process model has been developed that describes the manufacturing process of the product.

Critical ways of the product manufacturing were determined. The analysis of the identified critical paths made it possible to draw a conclusion about the possibility of performing operations lying on critical paths.

To fulfill a given production program, 89 workplaces were provided in the project based on the use of the process program with a two-shift work schedule (Table.1.)

Table 1. Workplaces specification of the shop floor

Workplace name	Quantity of workplaces according to project documentation
Worktable	1
Bench	5
Dry box	1
Electrical worktable	80
Test bench	2
Total:	**89**

The calculated values of the coefficients of loading the workplaces K_L of the production system for manufacturing the product are shown in figure 5 [1].

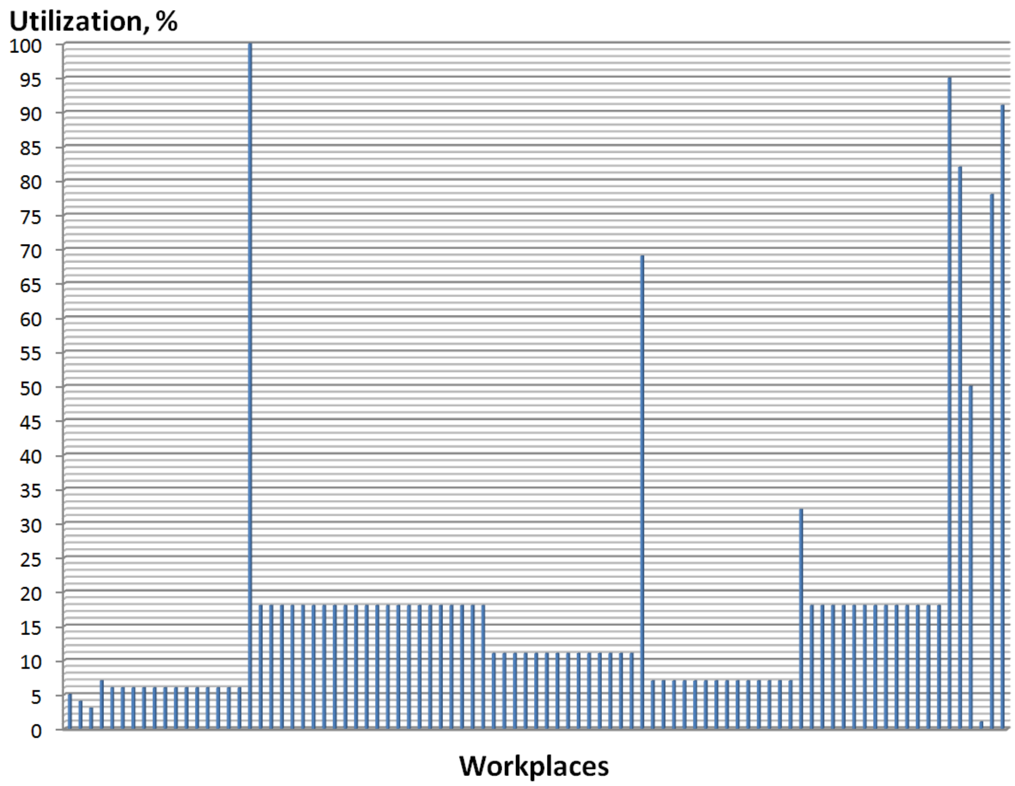

Figure 5. The diagram of workplaces loading of the manufacturing system project, obtained on the basis of the process model use.

The results of the analysis in figure 5 show that the projected manufacturing system is highly unbalanced - the lack of one jobs, with a clear surplus of others.

An analysis of the results obtained on the basis of the use of the process model made it possible to draw a conclusion about the impossibility of carrying out this program.

Next, a competitive resource model of the manufacturing system of the shop for making the product was built. A fragment of the competitive resource model is shown in figure 6, in which the dashed lines indicate the return loops of the assembled components of the product to the previous workplaces.

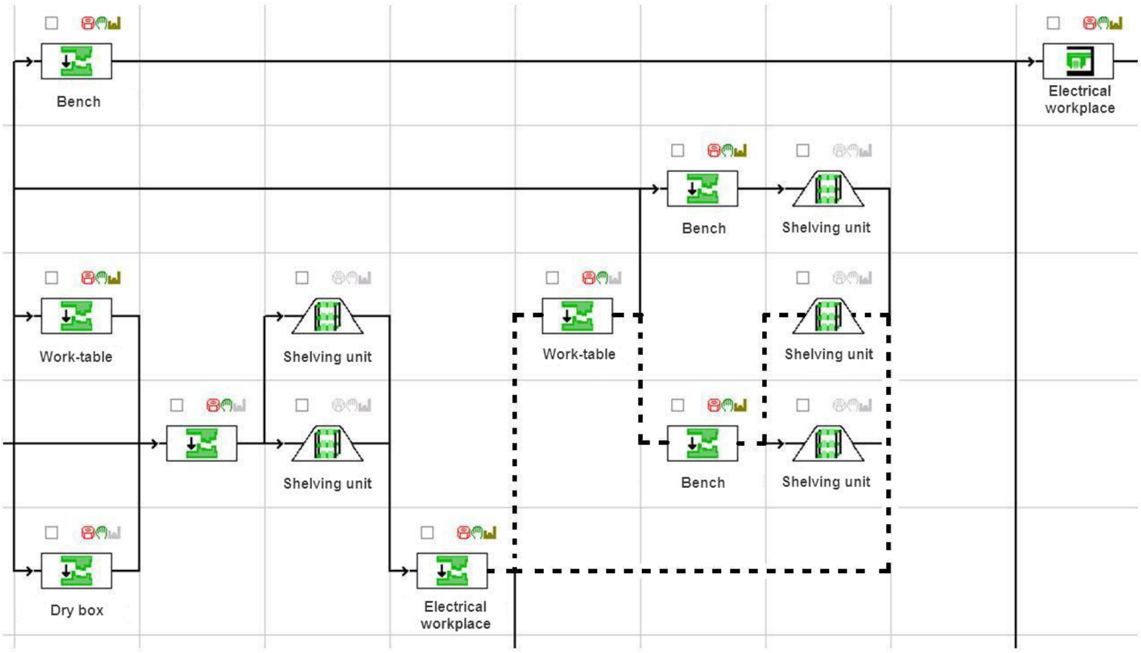

Figure 6. Fragment of the competitive-resource model of the shop manufacturing system.

Based on the results of the calculation using a competitive resource model, "bottlenecks" in the manufacturing system were identified. For their elimination, proposals were developed to adjust the specification of the workshop workplaces (Table 2).

Table 2 Adjust the specification of the workshop workplaces

Workplace name	Quantity of workplaces specified in the first stage	Quantity of workplaces specified in the second stage
Worktable	1	1
Bench	27	12
Dry box	1	1
Electrical worktable	49	36
Test bench	11	9
Automated workplace	–	3
Total:	**89**	**62**

Taking into account the developed proposals for adjusting the specification of workplaces, the design of the shop manufacturing system was adjusted and the performance indicators were calculated.

The calculated values of the coefficients of loading the workplaces of the manufacturing system for the product are shown in figure 7.

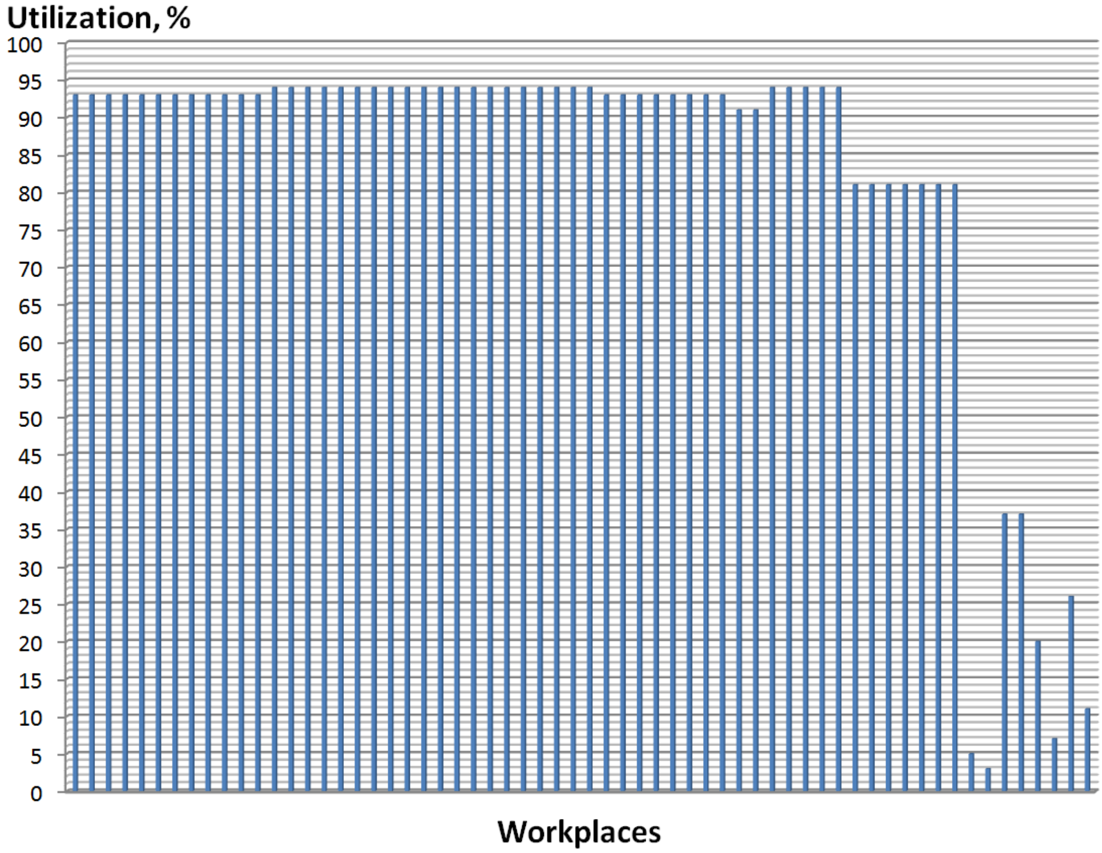

Figure 7. The diagram of loading workplaces of the corrected manufacturing system.

Calculations using a competitive resource model have shown that 62 workplaces are required to perform a given output volume with their relatively uniform loading, instead of the 89 planned.

Based on the analysis of the results obtained, a conclusion was made on the possibility of implementing the program.

4. Conclusions

To increase the efficiency of digital manufacturing systems, it is necessary to shift to the use of a competitive-resource information model of the manufacturing system, based on the use of personalized links of the different parts and elements of the manufacturing system, established by the processes of their production.

The introduced concept of a competitive-resource information model of the manufacturing system of parts production process has made it possible to expand the scope of determining the complexity of information links operating in the production process.

The developed competitive-resource information model of the manufacturing system of parts production process made it possible to determine the relationship between the operations of parts production and the elements of the manufacturing system.

Practical implementation of the model at the enterprise allowed reducing the number of workplaces at the enterprise for a given volume of output by 30%.

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