DOI: 10.17323/2587-814X.2023.4.73.93

Methods and models for substantiating application scenarios for the digitalization of manufacturing and business processes of network enterprises

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Abstract

The process of digital transformation of enterprises is associated with the organization of manufacturing and business processes within the framework of selected types of business models and digital platforms, the distribution and economic substantiation of the roles of participants in network interactions, and ensuring the semantic interoperability of their interaction. Currently, certain experience has been accumulated in the implementation of modern business models for the digital transformation of enterprises which is reflected in the concepts of the Industrie 4.0, the Industrial Internet of Things, the creation of cyber-physical production systems, smart enterprises and intelligent manufacturing. At the same time, the issues of conceptual modeling of the architecture of digital enterprises, which determines the construction of manufacturing and business processes, and its economic substantiation depending on various factors of the external environment and internal economic potential have not yet been sufficiently researched and developed. All of the foregoing determines the relevance of the work presented here. The purpose of the study was to develop ontological and economic methods for substantiating application scenarios for the digitalization of manufacturing and business processes depending on the selected types of business models and digital platforms. To solve the problem, methods of classification, ontological engineering, activity-based costing and analysis of cash flows of income and expenses are used. The article presents an analysis of enterprise digitalization scenarios depending on the types of manufacturing and business processes, the types of business models and digital platforms used. An ontological model of enterprise digital transformation has been constructed, providing a choice of application scenarios for the digitalization of manufacturing and business processes for various types of business models and digital platforms. An economic model is proposed to justify options for constructing application scenarios for the digitalization of production and business processes depending on the distribution of roles of participants in network interaction using methods of activity-based costing and cash flow analysis.

Keywords: network enterprise, application scenario of digitalization, type of business model, type of digital platform, manufacturing and business processes, ontological model, economic model

Citation: Telnov Yu.F., Kazakov V.A., Bryzgalov A.A., Fiodorov I.G. (2023) Methods and models for substantiating application scenarios for the digitalization of manufacturing and business processes of network enterprises. *Business Informatics*, vol. 17, no. 4, pp. 73–93. DOI: 10.17323/2587-814X.2023.4.73.93

Introduction

The implementation of modern digital technologies in industry leads to a transition from mass production to mass customization, whereby the manufacturing of small-scale and individual products becomes predominant [1]. The basis of digital transformation in industry is the use of advanced production technologies based on the industrial internet of things (IIoT), cyber-physical systems (CPS), digital twins and platforms, and artificial intelligence. In this regard, the requirements for enterprise management systems are changing in terms of adaptability of operational management and flexibility in configuring production chains not only at the level of enterprise, but also at the level of interaction between enterprises within the formation of networked business structures (network enterprises).

At the present stage, the organization of flexible production is based on the use of cyber-physical systems, intelligent assets equipped with RFID and supported by Industrial Internet of Things technology, and cyber-physical production systems (CPPS) which combine

individual assets into systems using digital twins and digital threads technology on the workshops, factories and supply chains levels [2–4].

The development of the Industry 4.0 modern production technologies significantly changes the architecture of enterprise management systems and the time intervals for operational and tactical planning and process regulation. First of all, the organization of digital production systems is characteristic of the level of management of individual equipment and production lines. At the same time, the spread of digital twin technology, implemented using multi-agent systems, to organizational entities that are participants in the value-added chain of networked enterprises, makes it possible to modernize manufacturing and business process management systems.

Existing digital twin systems, described in [5–7], are mainly focused on displaying the state of objects in the physical and/or virtual world with the organization of access to this information to all stakeholders involved in real manufacturing or business processes of the enterprise or managing these processes. Digital twins also allow for simulation of manufacturing and business processes to optimize the use of enterprise resources [8–10].

To improve the efficiency of production systems, the concept of an industrial agent is being actively developed. This is understood as "an autonomous and self-sufficient cyber-physical entity that represents the functionality of one or more industrial assets and manages them, providing permanent or temporary physical communication in order to perform functions and processes" [11]. The autonomy of industrial agents means their ability to respond to events arising in the external environment, making decisions and their execution. The construction of such production systems is based on the use of intelligent technologies associated with the development of dynamic multi-agent systems.

To integrate participants in network enterprises, the issues of creating and using digital platforms and connected intelligent agents come first. This should ensure the implementation of the principles of decentralization of management, vertical and horizontal integration of manufacturing and business processes, rapid reconfiguration of production chains and increased reliability of the entire production system [3, 4, 12].

From a technological point of view, the digital platform is a set of software services united by a common software environment to implement various functions of creating and operating a business ecosystem and individual network enterprises [13].

The work [14] summarizes the experience of using digital platforms at various industrial enterprises in Germany and Japan, thanks to which the authors propose a classification:

- The cloud platform implements, using cloud services, centralized collection and processing of manufacturing companies' data, which is processed for the purpose of timely diagnosis of deviations from plan and long-term performance forecasting of the production structure. Open cloud platforms operate for the entire business ecosystem, while closed cloud platforms operate only for participants in individual digital or networked enterprises.
- The edge platform extends the cloud platform with computing infrastructure deployed locally at remote sites corresponding to production assets such as equipment, production lines, workshops and factories. In this regard, the collection and primary processing of data is carried out at remote sites in a closed mode, and summarizing information and making centralized decisions is possible in an open cloud environment.
- The brokerage platform (market place) takes on the functions of organizing the interaction of enterprises with each other in terms of selecting the best business partners according to various criteria, and plays the role, in the simplest case, of a trading platform. Intermediary (brokerage) platforms usually have an open nature of forming a business ecosystem.
- A hybrid platform allows us to combine the functionality of different types of digital platforms for different types of business models of networked enterprises.

The choice of the digital platform type is closely related to the choice of the business model type of the production system, which determines the pattern of interconnected material, information and financial flows from the perspective of the overall digital transformation strategy, taking into account technological and resource limitations [15]. As a rule, this choice is

one-to-one, that is, the business model determines the requirements for the digital platform, and the digital platform sets restrictions on the implementation of the business model.

In [16], a generalized classification of business models for Industry 4.0 systems is given, according to which the following are distinguished: the industrial internet of things platform model, the value-adding services in operation model, the brokerage platform model, and the data trustee model. In [15], a multi-criteria model for choosing the type of business model was proposed, considering the network effects obtained, factors of the company's digital maturity, commercial risks and information security risks.

In principle, one enterprise can use different types of business models (BM) depending on the characteristics of the type of value-added chain and the life cycle stage of the products and/or services provided [17]. Consequently, the features of the enterprise's operating environment determine the requirements for building a business model, and the business model can radically transform the corresponding manufacturing and business processes using a certain application scenario of digitalization (use of digital technologies) [18]. Thus, types of digital platforms, types of business models and application scenarios of digitalization turn out to be highly interrelated, influencing each other.

At the same time, the implementation of modern digital technologies in the functioning of industrial enterprises remains an insufficiently researched area that requires generalization of the accumulated experience in the practical application of production technologies and the formation of a methodology for justifying the choice of certain application scenarios of digitalization in connection with the choice of types of business models and digital platforms.

The Plattform Industrie 4.0 AG2 (R&D Working Group) [19] generalized the practice of using digital platforms to organize manufacturing and business processes and proposed promising application scenarios for new projects of the digital transformation of enterprises. Based on the selected application scenarios, it is possible to build test benches on which it is possible to test various operating modes of enterprises. Similar work on the formation of standard scenarios of digitalization was carried out by the Smart Service Welt working group [20, 21] and in the approach to creating test benches of the Industrial Internet Consortium (IIC) [22], which allow for testing the proposed use cases for application scenarios, exploring promising technology development scenarios and forming standardization requirements.

A comparison of the listed approaches showed a very strong overlap in the content of the considered aspects of digitalization in the application scenario based on an analysis of the value of the collected operation data of assets, and the scenario for ensuring the transparency and adaptability of the supplied products. At the same time, the approach to building application scenarios in the concept of the Platform Industry 4.0 project is more complete in terms of implementing processes for all main types of manufacturing and business processes at various life cycle stages. Therefore, in the future, this approach will serve as the basis for studying application scenarios of digitalization for various types of business models and digital platforms.

The accumulation of experience in the implementation of business models, digital platforms and application scenarios of digitalization and its generalization in the form of reference models makes it possible to organize a knowledge-based system [23], which would make it possible to select appropriate scenarios and business models for the digital transformation of enterprises based on qualitative criteria, with the need to combine and adapt them to the operating conditions of a particular enterprise and calculate direct network effects from the application of selected scenarios. Moreover, all tasks are solved by constructing an ontology of digital transformation of enterprises, and the last task is based on the use of a combination of activity-based costing of performing manufacturing and business processes, and cash flow analysis to assess ROI in digital transformation. In accordance with the problem statement presented here, the article aims to develop methods and models for substantiating a scenario for the digitalization of manufacturing and business processes of enterprises, taking into account the choice of the type of business model and digital platform.

1. Methods for substantiating scenarios for digital transformation of an enterprise's manufacturing and business processes

From an architectural point of view, the transformation of enterprises based on digital technologies is carried out at several architectural levels [24, 25]:

- business organizations – identification of stakeholders, their vision of digital transformation, declared values, goals and objectives of the enterprise's digitalization;
- user participation – defining a sequence of activities involving users that provide the necessary functionality to achieve the capabilities of the digital production system;
- functional requirements – identifying the functional components of a digital production system, determining their structure and relationships, interfaces with the external environment;
- implementations – the use of technology to implement functional components, their communication patterns and life cycle procedures.

This article proposes methods for substantiating the digitalization of manufacturing and business processes of an enterprise which are determined by the interrelated choice of an application scenario of digitalization, the type of business models and the type of digital platform and it provides requirements for a digital production system at the level of business organization and user participation. The relationship between application scenarios of digitalization, types of business models and types of digital platforms is presented in the table of correspondence between the components of digital transformation of enterprises (*Table 1*), which is based on [14, 16, 19].

Examples of the implementation of application scenarios of digitalization based on the use of various types of business models and digital platforms in practice are reflected in works [26–31].

The proposed methodology for substantiating the digital transformation of enterprises is implemented within the framework of the created knowledge-based system and includes the consistent application of the following methods:

- Carrying out ontological engineering and analysis of the applicability of various application scenarios for the digitalization of manufacturing and business processes to the operating conditions of a particular enterprise as a result of which application scenarios of digitalization, types of business models and types of digital platforms that make up specific use cases are selected for various types of value chains.
- Perform an economic analysis of the applicability of selected use cases as a combination of application scenarios, business model type and digital platform type, based on the calculation of direct network effects for all parties involved.

When performing the stage of ontological engineering and analysis, it is proposed to reflect in the ontology of digital transformation of enterprises the types of processes within value-added chains and scenarios for their digitalization [19, 22, 32], types of business models [16, 17], types of digital platforms [14], factors for the need for digital transformation of manufacturing and business processes and factors for the choice of types of business models [15].

When describing application scenarios for digitalization of enterprises, it is necessary to define such main sections as [19, 22, 32]: stakeholders in digital transformation (actors); their roles in the transformation process; for each role, a vision of their implementation; key values and experience that the actor receives as a result of the implementation of the scenario; fundamental capabilities that characterize the features of ongoing innovations from the perspective of implemented technologies.

The basis for constructing an ontological representation of the type of business model and the type of digital platform is the framework for constructing a business model of St. Gallen [14–17, 33], which distinguishes the following main categories:

- participants in manufacturing and business processes, and their roles;
- value proposition at the output of processes, the result of the process;

Table 1.

Correspondence of components of digital transformation of enterprises

Value-added chain processes	Application scenario of digitalization	Business model type	Digital platform type
Product life-cycle management	IPD – value-added chain "Innovative Product Development," creating a concept and designing a product	Data trustee	Cloud platform
	SP2 – value-added chain "Smart Product Development for Smart Production," full cycle of development of intelligent products	Data trustee; IIoT platform model	Cloud platform
Production system life-cycle management	SPD – value-added chain "Seamless and dynamic plant engineering," organization and equipment of the factory (workshop)	Value adding services in operation	Edge platform
	AF – value-added chain "Adaptable Factory," management of production resources in the manufacturing process	Value adding services in operation	Edge platform
Supply chain management	OCP – value-added chain "Order-Controlled Production," managing the distribution of a common pool of resources between value chain participants	Value adding services in operation	Brokerage platform (marketplace)
			Cloud platform
	SAL – value-added chain "Self-organizing Adaptive Logistics," logistics routing	Value adding services in operation	Brokerage platform (marketplace)
			Cloud platform
Service	VBS – value-added chain "Value-Based Services"	IIoT platform model	Cloud platform
	TAP – value-added chain "Transparency and Adaptability of delivered Products," management and trusted access to product data	Data trustee	Cloud platform

- value chain, which determines the characteristics of the implementation of key work and the interaction of process participants;
- revenue mechanism that determines cash flows between process participants that create value for process consumers, as well as possible cost savings on work.

In addition, for digital platforms such additional characteristics are specified as [14]:

- features of concluding business contracts;
- description of key business model innovations (description of changes in the business model, qualitative characteristics of network effects);
- features of information security.

To carry out ontological analysis, the ontology of digital transformation of enterprises can be used in two modes:

- in reference mode, when any ontology category can be displayed to the decision maker for study with the necessary detail of properties and relationships;
- in the mode of selecting and justifying the use of certain components of digital transformation: appli-

cation scenarios, types of business models, types of digital platforms separately and in conjunction with each other from the perspective of various aspects and their combination when building value-added chains.

- In the second case, the query specifies the basic parameters of the enterprise, such as the type of enterprise, the type of production system, the characteristics of the product being manufactured, the life-cycle stage, and the proposed types of transformed manufacturing and business processes. Recommendations are provided in the corresponding responses to queries.

For the level of architecture of the digital production system, which characterizes the implementation of application scenarios of digitalization, the ontology of digital transformation of enterprises is expanded by describing the points of view on the use of the scenario from the position of each of the participants.

The description of the point of view covers a description of the type of activity associated with the application scenario use, which in turn includes the condition for its execution, the results obtained, restrictions and descriptions of the sequence of tasks (works) performed.

Based on such a detailed presentation of application scenarios, it becomes possible to carry out the second stage of the methodology for substantiating the enterprise's digital transformation, associated with an economic analysis of the possibility of implementing the scenario.

The essence of economic analysis comes down to assessing the network effect for each participant in network interaction according to the selected application scenario of enterprise digitalization. The effect of an individual participant is defined as the difference between the income received from the provision of services in the value chain and the costs associated with payments for the use of services provided by other participants in the value chain and the costs of performing the work themselves. The income and costs of each participant in the value chain are calculated on the basis of known payment items recorded in the "revenue mechanism" section of the ontological description of the type of business model (type of digital platform). The costs of performing their own work by each participant in the value chain are calculated using the method of activity-based costing for a set of tasks performed for each type of activity. In the same way, one-time costs for creating a digital platform and organizing manufacturing and business processes can be calculated. The method of economic analysis of the effectiveness of implementing an application scenario is discussed in detail in the corresponding section taking the example of two options for using a VBS application scenario.

2. Ontological model of digital enterprise transformation

Using the ontology of digital transformation of enterprises to create a knowledge-based system (KBS) that allows us to form business models and application scenarios for their use in specific digital enterprises provides the solution to the following tasks:

- Firstly, the ontology allows you to define a classification of typical business models, digital platforms and application scenarios according to which any digital enterprise can formulate appropriate requirements for its architecture.
- Secondly, in accordance with the ontology, consulting companies can accumulate knowledge bases of real precedents for using models of digital transformation of enterprises which can be selected by analogy and adapted to the operating conditions of specific digital enterprises.

The interaction scenario between the user and KBS is shown in *Fig. 1*.

One of the key elements of KBS is the digital transformation ontology based on the principles of constructing a design ontology [34] and reflecting methods and models for designing components of a digital transformation option (such as a business model, a type of digital platform and an application scenario of digitalization) of a networked enterprise focused on the implementation of the Industry 4.0 concept.

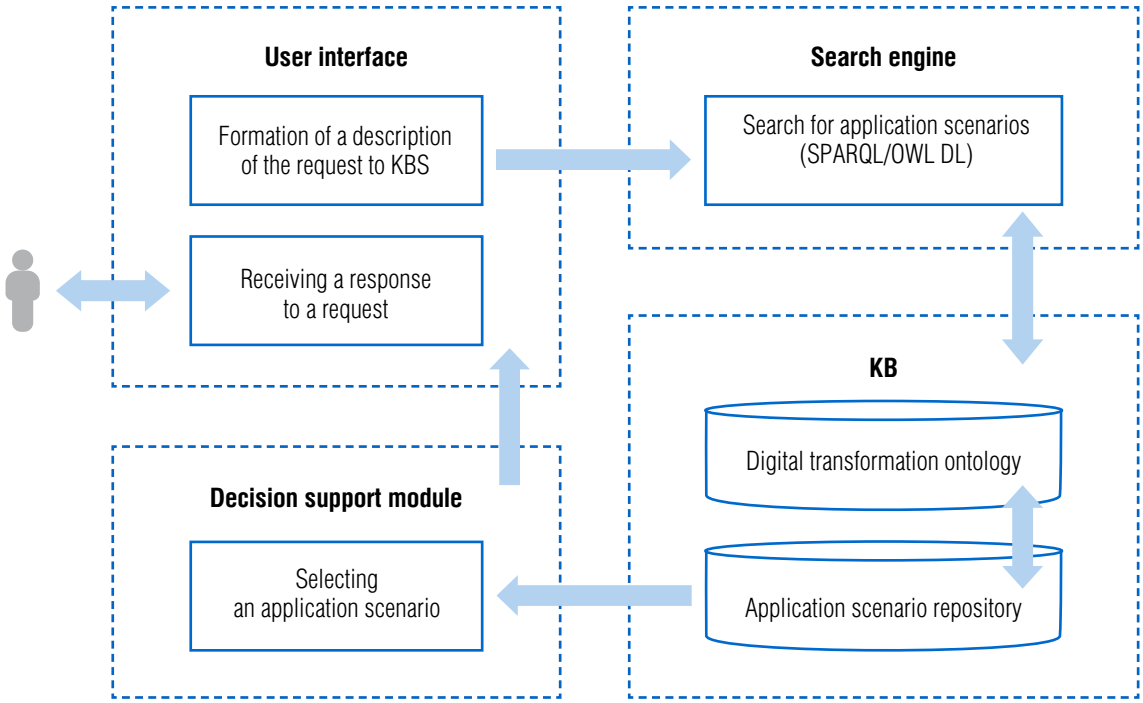

Fig. 1. Interaction between the user and the knowledge-based system to justify the option of digital transformation of the enterprise.

The user, through the interface, generates a query to KBS to select components of the digital transformation option and receives a response from KBS accordingly.

The search service selects components of the digital transformation option that correspond to the current problem situation defined by the user of KBS using the digital transformation ontology.

A knowledge-based system allows you to effectively accumulate and systematize the best experience of digital transformation projects in a repository that stores typical digital transformation options and specific implementations of application scenarios of digitalization.

The decision support module implements a qualitative and cost analysis of digital transformation options selected from the repository according to [35].

Let us consider the ontological model of digital transformation of a networked enterprise in more detail.

The key concepts of the digital transformation ontology are the traditional business entities of the business modeling ontology [36]: Enterprise, Product, Life-cycle Type and Life-cycle Stage, Strategy, Business Process, Business Model class, Roles, their Tasks, Risks, Costs, Value Propositions, and place in the Value Chain, the Revenue Mechanism as a whole. Along with this, for the purposes of KBS, the concepts of the domain of the Industry 4.0 are integrated into the ontology: digital platform, business model type, application scenario and its types according to [19].

The developed structure of the digital transformation ontology is divided conditionally for clarity into two parts, respectively related to the choice of the type of business model (*Fig. 2*) and the choice of an applied scenario of digitalization (*Fig. 3*).

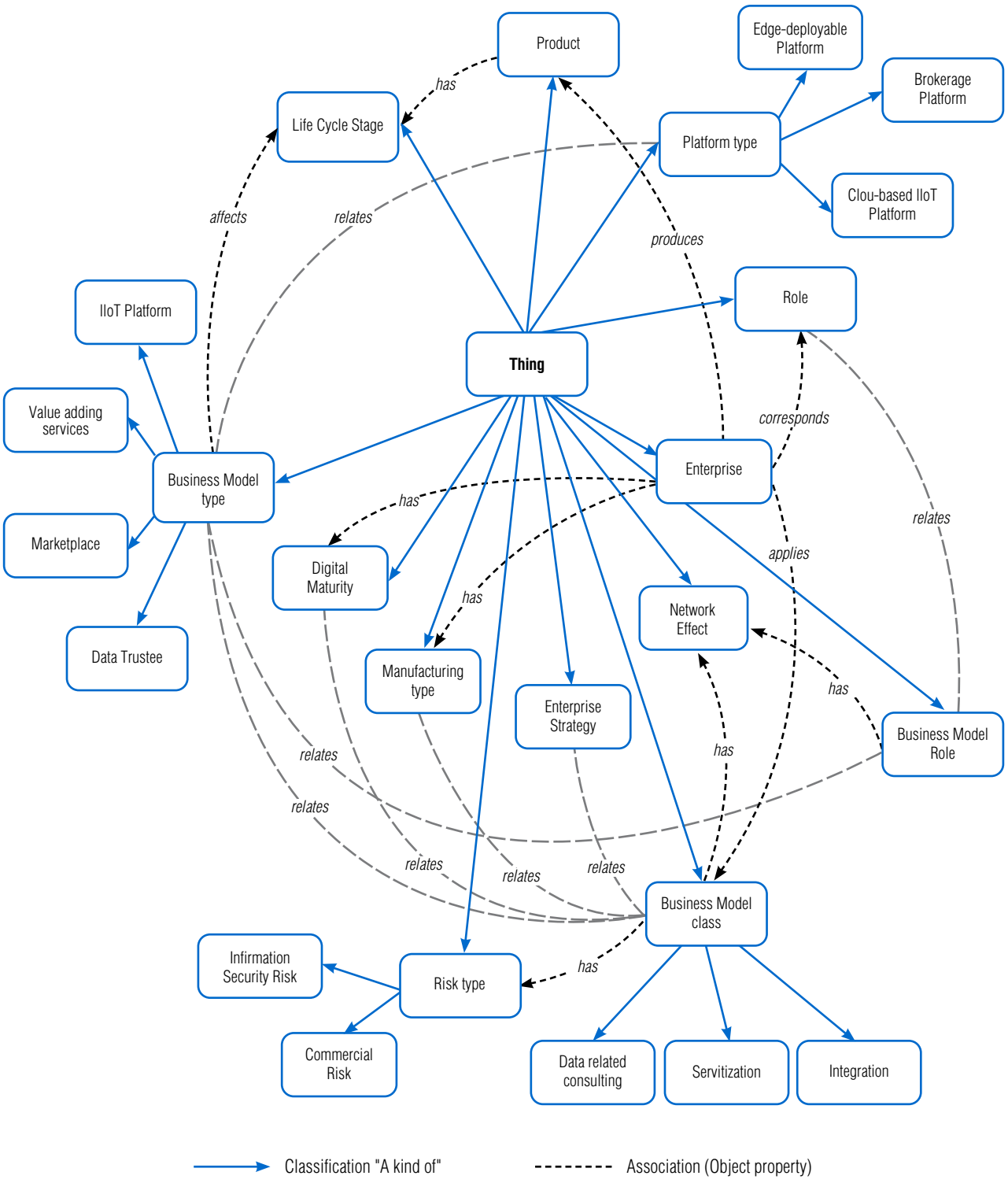

Fig. 2. Digital transformation ontology (part "Selecting a business model type").

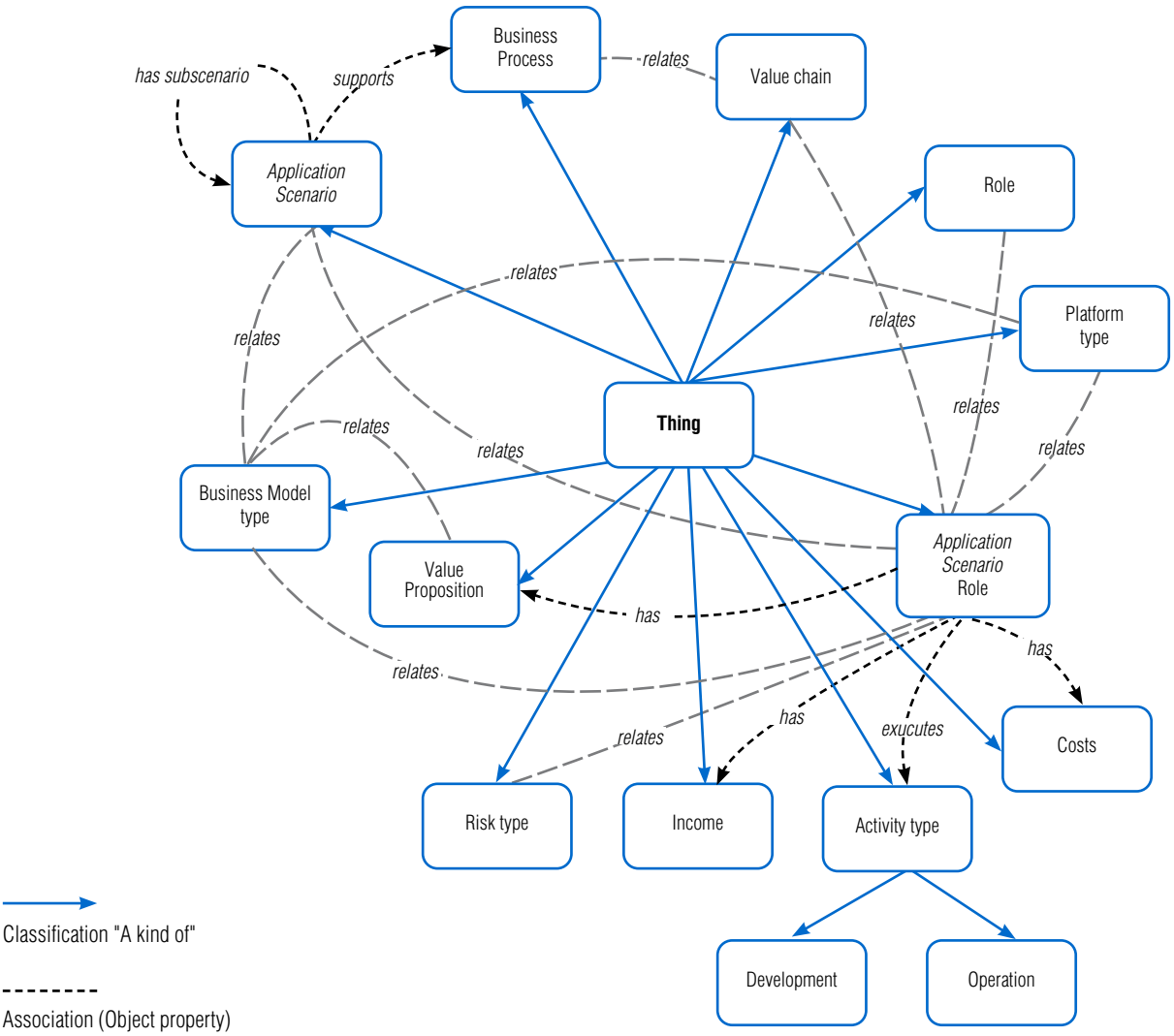

Fig. 3. Digital transformation ontology (part "Selecting an application scenario").

To justify the choice of the type of Industry 4.0 business model (type of digital platform), interrelated descriptions are specified that determine the correspondence of the characteristics inherent to the organization (corporate strategy, manufactured products and production system) and the characteristics of a possible business model (the required level of digital maturity, possible risks, network effects by digital transformation) (*Fig. 2*). Further actions of the KBS user allow you to select an option for the type of business model that meets the parameters of a specific organization [15].

The selected type of business model characterizes the way of organizing the functioning of a network enterprise based on a digital platform which can be detailed using typical application scenarios of digitalization [28, 30] (*Fig. 3*). The selection of application scenarios of digitalization tied to a specific type

of business model and including a description of roles, income and cost structure, and a set of tasks to be performed is carried out based on the execution of standard queries to the KBS repository.

The main entity for describing an Application Scenario is an Application Scenario Role, the description of which includes a number of characteristic attributes:

- a typical Role performed within a specific Application scenario;
- the peculiarity of the Role's participation in the Value Chain;
- Value proposition offered by the Role;
- Value proposition related Income;
- investment and operational Costs borne by the participant in the networked enterprise performing the corresponding Role in the Application scenario (including those associated with receiving value from another participant);
- specific Platform Activity in the field of design and operation of the platform that is related to the activities of the corresponding Role;
- Commercial risks and Information security risks associated with the activities of the Role in the Application Scenario.

Typical requests are a reference to a description of application scenarios for using business models from an ontological knowledge base and the selection of specific application scenarios based on various characteristics that are of interest to stakeholders in the creation of networked enterprises.

With the further development of KBS, along with standard application scenarios, new application scenarios can be entered into the knowledge base, reflecting the best experience of the enterprise, including a problem situation description and the generated activity model. At the same time, concepts and instances are created that correspond to the description of the activity, problem situation and other elements of the application scenario. After this, relationships are established between the special application scenarios created and the existing standard application scenarios. In this way, the knowledge base can be regularly updated with up-to-date knowledge about effective ways to digitally transform an enterprise and organize value-added chains based on modern business models and digital platforms.

3. Economic model for substantiating the application scenario of digitalization of a networked enterprise

Justification of the feasibility of implementing various options for the structural organization of manufacturing and business processes formed on the basis of the type of business model, type of digital platform and application scenario of digitalization requires a quantitative economic analysis proving the possibility and effectiveness of their implementation. As a method for assessing the option of digital transformation of a networked enterprise, it is proposed to use the NPV (net present value) method, which allows you to link together all cash flows of different time periods and determine their total value at the current time [37, 38]. The purpose of applying the NPV method is to decide whether the parent enterprise and potential participants should invest in the organization of a networked enterprise.

Unlike a traditional enterprise, which independently invests in organizing its manufacturing and business processes, a networked enterprise requires minimal or no initial investment from all its participants. Investments are made from stakeholders depending on their goals in the value network and resource capabilities. This reduces the barrier to entry for many participants in the business ecosystem.

In general, to organize any application scenarios of digitalization in a networked enterprise, investments are required primarily in the creation of a digital platform, software services and agents interacting on the platform from the platform operator, service provider and service developer, respectively. The use of any implementation options for application scenarios generates a periodic cash flow for each participant in the value-added chain, which includes incoming and outgoing payments of the enterprise and its internal expenses.

The decision on the participation of a potential participant in the networked enterprise is made based on calculating the total NPV value for all its roles, which must be above a certain threshold value:

$$NPV_i = \sum_{j=1}^{r_i} NPV_{ij}, i = 1, ..., k, \quad (1)$$

where NPV_i – net present value for i-th participant in the networked enterprise;

NPV_{ij} – net present value for j-th role of i-th participant in the networked enterprise

r_i – number of roles of i-th participant in the network enterprise;

k – number of the networked enterprise participants.

The main roles of participants in networked enterprises can be defined as follows [19]:

- Manufacturing Company;
- Equipment Supplier;
- Platform Operator;
- Service Provider;
- System Integrator;
- Service Developer;
- Platform Developer.

A networked enterprise usually includes a parent enterprise, most often with the role of a Manufacturing Company, which becomes the initiator of the project. It is engaged in the formation of orders for participants in the networked enterprise with the above roles. A networked enterprise, as a rule, is formed on the basis of a business ecosystem that has a digital platform.

The NPV value of one potential participant in the networked enterprise for each role in the value-added chain is determined by the formula:

$$NPV_j = -IC_j + \sum_{t=1}^{N} \frac{CF_{jt}}{(1-sd)^t}, j = 1, \ldots, r_i, \quad (2)$$

where IC_j – initial investment for the j-th role of a participant in the networked enterprise;

CF_{jt} – cash flow of the t-th period (in a certain year) for the j-th role of a participant in the networked enterprise;

sd – discount rate;

sd – number of periods of existence of the network enterprise.

Cash flow is calculated for each year of existence of a networked enterprise as the difference between income from payments from other organizations and costs, including payments to other organizations, internal expenses and risk costs. It must be economically profitable for each potential participant to join a networked enterprise.

The assignment of roles to participants in a network enterprise is carried out in accordance with the application scenario of digitalization, for which its own characteristic set of value-added chain roles is determined depending on the focus of use, for example, on product management processes, on production system management processes, on supply chain management processes or on service processes. At the same time, as part of the implementation of an application scenario, an enterprise can perform several roles, or many enterprises can participate in one role.

In the future, we will consider the formalization of the economic model for justifying the application scenario of digitalization using the example of the applied scenario "value-based service" (VBS) [28]. The essence of the application scenario is that a Manufacturing Company rents machines from an equipment supplier that can operate using IIoT technology and, if necessary, be created to individual requirements. The Software Service Provider supplies software services to the platform which are operated by the Platform Operator. The Platform Operator receives data from the manufacturing enterprise machines connected to the digital platform in three ways and offers services to the parent enterprise based on the received data. The services consist of an analysis of the received data followed by the formation of recommendations from the Platform Operator or Software Service Provider. In addition, the data may be transferred to the Software Service Provider for the development of new or updating existing software services. In this implementation of the application scenario, each role corresponded to one enterprise (*Fig. 4*).

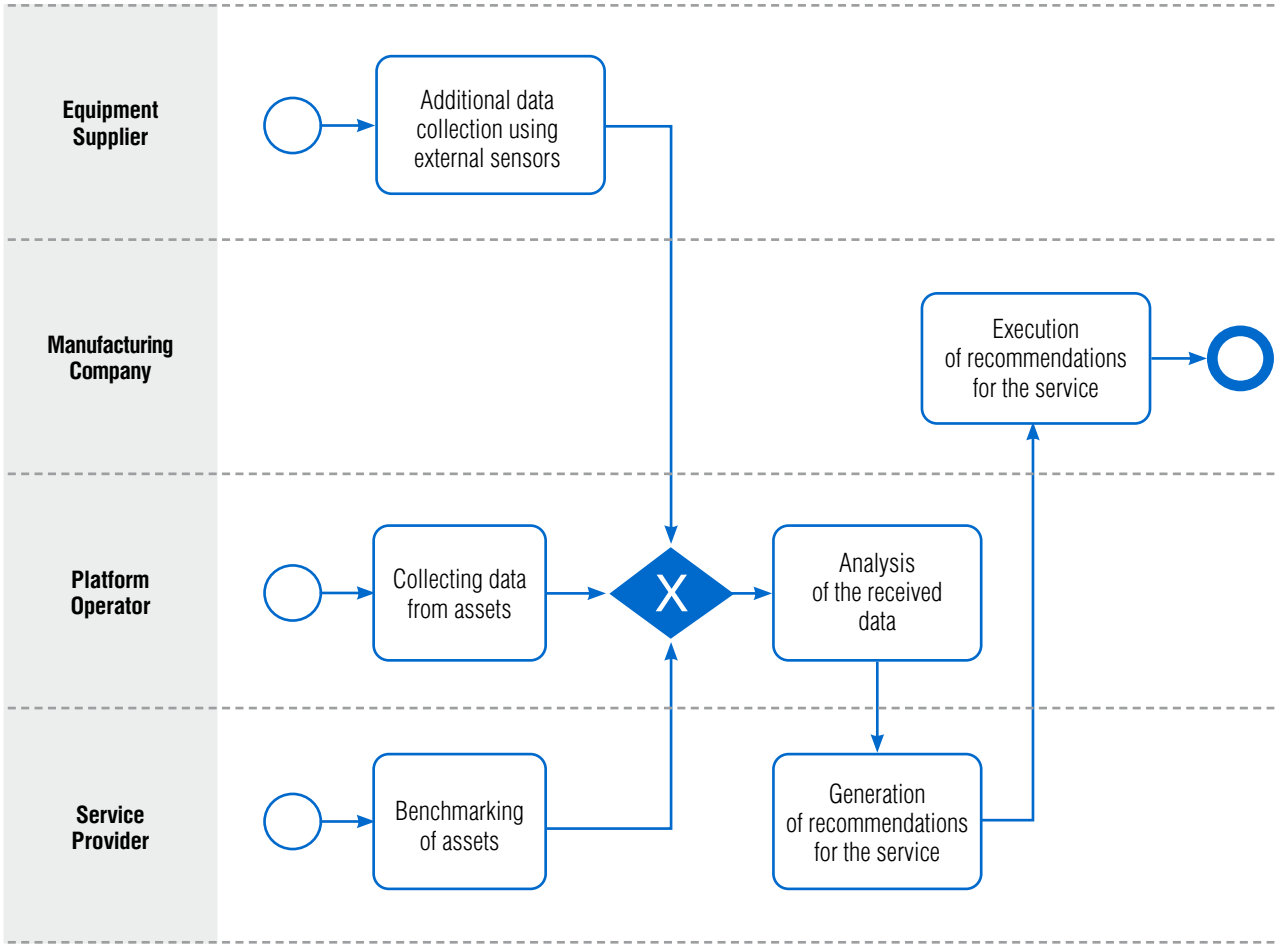

Fig. 4. The process of performing a service for collecting and analyzing of equipment operation data.

In another implementation of the VBS application scenario, the parent enterprise organizes its own digital platform, which allows it to control access to platform and software services. In this case, the parent company refuses to outsource work with the platform and assumes the role of Manufacturing Company and Platform Operator.

The decision to outsource digital services may be driven by the following factors:

- insufficient own financial and/or material resources to carry out certain business processes;
- insufficient motivation of the enterprise, for example, some business processes are not a priority for the enterprise, and their implementation can lead to a decrease in the rate of productivity of the main processes;
- the presence of restrictions, for example, related to confidential information, the leakage of which will lead to loss of competitiveness in the market.

In accordance with [28], the application scenario identifies work related to the organization of the platform and network enterprise which require initial investments from the following main roles of par-

ticipants in the network enterprise: Platform Operator (PO), Service Provider (SP), Equipment Supplier (ES), Manufacturing Company (MC). The list of works and their distribution by network interaction participants is presented in *Table 2*.

The calculation of the total cost of initial investment (IC_i) for each role of the VBS application scenario can be represented as the summation of all types of costs under a specific role:

$$IC_j = \sum_{i=1}^{N} a_{ij}, i = 1, ..., k, \quad (3)$$

where a_{ij} – table element of i-th type of initial investment and j-th role of the application scenario;

N – number of cost types;

k – number of application scenario roles.

The use of application scenarios of digitalization leads to a change in the value-added chain and, accordingly, a new structure of costs and income for each of its participants. This is because there is a distribution of risks in the activities of a networked enterprise, fixed and variable costs between participants, as well as the emergence of new items of income and costs which depend on the performed roles of the participant in the value-added chain and the application scenario itself.

Thus, the changed structure of costs and income of the annual cash flow (CF_i) for each participant in the networked enterprise can be determined by the formula:

$$CF_i = DP_i + DN_i - SP_i - VZ_i, i = 1, ..., k, \quad (4)$$

where k – number of enterprises participating in the application scenario of digitalization;

DP_i – income from receiving payment for the services of i-th enterprise;

SP_i – own payments for services provided by i-th enterprise;

DN_i– indirect network effect of i-th enterprise;

VZ – internal costs of i-th enterprise, which are calculated based on the application of the functional cost analysis method [39–41].

For a manufacturing company, the indirect effect is a reduction in costs for equipment repair and main-

Table 2.

Initial investments

Investments in installation and configuration of equipment	Roles			
	PO	SP	ES	MC
Setting up the platform for the networked enterprise	IDP			
Service development		IDS		
Equipment development (custom requirements)			IDE	
Equipment rent				IE
Product equipment manufacturing			IPE	
Connecting and setting up equipment	ICN_1		ICN_2	ICN_3

tenance. For a software services provider, this means creating new services based on equipment operation data of a manufacturing enterprise which will lead to an increase in licenses. For the platform operator, this is a reduction in the costs of operating and supporting the platform due to an increase in the number of platform participants by increasing the attractiveness of the platform for networked enterprise participants through new software services and platform services. For the equipment supplier, this means reducing costs by reducing equipment downtime, since an increase in the number of production plants will make it more likely that the equipment will be rented.

In addition to the costs listed in *Table 3*, internal costs include fees for risk prevention activities. These fees may include the costs of analyzing and forecasting risks, the costs of eliminating the consequences of unforeseen risks and the costs of insurance against selected risks.

For a manufacturing company in a networked enterprise, the following risks associated with operational failures can be identified:

- quipment;
- platforms (including restricting access to them);
- software services (including restriction of access to them);

Table 3.

Cash flow for the year

Costs type (items of income/costs)	Roles			
	PO	SP	ES	MC
Service fee	S			$-S$
Payment for platform services from the service provider	SP	$-SP$		
Payment for platform services from the equipment supplier	SE	$-SE$		
Equipment connection fee	$-CN$		CN	
Equipment setup fee	$-F$		F	
Payment of a license for the use of the application by the equipment operator	$-L$	L		
Platform maintenance costs	$-PL$			
Costs of developing an application for the service		$-DA$		
Service development costs		$-DS$		
Equipment rental fee			AE	$-AE$
Payment for risk prevention activities	$-R_1$	$-R_2$	$-R_3$	$-R_4$
Indirect network effect	DN_1	DN_2	DN_3	DN_4

- failures in the supply of equipment for individual orders;
- incorrectly executed individual orders for equipment;
- lack of need for the product among customers.

For a software service provider in a networked enterprise, the following risks can be identified:

- loss of the ability to deliver software services to the platform;
- refusal of the platform operator to provide a software service due to lack of demand or the creation of a similar and competitive software service;
- impossibility of integrating custom-made equipment and software services;
- identifying critical errors in the software service;
- leak of confidential data about processes and users of a software service.

For the platform operator in a networked enterprise, the following risks can be identified:

- refusal to work on the platform of the parent enterprise;
- inability to operate the platform due to lack of financial resources or technological problems;
- loss of reputation due to low-quality software services;
- leak of confidential data about processes and users of platform services.

For the equipment supplier in a networked enterprise, the following risks can be identified:

- refusal to individually develop equipment;
- impossibility of integrating custom-made equipment and software services;
- refusal of a manufacturing company to rent equipment due to lack of demand or the creation of similar and competitive standard equipment.

In *Table 3*, the minus sign means payment for the service or internal costs; the absence of a sign means receipt of payment. The calculation of the cash flow value () for each role of the VBS application scenario can be represented as the summation of all types of costs under a specific role:

$$CF_j = \sum_{i=1}^{N} a_{ij}, i = 1, ..., k, \quad (5)$$

where a_{ij} – table element of i-th costs type and j-th role of the application scenario of digitalization;

N – number of costs types;

k – number of application scenario roles.

Given that an enterprise can perform several roles when organizing a networked enterprise, the number of types of incoming and outgoing payments changes. Depending on what roles enterprises take on within the application scenario of digitalization, the structure of risk accounting changes, as well as the main types of operating costs in a networked enterprise, when payments are replaced by internal costs.

The proposed economic model to justify scenarios for organizing manufacturing and business processes of a network enterprise based on the NPV method and activity-based costing allows us to assess the attractiveness of a network enterprise for all its potential participants. Thanks to economic analysis, deciding on the implementation of application scenarios of digitalization to create a network enterprise becomes economically justified due to the provision of information about possible income, costs, risks and other factors associated with the value-added chain. The analysis allows us to evaluate for each enterprise and its corresponding roles the potential profit generated because of payments, direct and indirect network effects and internal cost savings, compare them with initial costs, and also determine the best option for implementing the application scenario of digitalization.

Conclusion

An analysis of the experience of implementing business models, digital platforms and application scenarios of digitalization at enterprises shows the need to develop ontological and economic methods for the formation and justification of the organization of manufacturing and business processes depending on the type and potential of participants in networked enterprises. Moreover, the ontologi-

cal model of digital transformation should serve as the basis for the formation of variants of application scenarios of digitalization for their subsequent economic justification.

The proposed method of ontological engineering and analysis of the feasibility of various application scenarios for the digitalization of manufacturing and business processes to the operating conditions of a particular enterprise involves mapping in the ontology the classification of types of business models, digital platforms and application scenarios themselves in interrelation for various types of value-added chains.

The article identifies the main types of queries to substantiate application scenarios for the digitalization of enterprises, which make it possible to select typical scenarios of digitalization based on individual or combinations of features that characterize the formation of value propositions, obtaining competitive advantages and ensuring positive cash flows depending on the performed roles of participants in network enterprises. The computer implementation of the ontology in the OWL format also allows for reference queries on the implementation of certain types of application scenarios.

In the future, the ontology of digital transformation of enterprises we developed can serve as the basis for accumulating an ontological database of precedents for the implementation of application scenarios, business models and digital platforms to search for the best practices of digital transformation and its adaptation to specific conditions.

Based on the economic analysis of network effects from the use of one or another option to construct an application scenario for the digitalization of enterprises, this article proposes the use of the NPV method, which determines investments in standard work preparing a digital platform for operation, as well as current income and costs in the form of mutual payments participants of network enterprises, considering the cost of performing internal work. From this point of view, the article defines the composition of income and cost items for a common application scenario to obtain value from the analysis of digital data. Comparison of the total network effect for various options for the role participation of stakeholders of a network enterprise allows you to select the best implementation of the application scenario. In the future, it is proposed to expand the method of economic analysis of options for constructing application scenarios by formalizing models for obtaining indirect network effects by expanding the number of participants in the business ecosystem.

The novelty of the proposed methods and models to justify options for the digital transformation of manufacturing and business processes of enterprises lies in the formulation and solution of the problem of the interrelated choice of the type of business model, type of digital platform and application scenario depending on the nature of the enterprise. At the same time, the ontological model of digital transformation serves as the basis for the formation of applied scenarios for the digitalization of enterprises, the choice of which is clarified because of applying the model for calculating economic efficiency using the NPV and activity-based costing methods. ■

Acknowledgments

This research was carried out thanks to a grant from the Russian Science Foundation № 22-11-00282, https://rscf.ru/project/22-11-00282/

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