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Integrated platform solutions and quality management in the planning and organization of production processes

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Abstract. The article deals with the task of coordinating digital and industrial platforms in the context of interaction between the subjects of the digital economy. Digital transformation should occur against the background of the systematic introduction of modern corporate governance methods, including: investment management, project management, financial management, personnel management, knowledge management, etc. The authors clarify the possibility of using ontologically oriented intellectual methods to support planning and organization of production processes. The article shows that the use of intelligent methods in building platform solutions begins with identifying, classifying and describing the main processes of an enterprise, establishing their sequence and interconnection. The authors propose ontologically oriented methods for coordinating the management and planning of production processes. The models are presented of production data support scenarios in accordance with the requirements of business processes. In addition, in addition to the production process scenarios, the solution includes a set of typical user access scenarios and basic data transfer services by experts.

1. Introduction

In the conditions of digital transformation, not only the production technologies themselves are updated, but also the principles and systems of management of industrial enterprises, which take into account not only technological shifts, but also the requirements of the external environment and changes in its qualitative, institutional and infrastructural composition [1]. The example of a digital platform solution is the enterprise information management system EIM (Enterprise Information Management), which is built on a combination of ERP (Enterprise resource planning ) [2], PLM (Product Lifecycle Management), MDC (Manufacturing Data Collection). In the integrated version, the solution allows creating a centralized digital platform used at all stages of the production project life cycle: for digital design, in the digital workshop, digital supply chain, logistics and digital adaptation to the product consumer during sales and service. In addition, this information integration provides operational production management, which is especially important to ensure the transition to fully automatic production, controlled at each stage of the product life cycle. The use of such integrated solutions should provide intellectual support for all types of planning and management of production processes [3]. As well as monitoring the production process and reducing its changes using the analysis of experimental data using quality control and management methods. [4]. The use of ontologically-oriented methods in planning and organizing production processes allows solving such important tasks as identifying internal
and external customers, suppliers and other stakeholders of the process, reviewing the stages, actions, flows, control methods, needs for training, equipment, technology, information, materials and other resources required to achieve the desired result, etc. [5]

2. Principles of digital transformation, modern economic methods and quality management of production processes

The founders of scientific management consider Weber, Fayol, Taylor, each of which contributed the principles to scientific management. The theories of Maslow and Mac Gregor, complementing each other, allow creating two completely opposite forms of organization management. General Quality Management (TQM) is impressed by Mac Gregor's “Y theory” and Maslow's theory, based on systemic approaches. A major contribution to the development of TQM, as well as one of the very first approaches aimed at improving quality, was the Deming Cycle.

The application of the principles of digital transformation in solving problems of planning and managing digital processes is determined by the emergence of ISO 9000 standards, in which a new model of Total Quality Management was introduced [6].

Digital transformation and transition to the TQM system should occur against the background of the systematic introduction of modern methods of general (corporate) management, including: investment management, project management, financial management, personnel management, knowledge management, including such specific approaches as “just in time”, cost engineering, business process reengineering and some others. The solution of such a complex of tasks is possible only with the creation and use of intellectual information support tools, Data mining methods and ontology engineering tools in the planning and organization of production processes.

3. Models of production processes in the planning and organization of production and ontologically-oriented methods

3.1 Basic principles of the process approach in the planning and organization of production in the conditions of digital transformation

The desired result is achieved more efficiently when activities and related resources are managed as processes.

The implementation of this principle in the organization involves the following actions:

- identifying the processes to achieve a desired result;
- identifying and measuring process inputs and outputs;
- establishing clear responsibility, authority and accounting for managing the process;
- identifying internal and external customers, suppliers and other stakeholders of the process;
- developing the processes of their stages, actions, flows, control methods, training needs; equipment, technologies, information, materials and other resources required to achieve the desired result.

The concept of the process is fundamental, both for modern management in general, and for quality management in particular. A process in the broadest sense is understood as a certain sequence of interrelated or interacting actions (works, operations), the purpose of which is to transform the “inputs” of the process into its “outputs” to achieve a certain result, usually creating some products or providing some services to consumers. The scope of the concept of "process" is not limited to technological and production processes, or service processes. In fact, any work done by people or machines is a process [7].

Thus, when constructing ontological descriptions, the process can be viewed, on the one hand, as the entire set of people, equipment, materials, methods, measurements and the external environment, which interact with each other in order to obtain the “output” of the required quality, and on the other hand, as a certain limited work or operation performed by a specific person or machine.

The quality management and process management system acts on a part of the inputs and intermediate process control points so that the output processes are stable, their variations are reduced, and the “outputs” or the results of the processes correspond to the established requirements [8].
Thus, in the declarative description we get two control loops: the process control loop and the quality control loop, which includes the commercial component.

3.2 Ontology-oriented modeling of the flow scenario of the production process

Process management typically includes:
- Design processing
- Management processing
- Improvement processing

Any activity aimed at building an organization quality management system and using intellectual methods in building platform solutions should begin with identifying, classifying and describing the basic processes of the organization, establishing their sequence and interrelation.

The main purpose of technological production is to add value to the product of labor at the lowest cost for each operation.

Influence on the process, and not on the result of the process - the basic concept of managing the processes of an enterprise operating in TQM. The main requirement for the control system is to prevent inconsistencies, and not to control the final result of the process [9].

To create digital platform solutions, it is proposed to use an ontology-oriented production process scenario, which is formed as a hierarchy of streaming process scenarios consisting of operations [10]. Each operation of the input process includes descriptions (declarants) for managing and controlling the operation and descriptions of the required operation resources production process. The interaction of declarants is described within the operation using special tables or charts. The image of the operation is shown in figure 1.

![Image](image_url)

**Figure 1.** Declarative description of the production process in control loops

The graphic description of the process consists of an external frame, inside of which there are images of operations and functions for works that connect operations between themselves and the process with the external environment. Functions are represented by arrows marked with the corresponding symbols. To the left of the frame are the functions of the external input $Fi$ marked with the names of input objects, and the arrows $Rj$ marked with the names of resources are entered in the process frame. To the right of the frame, external arrows $Fk$ are displayed for the output functions of the process.

The arrows inside the frame, called internal, are divided into input (free start, end associated with the image of the operation), output (start associated with the operation, free end) and intermediate (connect...
the two operations). Each input external arrow is assigned \( n \geq 1 \) input internal arrows, identically labeled by it. This means that the function of the object (resource), presented to the input of the process, transfers data to the inputs of \( n \) operations. Each output external arrow corresponds to only one output internal arrow, that is, the process output receives a function from one operation (otherwise the process is inconsistent). The authors distinguish three types of objects: objects of type 1 undergo processing 1 only, type 2 only processing 2, type 3 sequential processing 1 and processing 2.

Objects can be tangible products, documents, information in electronic form, etc. The system is a “production line” of three consecutive positions \( a1, a2, a3 \), where \( a1 \)-processing 1, \( a2 \)-processing 2, \( a3 \)-monitoring and sorting objects suitable (certified) for the functions \( F4f, F6f, F7f \) and defective in the functions \( F4d, F6d, F7d \).

A graphical description of the flow line scenario is shown in Figure 2.

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**Figure 2. Ontological scenario of the production process “sorting”**

Operations implemented at positions \( a1, a2, a3 \) are indicated by \( O1, O2, O3 \), respectively. Next to the image of the operation, we place the designation of the agent performing the operation, which we enclose in a circle.

Objects of type 1, 2, 3 in the script correspond to the input functions \( F1, F2, F3 \). Functions \( F1, F2, F3 \) are transferred to the input of operation \( O1 \), functions \( F2 \), to the input \( O2 \). Operation \( O1 \) converts the functions \( F1, F3 \), respectively, into the intermediate flows of functions \( F4, F5 \), and operation \( O2 \) converts the input stream of the functions \( F2 \) and intermediate \( F5 \) into intermediate flows of the functions \( F6, F7 \), respectively.

Objects of type 1, 2, 3 in the script correspond to input streams of functions \( F1, F2, F3 \). Functions \( F1, F3 \) are transferred to the input of operation \( O1 \), functions \( F2 \), to the input \( O2 \). Operation \( O1 \) converts the flows of functions \( F1, F3 \), respectively, into intermediate flows of functions \( F4, F5 \) and operation \( O2 \), the input stream of functions \( F2 \) and intermediate \( F5 \), into intermediate flows, respectively, \( F6, F7 \). Operation \( O3 \) receives input streams of functions \( F4, F6, F7 \) and generates output functions of suitable objects \( F4f, F6f, F7f \) and defective objects \( F4d, F6d, F7d \).

As another example, consider an order processing block. The order processing block accepts orders, collects them from inventory at the enterprise’s warehouse, replenishes stocks, if necessary, by
contacting the manufacturers, and delivers the generated orders to customers. A fragment of the graphic description of the image (declarative scenario) of the service order was given in Figure 3.

The graphical representation has three levels of the hierarchy of objects $O_0$, $O_1$, $O_{1.1}$, where $O_0$ is implemented on the basis of operations performed by agents $A_1$, $A_2$, $A_3$, image $O_1$ details the corresponding operation in $O_0$ and $A_{1.1}$, $A_{1.2}$, image $O_1$ is executed 1, the drill operation in $O_1$ consists of operations $O_{1.1}$, which are not drill-down in the script (terminal operations). The order of operations in scenarios $O_0$, $O_1$ is free, in the process $O_{1.1}$ - fixed.

At the input of operation $O_0$, the flow of functions $F_1$ and the information flow $R_1$ are presented in the image of the production process, which reflects the state of resources - the stock of products in the warehouse. The flow of functions $F_1$ is received at the input of operation $O_1$ and initiates the execution of the functions “receipt of an application” and “approval of an order” for implementation by agent $A_1$. The stream $R_1$ goes to the input of operations $O_{2}$ - checking the receipt of orders, $O_{3}$ - receiving orders, $O_{4}$ - waiting for incomplete information realized by $A_2$. Operation $O_1$ either rejects the request (function $F_2$ sent to the output of operation $O_0$), or accepts the request, pays and sends order data for operation

Figure 3. The hierarchical scenario “Service” in the planning and organization of production
O2 (intermediate stream of functions F3). Operation O2 determines whether the order is provided with R1 resources. If so, the reservation request for the corresponding products (output stream of functions F5) is sent to the warehouse, and data on the protected order is sent to operations O3 (intermediate stream of functions F4). If not, the application is sent to the product manufacturer (output stream of functions F7), and the data of the unsecured order is sent by operations O4 (intermediate stream of functions F6).

4. Integrated platform solutions and ontologically oriented tools in the planning and organization of production processes

Recently, there has been an active use of the so-called “platform effect”, in which organizations based on digital technologies create networks connecting sellers and buyers of a wide range of products and services to timely check the quality of products and services as well as to increase income due to economies of scale.

Digitalization and active formation of customer access systems at all stages of the creation and production of products make it necessary to integrate the enterprise into an active information environment in which “supplier-buyer”, “customer-executor” interactions are provided. Such an information environment can be built using ontologically-oriented means of intellectual support which are designed for the interaction of production processes of enterprises.

Such an environment should ensure vertical integration of processes throughout the organization, including data on operational processes, process efficiency, quality management and operational planning, optimized for various platforms, available in real time in an integrated network. And horizontal integration which covers suppliers, consumers and all key partners in the value chain, is ensured through the use of real-time intelligent tracking and control devices. Thus, a platform for interaction between storage media can be created that has certain separate ontological blocks of interactions.

4.1 Architecture of the ontological block

When forming a block-ontological architecture, the following types of scenarios of the production process were identified [11]:

• an individual process carried out by an individual;
• a functional or vertical process that reflects the company’s activities in the vertical interaction of managers, departments, divisions and employees of the company for quality management;
• a business or horizontal process that contains horizontal connections and interactions between structural units of the company and represents a set of interconnected integrated processes into a single production process that provides end results that are in line with the interests of the company.

The problem of establishing relationships between data in various scenarios is solved using the content integrator, which implements the comparison of equivalent data with each other [12].

The use of ontologically oriented tools for managing digital production is explained by the evolutionary process, which is reflected in the influence of information (knowledge) on the internal structure of an industrial enterprise, as well as in the widespread dissemination of digital technologies in the planning and organization processes. The solution also includes a set of sample user access scenarios and an expert expert basic data service. NSIs, including mechanisms and templates for processing user requests for creating / modifying data. A particularly important role is played by typical reference data libraries (basic dictionaries and reference books).

4.2 Formal description of the ontological block

To describe the subject areas of the production structure, the main ontology agent has the following formal description:

\[
ONT_{OB} = (U_{ob}, lm (R), F_{ob})
\]

where \( U_{ob} \) is a set of domain concepts defined by ontological blocks; \( lm (R) \) - the set of fuzzy (weighted) relationships between ontological units inside the \( F_{ob} \) is a description of the ontological “process” (interaction of ontological units).
Formally, the $OB$ block of a single operation can be defined by a tuple:

$$OB = (ONT\_OB, input, output, BP\text{gramm}),$$

where $ONT\_OB$ the main agent of the ontological block;

- $Input$ — a description of the inputs of the ontological block;
- $Output$ — a description of the outputs of the ontological block;
- $BP\text{gramm}$ - a description of the schemes for “refinement” of the ontological scenario for a single typical business process.

The ontological block [14] is a tool available to experts for the formation of conceptual specifications of objects for the stages of the product life cycle, determining the step-by-step dynamics of vertical control over the user interface, which forms the images of the corresponding models through the Demming cycle “planning, implementation, verification, action”.

5. Conclusion

The Industry 4.0 concept involves the integration of vertical and horizontal value chains [15]. Digitalization and the active use of cloud technologies in modern production, the formation of customer access systems at all stages of production necessitates the integration of the enterprise into an active information environment that uses technologies of “ontology engineering” and decision support systems.

Using an intelligent information environment and ontologically-oriented methods allows you to:

- apply the knowledge and practical experience of expert analysts participating in the process of formation and implementation of the enterprise development strategy;
- keep records of the need to coordinate the interests of various groups of decision makers;
- to focus on the requirements of end users of the system, improving the conditions for their activities.
- to support the full cycle of formation and implementation of the enterprise development strategy;
- provide a comprehensive analysis of the current activities of the enterprise in the context of financial, market and investment performance indicators.

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