DOI: 10.15276/ETR.04.2022.3
DOI: 10.5281/zenodo.7675702
UDC: 330.44:338.45:658.51.012.122
JEL: C100

INFORMATION AND ANALYTICAL SUPPORT CONSUMPTION FORECASTING OF RESULTS FOR ORGANIZATIONAL AND TECHNOLOGICAL SYSTEMS MODERNIZATION

ІНФОРМАЦІЙНО-АНАЛІТИЧНЕ ЗАБЕЗПЕЧЕННЯ ПРОГНОЗУВАННЯ СПОЖИВАННЯ РЕЗУЛЬТАТІВ МОДЕРНІЗАЦІЇ ОРГАНІЗАЦІЙНО-ТЕХНОЛОГІЧНИХ СИСТЕМ

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Received 12.07.2022

Захарченко В.І., Онешко С.В. Інформаційно-аналітичне забезпечення прогнозування споживання результатів модернізації організаційно-технологічних систем. Науково-методична стаття.

Одним з найважливіших завдань, що з’являються під час очікування споживачів результатів діяльності сучасних організаційно-технологічних систем у промисловому виробництві в межах визначеного територіального утворення, є прогнозування рівня споживання результатів діяльності високотехнологічних підприємств, що модернізуються. Сьогодні фактор переваги вимог споживачів відіграє достатньо значиму роль у сфері високотехнологічних продуктів і послуг. Необхідність вирішення цього завдання обумовлено тим, що в силу різних причин високотехнологічні підприємства розташовані вкрай нерівномірно. Виникає проблема раціонального просторового їх перерозподілу. Для вирішення такого завдання використовуються класична або модифікована моделі Рейлі, які уявляють собою гравітаційні аналоги визначення переваг споживача. При цьому вплив фактору відстані на вибір споживача відображається з використання гіпотез: у класичній моделі – пропорційного квадрату відстані між центрами, тобто організаційно-технологічною системою та споживачем; у модифікованій моделі – у відповідність з експоненціальним законом. Запропонована модель прогнозування поведінки споживача високотехнологічної продукції, яка дозволяє вирішувати завдання: за відомої фінансової достатності споживача та заданої «геометрії» територіальної освіти можливо розрахувати оптимальні точки розміщення центрів споживання з необхідним рівнем якості послуг; для наявних підприємств та його організаційно-технологічних структур розробити рекомендації щодо підвищення необхідної якості послуг, що дозволяють залучати споживачів; за відомою якістю та розміщенням центрів споживання побічно визначити фінансову достатність споживачів даної територіальної освіти.

Ключові слова: система, інфраструктура, модель, споживання, центр, байдужість, тяготіння, координата, функція

Zakharchenko V.I., Oneshko S.V. Information and Analytical Support Consumption Forecasting of Results for Organizational and Technological Systems Modernization. Scientific and methodical article.

One of the most important challenges that appear when consumers expect the results of modern organizational and technological systems in industrial production within a certain territorial formation, is to forecast the level of the results consumption of high-tech enterprises that are being modernized. Today, the advantage factor of consumer requirements plays a significant role in the field of high-tech products and services. The need to solve this problem is due to the fact that due to various reasons, high-tech enterprises are located very unevenly. There is a problem of rational spatial redistribution. In order to solve this problem classic or modified Reilly models are used, which are gravitational analogues to determine consumer preferences. The influence of the distance factor on the consumer's choice is reflected in using the hypotheses: in the classical model is a proportional square of the distance between the centres, i.e. the organizational and technological system and the consumer; in the modified model is in accordance with the exponential law. The proposed model for predicting consumer behaviour of high-tech products, which allows to solve the problem: according the known financial sufficiency of the consumer and a given "geometry" of territorial education it is possible to calculate the optimal location of consumption centres with the required level of service quality; for existing enterprises and its organizational and technological structures to develop recommendations for improving the required quality of services to attract consumers; by known quality and location of consumption centres indirectly determine the financial sufficiency of consumers of this territorial education.

Keywords: system, infrastructure, model, consumption, centre, indifference, gravity, coordinate, function

The National Economic Strategy for the period until 2030 declares the vision of the mission of this Strategy as "... creating an opportunity to realize the available geographical, resource and human potential of the country to ensure the appropriate level of welfare, self-realization, security, rights and freedoms of every citizen of Ukraine through innovative, anticipatory economic growth..." [1, p. 8]. It was also emphasized that according to direction 13 – Transport and infrastructure – the vision of this direction is that Ukraine is a logistics and production hub that provides the economy needs and enables the export and transit potential realization [1, p. 23].

In the context of this Strategy implementation, the authors consider the task for industrial enterprises in the creation of modern organizational and technological systems capable of producing competitive high-tech products and services with great added value.

One of the most important challenges that appear when consumers expect the results of the activities of modern organizational and technological systems (OTS) within the defined territorial formation is forecasting the level of the results consumption of newly implemented or modernized high-tech enterprises. The factor of consumer preference plays a fairly significant role in the field of high-tech services. Talking about the consumer, one should not mean a single individual, but rather a whole group of modern enterprises. The analysis of the field of domestic high-tech production which was carried out within the framework of numerous research works of the creative team of the Institute of Business, Economics and Information Technologies of Odesa Polytechnic National University (see the portal

"Economics: time realities" – https://economics.net.ua /journal), including on request of the Ministry of Education and Culture of Ukraine, proved that due to various reasons, high-tech enterprises are located extremely unevenly. The issue of their rational spatial redistribution arises.

Analysis of recent research and publications

When conducting this study, the authors relied on the works of such scholars as: P. Voronzhak and S. Filyppova [2], S. Yermak [3], A. Zahorodnii i Z. Koval [4], S. Illiashenko ta O. Bilovodska [5], Yu. Lysenko [6], O. Malin [7], A. Usov and H. Oborskyi [8], N. Chukhrai, R. Patora [9], B. Yukhymenko [10].

Thus, B. Yukhymenko understands the economic model as "... a schematic representation of an economic phenomenon or process, obtained as a result of scientific abstraction of the characteristic features of the surrounding economic reality and economic mechanism" [10, p. 11]. Many scientists, for example, Yu. Lysenko, A. Usov, H. Oborskyi, warn that it is not necessary to consider the modeling results as a final result, as some algorithm, by substituting numerical values corresponding to this or that real situation, it is possible to get a comprehensive answer on the question of how to manage innovative development [6, 8].

S. Illiashenko and O. Bilovodska considers in detail "… the main organizational forms of the risky innovative business …" and make a conclusion "… that using the specific organizational structures is determined by the specifics of the enterprise itself and the peculiarities of the market or industry" [5, p. 265].

S. Filyppova and P. Voronzhak discovered "the growth of information and communication capabilities of enterprises in terms of management information support technologies and intellectual needs regarding the organizational and economic management tools for the strategy of innovative development in terms of smart management technologies" [2, p. 230]. In his study, S. Yermak conducts a generalization and systematization of inclusive business models which create potential for enterprises both in the form of profit and for the satisfying social interests [3, p. 353].

O. Malin, in turn, conducts changes systematic-zation in the innovative environment of public-private partnership, which allows to group the accumulation of quantitative and qualitative changes of digitization, innovative and sustainable development [7, p. 397]. N. Chukhrai and R. Patora develop "... models for distribution optimization, selecting the implementation option, optimal distribution of types of products according to the channels of its implementation, the reliability assessment of the relationship between the enterprise and consumers and intermediaries, a model for the enterprise relationships organization with product consumers, a network model of comparing the advantages of the company product distribution channels, and a model of comparing the importance of the contribution of each of the company product distribution channels based on the results of approbation of economic-mathematical modeling methods for evaluating relations with consumers" [9, p. 282]. A. Zahorodnii and Z. Koval emphasize: "A prerequisite for the successful implementation of the product innovation policy at the enterprise is the effective management of the enterprise technological development" [4, p. 202].

The aim of the article is to develop a mathematical model for predicting consumer behaviour as a result of the organizational and technological system operation with the purpose of determining the optimal placement points of consumption centres with the required level of service quality.

The main part

In order to solve the above-mentioned objective it is possible to use classic or modified Reilly models, which are gravitational analogs of determining consumer preferences [11].

At the same time, the influence of the distance factor on the consumer choice is reflected using the following hypotheses: in the classical model it is proportional to the square of the distance between the centre and the consumer; in the simulated model is in accordance with the exponential law.

Thus, let there be two consumption centres. One of them (A) has a high quality service, a large range of services and fairly reasonable prices. Another consumer (B) implements harder pricing policy on a small range, but is located closer to the client. To solve the problem of choice, Reilly used the gravitational model of "attractive centres of gravity".

According to the model proposed by Reilly, the attraction F created by the consumption centre is directly dependent on this centre attraction and inversely on the distance between the centre and the point under consideration. At the same time, the centres attractiveness is determined by the level of quality, which is determined by the coefficients k_A and k_B, where $k_A > k_B$, and the distance between the centres and the consumer is S_A and S_B, respectively.

In the classical model, the system of dependencies reflecting the centres attraction has the following form:

$$F_1 = k_A/(S_A)^2, \quad F_1 = k_B/(S_B)^2, \qquad (1)$$

From the condition of indifference $F_1 = F_2$ we get:

$$(S_A)^2 = k/(S_B)^2, \qquad (2)$$

where $k = \frac{k_A}{k_b}$ – is a coefficient reflecting the quality of services. In this case $k>1$.

Let the distance between the centres be 2a. In the Cartesian coordinate system, with the known coordinates of the points A(–a,0), B(a,0), P(x,y), we obtain from the equation (2):

$$(x + a)^2 + y^2 = k\,[(x – a)^2 + y^2]. \qquad (3)$$

After the described transformations and the variables replacement $m = \frac{k+1}{k-1}$ we arrive at the equation of a circle shifted relative to the origin by the amount am:

$$(x - am)^2 + y^2 = a^2(m^2 - 1). \quad (4)$$

When adopting the modified Reilly model, the system characterizing the centres attraction has the form:

$$\begin{aligned} F_1 &= k_A \exp(-S_A), \\ F_2 &= k_B \exp(S_B). \end{aligned} \quad (5)$$

From the condition of indifference $F_1 = F_2$, after logarithmization we get:

$$S_A - S_B = \ln \frac{k_A}{k_B}. \quad (6)$$

The expression (6) is a hyperbola equation.

We note that in the classic Reilly model, the result of the decision is a circle (Fig. 1, a), called the line of indifference advantages. The decision interpretation the is as follows: for any point P located inside the circle, the attraction of the enterprise B will exceed the attraction of the enterprise A, so the customer will prefer the enterprise B. In the event that the customer (point P) is outside this circle, he will choose the enterprise A.

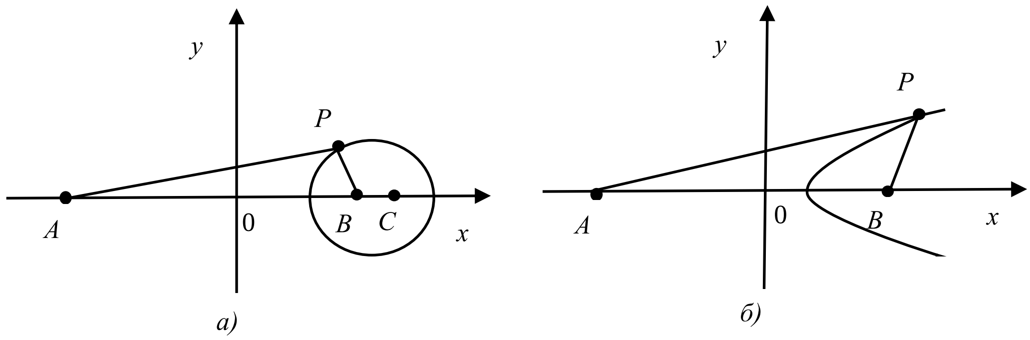

Figure 1. Graphic Proposal for the Application of the Classic (a) and Modified (b) Reilly models
Source: authors' own development

When using a modified model (the attraction decrease with increasing distance from the consumer to the enterprise with its newly created OTS according to the exponential law), the result of the solution is the line of indifference in the form of a hyperbola (Fig. 1, b). The second hypothesis application significantly expands the scope of the enterprise that is less attractive from the viewpoint of the consumer.

As a rule, there is an opportunity to consider some territorial entity (not necessarily a region, city or other) from the viewpoint of researching the consumer behaviour in the presence of some infrastructure centre. Such a centre can be a local transport junction, a stop of traffic flow, etc. In this case, it is possible to distinguish the average flow of the consumer from the location to the infrastructure centre or back. Then the consumer preferences are determined taking into account the average flow.

The Figure 2 shows a calculation scheme that allows to determine in a general way the limits of indifference of consumer preferences in the presence of the infrastructure centre. Here, the angle φ characterizes the direction of the consumer average flow to the infrastructure centre relative to the location of the two consumption centres. Shown in the Figure 2, the calculation scheme for determining the preferences indifference lines allows to apply coordinate transformation formulae and obtain a solution in a more general form.

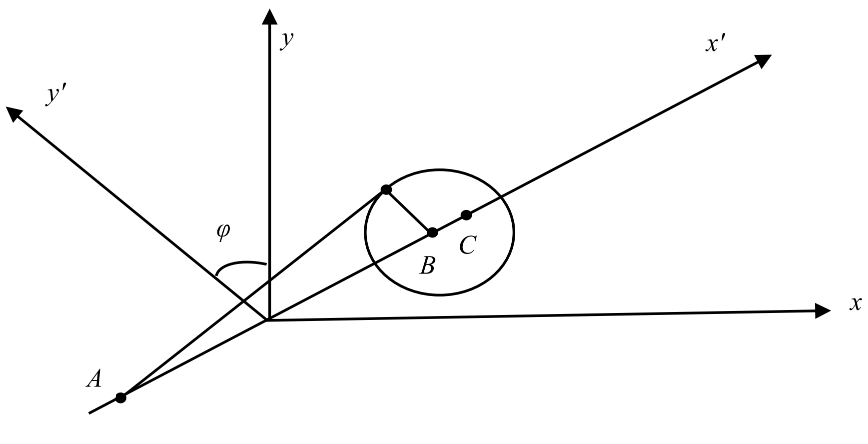

Figure 2. The Determination Scheme of General Form of Indifference Boundaries of Consumer Preferences in the Presence of the Organizational and Technological System
Source: authors' own development

Thus, the connection of coordinates is described by the expression:

$$x' = x\cos\varphi + y\sin\varphi; \quad y' = -x\sin\varphi + y\cos\varphi. \tag{7}$$

Solving the problem according to the given methodology and taking into account (7), to determine the preferences indifference line we have:

$$(x - am\cos\varphi)^2 + (y - am\sin\varphi)^2 = a^2(m^2 - 1). \tag{8}$$

The formula (8) makes it possible to construct the preferences indifference line with an available centre of infrastructure and an average flow of consumers directed to it.

When φ=0, we get the dependence used in the classic model of Reilly preferences. Thus, the classical model of Reilly preferences is a special case of expression (8). Similar considerations are applied to the modified R model.

Further it should be noted that the approaches to determining preferences are quite "static". As a rule, even if the consumption is necessary, the consumer is limited by the influence of a number of factors. The most important, in our opinion, are the time factor, which appears during the consumer movement from the location to the infrastructure centre or back, and the financial sufficiency factor (budgetary restrictions).

In this case, solving the problem of preferences should be considered from the viewpoint of dynamics, namely, solving the motion equation. For this, that is, taking into account the consumer movement, we will also use a physical analogy, namely, the movement of a material point in the field of gravitational forces. Here, the consumer acts as a material point. As in the problems of physics, a material point is characterized by the so-called "mass", which can be interpreted as some expertly determined function of the consumer's financial sufficiency and the degree of consumption necessity. The gravitational field in this model is created by the service sector enterprises, based on the newly created OTS, each with its own levels of supply of products, services, nomenclature, etc. the The local infrastructure centre affects, but to a lesser extent.

It is known if the consumer is considered as a material point, his movement is described by a system of differential equations. In the projections on the axis of fixed Cartesian coordinates, the axes have the form:

$$m\ddot{x} = \sum_{k=1}^{n} F_{kx}, m\ddot{y} = \sum_{k=1}^{n} F_{ky}, \tag{9}$$

where x, y – are acceleration projections;

F_{kx}, F_{ky} –are the projections of the generalized force on the corresponding axes of Cartesian coordinates.

In consequence of differential equations of a material point motion, it is possible to solve two main problems of dynamics, i.e. direct and inverse: the direct problem is a problem in which its movement is determined by the given movement and mass of the material point. In our opinion, the most obvious analogy is the inverse problem for consumption forecasting. In this case, given the known (predicted) coordinates and the attractiveness degree of consumption centres, as well as the financial sufficiency of the consumer ("mass"), it is possible to determine the consumer flow trajectory from the point of the conditional centre of residence to the infrastructure centre of the region or other territorial formation.

The equation that models the consumer's movement in the force field of consumption centres will be taken as:

$$m_п = \frac{d^2\rho_i}{dt^2} = \sum_{i=1}^{N} F_i + F_ц, \tag{10}$$

where $m_п$ –is the consumer's financial sufficiency (budget restrictions);

ρ_i – position vector from consumption to i-consumption centre;

$\sum_{i=1}^{N} F_i$ – are the "attraction" forces of consumption centres;

$F_ц$ – is the "attraction" force of the infrastructure centre;

N – is the number of consumption centres of a specific type.

Let's consider the quantities entering the equation. As it has been mentioned, the consumer financial sufficiency the must be determined by an expert way. Here, statistical data on the consumer demand of the region can be used as a starting point, correlation dependences with the average cost of products in the given region can be used.

The "attraction" forces of consumption centres can be determined (as from the Reilly model):

$$F_i = \frac{k_i}{(\rho_i)^2}, \tag{11}$$

where k_i – is the consumption centres attractiveness;

ρ_i – is the distance from the centre to the consumer.

The attractioin force of the infrastructure centre can be neglected when solving. However, it is used as a value that determines the average movement direction of the consumer flow, and indirectly allows to determine the time of movement. Thus, the minimum time is the ratio of the distance between the infrastructure centre and the consumer to the average pedestrian speed. Such a marginal option is possible in the case of the consumer's movement from the place of permanent deployment to the consumption place of the OTS results. For our calculations, this option is unacceptable, because even if there is a need, it is impossible to meet the requirments.

When solving inverse problems of the material point dynamics, it is customary to adhere to the following sequence of actions:

1) select a coordinate system;
2) record the initial conditions of motion;
3) make differential equations of motion;
4) integrate the system of differential equations of motion. Using the initial conditions of motion, determine constant integrations;
5) using the equations of the material point motion obtained in the previous point, determine the required values.

Taking into account the defined sequence, let's try to get the desired solution to the given task. When choosing a coordinate system, let's stop at a simple Cartesian coordinate system with the centre at the initial point of the consume location (Figure 3).

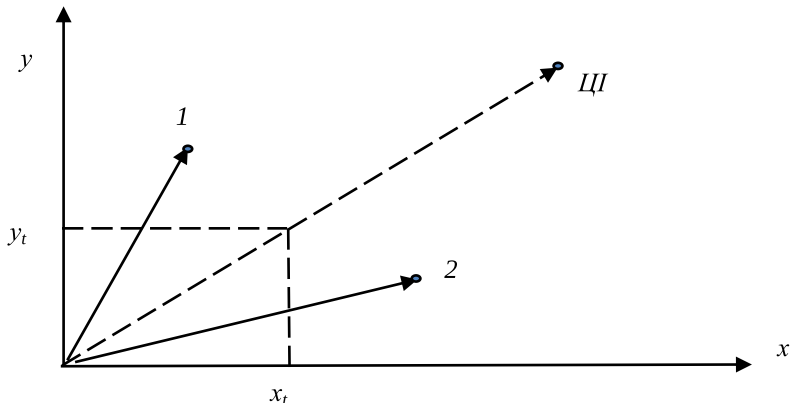

Figure 3. The Cartesian Coordinate System with the Centre (initial point) of the Consumer Location
Source: authors' own development

In this case, the basic enabling equation is the type expression (10):

$$m_n = \frac{d^2\rho_i}{dt^2} = F_{i1} + F_2$$

or

$$\begin{cases} m_п = \dfrac{d^2x}{dt^2} = F_1^x + F_2^x; \\ m_п = \dfrac{d^2y}{dt^2} = F_1^{xy} + F_2^y. \end{cases} \quad (12)$$

where $m_п = f$ – is the function of the consumer's financial sufficiency;

$F_1 = \frac{k_1}{(x_1-x_t)^2+(y_1-y_t)^2}$, $F_2 = \frac{k_1}{(x_2-x_t)^2+(y_2-y_t)^2}$ – are attraction forces of the consumption centres during the the consumer movement to the infrastructure centre with coordinates (X_{IC}, Y_{IC});

k_1, k_2 – are coefficients reflecting the attractiveness level of the consumption centres;

(X_t, Y_t) – are the consumer current coordinates while moving to the infrastructure centre;

$F_{21}^x, F_2^x, F_1^y, F_2^y$ – are the attraction forces projections of consumption centres on the coordinate axes.

As a result of the integration of system (12), the consumer movement law in Cartesian coordinates is determined:

$$X_п = f_1(t),\ Y_п = f_2(t). \quad (13)$$

Let's assume that the attraction forces of consumption centres depend only on their coordinates and characterize the need for consumption, which allows us to obtain a solution to the problem in an analytical form.

Since system (12) consists of two equations of the second order, its integration results in four arbitrary constants: C_1, C_2, C_3, C_4. In order to determine them, the conditions of the task must include the initial conditions of the consumer movement, which determine his position and speed at a certain moment in time

In our case, the initial conditions have the form:

$$t_0 = 0,\ x = 0,\ y = 0, \\ x' = v_x,\ y' = v_y. \quad (14)$$

At the same time, it should be noted that the minimum travel time is determined by the ratio of the distance from the consumer to the infrastructure centre to the average pedestrian speed (5 km/h).

After the expression integration (13) we will get:

$$x' = F^x t + C_1, \\ y' = F^y t + C_2. \quad (15)$$

The constants C_1, C_2 are at the initial conditions (15), whence:

$$C_1 = v_x,\ C_2 = v_y. \quad (16)$$

Substituting expression (16) into (15), we get:

$$x' = F^x t + v_x, \\ y' = F^y t + v_y. \quad (17)$$

The law of motion is determined by integrating the expression (17):

$$x' = F^x t^2 + v_x t + C_3,$$
$$y' = F^y t^2 + v_y t + C_4. \quad (18)$$

The constants C_3, C_4 are found after substituting in (18) the initial conditions of motion at the zero moment of time, that is, we have $C_3 = C_4 = 0$. By substituting these ranges in (18), we obtain the consumer motion equation:

$$x' = F^x t^2 + v_x t,$$
$$y' = F^y t^2 + v_y t. \quad (19)$$

The obtained equations (19) make it possible to construct the indifference trajectory of the consumer preferences as he moves to the infrastructure centre, that is, the modernized OTS.

Conclusions

Thus, it should be noted that the proposed model of forecasting the consumer behaviour of high-tech products can allow solving the following tasks: given the known consumer financial sufficiency and the given "geometry" of the territorial formation, it is possible to calculate the optimal placement points of consumption centres with the required level of service quality; for existing enterprises and their organizational and technological structures, develop recommendations for improving the necessary quality of services that allow attracting consumer; based on the known quality and placement of consumption centres, indirectly determine the consumers financial sufficiency of the particular territorial education.

Abstract

One of the most important tasks that appear when consumers expect the results of modern organizational and technological systems in industrial production within a certain territorial formation, is to forecast the consumption level of the results of high-tech enterprises that are being modernized. Today, the excellence factor of consumer requirements plays a significant role in the field of high-tech products and services. The aim of the article is to develop a mathematical model for predicting consumer behaviour as a result of the organizational and technological system operation with the purpose of determining the optimal placement points of consumption centres with the required level of service quality. The need to solve this problem is due to the fact that high-tech enterprises are located very unevenly because of various reasons. There is a problem of rational spatial redistribution. In order to solve this problem, classic or modified Reilly models are used, which are the attraction analogues to determine consumer preferences. The influence of the distance factor on the consumer choice is reflected in the use of hypotheses: in the classical model it is a proportional square of the distance between the centres, i.e. the organizational and technological system and the consumer; in the modified model – in accordance with the exponential law. The proposed model for predicting consumer behaviour of high-tech products, which allows to solve the problem: with the known financial sufficiency of the consumer and a given "geometry" of territorial unit it is possible to calculate the optimal location of consumption centres with the required level of service quality; for existing enterprises and its organizational and technological structures to develop recommendations for improving the required quality of services to attract consumers; by known quality and location of consumption centres indirectly determine the financial sufficiency of consumers of this territorial education.

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Посилання на статтю:
Zakharchenko V.I. Information and Analytical Support Consumption Forecasting of Results for Organizational and Technological Systems Modernization / V.I. Zakharchenko, S.V. Oneshko // Економіка: реалії часу. Науковий журнал. – 2022. – № 4 (62). – С. 25-31. – Режим доступу до журн.: https://economics.net.ua/files/archive/2022/No4/25.pdf.
DOI: 10.15276/ETR.04.2022.3. DOI: 10.5281/zenodo.7675702.

Reference a Journal Article:
Zakharchenko V.I. Information and Analytical Support Consumption Forecasting of Results for Organizational and Technological Systems Modernization / V.I. Zakharchenko, S.V. Oneshko // Economics: time realities. Scientific journal. – 2022. – № 4 (62). – P. 25-31. – Retrieved from https://economics.net.ua/files/archive/2022/No4/25.pdf.
DOI: 10.15276/ETR.04.2022.3. DOI: 10.5281/zenodo.7675702.

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