Issues of Formalization of Production Processes in the Conditions of Digital Transformation of Enterprises

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Abstract: The issues of identifying links between production processes at the stages of the life cycle are considered, a model is proposed that clearly shows the presence, number and places of formation of critical nodes in which information flows are combined. The functional dependencies arising in the production activity of the enterprise are analyzed, the interrelations between the main production processes from the point of view of the process approach are revealed, a mathematical model of the production process is proposed.

1 INTRODUCTION

Increasing productivity, increasing the flexibility and adaptability of production currently continues to be an urgent task, especially in the context of digitalization. Automated production, covering the entire spectrum of information about the state of technological processes, equipment, inventory and realizing the ability to quickly make changes to all stages of the production cycle, optimize supply chain management and flexibly respond to any new consumer requests, provides the opportunity to move to a more profitable position of the company in a competitive market (Meshkov, Kozlova, 2022; Egorov, Kapitanov, Kozlova, 2020). It should be noted that the vast majority of tasks solved in digital production are solved using various software products and databases.

Software products related to production activities freely transfer data to each other, and access to blocks of production processes and related business functions that integrate automated systems is possible thanks to a common database, while the probability of errors and, as a result, incorrect and untimely decisions is practically reduced to zero, since human participation is minimized. Of course, such an approach to the activities of a manufacturing enterprise in order to optimize internal processes significantly increases organizational and personnel efficiency.

2 MAIN PART

Practical experience in the creation and operation of modern automated production facilities shows that no stage of the product life cycle can be left without due attention: starting from the design, manufacturing processes and ending with the sale and disposal of products. At the same time, the classical approach assumes such a structure of the enterprise information system, on which three main, hierarchically interconnected levels can be conditionally distinguished. The so-called upper level of management includes subsystems that perform production planning tasks, the middle level is occupied by production design subsystems, and at the lower level there are subsystems for managing production equipment. Depending on the type of enterprise, the classification, number and typification of these systems can vary greatly (Meshkov, Kapitanov, Feofanov, 2022; Kapitanov, Egorov, Meshkov, 2021; Meshkov, 2022). As a rule, the main top-level systems include (Fig.1) Enterprise Resource Planning ERP, Manufacturing Resource Planning MRP II, Production Planning Systems PPS, Artificial Intelligence AI, etc.

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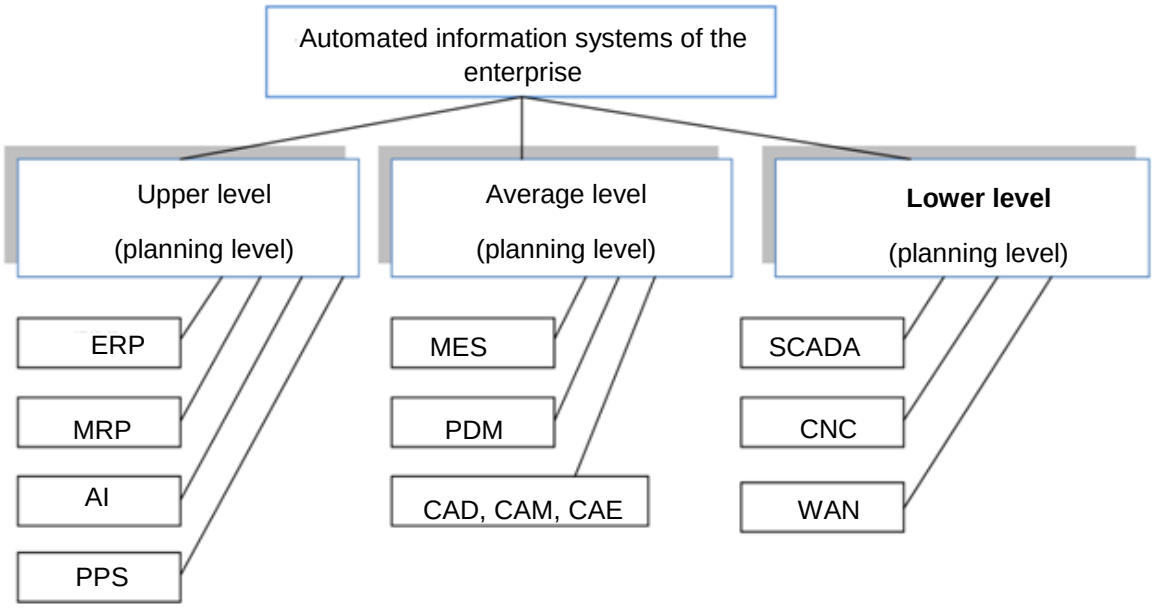

Figure 1: Classification of information systems.

The middle level is usually represented by MES (Manufacturing Execution Systems), PDM (Project Data Management systems), integrated technologies of computer-aided design, engineering analysis and technological preparation of production (CAD/CAE/CAM systems and their modifications), etc.

The basis of the lower level - the management of production equipment - consists of dispatching control and data acquisition SCADA (Supervisory Control And Data Acquisition), numerical control CNC (Computer Numerical Controlled Machine Tools), distributed WAN (Wide Area Network), etc.

At the same time, taking into account the specifics of a particular enterprise, there is no single solution for the integration of automated systems. This is especially true for enterprises focused on the production of single and small-scale products, because in the conditions of modern market relations it is necessary to have an individual approach to each order. Therefore, the difficulties that arise lead to the fact that it is quite difficult for such organizations to take a step towards digital transformation, since the ready-made solutions presented on the market at the moment do not fully meet the requirements of such productions (Meshkov, 2023; Meshkov, Kozlova, 2022; Kapitanov, Kozlova, 2019; Meshkov, Kozlova, 2022).

The study of the operational activity of the enterprise from the point of view of the life cycle shows that the relationships that arise between the main production processes make it possible to identify ways of exchanging information and material flows (Fig. 2).

It is more convenient to use standard algorithmization methods to describe them. Thus, a structure is created containing data in digital form, including the organization of processes, management, as well as changing the way of thinking and behavior of employees in the context of digital transformation, which can be represented by the principle of a process approach (Ibatulin, Meshkov, 2022; Odincov, 2019). At the same time, in the conditions of an idealized representation, a certain part of the interrelated processes is lost due to the fact that the real connections in the processes are stochastic and nonlinear, which complicates the understanding of the functional structure of the enterprise.

The analysis of the revealed interrelations showed a significantly distributed nature of information data flows – in the sense that each of the management functions has its own interpretation in all phases of the life cycle and at all levels of the organizational hierarchy, which can be represented in the form of a three-dimensional flow-information model (Fig. 3).

A two-dimensional model is presented to illustrate the presence, number and places of

formation of critical nodes in which information flows are combined and/or intersected (Fig.4).

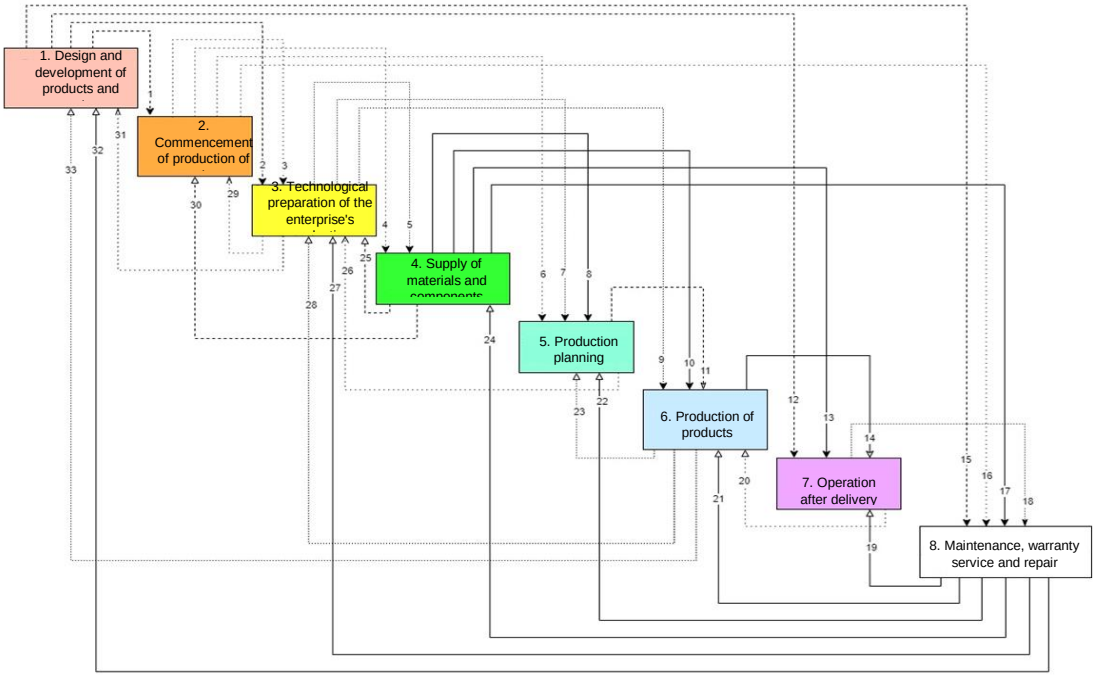

Figure 2: Relationship between processes.

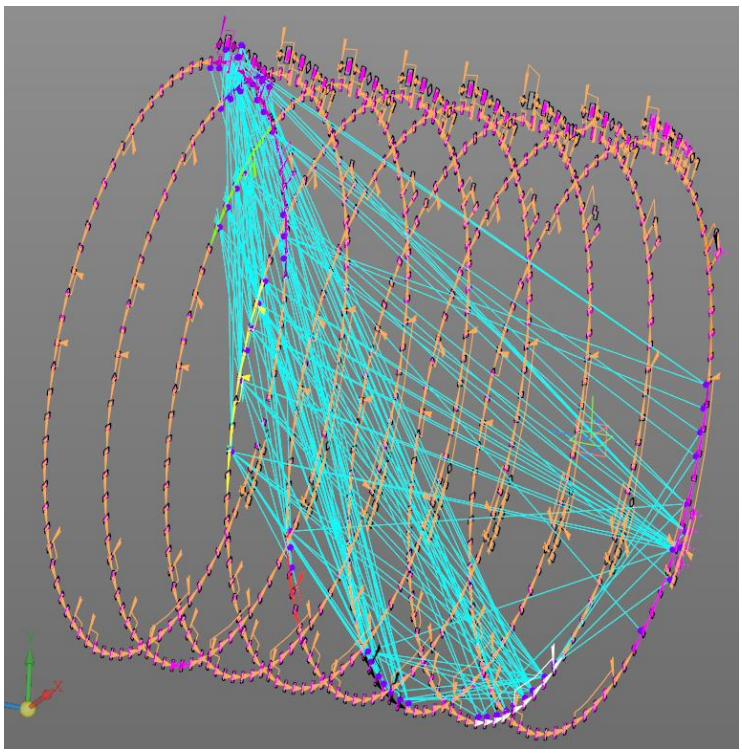

Figure 3: Three-dimensional flow-information model.

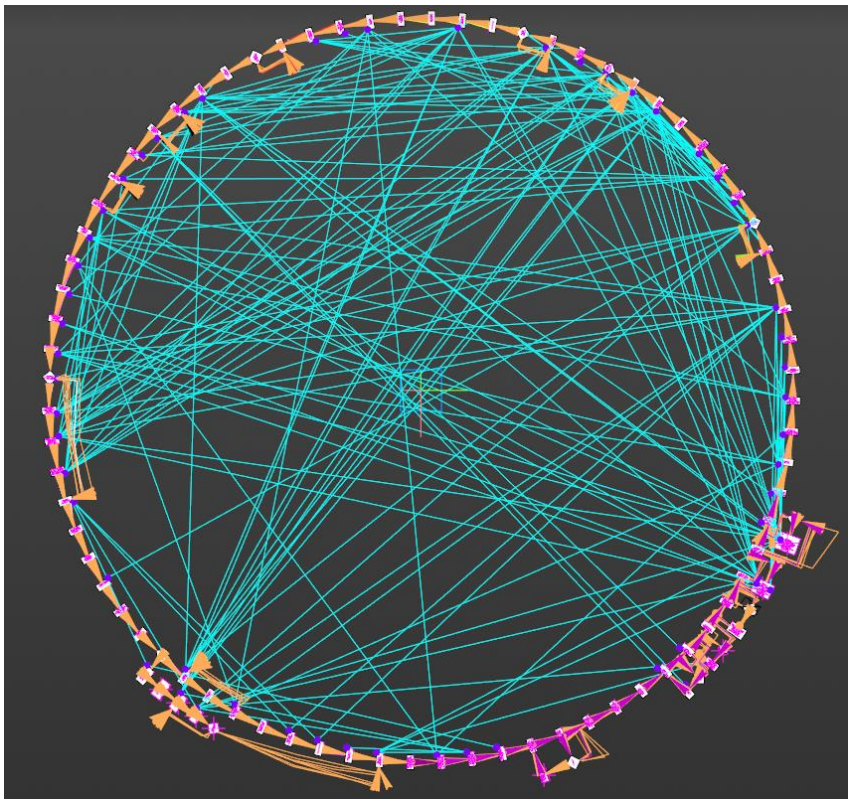

Figure 4: Two-dimensional flow-information model.

When processing production tasks, it is necessary to take into account various features of the assignment of tasks for execution, which is inherent

$$\delta_{kb}(y_{k1}, y_{k2}, \dots, y_{kr_k}, \alpha_{k1}, \alpha_{k2}, \dots, \alpha_{kp}, \dots,$$

$0, (b = 1, 2, \dots, b_k)$.

in a particular production. At the same time, it is obvious that modeling of production processes requires a formalized description of each object of the production process and the relations between them (Bykova, Kapitanov, 2023; Kozlova, 2021).

The mathematical model of the production process *M* can be presented in the following form:

$$\begin{cases} x_1(t) = x_1(q_1, q_2, \dots, q_j, \dots, q_m, t), \\ x_2(t) = x_2(q_1, q_2, \dots, q_j, \dots, q_m, t), \\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots \\ x_i(t) = x_{n-1}(q_1, q_2, \dots, q_j, \dots, q_m, t), \\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots \\ x_n(t) = x_n(q_1, q_2, \dots, q_j, \dots, q_m, t), \end{cases}$$

where the process indicators are represented as functions $x_1(t),\ x_2(t), \dots, x_n(t)$, and the values $q_1, q_2, \dots, q_j, \dots, q_m$ serve as process parameters. In this case , the subprocesses $M_к$ are characterized by functions $y_{kl}(t),\ (l = 1, 2, \dots, r_k)$ and in general, some of them may coincide with $x_1(t),\ x_2(t), \dots, x_n(t)$, and the parameters $\alpha_{kp}, (p = 1, 2, \dots, h_k)$ –, respectively, with $q_1, q_2, \dots, q_j, \dots, q_m$. Obviously, the model of subprocesses is described by the relation

The functions of the form δ_{kb} allow to represent the indicators of subprocesses through the simplest parameters, covering the entire production process *M* in aggregate, and the relations of the form

$$\gamma_a(x_1, x_2, \dots, x_m, q_1, q_2, \dots, q_j, \dots, q_m, y_{k1}, y_{k2},$$
$$= 0$$

describe analytically the relationship of the subprocesses of the process *M*.

For the information environment of a digital enterprise, a characteristic feature is the multiplicity of tasks e_k and performers, while certain tasks must be completed in a certain time interval t. The queue of incoming tasks forms a flow u_k. All tasks are considered at the time of receipt under the assumption of equivalence, unification, independence of receipt and the absence of the impact of execution on subsequent processing.

Information flow indicators are related by functional dependence

$$F = F(e_k, u_k, V_k, t_k, t_0, \Delta t_k),$$

where e_k is the task, u_k is the task flow, V_k is the

task execution speed, t_k is the start time of work on the task; t_0 is the time of receipt of the task, $t_0 \leq tk$, Δt_k – the standard duration of task processing.

These indicators allow us to describe the process of transformation of the existing production system to modern digital production, taking into account such a distribution of incoming tasks so that their processing is carried out with maximum efficiency indicators, the definition of which is solved by modeling the structure of the enterprise under specified conditions.

3 CONCLUSION

Modern world trends prescribe production to build its processes and operations into a single pulling flow. When creating a value chain, there are needs for organizational support at all levels from suppliers to consumers of products, sharing risks, costs, profits, information exchange and knowledge between all participants in supply chains. The conducted studies have shown that a significant number of flow elements move randomly, while their formalization makes it possible to describe subprocesses with variables and constants, as well as relations linking them in a certain way with each other.

The established relationships and the mathematical model of the process allow us to analyze the functional dependencies that arise in production activities and identify problem areas in which the formation of so-called critical nodes is possible, where information flows are combined. This circumstance significantly affects the change in the production system and its characteristics, increasing the time and increasing the cost of manufacturing products.

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