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Choosing the type of business model to implement the digital transformation strategy of a network enterprise

Yury F. Telnov
E-mail: Telnov.YUF@rea.ru

Aleksey A. Bryzgalov
E-mail: Bryzgalov.AA@rea.ru

Petr A. Kozyrev
E-mail: Kozyrev.PA@rea.ru

Daria S. Koroleva
E-mail: Koroleva.DS@rea.ru

Plekhanov Russian University of Economics
Address: 36, Stremyanny Lane, Moscow 117997, Russia

Abstract

The digital transformation of enterprises and organizations in modern conditions is carried out through the development and implementation of new business models based on various digital technologies which are collectively accumulated as part of digital business platforms. Insufficient development of methods and means of choosing adequate business models for the functioning of network enterprises at the present time, depending on the competitive strategy used, production technologies, digital maturity, and security policy, determines the relevance of this study. The aim of the work is to develop a method to justify the rational choice of the type of business model of digital transformation of a network enterprise under the conditions of multi-criteria evaluation of various factors of obtaining network effects, digital maturity and ensuring economic and information security. To achieve the goal, methodological approaches are used as approaches to solve the problem: to formalize the business model based on the St. Gallen framework, to classify business models of the working group on business models Industry 4.0 to build a knowledge-based system using fuzzy sets of production rules. A method is proposed for classifying the types of business models of a network enterprise depending on the competitive strategy applied, the stage of the life cycle of products and services provided, the type of production and the method of using digital business platforms. In accordance with the classification of the working group on business models of Industry 4.0, network effects are determined for the main roles of participants in network interaction for each type of business model. A conceptual multi-criteria model for choosing the type of business model has been developed, implemented in the form of sets of production rules of a knowledge-based system which include an assessment of network effects, digital maturity, commercial risks and information security risks.

Keywords: business model, digital transformation strategy, digital platform, network enterprise, network effects, digital maturity, commercial risks, information security risks, multi-criteria choice, knowledge-based system

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Introduction

One feature of economic development in modern conditions is the creation of business ecosystems based on the use of digital platforms within which there is a radical transformation of business models and business processes of enterprises and organizations. Such transformations are called digital transformation of enterprises; it involves "qualitative changes in the business models of economic activity, and significant socio-economic effects from their implementation" [1].

According to the Strategy of the Ministry of Industry and Trade of Russia, "Digital transformation of industry is a priority for the development of the domestic economy, providing high adaptability in the formation of business models and the operation of production processes through the integration of end-to-end digital technologies" [2]. In [3] it is argued that "Digital transformation represents a sharp reduction in transaction costs due to platforms as a result of the emergence of new business models. Combining the capabilities of technology and the traditional scope of the organization leads to the emergence of new products and processes with fundamentally different qualities." Work [4] emphasizes the role of digital transformation in the transition to digital business "based on a comprehensive transformation of the company's activities, its business processes, competencies and business models, the fullest use of digital technology capabilities in order to increase competitiveness, create and build value in the digital economy." As the Working Group on "Digital Business Models in Industry 4.0" (BMWK) defines Industry 4.0: "Business models are the foundation of entrepreneurial success. They embody the corporate mission and corporate strategy, and are the basis for investment decisions and organizational management" [5].

In [6] it is argued that innovations in business models bring a more tangible effect compared to innovations separately in products, processes and technologies. In this regard, a business model is not just a scheme of monetization of the company's income, but the entire set of business processes, technologies and personnel organization which determines the scheme of interrelated material, information and financial flows from the perspective of the overall strategy of digital transformation, taking into account technological and resource constraints. Therefore, the rational choice of the type of business model is a determinant condition for the success of the digital transformation of enterprises. The purpose of this paper is to develop a method to justify the rational choice of the type of business model for digital transformation of a network enterprise under the conditions of multi-criteria evaluation of various factors of network effects, digital maturity and economic and information security.

Aspects of creating business models based on multilateral digital platforms are discussed in articles [7–9]. A key conclusion of the analysis of existing business models is that digital services depend on the organization of value networks in which all participants in network interactions receive economic effects (network effects). Methods and models for creating network businesses using digital platforms are developed in [10–12]. Application of various business models has a significant impact on the change of organizational schemes of interaction of the enterprises participating in joint activity, in the creation of network enterprises [13].

One of the main conditions for the successful selection and application of a business model is its alignment with the defining strategy of digital transformation. Digital transformation strategy can be considered both in the classical sense of competitive strategy implementation: broad differentiation, cost leadership, optimal costs, focused strategies (segmentation) [14], and in the narrow sense as a way (direction) of applying digital technologies to implement business models and create new competitive business potential. In the first case, the choice of business model is determined by the competitive strategy; in the second case, the type of business model, on the contrary, determines the methods of digitalization of all related processes [15–17].

The study of its application at different stages of the life cycle of products and services plays an important role in the choice of a business model of interaction of enterprises in the ecosystem [18]. Consideration of features of the type of production: single, serial, mass production is also important when choosing the type of business model for creating network enterprises [19].

Given the above-mentioned features of business model application related to the analysis of competitive strategy, life cycle of products and services, as well as type of production, it is advisable to develop a classification of business models which would allow the preliminary choice of a business model for application. A more in-depth analysis of the application of various business models involves a study of the economic potential of enterprises to assess the possibility of digital transformation according to the chosen business model.

Economic analysis of the potential of the network enterprise is reduced to an assessment of the possible network effects [12, 20, 21] which can be obtained as a result of creating a network enterprise and assessment of the resources used, reflecting, on the one hand, its digital maturity in terms of knowledge of modern digitalization technologies, and on the other hand, aimed at preventing violations of economic and information security.

Works [7, 22, 23] are devoted to measuring the digital maturity of an organization for digital transformation. The key issue is the selection of indicators for measuring digital maturity. The most important indicators of digital maturity include: the level of digital culture and personnel competencies, the quality of organization of processes and products, access to data, and the organization of an information infrastructure [3].

On the other hand, the assessment of digital maturity should be conducted in conjunction with an analysis of the risks of default in the implementation of commercial transactions, the risks of selecting strategic partners and suppliers of components and materials, the risks of marketing errors in assessing internal market prospects, the risks of a long time to bring a new product to market [2], as well as information security risks [24–26].

To implement an appropriate choice of business model of the network enterprise, this article proposes the development of a method that, on the one hand, allows the best way to realize the strategic objectives of the digital transformation of the enterprise and provides high network effects, and on the other hand, makes it possible to assess the readiness of the enterprise to implement this or another type of business model, given the sufficiency of the economic potential of the enterprise.

From this point of view, the paper proposes a classification of the types of business models on the basis of compliance of the business model with the competitive strategy, stage of the life cycle, type of production and method of application of digital business platforms based on classifications [5, 6], and a multi-criteria model of business model type selection for its implementation in terms of obtaining network effects, sufficiency of digital maturity and minimizing commercial risks and information security risks using a knowledge-based system [27, 28]. The need for knowledge-based systems (expert systems) is due to the qualitative nature of the evaluation factors of the network effects, the level of digital maturity, commercial risks and information security risks, creating the need to formalize the selection process of the network enterprise business model based on the knowledge base of fuzzy rules and the application of the logical inference mechanism.

1. Classification of business model types

Modern concepts of the definition of business models combine the external side of the application, aimed at the implementation of value chains and monetization of financial flows, and the internal side, aimed at the organization of all interrelated business processes [9].

To the greatest extent, this concept of business model is reflected in the interpretation of Osterwalder [29]. In this model, on the one hand, material flows and on the other hand, financial flows are reflected. In the material flow, the output of the business model determines the receipt of value by the final consumer through various channels of distribution of products and services, and the input, respectively, the receipt of necessary material resources through various sources for the production of the required value.

The financial flow reflects in the opposite direction of the value chain the cash flows associated with the receipt and use of income to pay for the resources invested. And the financial flow may not always be directly related to the material flow of value creation, for example, as a consequence of the income from related advertising; nevertheless, one way or another, both flows are tied to a common model of value creation. Osterwalder's model in many respects reflects the classical scheme of business organization, in which the producing company is in the center, and suppliers and subcontractors are considered as business partners, on the one hand, and consumers and users, on the other hand.

In digital business, the network business model affects the functioning of enterprises along the entire value chain. Therefore, the efficiency of a network enterprise is determined not only by the efficiency of the parent enterprise, but also by the efficiency of all interrelated participants, which is called network effects. If the network effects for the participants of the network enterprise will not be obtained, such business model is doomed to failure: the interacting enterprises will not be interested to form a common structure within the unified business concept.

For reflection of network interaction of the enterprises within the limits of the uniform business model, there is the widely applied St. Gallen model [30, 31] in which for each participant of network interaction (for each role in a value chain) the independent model by means of four dimensions is defined: Who (Customer), What (Value proposition, value offer, product or service), How (How — Value Chain, Internal value chain as set of interconnected activities), and Value (Revenue mechanism, Cost structure and income mechanisms applied, etc.). A unified business concept is considered taking into account the network effects for all interacting participants of the value chain. If at least one of participants of interaction does not receive the effect, the business model ceases to be viable. Due to the possibility of the best reflection of network interactions and effects in the future, we will use the model of St. Gallen.

The Working Group on "Digital Business Models in Industry 4.0" is currently developing the use of the St. Gallen framework to formalize digital business models. In the digital business models of Industry 4.0, the key digital technology on which the new business organization is based is the use of digital platforms, and other technologies are based on the use of the Internet of Things, big data and artificial intelligence technology.

The use of the Internet of Things technology makes it possible to implement feedback from technological equipment and manufactured products into the loop of operational production management, which, on the one hand, makes it possible to implement a real-time management process and, on the other hand, to accumulate large amounts of data for analysis and improvement of all interconnected production and business processes. In this case, a new service business model of consumer-producer relations is formed instead of traditional commodity trading.

The use of digital platforms opens up opportunities to integrate network enterprise participants in common business processes, and intelligent technologies together with the Internet of Things technology allow to us to create multi-agent systems, in many cases automating the interaction of value chain participants with minimal staff participation.

In accordance with the above, the BMWK project identifies four types of Industry 4.0 business models based on different ways of applying digital business platforms [5] (*Table 1*).

These types of models reflect a service approach to the organization of customer needs and ultimately implement mediated relationships between consumers and producers through digital platforms that take on intermediary functions (marketplace, digital data platform). However, the variety of business models based on digital platforms is much broader [32, 33]. Therefore, the types of business models of the Industry 4.0 reviewed can be considered as technological frameworks (type models) for the construction of more complex models [34, 35] in which the types of business models examined can be combined.

One of the most successful works on the presentation of more complex archetypes of business models is [6] which differentiates business models according to their purpose: the integration of participants in the value chain, customer service products and services, consulting based on data.

In a broader context, the use of digital platforms makes it possible to manage more complex end-to-end value chains through integration business models that emphasize a special role for one of the enterprises, called

Table 1.

Business models of Industry 4.0

No.	Name of the type of business model Industry 4.0	The essence of the model	Technological principles used	Network effects of the business model
1.	IIoT platform provider	Collection of product use data throughout the product lifecycle, an on–demand data service, getting a data analysis service to improve the product.	Industrial Internet of Things, Data collection and analysis, Machine Learning	**Platform operator/provider:** The revenue model is directly proportional to the number of connected IIoT hardware units and the amount of data being transmitted and analyzed in the value chain. **User:** Outsourcing activities that are not part of its core business. **Service Provider:** Optimize resource utilization with multiple orders from the platform, reducing equipment downtime.
2.	Value adding services in operation	Leasing a finished product or equipment	Industrial Internet of Things, Data collection and analysis, Machine Learning, Multi–Agent Technologies	**Technologies Provider of solutions for IIoT:** Expanding the value proposition by organizing interactions between value chain participants, providing a platform for application development needed to integrate IIoT equipment. **User:** User can outsource activities that are not part of their core business. **Service Provider:** Optimize product usage by analyzing data from the IIoT platform and, as a result, improve the user experience as a result of new insights. **Produce:r** Based on the data received from the service provider on the use of the product by the user, optimizes the product and its processes. **Technical service network:** Reduces transaction costs in the value chain due to direct product delivery from the manufacturer bypassing the owner–service provider **IIoT Equipment Integrator:** Expanding the value proposition to include installation, development and integration of IIoT applications and technologies
3.	Marketplace (Brokerage Platform)	The platform that conditions the connection between suppliers and consumers	Data collection and analysis, Multi–agent Technologies	**The platform (Marketplace) Provider:** The revenue model is directly proportional to the number of connected Buyers and Product Suppliers and the balance of sufficient supply and demand on the trading floor. **Component Buyer:** Fast delivery and minimizing the risk of default by selecting reliable suppliers and being able to replace them quickly in case of unforeseen circumstances. **Product supplier:** Increased ordering, reduced transaction costs in the value chain.

No.	Name of the type of business model Industry 4.0	The essence of the model	Technological principles used	Network effects of the business model
4.	Data trustee	Collection of relevant data to optimize products or use additional data for research and development	Collection and analysis of secure data, Artificial Intelligence and machine learning	**Trusted data storage:** Expanding the value proposition by providing and engaging anonymous data from manufacturers on a digital platform. **Data producer:** Generating revenue from submitted data on a secure, neutral platform. **Producer accessing data:** Gaining access to an integrated base of primary and aggregated data, in a secure and standardized way. **System integrator:** Gaining revenue from supporting integrated data protection technologies. **Supplier of smart RFID devices** Revenue model is directly proportional to the number of connected pieces of equipment and the volume of data transmitted and analyzed.

the Integrator. In this type of business model, there are no intermediaries where a manufacturing company entrusts the marketing of its products to a trading company and does not get into the heart of the trading process. The Integrator business model type assumes that the "vendor" is embedded in the overall value chain, for example through its own or integrated online stores. Meanwhile, customers and other participants are embedded in the value chain by actively participating in the innovative development of products and all related processes. Production becomes decentralized to different markets with a focus on customer types.

The subtypes of integration business models are:

- The business model of crowd sourced innovation which is characterized by the union of all stakeholders of joint activities in the development of new products. In this case, there is a close integration of efforts of many participants of the joint project: customers, marketers, designers, technologists, suppliers, logisticians, distributors in product development, taking into account the subsequent implementation of the entire value chain.
- The "Production as a Service" business model. In this model, the customer becomes the key figure in determining the design of the products, the components of the manufactured products and the technologies used. The production processes must be individualized with respect to the customer, i.e. a single production is realized.
- The business model "Mass customization" involves adapting customer-selected variants of product types to their needs. In this case, serial production is carried out in accordance with consumer categories.

From the point of view of representation of service business models (Servitization), models of continuous customer service during the whole period of operation (Life-long partnerships), organization of services related to the end product, which is leased to the customer (Product as a service), and services based on the provision and analysis of end-use data, when the relevant process is outsourced to the service provider (Manufacturer) are considered (Result as a service).

Data-driven consulting business models (Expertise as a service) are based on trusted data access models related to analytics on digital data platforms that are collected through the Internet of Things and include the following subtypes:

- Fulfillment of requests for analytics of accumulated large amounts of data.
- Product-related consulting that complements product sales with advice and consultancy based on the company's own experience with products in other companies.
- Consulting related to the process of implementing related enterprise digital transformation processes.

The diversity of business models of network enterprises poses the problem of their choice depending on the corporate strategy of the company, product lifecycle and type of production (mass, serial, single). The classification model of business model types is presented in *Table 2*, which establishes the relationship between business model type and corporate strategy, product lifecycle stage, production type and Industry 4.0 business model type, reflecting the way digital business platforms are applied.

Competitive strategies determine the nature of the use of business models [35–37]. For example, strategies of broad product differentiation or market segmentation by various consumer categories are associated with the need to continuously update the product range, bring new types of goods and services to market, customize existing types and perform cyclical work on design and technical preparation of production. In this regard, the development and renewal of product types requires business models of integration and trusted data access which more closely connect all stakeholders of joint activities.

Thus, the initial stage of the lifecycle on the formation or development of requirements determines the application of the crowdsourcing model based on big data analysis, and at the stage of design and technical preparation of production – the model of production as a service or the model of mass customization of production, depending on the type of production.

A competitive cost-saving strategy focuses on improving the efficiency of operational processes. Therefore, various digital service business models will be most appropriate for these purposes. In this case, the application of the "Product as a Service" business model type will be more typical for single production, and the "Process as a Service" business model will be more typical for batch production.

Finally, the implementation of the market segmentation strategy is largely driven by consulting models and corresponding Industry 4.0 business models for data trustee.

As a result of the analysis of applying business model possibilities according to the classification table, it may turn out that some combination of corporate strategy, life cycle stage and production type may correspond to several alternative or complementary business models. In this case, it is necessary to conduct a more detailed analysis which will prove the necessity and possibility of applying a particular type of digital business model, taking into account the multi-criteria evaluation of various factors of obtaining network effects, digital maturity, economic and information security.

Table 2.

Classification of business model types

Type of business model	Integration of value chain participants			Customer service f or products and services			Data-driven consulting			
	Crowd sourced innovation	Production as a service – embedding the consumer in the develop–ment process	Mass customi–zation – adapt–ing the product to customer categories	Solution main–tenance – Life–long partnerships	Product as a service – Payment for use and access – re–source sharing	Process as a service – Process Outsourcing	Product Management Consulting (Consultations on the operation of products)	Consulting on organization of processes (produc–tion)	Intermediary services	Process efficiency analysis
Corporate strategy	Wide differentiation			Economy on costs			Market segmentation, value added services			
Product lifecycle stage	Product requirement, design, devel–opment	Design and Technical Production Preparation	Design and Technical Production Preparation	Operation, Maintenance	Operation, Maintenance	Operation, Maintenance	Operation, Maintenance	Design and Technical Production Preparation	Operation	Product requirement, design, development
Type of production	Single	Single	Serial	Single	Single	Serial	—	—	—	—
Industry 4.0 Business Model	Data trustee model	Value adding services in operation model	Value adding services in operation model	IIoT platform provider model	IIoT platform provider model	IIoT platform provider model	Data trustee model	Data trustee model	Marketplace Model	Data trustee model

2. Multi-criteria model for selecting the type of business model

Any management decision is usually considered from the position of assessment of necessity and possibility of its implementation. The need for realization of the decision is usually justified by the set of competitive advantages that result from its implementation, and the possibility is conditioned by an analysis of the sufficiency of various resources for implementation. For the business model of the network enterprise, these competitive advantages correspond to a set of network effects obtained by the participants of the value chain based on the digital platform. The assessment of the feasibility of implementation, on the other hand, is determined by the sufficiency of potential in the form of an assessment of digital maturity and risks of adverse effects related to the violation of economic and information security.

The variety of qualitative and uncertain factors in the feasibility of different types of business models leads to the construction of a multi-criteria model for selecting the type of business model and its implementation using a knowledge-based system that includes a knowledge base of production rules and a fuzzy inference mechanism to evaluate and convolution of expertise [27, 28].

The use of the mathematical instrument of fuzzy logic in comparison with the simpler methods of expert assessments used in scoring models facilitates the qualitative assessment of the factors with the help of linguistic variables which translate quantitative values of the evaluated indicators into fuzzy values on formalizable interval scales [38–41]. Thus, with the help of linguistic variables, it is possible to reflect the experts' experience in evaluating the factors in the knowledge base of fuzzy production rules. In addition, the system of fuzzy rules is used to display multilevel models of evaluation in which the assessment of intermediate factors is carried out with the help of appropriate subsets of rules.

A multi-criteria model for selecting the type of business model for the subsequent construction of a knowledge-based system in the form of an "AND – OR" graph is presented in Figure 1. It is assumed that this model evaluates one type of business model which receives a satisfactory or unsatisfactory value for use with some coefficient of confidence on a scale of [0, 1]. Satisfactory use of the type of business model is recognized when it exceeds some threshold value, for example, 0.8. If there are several applicants for the choice of business model type, the type with the highest confidence coefficient is selected.

The multi-criteria model uses the following designations of factors – fuzzy variables with values "satisfactory" or "unsatisfactory," for which the confidence coefficient is set on a scale of [0, 1]:

BM – choice of a business model;

NE – the network effect of the value chain (network enterprise);

NE_1 – the network effect of the first enterprise participating in the value chain (the first participant);

NE_k – network effect of the *k*-th enterprise participating in the value chain (*k*-th participant);

D – digital maturity;

DC – digital culture level;

PC – personnel competence level;

BP – quality of organization of business processes;

Prod – product quality;

Data – data availability;

Infra – IT infrastructure organization;

R – risks;

ES – commercial risks;

Trans – the risk of default in commercial transactions;

Sup – the risk of choosing strategic partners and suppliers of components and materials;

Mark – the risk of marketing mistakes in assessing internal market prospects;

Dead – the risk of a long time to bring a new product to market;

IS – information security risks;

Secr – the risk of violation of trade secrets;

Pers – the risk of personal data breach

Own – violations of data ownership rights.

Consider the mapping of the business model type selection model as a set of knowledge-based system production rules in more detail.

At the top level of the model, the Productive Rule of Conjunction of Network Effects (*NE*), Digital Maturity (*D*) and Risk (*R*) factors determines a satisfactory or unsatisfactory assessment of the target variable "Choice of a Business Model" (*BM*):

$$NE \text{ and } D \text{ and } \neg R \rightarrow BM, \quad (1)$$

where → – implication sign, ¬ – the sign of negation.

This production rule in its expanded form has the form:

$$\begin{gathered}\text{IF } NE = \text{“satisfactory” and } D = \\ \text{“satisfactory” and } \neg R = \text{“satisfactory”} \\ \text{THEN } BM = \text{“satisfactory”}.\end{gathered} \quad (2)$$

Each factor represents a term with a value of "satisfactory" or "unsatisfactory". If at least one of the factors takes an unsatisfactory score, then the type of business model receives an unsatisfactory score. In this sense, the condition that all factors must be satisfied in order for the production rule to work must be satisfied. Otherwise, the target variable receives an unsatisfactory value.

In this case, the factor associated with the assessment of network effects reflects the resulting competitive advantages of the value chain formed, and factors of assessment of digital maturity and commercial risks and risks of information security reflect the possibility of its implementation.

Similarly, product conjunction rules are defined for network effects (*NE*), risks (*R*), commercial risks (*ES*) and information security (*IS*).

Thus, the rule of estimation of network effects is formed from the conjunction of estimates of network effects from the participation of all stakeholders (enterprises) in the value chain (network enterprise) for the type of business model under consideration:

$$NE_1 \text{ and } NE_2 \text{ and } \dots NE_k \rightarrow NE. \quad (3)$$

The composition of participants in the value chain of each type of business model will differ depending on the nature of the network enterprise, so k – the number of chain participants (enterprises participating in the network enterprise) has a variable value.

The composition of the components determining the network effect of each type depends on the role played by the value chain participant in the business model (*see Table 1*). For example, a product supplier gets a network effect by increasing the number of orders and reducing transaction costs in the value chain. The number of components of the network effect can be different for each participant. In general, the network effect estimates for the i-th participant is calculated as the conjunction of the results of checking the terms of the j-th effect components:

$$NE_i = \wedge_j NE_{i,j}. \quad (4)$$

The assessment of risks in the product rule (1) is interpreted in terms of their logical negation by ensuring the economic and information

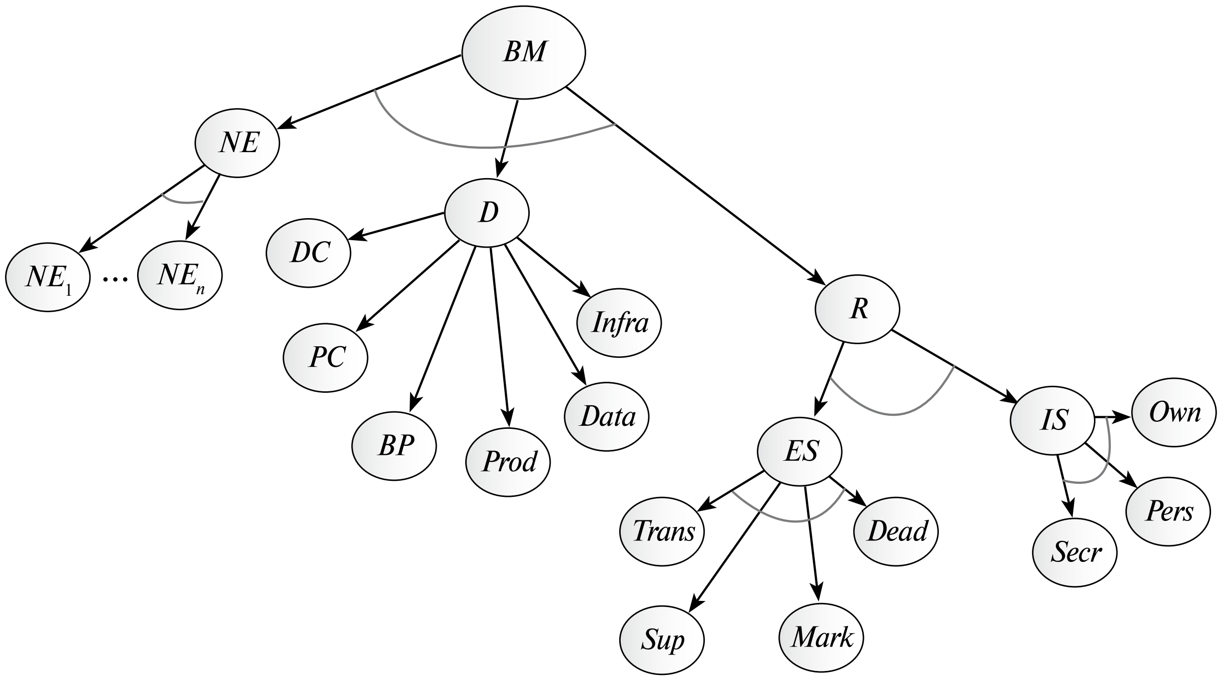

Fig. 1. Multi–criteria model of business model type selection
(the arc crossing the subordinate factors to the superior factor denotes conjunction of factors;
non–crossing arcs of subordinate factors denote disjunction).

security of the digital platform, and, accordingly, the risks are associated with the possibility of security violations. Thus, the assessment (*R*) depends on the conjunction of factors associated with commercial risks leading to a violation of economic security (*ES*) and information security (*IS*).

$$ES \text{ and } IS \rightarrow R. \quad (5)$$

Accordingly, commercial risks (*ES*) are determined by the conjunction of estimates of the risk of default in commercial transactions (*Trans*), the risk of choosing strategic partners and suppliers of components and materials (*Sup*), the risk of marketing mistakes in assessing the internal market perspective (*Mark*), and the risk of a long time to bring a new product to market (*Dead*):

$$Trans \text{ and } Sup \text{ and } Mark \text{ and } Dead \rightarrow ES. \quad (6)$$

The composition of commercial risks is defined in the Strategy of digital transformation of manufacturing industries [2].

Similarly, the risk of information security breach (*IS*) depends on the conjunction of the risks of violation of trade secrets (*Secr*), personal data (*Pers*), and data ownership rights (*Own*):

$$Secr \text{ and } Pers \text{ and } Own \rightarrow IS. \quad (7)$$

The most significant risks associated with cybersecurity in the Internet environment are highlighted as risks of information security violation.

Each of the above risk factors must be associated with a certain digital platform service, the work of which should be aimed at eliminating the risk factor. In this regard, to assess the risk for one or another factor ($FactR_i$) when selecting the type of business model, it is necessary to obtain an expert assessment of the quality (reliability) of the service (*Serv*) used to eliminate the risk factor, which receives a fuzzy confidence coefficient on a scale [0, 1] and correlates with the assessment of the risk factor:

$$Serv_i \to FactR_i, \quad (8)$$

where $FactR_i \in \{Trans, Sup, Mark, Dead, Secr, Pers, Own\}$.

An expanded representation of a production rule looks like this:

$$\text{IF } Serv_i = \text{“satisfactory” THEN} \oplus <FactR_i, \text{“satisfactory”}, F_i\,(FactR_i)>, \quad (9)$$

where $\oplus$ – fuzzy value addition operator;

F_i – an membership function that calculates the confidence coefficient for a variable on the [0, 1] scale.

The nature of the membership function is determined by the type of variable $FactR_i$, in the simplest case some number in the interval [0, 1].

The digital maturity factors used to assess the type of business model $FactM_j$, unlike the risk factors, have an additive reinforcing nature. Therefore, their impact on the overall assessment of digital maturity *D* is considered using product rules separately:

$$FactM_j \to D, \quad (10)$$

where $FactM_j \in \{DC, PC, BP, Prod, Data, Infra\}$.

An expanded representation of a production rule looks like this:

$$\text{IF } FactM_j = \text{“satisfactory” THEN} \oplus <D, \text{“satisfactory”} F_j\,(D)>, \quad (11)$$

where $\oplus$ – fuzzy value addition operator;

F_j – a membership function that calculates the confidence coefficient for a variable on the scale [0, 1]. The nature of the membership function is determined by the type of variable $FactM_j$, in the simplest case some number in the interval [0, 1].

In this case, each $FactM_j$ production rule forms some fuzzy confidence coefficient estimate of the *D* (Digital Maturity) variable individually on the [0, 1] scale and reflects the value of the sufficiency sign.

The rules for evaluating each factor separately can be expanded into an independent knowledge base of rules interpreting linguistic variables, resulting in a fuzzy assessment of the confidence factor on the scale [0, 1]. Then the additive evaluation of the confidence coefficient of the maturity factor is carried out by the algorithm of fuzzy addition with recursion:

For *i* from 1 to 6:

$$1.\ CF(D_1) = CF(Fact_1),$$
$$2.\ CF(D_i) = CF(D_{i-1}) + CF(FactM_j) - CF(D_{i-1}) \cdot CF(FactM_j), \quad (12)$$

where *CF*(*Variable*) – the confidence coefficient extraction function for the value of the fuzzy variable.

In the business model maturity assessment algorithm, you need to set an acceptable confidence threshold value, such as 0.8, at which the Digital Maturity variable gets a satisfactory value.

In the assessment of other factors – fuzzy variables of a multi-criteria model of business model type evaluation connected conjunctively can also get fuzzy values. To combine the fuzzy numbers for these factors, a multiplicative rule is used, such as choosing the minimum confidence coefficient:

$$CF(Left\ part\ of\ rule) = \min\{CF(NE_1), CF(NE_2), ..., CF(NE_k)\}. \quad (13)$$

When combining the confidence coefficients of the left and right parts of product rules (implications), either the minimum confidence coefficient is chosen or the fuzzy multiplication of the left and right confidence coefficients is performed.

In order to accept a positive assessment of the final choice of the type of business model one can also set a threshold level of confidence coefficient, for example, 0.8.

The implementation of a multi-criteria model for assessing the choice of the type of business model under conditions of fuzzy interpretation of qualitative factors using the tools of knowledge-based product system, together with the implementation of a preliminary classification of model types according to certain characteristics, will formalize the decision-making process to justify an effective strategy for the digital transformation of enterprises.

Conclusion

Analysis of approaches to the application of business models of network enterprises showed their diversity, determining the need to develop methods and tools to justify a rational choice of the type of business model in accordance with the strategy of digital transformation of the enterprise and the expected network effects, digital maturity, commercial risks and information security risks.

For representation of the components of a business model, one applies the framework St. Gallen which allows us to map processes of reception of network effects for all participants of the network enterprise. For the types of business models identified by the Industry 4.0 Business Model Working Group, the sources of network effects for the different roles of enterprises in the value chain are identified.

This paper proposes a method for substantiating the rational choice of the type of business model of a network enterprise based on a preliminary classification of business model types according to the characteristics of compliance with the competitive strategy of the enterprise, the stage of the life cycle of products and services, the type of production, the business model used Industry 4.0, and the subsequent multi-criteria assessment of the applicability of business model, taking into account the assessment of the resulting network effects, digital maturity, commercial risks and information security risks. As a tool to implement the multi-criteria model of business model type selection presented, it is proposed to use a knowledge-based system with a set of production rules implementing fuzzy inference on qualitative factors (variables).

The novelty of the proposed method for justifying a rational choice of the type of business model of network enterprise lies in the improvement of classification and development of a multi-criteria model of choice of the type of business models for the network enterprise, implemented with the help of a knowledge-based system with a fuzzy inference mechanism. The practical significance of the results obtained is determined by the possibility of applying the developed method in the implementation of modern digital platforms in the real practice of economic activities of network enterprises. In future research, it is necessary to continue refinement of the methods of formalization of qualitative assessment of diverse factors of applying business models for network enterprises. ■

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About the authors

Yury F. Telnov

Dr. Sci. (Econ.), Professor;

Head of the Department of Applied Information Technologies and Information Security, Plekhanov Russian University of Economics, 36, Stremyanny Lane, Moscow 117997, Russia;

E-mail: Telnov.YUF@rea.ru

ORCID: 0000-0002-2983-8232

Aleksey A. Bryzgalov

Assistant, Plekhanov Russian University of Economics, 36, Stremyanny Lane, Moscow 117997, Russia;

E-mail: Bryzgalov.AA@rea.ru

ORCID: 0000-0002-5001-4326

Petr A. Kozyrev

Senior Lecturer, Department of Applied Information Technologies and Information Security, Plekhanov Russian University of Economics, 36, Stremyanny Lane , Moscow 117997, Russia;

E-mail: Kozyrev.PA@rea.ru

ORCID: 0000-0002-8021-2665

Daria S. Koroleva

Assistant, Plekhanov Russian University of Economics, 36, Stremyanny Lane, Moscow 117997, Russia;

E-mail: Koroleva.DS@rea.ru

ORCID: 0000-0002-0051-0655