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FEATURES OF USING MATHEMATICAL MODELS TO CALCULATE THE EFFECTIVENESS OF A DIGITAL PLATFORM FOR ECOLOGICAL MONITORING

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ABSTRACT

The research purpose is to determine the conditions for using mathematical models to calculate the effectiveness of a digital platform for ecological monitoring. The analysis method, parametric method, and simulation were used as research methods. A platform interaction scheme between the participants of relationships in the ecological monitoring market in the field of nuclear energy was proposed. When evaluating the effectiveness of using digital platforms for ecological monitoring with respect to customers, it is proposed to consider as a benefit the economic profit obtained due to the difference in the composition and performance quality of the functions (considering also possible risk events) provided when using the platform and a similar solution by comparative analysis and determining the indifference price. Based on the indifference prices, it is proposed to determine the recommended range of the cost of a set of digital platform functions for ecological monitoring. The price range of the set of functions for the nuclear energy market has been determined. It is proposed to determine the optimal distribution of profits between suppliers of functions and equipment based on investments in the digital platform and existing production restrictions. The proposed conditions for the application of mathematical models will serve as the basis for launching a digital platform developed by the Leading Research Center Trusted Sensor Systems of the National Research University Moscow Institute of Electronic Technology.

Keywords: *Ecological Monitoring, Efficiency, Mathematical Model, Platform Interaction*.

1. INTRODUCTION

The recent rapid development of the digitalization of society, caused by the growth of science and technology progress, has contributed to the emergence of new forms of interaction between participants in various markets in the form of digital business ecosystems [1-11]. In terms of institutional economics, digital platforms (DPs) represent a new generation intermediary institution with various formats of interaction [4].

The variety of objects and subjects of economic, entrepreneurial, and industrial activities of the platform interaction participants contributes to the emergence of various risk factors, specific both for an enterprise or other economic agent that is part of the business ecosystem, on the one hand, and for the entire ecosystem in general, on the other [2].

The analysis has shown that, by analogy with the physical processes of oppositely charged particles moving away from each other, as the manufacturer moves away from the service and consumption spheres, they experience the need to strengthen mutual ties, prompting conducting the analysis and transformation of the organizational structure of the partners' interaction in the market of high-tech products, depending on its life cycle and considering existing needs [12, 13].

New forms of interaction between DP participants contribute to the transformation of value chains for customers, challenging the current regulators, which, considering the diversity of participants in platform interaction, contributes to the emergence of inequality in terms of profit distribution [14].

Considering DPs as a special kind of network causes a need to overcome possible discrimination of participants in platform-based interaction, which can contribute to slowing down the development of not only the DP but also the industry in general [6, 15].

Despite a range of existing publications on organizing the maintenance of technical systems, the problems of ensuring the effectiveness of platform

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interaction of DP participants remain insufficiently studied.

Thus, the research purpose was formulated, which is to determine the conditions for using mathematical models to calculate the effectiveness of a DP for ecological monitoring.

Further research will focus on the software implementation and verification of the proposed mathematical models in the real sector of the economy.

2. RESULTS

2.1 The Essence of Evaluating the Effectiveness of Using DP for Ecological Monitoring in the Real Sector of the Economy

To achieve the effectiveness of using a DP for ecological monitoring in the real sector of the economy, each of the participants should benefit from platform-based interaction, i.e. equipment suppliers and/or functions providers, buyers of equipment and/or functions, and the owner of the DP.

Let us consider the scheme of balanced interaction between DP participants. To do this, we introduce the following basic concepts.

f_k – function, $f \in F$;

k – function's number, $k \in K$;

c_k^f – the price of the function;

v_k^f – the prime cost of the function;

i – the number of the buyer of functions and equipment, $i \in I$;

x_{ik} =1, if the i-th customer buys the function k, 0 – otherwise;

j – the reference number of the equipment resource for performing the set of functions F, $j \in J$;

m_j – the resource of the equipment j for performing the set of functions F, $m \in M$;

c_j^m – the price of the equipment resource;

c_j^m – the prime cost of equipment resource;

y_{ij} =1, if the i-th customer buys the equipment resource j, 0 – otherwise;

p – the reference number of the functions and equipment supplier, $p € P$;

b_p – p supplier of functions and equipment, $b € B$;

l – risk event number, $l € L$;

r_l – a risk event at an alternative execution of the functions F, $r \in R$;

c_l^r – the cost of losses from a risk event;

p_l – the probability of occurrence of a risk event, $p \in P$;

c_{it}^a – the cost of alternative execution of functions F for the i-th client (interchangeable functions);

g – the number of the time period, $g € G$;

t_g – time period, $t € T$;

n_i – the number of points of the i-th client, equipped with a set of equipment;

γ_g – discount rate per year (period) t_g;

$Gp^{t'}$ – p supplier investment in the creation of a DP in t'_g year;

t'_g – the period of investment, $t' € N$;

v_p^D – the cost of using the DP/IP (intellectual property), paid to the platform owner in the form of ROYALTIES;

w_p^D – profit from using DP.

Characteristics of the f function include: name, number, price, prime cost, significance, required equipment (i.e., this function cannot be selected without selection of equipment).

The function name is set by the Function Provider. The function number is assigned automatically as it is added, starting from 1 and ending with K.

The price of the c_k^f function is set by the Function Provider.

The recommended price of the function is a range (set) of calculated values.

The prime cost of the v_k^f function is set by the Function Provider.

Functions can be complementary, interchangeable, or independent.

Complementary functions are usually different (heterogeneous) functions (for example, service and production). A necessary condition for determining the complementarity of two functions is the absence of at least one of them in one of the subjects of interaction.

Interchangeable functions are usually identical (homogeneous) functions involving the use of standardized resources (for example, service, and transport). There is a synergistic effect due to minimizing costs resulting from sharing resources. Most often, interchangeable functions are not the main functions of the company.

Independent functions are usually identical (homogeneous) functions involving the use of non-standardized (individual, specific) resources (for example, finance), or specific functions that can be used only by one of the participants in the relationship [13].

Functions can be both basic and of minor importance [16].

The main functions include those used for performing the main function of the DP –ecological monitoring, for example:

- Determining air temperature;
- Determining air humidity;
- Determining the radiation background;
- Determining CO_2;
- Determining the concentration of a certain gas in the air.

Each of the functions includes measurement, prediction/notification of the values, exceeding the limit.

Functions of minor importance include those that complement the basic functions, serving for convenience, security, and obtaining additional information, for example:

- Making electronic payments for purchased equipment and/or functions;
- Installing equipment;
- Maintaining the power of attorney and ensuring security;
- Predicting performance;
- Calculating factual efficiency.

Characteristics of m_j equipment include name, number, price, primary cost, functions performed, the maximum volume of delivery (output) in the period T.

The name of the equipment is set by the Equipment Supplier. The equipment number is assigned automatically as it is added, starting from 1 and ending with J.

The price of the equipment is set by the Equipment Supplier and may vary depending on sales volumes.

The prime cost equipment v_j^m is set by the Equipment Supplier.

Limits on the volume of equipment supply are set by the Equipment Supplier.

Characteristics of b_p supplier include name, description, number, binding to equipment, functions, delivery dates, amount of investment in the DP ($Gp^{t'}$sum (summarily), by cost items option), profit share (input or calculation), roles (supplier of equipment, functions, owner of the DP), the right to set the cost price, determine the price, get the recommended price, return on investment forecast, profit forecast.

Types of suppliers:

- Equipment suppliers;
- Function providers;
- Platform owner.

Characteristics of buyers include name, industry, and number.

Characteristics of risks include name, cost, and probability.

The characteristics depend on the industry and are introduced to the owners of the DP. It is allowed to enter alternative data by the Buyer.

Alternative performance of functions includes name and cost. Function characteristics include name, importance, value, and ideal value. The list of characteristics is entered by the DP owner, while other parameters can be entered by the DP owner and adjusted by the buyer. The characteristics depend on the industry.

Characteristics of the branch include name, number, number of potential buyers in the industry.

Input values:

- Suppliers, role, profit share;
- Functions, their price, prime cost;
- Buyers, their final quantity;
- Equipment, its price, and cost;
- Risks.

Calculated values:

- Sales forecast for various options (optimistic, pessimistic).
- Distributing profits between suppliers and the owner of the DP.
- Calculating the return on investment for the suppliers/owner of the DP for various options (optimistic, pessimistic).
- Calculating the actual profit for period T.
- Determining efficiency for Buyers.
- Calculating the recommended price of functions.
- Calculating optimal profit distribution between suppliers and the DP owner.

Output values:

- Predicting the efficiency for clients (economic profit, the payback period of investments, including that with consideration of discounting).
- Efficiency for suppliers/DP owner (predicted/actual profit, the payback period of investments, including that with consideration of discounting).
- Recommendation on the cost of functions.
- Recommendations on the distribution of profits between suppliers.

The cost of using the platform can be fixed and/or calculated as a percentage of each sale. The fixed cost of using the platform can be one-time, paid by the counterparty when connecting to the platform, or paid from each sale of equipment and/or functions. The disadvantage of the first option is that

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users must invest immediately, before getting the effect from using the platform, which is also not profitable for the DP owner, because in this case, having no economic profit from further platform interaction, he is in some sense eliminated from the further development of the platform. Such a solution is possible only if the owner sells his product through the platform. But it may not be very profitable for the buyer to invest immediately to get a return in the future, especially when it concerns innovations and novel developments, as in the case under consideration of the implementation of a platform solution in the field of ecological monitoring, rather than when it concerns the usual product. While assuming that a fixed one-time fee is charged from the supplier of functions and/or equipment, then the feasibility of such an option will depend on the number of suppliers. In this case, at the implementation stage of DP, the number of suppliers of functions and/or equipment will be limited by the participants in its creation, and therefore this option is not advisable. In the case of a fixed fee for the sale of equipment and/or functions through platform interaction, the issue arises with its volume, comparable to the cost of purchased products, which varies greatly with respect to equipment and functions. Therefore, the most optimal choice seems to be in favor of a percentage of sales on the DP of any product, be it equipment or function.

The owner of the DP transfers the right to the IP suppliers of equipment for its production by selling an ordinary license, while the latter pays royalties to the DP owner for using the IP in the form of ROYALTIES from sales of equipment produced under the license (Figure 1).

Also, the owner of the DP transfers the IP right to the function providers by selling an ordinary license, while the latter pays royalties to the DP owner for using the IP in the form of ROYALTIES from the sale of functions carried out through the DP. In turn, the functions providers transfer the IP right in the form of a sublicense to an industrial partner, who, in turn, resells the right to use IP to buyers of functions in a particular market, retaining part of the percentage from sales and transferring the rest of the percentage from sales in the form of ROYALTY rate to the providers of functions.

The owner of the DP transfers the IP right (digital solution) to an industrial partner by selling him an ordinary license, who, in turn, resells the IP right to buyers of functions in a particular market, retaining part of the percentage from sales and transferring the rest of the percentage from sales in the form of royalties to the DP owner.

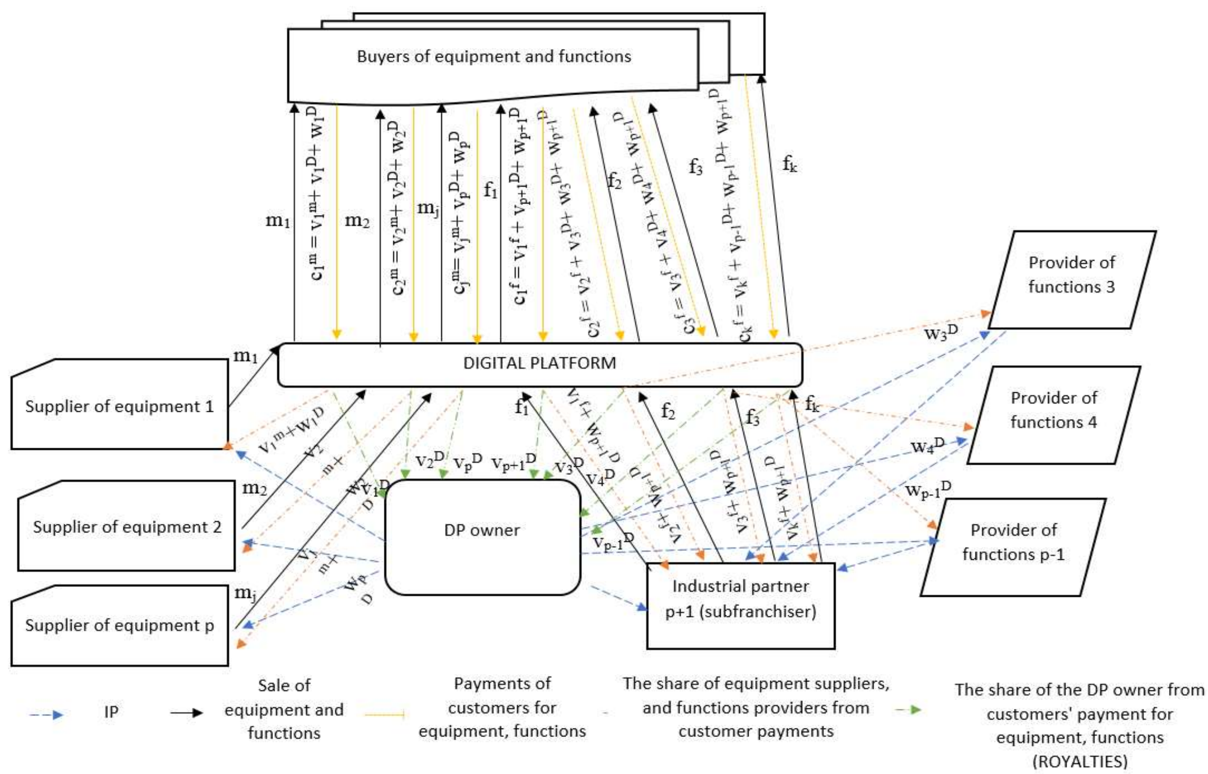

Figure 1: Diagram of Platform-Based Interaction between Participants

As an alternative, one can consider the option when an Industrial Partner, having received a license to use the platform's functions, can sell through it his services (function) for deploying, including installation and commissioning of DP at enterprises in his industry. It should be noted that an industrial partner can act both as a buyer of functions and solutions, and as a supplier of functions and solutions.

2.2 Features of Applying a Mathematical Model of DP Efficiency in the Real Sector of the Economy for Buyers

Purpose:

- DP should allow evaluating the effectiveness of the Platform application in the real sector of the economy for buyers;
- evaluating the effectiveness of the Platform, considering discounting;
- calculating the cost limits of the complex of functions F.

Description:

k – the function number, k ∈ K;

f_k – a function, f ∈ F;

c_k^f – the price of the function;

i – the number of the buyer of functions and equipment, i ∈ I;

x_{ik} =1, if the i-th customer buys the function k, 0 – otherwise;

j – the number of the equipment resource for performing the set of functions F, j ∈ J;

m_j – the equipment resource j for performing the set of functions F, m ∈ M;

c_j^m – the price of the equipment resource;

y_{ij} =1, if the i-th customer buys the equipment resource j, 0 – otherwise;

l – the number of the risk event, l € L;

r_l – the risk event at the alternative execution of the functions F, r ∈ R;

c_l^r – the cost of losses from the risk event;

p_l – the probability of occurrence of a risk event, p ∈ P;

c_{it}^a – the cost of alternative execution of functions F for the i-th client (interchangeable functions);

g –the number of the time period, g € G;

t_g – time period, t € T;

n_i – the number of points of the i-th client equipped with a set of equipment;

t_g – discount rate per year (period) t_g.

Conditions for the effective use of the Platform in the real sector of the economy for the i-th buyer:

$$\sum_{t_g=1}^{T} n_i * \left(\sum_k c_k^f * x_{ik} + \sum_j c_j^m * y_{ij}\right) < \sum_{t_g=1}^{T}\left(c_{it}^a + \sum_l c_l^r * p_l\right) \tag{1}$$

Including considering discounting:

$$\sum_{t_g=1}^{T} n_i * \left(\frac{\sum_k c_k^f * x_{ik} + \sum_j c_j^m * y_{ij}}{(1+\gamma_g)^{t_g}}\right) < \sum_{t_g=1}^{T}\left(\frac{\sum_l c_l^r * p_l + c_{it}^a}{(1+\gamma_g)^{t_g}}\right) \tag{2}$$

Efficiency criterion for the i-th buyer:

$$\sum_{t_g=1}^{T}\left(c_{it}^a + \sum_l c_l^r * p_l - n_i * \sum_k c_k^f * x_{ik} - n_i * \sum_j c_j^m * y_{ij}\right) \to max \tag{3}$$
$$\mathrm{T} \to min$$

Including considering discounting:

$$\sum_{t_g=1}^{T}\left(\frac{\sum_l c_l^r * p_l + c_{it}^a - n_i * \sum_k c_k^f * x_{ik} - n_i * \sum_j c_j^m * y_{ij}}{(1+\gamma_g)^{t_g}}\right) \to max \tag{4}$$
$$\mathrm{T} \to min$$

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We propose a block construction of a mathematical model. The allocation of blocks is made considering the division of the model by stages and modes of system operation into several stages: the 1st stage concerns the implementation of the Platform, the 2nd stage concerns the development of the DP, the 3rd stage is the transformation stage. Operation modes include pessimistic, optimistic, and optimal.

Let us simplify the mathematical model while preserving the essential properties of the system.

The 1st stage – the implementation of the DP – involves considering the mathematical model under conditions of the limited application of the DP on the example of the implementation into the nuclear energy industry. The number of m_j – equipment resources j to perform a set of functions F, as well as functions f_k, is limited by the initial set of proposals from the DP developers.

The price of the equipment resource c_j^m=const.

The totality of risk events R at alternative execution of functions F, the cost of alternative execution of functions F for the i-th client c_{it}^a, and the cost of losses from risk events c_l^r are the same for the entire set of buyers. The probability of occurrence of a risk event p_l depends on the category of the i-th buyer.

At the first stage of the DP implementation, it is assumed that the buyer at the beginning of the t_1 period simultaneously acquires a set of equipment for carrying out functions F. Each time period t_g is equal to one year, and it is assumed that the cost of the function c_k^f provides for its use by the i-th buyer during this period.

Considering the above, the number of sales of the set of functions F per year (period t_g) will be equal to the number of purchases of the minimum set of equipment.

Let us consider this solution considering the difference in the composition and quality of performing functions provided when using the platform, and a similar solution by comparative analysis and determining the indifference price. The indifference price should be considered as the maximum possible price of a product at which a potential consumer, other things being equal, will not care whether to buy the offered product (service) or a competitor's product (service). The execution order (algorithm) is shown in Figures 2 and 3. In this case, the indifference price will take into account, among other things, the possibility of reducing risk events.

Figure 2 shows an algorithm for evaluating the effectiveness of the platform application, considering the available similar solutions for the case where the qualitative characteristics of the services (functions) provision evaluated using points are considered as parameters for comparison.

The price of a competitor P_a can be calculated by the formula:

$$P_a = \sum_{t_g=1}^{T} c_{it}^{a} \tag{5}$$

The significance of α_u is transformed (determined) from the score of each characteristic according to the formula:

$$\alpha_u = \frac{b_u}{\sum_u b_u} \tag{6}$$

where b_u is the importance of characteristic u, estimated by a 10-point system.

The indifference price of P_l^a relatively to alternative solution a in the case of comparing only qualitative characteristics can be calculated by the formula:

$$P_l^a = \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u^{\text{п}} * P_a}{\sum_u \frac{b_u}{\sum_u b_u} * q_u^a} \tag{7}$$

where q_u^p is the value of the u-th characteristic of the platform, q_u^a is the value of the u-th characteristic of alternative solution a.

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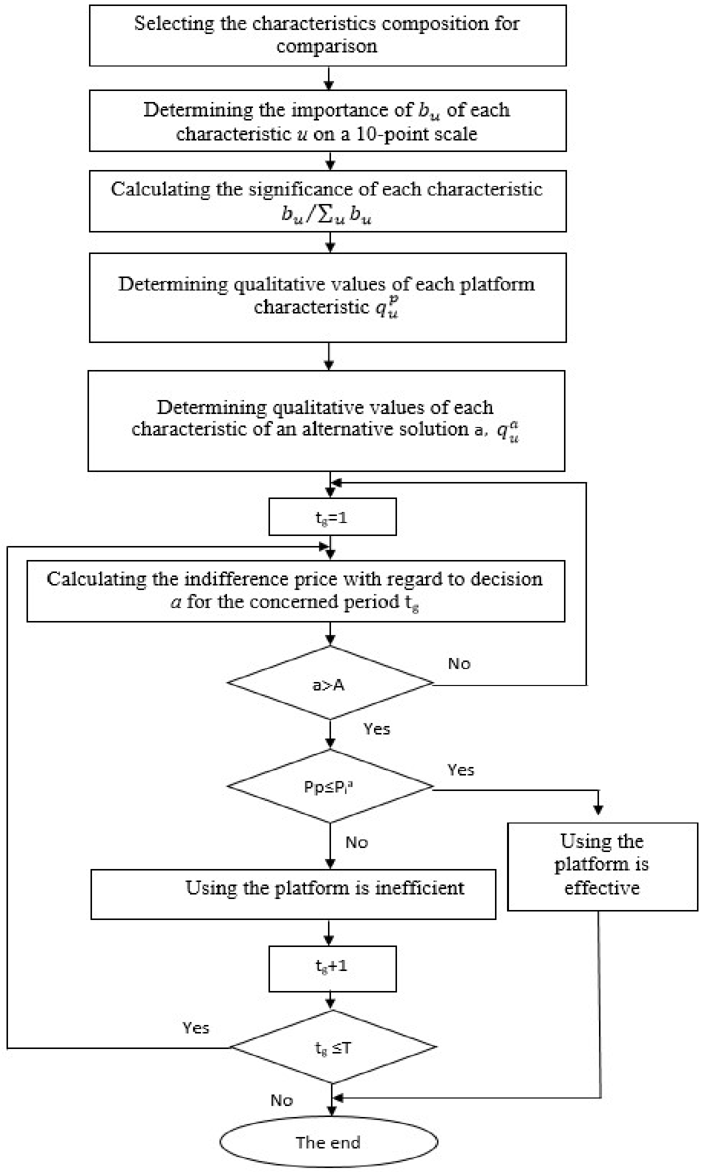

Figure 2: Algorithm for Evaluating the Effectiveness of the Platform Application, Considering Existing Similar Solutions Based on Qualitative Characteristics

The price of the platform will consist of equipping n points with the required equipment and the cost of functions. Thus, it is possible to write down the condition for the effectiveness of using the platform, considering the available similar solutions based on qualitative characteristics:

$$n_i * \left(\sum_k c_k^f * x_{ik} + \sum_j c_j^m * y_{ij} \right) \leq \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u^{\text{п}} * P_a}{\sum_u \frac{b_u}{\sum_u b_u} * q_u^a} \quad (8)$$

In the case of evaluating the effectiveness of using the platform, considering the available similar solutions based on qualitative and quantitative characteristics, they are compared with respect to the ideal model. The characteristics of an ideal model can be set for a particular industry or, in the absence of strict requirements, are determined based on the best value of each characteristic of the

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product (service) under consideration among all possible ones.

In the presence of both qualitative and quantitative characteristics, the indifference price P_i^a with regard to alternative solution *a* can be calculated by the formula:

$$P_i^a = \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^p * P_a}{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^a} \qquad (9)$$

where $q_u'^p$ is a parameter, characterizing how much the value of the u-th characteristic of the platform is close to the ideal value; $q_u'^a$ is a parameter, characterizing how much the value of the u-th characteristic of the alternative solution *a* is close to the ideal value.

Two variants of formulas can be used for calculation:

- if the characteristic of the ideal model has the minimum possible value (tends to the minimum):

$$q_u'^p = \frac{q_u^{id}}{q_u^p} \qquad (10)$$

$$q_u'^a = \frac{q_u^{id}}{q_u^a} \qquad (11)$$

- if the characteristic of the ideal model has the maximum possible value (tends to the maximum):

$$q_u'^p = \frac{q_u^p}{q_u^{id}} \qquad (12)$$

$$q_u'^a = \frac{q_u^a}{q_u^{id}} \qquad (13)$$

Thus, one can write down the condition for the effectiveness of using the platform, considering the existing similar solutions based on qualitative and quantitative characteristics:

$$n_i * \left(\sum_k c_k^f * x_{ik} + \sum_j c_j^m * y_{ij} \right) \leq \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^{\text{п}} * P_a}{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^a} \qquad (14)$$

The condition for the effectiveness of the platform application, considering the available similar solutions based on qualitative and quantitative characteristics, can be written as a system of equations:

$$\begin{gathered} n_i * \left(\sum_k c_k^f * x_{ik} + \sum_j c_j^m * y_{ij} \right) - \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^{\text{п}} * P_a}{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^a} \to max \\ \frac{b_u}{\sum_u b_u} \leq 0 \\ q_u'^p \leq 1 \\ q_u'^a \leq 1 \end{gathered} \qquad (15)$$

Proceeding from (15), and knowing the cost of a set of equipment for one point, the number of points *n*, and calculating the indifference price P_i^a with regard to alternative solutions *a*, it is possible to determine the maximum allowable limit of the cost of a set of functions F:

$$\sum_k c_k^f * x_{ik} = \frac{\sum_u \frac{b_u}{\sum_u b_u} * q_u'^{\text{п}} * P_a}{n_i * \sum_u \frac{b_u}{\sum_u b_u} * q_u'^a} - \sum_j c_j^m * y_{ij} \qquad (16)$$

In relation to the nuclear energy market, the recommended cost of the set of functions F amounted to 180,000 rubles per year.

This mathematical model can be used to simulate the optimal cost of the functions c_k^f to run the DP, which in the future can be used to predict the return on investment of a potential buyer, to

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calculate the recommended price of a new function for an existing/new function provider, as well as to check the balance of the system of platform interactions.

2.3 Features of Using a Mathematical Model of DP Application Efficiency in the Real Sector of the Economy for Suppliers of Functions and Solutions

Purpose:

- the DP should allow evaluating the efficiency of DP application in the real sector of the economy for suppliers of functions and solutions;

- the DP should allow evaluating the efficiency of the DP application, considering discounting;

- the DP should allow automatically distributing profits among the participants of the DP.

Description:

k – the function number, k ∈ K;

f_k – a function, f ∈ F;

c_k^f – the price of the function;

v_k^f – the prime cost of the function;

i – the number of the buyer of functions and equipment, i ∈ I;

p – the number of the functions and equipment supplier, p € P;

b_p – supplier p of functions and equipment, b € B;

x_{ikp} =1, if the i-th customer buys the function k of the provider p, 0 – otherwise;

j – the number of the equipment resource for performing the set of functions F, j € J;

m_j – the equipment resource j for performing the set of functions F, m € M;

c_j^m – the price of the equipment resource;

v_j^m – the prime cost of equipment resource;

y_{ijp} =1, if the i-th customer buys the equipment resource j of the supplier p, 0 – otherwise;

$Gp^{t'}$ – supplier p's investment in the creation of the Platform in the year t'_g;

g – the number of the time period, g € G;

t_g – time period, t € T;

t'_g – investment period, t' € N;

v_p^D – the cost of using the DP/IP, paid to the owner of the DP in the form of ROYALTIES;

w_p^D – profit from using the Platform;

γ_g – discount rate per year (period) t_g;

w_p^D – profit from using the DP;

γ_g – discount rate per year (period) t_g.

Conditions of the effective application of the DP in the real sector of the economy for the vendor b_p:

$$\sum_{t=1}^{T}\left(\sum_{ik}(c_k^f - v_k^f) * x_{ikp} + \sum_{ij}(c_j^m - v_j^m) * y_{ijp} - v_p^D + w_p^D\right) > \sum_{t\prime=1}^{N} G_p^{t\prime} \tag{17}$$

Profit-sharing options:

- based on the investments;
- based on the achievement of payback.

Then the objective function of the problem will be presented in the following form:

$$\sum_{t=1}^{T}\left(\sum_{ik}(c_k^f - v_k^f) * x_{ikp} + \sum_{ij}(c_j^m - v_j^m) * y_{ijp} - v_p^D + w_p^D\right) - \sum_{t\prime=1}^{N} G_p^{t\prime} \rightarrow max \tag{18}$$

Considering discounting:

$$\sum_{t=1}^{T}\left(\frac{\sum_{ik}(c_k^f - v_k^f) * x_{ikp} + \sum_{ij}(c_j^m - v_j^m) * y_{ijp} - v_p^D + w_p^D}{(1+\gamma_g)^t}\right) - \sum_{t\prime=1}^{N} \frac{G_p^{t\prime}}{(1+\gamma_g)^{t\prime}} \rightarrow max \tag{19}$$

Since one buyer can purchase a different amount of equipment per object, and he may have a different number of objects to equip with this equipment, further we will consider variable x as the total number of purchases. It should be assumed that one minimum set of equipment is purchased per one point of the facility, which will be operated and perform a certain set of functions during its operation period of 10 years. Suppose that during the operation of a minimum set of equipment, payment will be made for a unit of function.

Then, while denoting the number of purchases of a unit of a set of equipment for one point as x, the number of purchases of a unit of a function in each period under consideration will also be equal to x.

The cost of the function can be:

- constant for the entire period under review (ideal conditions);
- vary depending on the number of customers;
- be fixed for a certain period (for example, during one year).

There is a restriction on the production of equipment, which varies depending on the period under consideration. Also, the cost of equipment may change as sales increase.

The number of equipment purchases can grow linearly, by square law, and exponentially.

In this case, the number of unknown quantities is reduced to three groups:

- the cost of a set of functions (we can assume that buyers will buy a given set of functions in each period under consideration);

- the number of purchases in each period;

- the cost of using the DP/IP which reduces the profit of suppliers received from platform interaction.

Let us consider a problem statement option when the price of a set of functions is set.

In this case, the number of unknown quantities is reduced to two groups:

- the number of purchases in each period;

- the cost of using the DP/IP which reduces the profit of suppliers received from platform interaction.

The minimum set of equipment is presented in Table 1.

Table 1: Main Characteristics of the Equipment and Functions of the Platform

Equipment, Function		**Supplier**	**Price**	**Prime cost**	**Profit**	**Quantity in the minimum set, items**	**Cost of using DP/IP**	**Deductions from using DP/IP, % of price**	**Investments during period T**	**Interpretation**
Title	**Designation**	**Designation**	**Designation**	**Designation**	**Designation**				**Designations**	
Border gateway (BG)	m_1	b_1	c_1^m	v_1^m	w_1^D	2	v_1^D	D_1	G_1	Is produced
End-user device (EUD)	m_2	b_2	c_2^m	v_2^m	w_2^D	4	v_2^D	D_2	G_2	Is produced
Gas analyzer (GA)	m_3	b_6	c_3^m	v_3^m	w_6^D	2	v_6^D	D_6	-	Is produced
Automated workstation (AWS)	m_4	-	c_4^m	v_4^m	-	3	-	-	-	Is purchased
Radiation monitoring device (RMD)	m_5	-	c_5^m	v_5^m	-	2	-	-	-	Is purchased
Function (set)	$\sum f_k$	b_7	c_k^f	v_k^f	w_7^D	1	-	-	G_7	Is produced
		b_3			w_3^D		v_3^D	D_3	G_3	Is produced
		b_4			w_4^D		v_4^D	D_4	G_4	Is produced
		b_5			w_5^D		v_5^D	D_5	G_5	Is produced

Restrictions on sales of equipment and functions are presented in Table 2.

According to the minimum configuration, if we denote the number of sales of GA in year t_g as x_g, then the equipment sold for the same period will be x_g BG, $2x_g$ EUD, $1.5x_g$ AWS, x_g RMD. The number of functions sold in the year t_g will amount to $0.5 * \sum_{t_g} x_g$.

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Table 2: Sales Volume Based on Production Capabilities

Title/Period	t_1	t_2	t_3	t_4	t_5
BG	x_1	x_2	x_3	x_4	x_5
EUD	$2x_1$	$2x_2$	$2x_3$	$2x_4$	$2x_5$
GA	x_1	x_2	x_3	x_4	x_5
AWS	$1.5x_1$	$1.5x_2$	$1.5x_3$	$1.5x_4$	$1.5x_5$
RMD	x_1	x_2	x_3	x_4	x_5
Function	$0.5x_1$	$0.5x_2$	$0.5x_3$	$0.5x_4$	$0.5x_5$

When distributing profit among function providers, proceeding from the amount of self-financing for the creation of a DP (Tables 1 and 2), we can write:

$$w_p{}^D = 0.5 * \sum_{t_g} x_g * \frac{G_p}{G} * \sum_k \left(c_k^f - v_k^f\right) - v_p^D \tag{20}$$

where

$$v_p^D = c_k^f * Dp \tag{21}$$

Considering the existing restrictions on production A_g, when fully loaded, the restrictions will take the following form:

Direct restrictions:

$$x_1 \leq A_1 \tag{22}$$

$x_2 \leq A_2$
$x_3 \leq A_3$
$x_4 \leq A_4$
$x_5 \leq A_5$
$t_1 = t_2 = t_3 = t_4 = t_5 = 1$
$T = t_1 + t_2 + t_3 + t_4 + t_5 = 5$

Let us define functional constraints based on (17).

For partner b_1:

$$\left(w_1^D - c_1^m * D_1\right) * (x_1 + x_2 + x_3 + x_4 + x_5) \geq G_1 \tag{23}$$

For partner b_2:

$$2 * \left(w_2^D - c_2^m * D_2\right) * (x_1 + x_2 + x_3 + x_4 + x_5) \geq G_2 \tag{24}$$

For function providers, the number of their sales for the period t_g from 1 to T, where T=5 years, g=1÷5, will be:

$$0.5 * \sum_{t_g} x_g = 0.5 * \left(x_1 + (x_1 + x_2) + (x_1 + x_2 + x_3) + (x_1 + x_2 + x_3 + x_4) + (x_1 + x_2 + x_3 + x_4 + x_5)\right)$$
$$= 0.5 * (5x_1 + 4x_2 + 3x_3 + 2x_4 + x_5)$$
$$0.5 * \sum_{t_g} x_g = 0.5 * \sum_{1}^{T} (T + 1 - g) * x_g$$

At that

$$\sum_t v_k^f = T * v_k^f \tag{25}$$

For partner b_3:

$$\left(0.5 * (5x_1 + 4x_2 + 3x_3 + 2x_4 + x_5) * c_k^f - T * v_k^f\right) * \left(\frac{G_3}{G_3 + G_4 + G_5 + G_7} - D_3\right) \geq G_3 \tag{26}$$

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For partner b4:

$$\left(0.5*(5x_1+4x_2+3x_3+2x_4+x_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_4}{G_3+G_4+G_5+G_7}-D_4\right)\geq G_4 \tag{27}$$

For partner b5:

$$\left(0.5*(5x_1+4x_2+3x_3+2x_4+x_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_5}{G_3+G_4+G_5+G_7}-D_5\right)\geq G_5 \tag{28}$$

For the partner (the platform owner) b7 and equipment supplier b6:

$$\left(0.5*(5x_1+4x_2+3x_3+2x_4+x_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_7}{G_3+G_4+G_5+G_7}+D_1+D_2+D_3+D_4+D_5+D_6\right)\geq G_7 \tag{29}$$

To determine the maximum possible cost v_p^D of using the DP/IP v_p^D for suppliers of functions and equipment, it is necessary to convert functional constraints into equations by replacing the inequality sign with an equal sign and substituting all known quantities into the resulting equations.

For partner b1:

$$\begin{gathered}(w_1^D-c_1^m*D_1)*(A_1+A_2+A_3+A_4+A_5)=G_1\\ D_1=\left(w_1^D-\frac{G_1}{A_1+A_2+A_3+A_4+A_5}\right)/c_1^m\end{gathered} \tag{30}$$

For partner b2:

$$\begin{gathered}2*(w_2^D-c_2^m*D_2)*(A_1+A_2+A_3+A_4+A_5)=G_2\\ D_2=\left(w_2^D-\frac{0.5*G_2}{A_1+A_2+A_3+A_4+A_5}\right)/c_2^m\end{gathered} \tag{31}$$

For partner b3:

$$\begin{gathered}\left(0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_3}{G_3+G_4+G_5+G_7}-D_3\right)=G_3\\ D_3=\frac{G_3}{G_3+G_4+G_5+G_7}-\frac{G_3}{0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*\ c_k^f-\ T*v_k^f}\end{gathered} \tag{32}$$

For partner b4:

$$\begin{gathered}\left(0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_4}{G_3+G_4+G_5+G_7}-D_4\right)=G_4\\ D_4=\frac{G_4}{G_3+G_4+G_5+G_7}-\frac{G_4}{0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*\ c_k^f-\ T*v_k^f}\end{gathered} \tag{33}$$

For partner b5:

$$\begin{gathered}\left(0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*c_k^f-T*v_k^f\right)*\left(\frac{G_5}{G_3+G_4+G_5+G_7}-D_5\right)=G_5\\ D_5=\frac{G_5}{G_3+G_4+G_5+G_7}-\frac{G_5}{0.5*(5A_1+4A_2+3A_3+2A_4+A_5)*\ c_k^f-\ \mathrm{T}*v_k^f}\end{gathered} \tag{34}$$

For partner b_6:

$$(0.5 * (5A_1 + 4A_2 + 3A_3 + 2A_4 + A_5) * c_k^f - T * v_k^f) * \left(\frac{G_7}{G_3 + G_4 + G_5 + G_7} + D_1 + D_2 + D_3 + D_4 + D_5 + D_6\right) = G_7$$
$$D_6 = \frac{G_7}{0.5 * (5A_1 + 4A_2 + 3A_3 + 2A_4 + A_5) * c_k^f - T * v_k^f} - \frac{G_7}{G_3 + G_4 + G_5 + G_7} - D1 - D2 - D3 - D4 - D5 \quad (35)$$

3. DISCUSSION

Currently existing approaches to determining the effectiveness of DPs are based mainly on the assessment of network effects [17-19], which is appropriate for DPs operating in the b-to-c market.

Some authors consider achieving the efficiency of DPs by minimizing the cost of DP development within the allocated budget [20].

Along with the need to create an effective mechanism for redistributing value or cost within the business ecosystem of the DP, some authors note the complexity of the task due to the problem of forming an accurate forecast of the business ecosystems development, and as a consequence, their management [21, 22].

At the same time, the task of overcoming possible discrimination of platform interaction participants remains urgent, which can contribute to slowing down the development of not only the DPs, but also the industry in general [6, 15].

Within the framework of the present article, a scheme of platform interaction between the participants of relations in the environmental monitoring market in the b-to-b segment is proposed with regard to the nuclear energy sector. To assess the effectiveness of using DP for environmental monitoring in relation to customers, it is proposed to consider as a benefit the economic profit, which is formed due to the difference in the composition and quality of functions in platform interaction compared with similar solutions and is determined by calculating the indifference price. Based on the indifference prices, the price range of a set of functions for the nuclear energy market is determined. It is proposed to determine the optimal distribution of profits between suppliers of functions and equipment based on investments in the DP and existing production restrictions.

The limitations in the application of the developed mathematical models concern the lack of historical information, which can be compensated by simulating various development options of the DPs.

4. CONCLUSION

The proposed conditions for using mathematical models allow determining the recommended cost of functions, simulating the optimal distribution of profits between suppliers of functions and equipment resources for running a DP developed by the Leading Research Center Trusted Sensor Systems of the National Research University MIET, and will serve as a basis for verifying the balance of the platform interactions system. According to the above, it can be concluded that the purpose of the conducted study has been achieved.

The proposed conditions for applying mathematical models will serve as the basis for launching the DP, developed by the Leading Research Center Trusted Sensor Systems of the National Research University MIET to form a balanced mutually beneficial interaction between the participants in various markets in the context of the digital economy and business transformation.

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