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Sequential analysis of variants as a new method of dynamic modeling in making scientifically grounded business decisions

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Abstract

Purpose. The purpose of the research is to study methods of dynamic modeling, substantiate the feasibility of the use of sequential analysis of variations in business in managing a competitive business, and develop an original approach to forecast business development on this basis. The object of research is the development of dynamic modeling methods.
Methodology. The methodological framework involves the theoretical (formalization) and general logical (system approach, static, and dynamic modeling methods) methods of inquiry.
Findings. The article considers the methods of dynamic modeling and the features of their practical implementation for making scientifically sound business decisions. The article provides the classical theory of economic dynamics and forecasting, and its development in the Ukrainian school of dynamic modeling with practical applications in business management under certainty, risk, and uncertainty. The application of sequential analysis of variants, a new method of dynamic modeling, is substantiated.
Practical implications. The practical results of the research include the determination of relevant priorities for business support and development under modern conditions. The authors suggest an original approach to forecast business development and optimize the investment allocation, logistical and human resources, the efficiency of calculations of production plans and programs, etc. The article enriches the scientific literature with another example of the implementation of the method of dynamic modeling, which is a sequential analysis of variants for making scientifically grounded business decisions. The research is relevant and original since it solves such a problem as the optimization of the distribution of funds for consulting services provided by the advisory service over the years.

Keywords: forecasting, risk, consulting services, sequential analysis of variants, investment allocation.

JEL Classification: C32, C61

1. Introduction

Modern society, being absorbed by information technologies, needs a continuous introduction of innovations to develop effectively. Modern mathematical methods are becoming increasingly important in making scientifically grounded decisions. The dynamic approach to business development meets the requirements of time most fully. Dynamic modeling is used to optimize multi-step control processes both in space and time, deterministic and stochastic systems of the market economy. The motive of the article is the need for effective fund distribution for the provision of socially necessary advisory services that develop in the agricultural sector and is essential for introducing innovations under market conditions.

For a hundred years, economists have been developing and refining models of static economics. Even the theory of Keynes (2002) is mostly static. Among economists who paid considerable attention to dynamic economics, we should highlight Marx (Maslov, 2018) who discovered the model of expanded reproduction, and Leontiev, who developed the first intersectoral balance of production and distribution in the national economy for 1923-1924 (Mason, 2015). An example of macroeconomic dynamics can be the Harrod-Domar model, the economic growth model (Uzawa, 2018), which describes the interdependence between the dynamics of investments and profit, and its distribution between consumption and accumulation.

The Nobelist Solow (1998) introduced another type of economic growth model, which allows the features of macroeconomic processes to be more accurately described, taking into account the dynamics of technological progress and human resources. Further development of the apparatus of dynamic modeling belongs to the American scientist Wald (1935). Thanks to scientists' works on sequential statistical solutions, new methods of optimal solutions have been well developed by the end of the 1940s (Biletsky et al., 2020). Dynamic programming appeared in the United States in the early 50s of twentieth century. It was developed by Bellman (1957), and the rule of selecting options for solving multi-step optimization problems was called Bellman's principle of optimality. However, Bellman (1957) said that this method has one significant flaw, the so-called curse of dimensionality: a small increase in the number of states and steps leads to so many solution options that the problem becomes unsolvable.

The sequential analysis of variants, a new method of solving multi-step optimization problems, was developed under the leadership of academician Mikhalevich (1965) at the Glushkov Institute of Cybernetics in Ukraine in the early 60s. This method involves other rules for selecting options according to the problem specifics and the properties of the criterion function. The modern development of the Ukrainian school of dynamic modeling comprises various methods of sequential analysis of variants for both deterministic and stochastic problems (Mikhalevich & Kuksa, 1983; Kalna-Dubinyuk, 2002; Voloshin & Kudin, 2015; Sipko, 2011). A partial case of these methods is dynamic programming. Economics and its modern applications allow practitioners set and solve important problems of economic dynamics, ensuring the adoption of scientifically grounded decisions. Modern business operates in a dynamic environment, where technologies are rapidly and constantly changing. Companies with traditional approaches and technologies will not remain competitive without introducing innovation.

Dynamic modeling methods enable practitioners to obtain the most acceptable solution for the fund distribution between certain objects for reconstruction, building, and modernization.

Such tasks as equipment replacement and change and storage of products can also be solved by these methods (Kuzheliev & Britchenko, 2016; Ivashchenko et al., 2018). The purpose of the study is to apply methods of dynamic modeling aimed to optimize resources allocation to develop a competitive production under risk and uncertainty. As a result, a dynamic model has been developed, which takes into account probabilistic assessments of the economic system state parameters (business structure) and changes across states over time. The article provides a calculation algorithm and assessment of the solution found by establishing the relevant rule of selecting competitive variants.

The material presented in the article will be of interest to both scientists and practitioners. They will learn about solving the problem of optimizing the long-term distribution of funds for the provision of information and consulting services by the method of sequential analysis of variants. It is also possible to apply the presented approach for making scientifically grounded business decisions, which makes this study original. The authors of this article have developed an original algorithm for solving such problems in a consultancy sphere under conditions of risk and uncertainty.

2. Materials and Methods

2.1. Applications of sequential analysis of variants for allocating funds to consulting services provided by the advisory service

Market conditions impose new requirements on enterprises and require scientifically grounded solutions, taking into account the prospects, risks, and uncertainty. Dynamic modeling methods, also called methods of sequential analysis of variants, fully meet all these requirements. Their practical application shows that in-depth analysis is needed to choose one of these methods for solving a multi-step problem. Thus, the following are subject to analysis: features of the problem; properties of the criterion function; the principle of optimality, which underlies the rule for selecting variants (Kalna-Dubinyuk, 2002). All this ensures the uniqueness of the method of sequential analysis of variants applied in each specific task.

This method is based on the idea of presenting a solution as a multi-step structure similar to the structure of a complex test. Each step is associated with checking the presence of certain properties in variants taken together or separately. This step should lead to a reduction of the initial set of variants or its preparation. The method of sequential analysis of variants is characterized by reducing both a set of variants and tests that must be performed to continue the search result. When solving problems with a step-by-step decision-making process, the use of the method of sequential analysis of variants is based on Bellman's principle of optimality, formulated as the basis of dynamic programming problems. This principle is an exceptional case of the method of sequential analysis of variants formulated for using additive monotone recursive functions.

In such problems, the criterion function is fractional-linear with Boolean variables. Solving problems of this type by using Bellman's principle of optimality holds the following: the previous behavior of the system does not matter in determining the next steps (Smirnova, 2018). If it turns out in solving that the future development of the system (business decision) depends on the past, it is necessary to add to the notion of the system state the parameters on which its development depends. For example, the initial state changed but still affecting the development of the system, should be included in the definition of the system state as an additional parameter. Below, the authors prove that the problem of making scientifically grounded business decisions under risk and uncertainty is a dynamic model and can be solved by the method of sequential analysis of variants.

This task can be presented as follows: T is a step-by-step decision-making process in which each decision made at the t-th step, t ∈[1; T], is to select one or more values of controlled variables. When considering the problem consisted of *t* steps, a set of parameters can be set, which characterize the system state, i.e., parameters that affect the values of controlled variables. This set can be set so that it will characterize the system state regardless of the number of steps. So, a choice of the controlled variable at the t-th step will not depend on previous ones.

The above considerations conclude that the method of sequential analysis of variants as a new method of dynamic modeling is advisable for making informed business decisions under different conditions. In the research, a dynamic model of the problem of allocating funds for consulting services over the years, provided by the advisory service, is suggested, and the optimal solution is found by the method of sequential analysis of variants.

Below, the authors determine the optimal variant for allocating funds for consulting services provided by the advisory service. The set problem is to define the sequence of a set of consulting services, which would provide the minimum realizable cost for the period from 2021 to 2027.

The criterion for optimizing the problem is the overall (capital and operating) cost minimization taking into account the probability of their allocation over time:

$$\text{Min } L = \left\{K_0 + \sum_{i=1}^{N} \sum_{j=1}^{N} \sum_{t=1}^{T} \left[K_{ij} \cdot R_{ij} \cdot x_{ij}^t + E_j\right] x_j^t B^t\right\} \quad \rightarrow \quad min \tag{1}$$

where L is optimization criterion, overall consolidated costs for the provision of consulting services, taking into account their allocation over time; K_0 is the initial cost of a set of services according to the relevant state; K_{ij} is the cost of transition from state i to state j; R_{ij} is transition probability from state i to state j; E_j is operating costs in state j; $x_j^t = \{0,1\}$ is a Boolean variable assigning the possibility for transition to state j in year t for t ∈[1; T], i, j ∈[1, N], $x_{ij}^t = \{0,1\}$ is a Boolean variable determining the possibility of adjacency of states i and j in year t, for t ∈[1, T], and Bt is the cost reduction factor for calculating the cost-discount factor (interest rate for periods).

The optimization criterion is an additive and monotone recursive function.

The expected cost of a set of consulting services should not exceed the cost of the same set over states:

$$Q_{ex.}^t \leq \Pi_j x_j^{(t)}, \;\; t \; \in [1;\; T], \;\; j \; \in [1,\; N] \tag{2}$$

where $Q_{ex.}^t$ is tje expected cost of consulting services; P_j is the probable cost of the state *j*; and $x_j^{(t)} = \{0,1\}$ is a Boolean variable showing how state *j* deals with the expected cost of consulting services in year *t*.

It is assumed that restrictions on financial and production resources are not imposed. This will provide an opportunity to determine their optimal needs as a result of solving the problem.

Limit on the number of consulting services: the probable number of services may not exceed the expected (even in one of the system parameters) this year:

$$K_j x_j^{(t)} \leq K_{ex.}^t, \; t \in [1;\; T], \; j \in [1;\; N] \quad (3)$$

where $K_{ex.}^t$ is the expected number of consulting services in year *t* and K_j is the probable number of consulting services.

The sequential analysis of variants in the form of additive and monotone recursive functionals is used to solve the set problem. To solve the problem is to sequentially search for all possible variants of states for the years consulting services have been provided, taking into account the main limitations - reduction of non-competitive solutions at each step following the rules of selecting variants (Midlyar, 2009). This is the way to find the best trajectory for economic system (business) development. The authors of this article take agricultural producers of Ukraine as a unit of measurement due to the economic instability of this industry since their macro environment has elements that are not in constant connection with the business entity but indirectly affect it. The principal elements of the macro-environment of the enterprise are economic, political, social, natural, environmental, and technological. It should be noted that the imbalance of the economy directly affects this industry, which makes the study of the dynamics of the provision of various consulting services to agricultural producers relevant in retrospect and perspective.

It is assumed that restrictions on technical and production resources are not imposed. This will provide an opportunity to determine their optimal needs as a result of solving the problem. The sequential analysis of variants in the partial form for additive and monotone recursive functionals is used to solve the set problem. The rule of selecting variants is based on the general principle of optimality, which is formulated as follows: if two variants of behaviors are applied to the same state, obtained at a particular step of the solution process, and the first variant gives less value to the criterion function than the second, the second variant cannot be a part of the optimal trajectory in minimizing the functional (Mikhalevich, 1965).

2.2. Data used for solving the task

System states are characterized by a certain set of parameters. Thus, to determine the number of system states, one should determine the variations of each parameter, which is done by the method of forecasting. To analyze the dynamics of the provision of various consulting services to agricultural producers both in the past and in the future, the authors used MS Excel, a spreadsheet that has numerous tools for economic and mathematical analysis. The analysis and forecasting will be based on the method, which is reduced to the construction of trends. A trend is the expression of a certain tendency in a certain mathematical equation, which best approximates the real tendency to a given series. Trend lines are usually used in forecasting problems. These problems are solved using the methods of regression analysis. Regression analysis allows constructing an optimal trend line, i.e., extrapolating (making predictions based on known facts in the past) beyond the limits with already known data and showing the trend of their change. Table 1 shows statistics of various consulting services provided during 1997-2020. The authors selected such a timeframe because the first data on the provision of various consulting services can be tracked (and documented) since 1997. The date 2020 is listed as the last constant (due to subsequent restrictions caused by Covid-19 and military escalation by the Russian Federation). All data on the dynamics of various consulting services provided rely on official sources, such as the Website of the Ministry of Agrarian Policy and Food of Ukraine

(2020), the National Institute for Strategic Studies (2020), and the Website of the Verkhovna Rada of Ukraine (2020).

Table 1. Dynamics of the number of various consulting services provided between 1997-2020.

Year (t)	Number of services provided (N)			
	Seminars (*S*)	Demonstrations (*D*)	Printed publications (*P*)	Individual services (*I*)
1997	10.0	3.0	21.0	35.0
1998	23.0	4.0	24.0	39.0
1999	34.0	4.0	19.0	46.0
2000	41.0	5.0	27.0	52.0
2004	54.0	6.0	32.0	75.0
2005	57.0	7.0	42.0	84.0
2008	64.0	8.0	54.0	93.0
2009	73.0	9.0	67.0	120.0
2010	79.0	10.0	72.0	190.0
2014	86.0	12.0	86.0	245.0
2015	88.0	15.0	98.0	321.0
2016	90.0	17.0	123.0	389.0
2017	94.0	19.0	144.0	424.0
2020	96.0	23.0	145.0	492.0

Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

Based on the data presented in Table 1, we will find the analytical form of this relationship, which best describes the dynamics of various consulting services (seminars, demonstrations, printed publications, and individual services) provided to agricultural producers. As it has been already analyzed above, trend lines are based on the analytical indicator-time relationship. In this case, the functional relationship that describes the holding of seminars will be in the form of a polynomial function of the fourth power:

$$y = 0.0014x^4 - 0.032x^3 - 0.1634x^2 + 11.851x - 0.6967. \quad (4)$$

To assess the quality of the trend equation (to check its validity), we find the approximation factor R^2 (coefficient of multiple determination or squared multiple correlation coefficient). The closer this coefficient of the trend equation tends to unity, the better this trend describes the processes that cause changes in this indicator. In our case, $R^2 = 0{,}9965$, and this explains all corresponding processes on the graph. If the coefficient value tended to zero, it would indicate the poor quality of the built mathematical model. The dynamics of the seminars held between 1997-2020 are provided in Fig.1. It shows that the dynamics are characterized by the gradual growth of seminars conducted (Y-axis) throughout the studied period (X-axis).

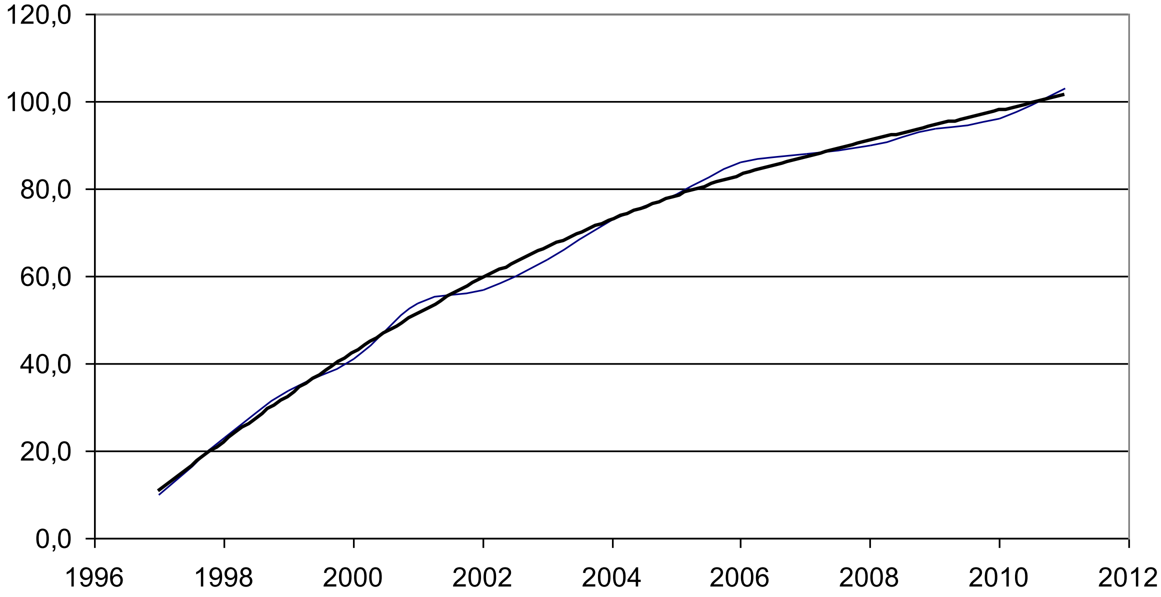

Figure 1. Dynamics of seminars held
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

The next step of the research is to find the functional relationship that describes the demonstrations in the best way. It is in the form of a polynomial function of the second power (Fig.2):

$$y=0.112x^2 - 0.2221x + 3.7637. \quad (5)$$

and then the corresponding approximation factor is equal to:

$$R^2=0.9946. \quad (6)$$

Figure 2 indicates that the dependence of the number of demonstrations (Y-axis) is characterized by an increase throughout the studied period (X-axis).

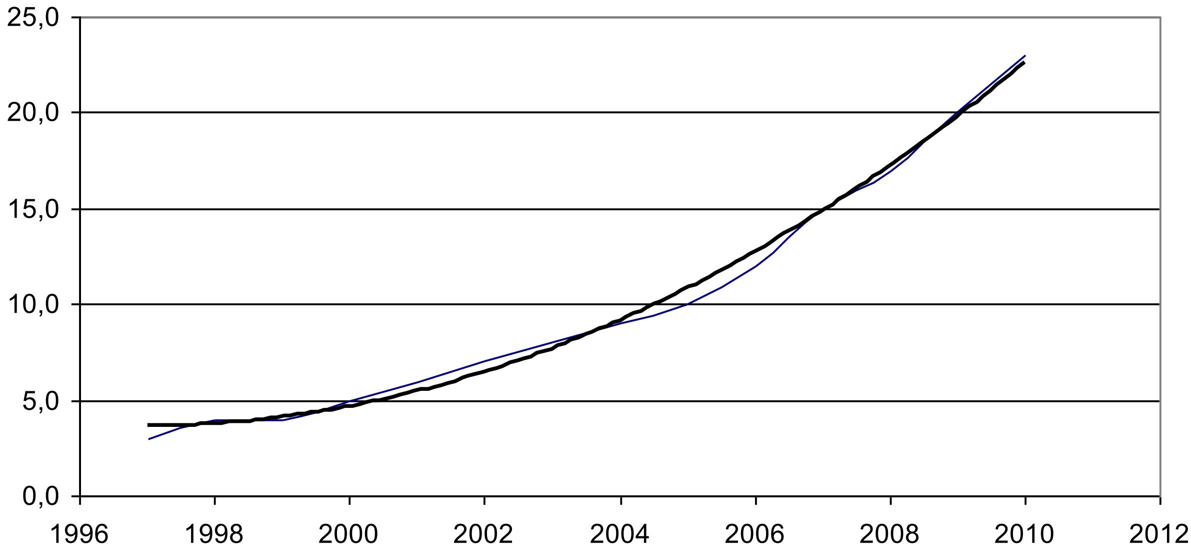

Figure 2. Dynamics of demonstrations held
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

The equation that describes printed publications most optimally is in the form of a polynomial function of the second power (see Fig. 3):

$$y = 0.6951x^2 - 0.0126x + 17.846. \quad (7)$$

and then the corresponding approximation factor is equal to:

$$R^2 = 0.989. \quad (8)$$

Figure 3 indicates that the dependence of the number of printed publications (Y-axis) is characterized by an increase throughout the studied period (X-axis).

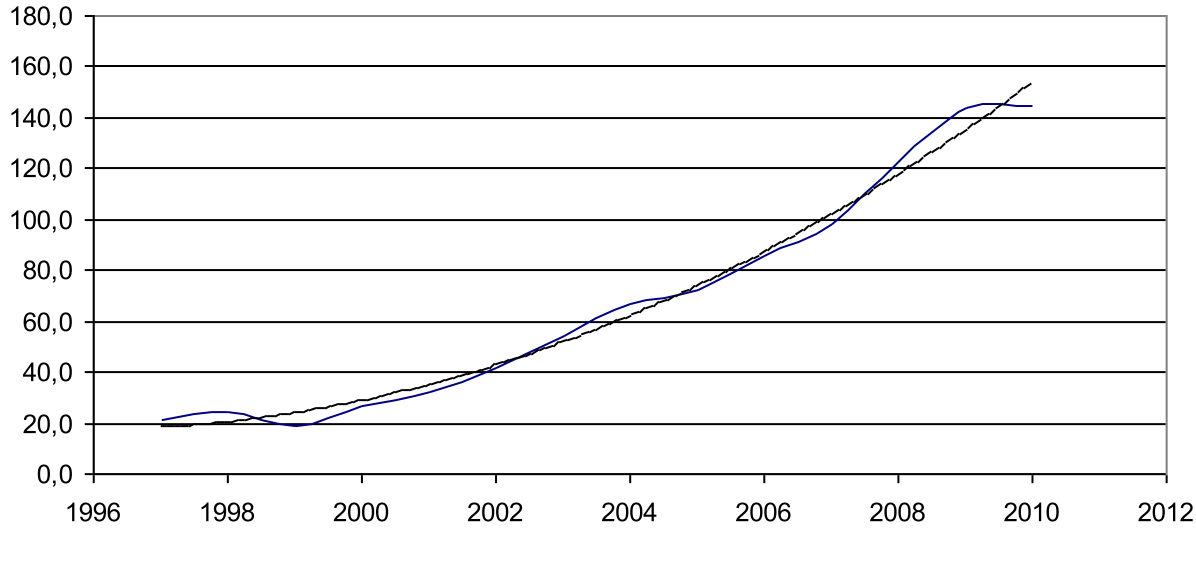

Figure 3. Dynamics of printed publications
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

The functional relationship that describes individual services in the best way is in the form of a polynomial function of the second power (Fig.4):

$$y=3.4299x^2 - 15.535x + 53.912. \quad (9)$$

and then the corresponding approximation factor is equal to:

$$R^2=0.9903. \quad (10)$$

Figure 4 indicates that the dependence of the number of individual services (Y-axis) is characterized by an increase throughout the studied period (X-axis).

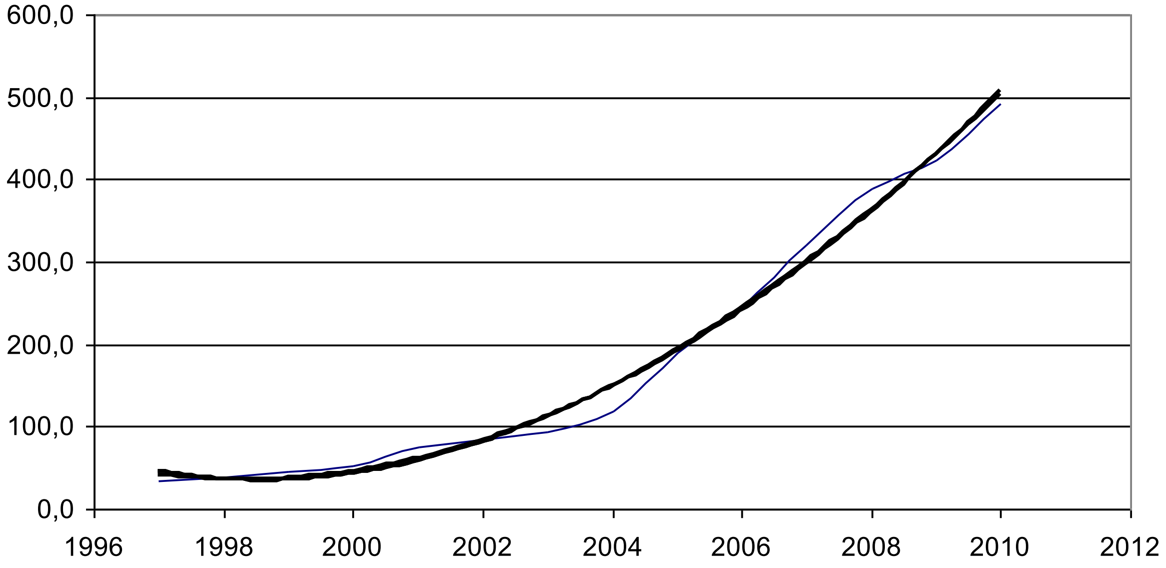

Figure 4. Dynamics of individual services provided
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

To show the general trend of seminars held, the forecasting of the indicators was made based on the analysis of series of dynamics and found mathematical equations. Table 2 includes the forecasting obtained. Forecasting the agricultural consulting services provided is a scientifically grounded prediction, development, and explanation of certain areas and probable opportunities for their development based on scientific and technological progress. Scientifically grounded business decisions can be made only if based on scientifically predicted, calculated values.

Table 2. Forecasting the number of consulting services between 2011-2020.

Year (t)	Number of services provided (N)			
	Seminars (*S*)	Demonstrations (*D*)	Printed publications (*P*)	Individual services (*I*)
2011	103.2	25.6	174.1	592.6
2014	107.9	28.9	195.6	683.4
2016	113.3	32.4	218.5	781.1
2018	120.0	36.1	242.8	885.6
2020	129.0	40.0	268.5	996.9

Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

Figures 5, 6, 7, and 8 provide forecast curves according to the type of service, where the Y-axis shows the number of provided services of a particular type, and the X-axis shows the studied period.

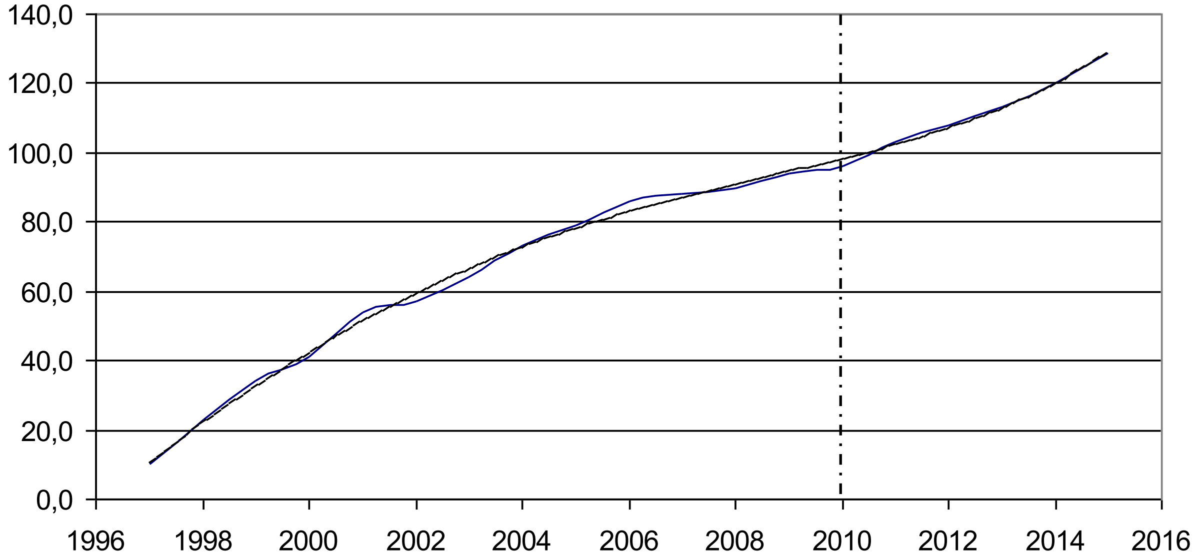

Figure 5. Forecasting the number of seminars
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

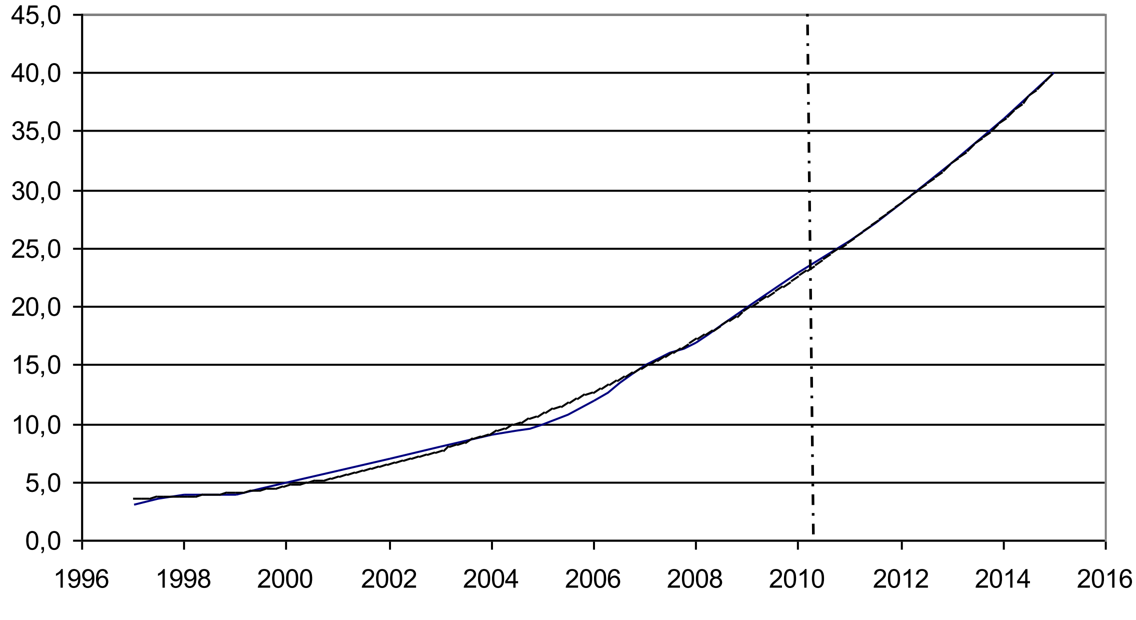

Figure 6. Forecasting the number of demonstrations
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

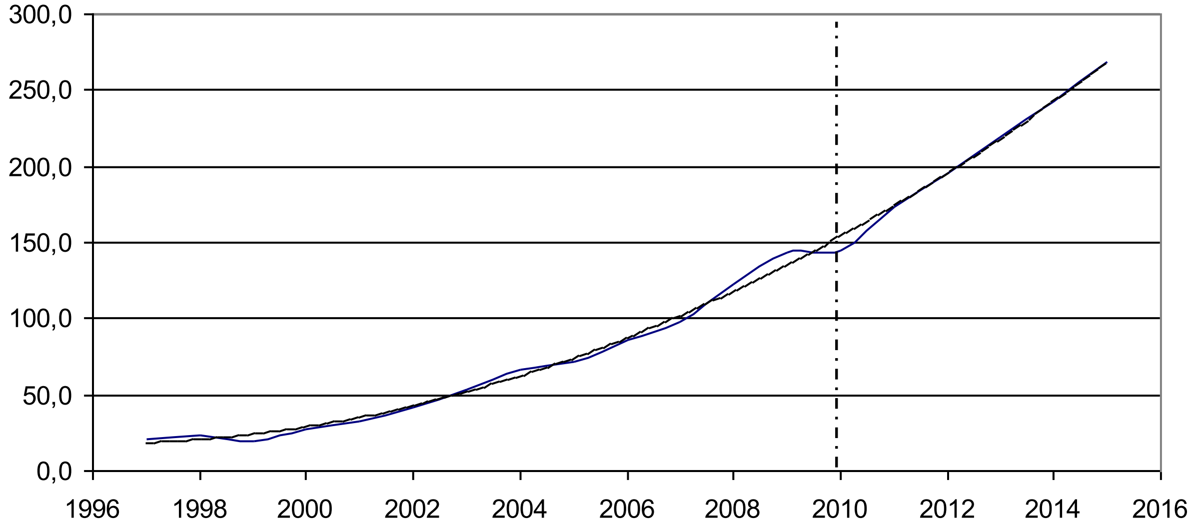

Figure 7. Forecasting the number of printed publications
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

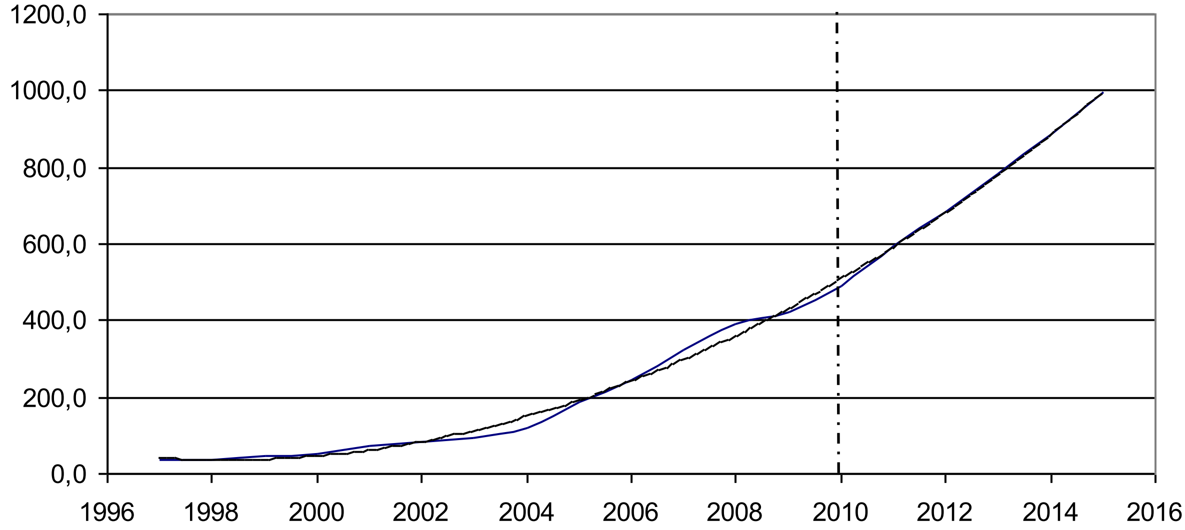

Figure 8. Forecasting the number of individual services
Source: developed by authors according to data provided by the Ministry of Agrarian Policy and Food of Ukraine (2020).

The analysis of forecasting various consulting services provided to agricultural producers affords grounds for the following conclusion. In the domestic market of agricultural consulting services, there has been a tendency to their gradual growth in recent years prompted by the development of market relations. Nowadays, the number of private enterprises is growing, innovations are being introduced, and the state is increasing its role in providing socially-oriented consulting services. Table 3 presents the plan for the provision of consulting services by year.

Table 3. Plan for the provision of consulting services by year, thousand UAH

Years (t)	Plan $Q_{pl.}^{t}$
2021	290
2022	383
2023	441
2024	507
2025	583
2026	671
2027	754

Source: developed by authors

Each object is characterized by a set of possible states, which, in turn, are described by a certain set of parameters. If at least one of the parameters under the action of the selected control is changed, the system will transit to a certain corresponding state. The number of states depends on the possible ratio of parameters. In this problem, the authors assume that the state is a set of consulting services with parameters S, D, P, I (Table. 4).

Table 4. Types of consulting services and their cost

Type of the consulting service	Designation of the service	Cost of the consulting service, UAH
One-day seminar (participants - 25 people)	S	2000.00
Demonstration (participants – 30 people)	D	3294.24
Printed publications: booklets, support flyers, brochures (per copy)	P	200.00
Individual consulting service (per hour)	I	25.00

Source: developed by authors according to the data of the National Institute for Strategic Studies (2020).

The set of S, D, P, and I parameters determines the state of consultancy system and forms the cost of consulting services provided by the advisory service.

To construct all possible system states, the method of a simple search of state parameters is used

$$\min(p) \le state \le \max(p) + 10\%, \qquad (11)$$

where *n* is the expected cost of a state (P_j).

The states are constructed taking into account the following restriction:

$$N_{plan.} \le K \le N_{plan.} + 10\%, \qquad (12)$$

where K is state of the system and $N_{plan.}$ is plan for providing consulting services $Q_{pl.}^{t}$ (Table 5).

Table 5. Plan indicators of consulting services cost, thousand UAH

Type of the consulting service	Number of services provided (N)		
	2021 (fact)	2022	2027 (forecast)
Seminars (S)	S_1=94	S_2=188	S_3=246
Demonstrations (D)	D_1=19	D_2=33	D_3=48
Printed publications (P)	P_1=144	P_2=262	P_3=381
Individual services (I)	I_1=424	I_2=765	I_3=1107

Source: developed by authors

Each of the S, D, P, and I parameters can take three different values, as shown in Table 5. The sources of these values are forecasts. Under such conditions, the number of possible states will be equal to 3^4=81.

It is needed to choose the most competitive states from all the possible, in other words, states fulfilling the plan of consulting services provision. Thus, Table 6 presents cost calculations of a set of consulting services for 22 different states. In this model, transitions will be impossible under the following conditions:

1) it is impossible to transit from state *i* to state *j* if its cost is less;

2) it is impossible to transit from state *i* to state *j* if the number of consulting services provided (even of one type) is less.

The cost of a state consists of state and operating costs of providing the services included in a state. Operating costs are calculated according to the following scheme: 20% of their cost is spent on seminars, 30% on demonstrations, 40% on printed publications, and 20% on individual services. Table 6 provides cost calculations of a set of consulting services according to the calculated states.

Table 6. Cost calculations of a set of socially-oriented consulting services by states

No. state	State	Cost of the state (P_j) (thousand UAH)	Operating costs (Oj) (thousand UAH)
1	$S_1D_1P_1I_1$	290	70
2	$S_1D_1P_3I_3$	354	92
3	$S_1D_3P_1I_1$	385	99
4	$S_1D_3P_2I_2$	417	110
5	$S_2D_1P_1I_1$	478	108
6	$S_2D_1P_1I_2$	486	109
7	$S_2D_2P_1I_1$	524	121
8	$S_2D_2P_3I_1$	571	140
9	$S_2D_3P_1I_1$	573	136
10	$S_2D_2P_3I_3$	588	144
11	$S_2D_3P_2I_2$	605	147
12	$S_2D_3P_3I_1$	620	155
13	$S_3D_1P_2I_2$	626	142
14	$S_2D_3P_3I_3$	638	159
15	$S_1D_3P_1I_3$	661	102
16	$S_3D_2P_3I_2$	695	165
17	$S_3D_3P_1I_3$	706	163
18	$S_3D_3P_3I_1$	737	178
19	$S_3D_3P_3I_2$	745	180
20	$S_3D_3P_3I_3$	754	182
21	$(3S_1)D_2P_3I_3$	777	181
22	$S_2(3D_1)(2P_2)(5I_3)$	807	201

Source: developed by authors according to the data of the National Institute for Strategic Studies (2020).

We will calculate K_{ij}, which is the cost of transition from state to state. Indicator K_{ij} is the difference between the values of the states we transit from and to. The shaded cells in Table 7 refer to impossible transitions between states, i.e., those that do not satisfy the imposed restrictions of the problem. Table 7 provides the data on the cost of transitions from *i* state to *j* state, where $i, j \in [1;\ 22]$, and Table 8 presents the probability R_{ij} of these transitions.

Below, the authors build a schedule grid of possible variants for providing consulting services to solve the problem (Fig. 9). According to Figure 9, the X-axis shows years (t), and the planned cost of consulting services for this year $Q_{pl.}^{t}$ is placed above them. The Y-axis plots possible states, the segments of which indicate possible transitions between states (ij). The symbol "*" indicates the points at which the imposed restrictions are not met.

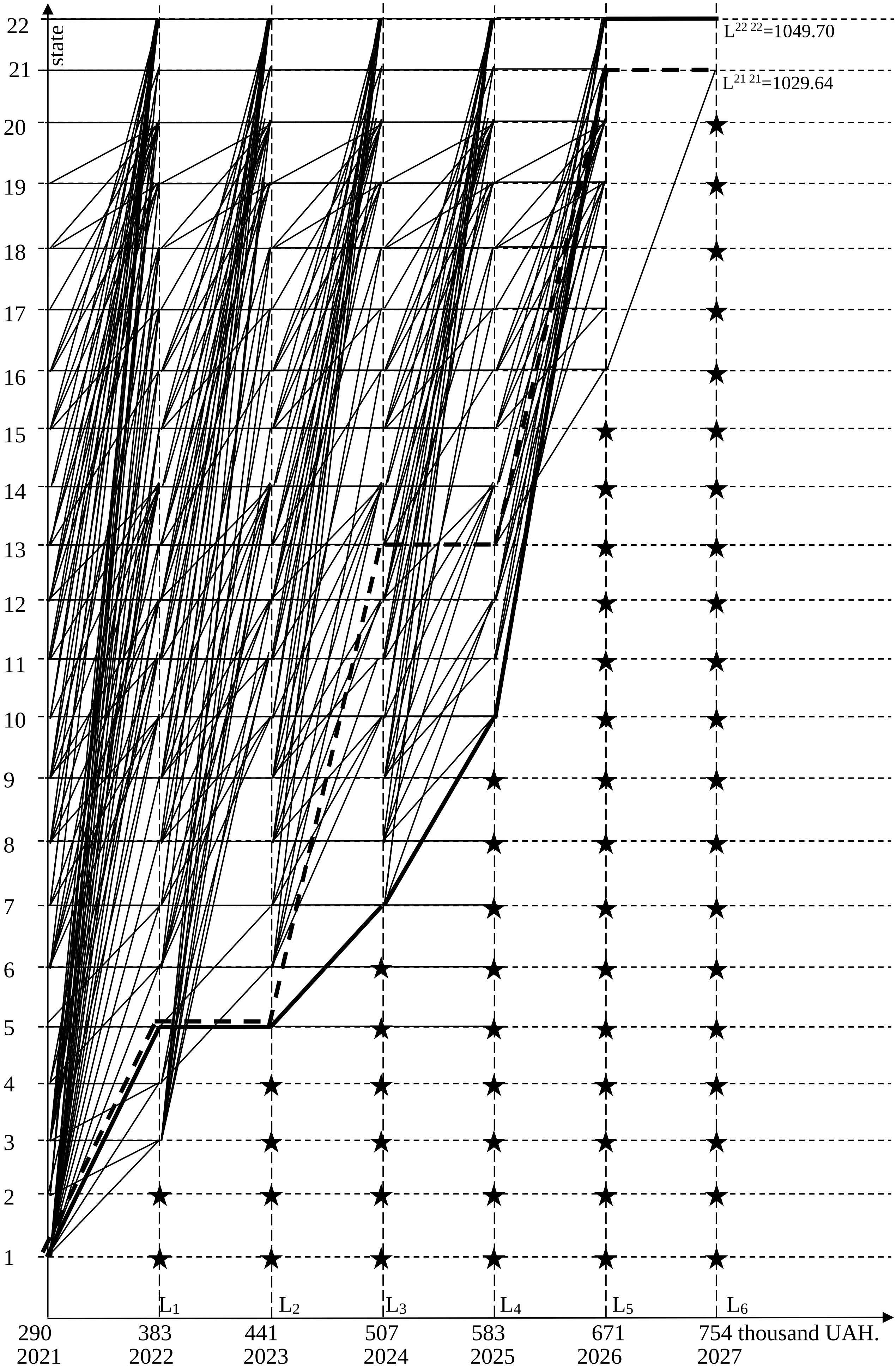

Figure 9. Possible variants for providing consulting services

Source: developed by authors

It is needed to build a calculation of the L criterion in order to find the optimal solution to the problem. To calculate partially optimal values of the L criterion for state 1 in the year t = 2022, we apply the formula for the L criterion for two possible transitions: from state 1 to state 3 (L_1^{13}) and from state 3 to state 3 (L_1^{33}):

$$L_1^{13} = K_0 + \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{T}\left[K_{ij} \cdot R_{ij} + E_j^t\right] x_{ij}^t B^t$$

$$= 289.99056 + (95 \cdot 0.1 + 98.677056) \cdot 0.952 = 393.02586. \quad (13)$$

According to Mikhalevich's rule of selecting variants (1965), the partially optimal value, which is the smallest value according to the function-criterion, which is:

$$L_1^{13} = 393.02586 \quad (14)$$

and

$$L_1^{33} = 479.46408\ . \quad (15)$$

Thus, the partially optimal value will be

$$L_1^{13} = 393.02586 = L_1. \quad (16)$$

By analogy, we calculate all other partially optimal values (Fig. 9).

In the final step, the authors of this article determine the optimal solution to the problem by returning the value of the criterion function of the corresponding years to the first year, characterized by the sequence of found optimal states, by partially optimal points (Figure 9):

- state 1 is selected in 2021,
- state 5 is selected in 2022,
- state 5 is also selected in 2023,
- state 13 is selected in 2024,
- state 13 is also selected in 2025,
- state 21 is selected in 2026,
- state 21 is also selected in 2027.

If this solution is applied, the overall consolidated costs are the lowest and amount to 1,024.64 thousand UAH, according to the value of the function-criterion $L^{21\,21}$.

It is also possible to determine the variant close to the optimal one by the value of the criterion function $L^{22\,22}$ (see Fig. 9):

- state 1 is selected in 2021,
- state 5 is selected in 2022,
- state 5 is selected in 2023, and state 7 is selected in 2024,
- state 10 is selected in 2025,
- state 22 is selected in 2026,
- state 22 is selected in 2027.

If this solution is applied, the overall consolidated costs are equal to 1,049.70 thousand UAH.

3. Results

The proposed and constructed model of allocating funds for consulting services by years with the optimal solution to this problem is the example of a dynamic model of decision-making, taking into account probabilistic estimates of the parameters of the economic system and changes over time. An estimate of the solution is obtained relying on the above calculation algorithm based on the determination of the appropriate rule for selecting competitive variants

(Safonova & Kalna-Dubiniuk, 2018). Thus, the obtained optimal solution to the problem is characterized by the sequence of states, which is shown by the dot-and-dashed line in Figure 9. It gives the best options for allocating funds for consulting services by year. In addition to the optimal value of the criterion function, we also regard values close to the optimum in most cases. This solution to the problem is found and represented by a solid polyline in Fig. 9. To obtain such values of the criterion function, we allow the parameters to fluctuate within a certain allowable range and examine the sensitivity of the optimum to such fluctuations. With the method of sequential analysis of variants, you can carry out such analysis and receive such information, which cannot be obtained by any other method.

Behaviors close to the optimum, which differ slightly from it, can be just as important as the exact solution. They can be even more important than the exact solution when there is, for example, the need to obtain simple approximations in a difficult situation. The method of sequential analysis of variants also presupposes obtaining such optimums. Common to all algorithmic schemes is a step-by-step optimization process when certain properties of a subset of variants are checked at each step. This narrows their original set and provides high efficiency of this method. This principle was the basis of Mikhalevich's rules for selecting variants (1965) for problems with a monotone recursive criterion function: if two variants of behaviors are applied to the same state, obtained at a particular step of the solution process, and the first variant gives less value to the criterion function than the second, the second variant cannot be a part of the optimal solution in minimizing the function. The following model was also used and thoroughly described in such scientific works as "Dynamic sustainable business modelling: exploring the dynamics of business model components considering the product development framework" (Maresova et al., 2022), "Multivariate dynamic modeling for Bayesian forecasting of business revenue" (Yanchenko et al., 2022) and "Evaluation of the effectiveness of information and consulting support for the spread of innovative biotechnologies in conditions of risk and uncertainty" (Kalna-Dubiniuk & Lytovchenko, 2014). It can be excluded from further calculations as prospectless without the risk of losing the optimum.

The method of sequential analysis of variants significantly reduces the time spent on calculations and requirements to computer system powers to make these calculations. In a case of an economic system consisting of N states and a period of research in $[0;T]$ years, $N^{(T+1)}$ trajectories of variants for providing consulting services must be analyzed by a complete search. When applying the method of sequential analysis of variants, only $N^{(T+1)}$ trajectories need to be analyzed (Lytvynenko et al., 2022). Thus, this method is more effective and appropriate in use than a simple study of all cases. Therefore, the methods of sequential analysis of variants are not standard procedures as they take into account the problem specifics to build a system of rules for eliminating non-competitive variants. Since the reduction of non-competitive variants eliminates the whole set of their extensions, it leads to significant savings in computing costs.

The article analyzes the literary sources by the classics and the publications of scientists who, on their basis, practically applied methods of dynamic modeling to make scientifically grounded business decisions, which are original approaches for each task. As of today, not every person can apply such dynamic methods due to their complex nonlinear calculations.

4. Conclusions

This article examines the theory and practice of dynamic modeling for making scientifically grounded business decisions. Having analyzed the development of the classical theory of economic dynamics, which originated from Marx's model of expanded reproduction and Leontiev's intersectoral balance of production, we discovered that approaches to solving dynamic problems improved gradually with the complication of economic relations. Models of macroeconomic dynamics introduced by Harrod-Domar and Solow, and models of sequential statistical decisions introduced by Wald have been well developed. In the early 1950s, dynamic programming has been well developed, the history of which is closely connected with the name of Bellman and others. All these models have been successfully used at certain stages of business development.

The modern business operates under constant technological changes. The original mathematical apparatus - a method of sequential analysis of variants, appeared in the second half of the twentieth century, and most fully meets all the requirements of business in the XXI century. This method allows for finding the best variants for implementing innovation with all the prospects, risks, and uncertainty. The continuous changes in the market situation require a business to make efficient, scientifically grounded decisions, in other words, specify previous decisions and move forward to be competitive.

As demonstrated by the practice of its applications in the business of various industries, the proposed method of dynamic modeling (the sequential analysis of variants) provides such an opportunity. The prospect to further develop dynamic models in business is due to their usefulness in the applications, based on the use in both the business of digital networks and technologies, and relying on which the competitive advantages of business formations are established. Thus, the presented approach enriches the scientific literature with the applicatoins of the implementation of the method of dynamic modeling, which is a sequential analysis of variants for making scientifically grounded business decisions. The research is relevant and original since it solves such a problem as the optimization of the distribution of funds for consulting services provided by the advisory service over the years. The motive of the article is the need for effective fund distribution for the provision of socially necessary advisory services that develop in the agricultural sector and is essential for introducing innovations under market conditions. The material presented in the article will be of interest to both scientists and practitioners. They will learn about the method of sequential analysis of variants and an original (developed by authors) algorithm for solving dynamic problems in a consultancy sphere under conditions of risk and uncertainty. This research is original since it allows solving the problem of optimizing the long-term distribution of funds for the provision of information and consulting services by the method of sequential analysis of variants. It is also possible to apply the presented approach for making scientifically grounded business decisions, which makes this study original. Prospects for further study of the application of dynamic modeling methods in practice are associated with the use of digital networks and technologies in business that are the basis for establishing the competitive advantages of business formations.

The introduction of such an approach will achieve the following competitive advantages: improving business planning, creation of flexible integrated management structures, increasing information availability, increasing the reliability of management activities, increasing efficiency by timely updating data and reduction of information processing time, reducing production risks, and increasing business efficiency by optimizing costs.

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Appendix

Table 7. Cost of transitions from state to state (K_{ij}) (thousand UAH)

From *i* state \ To *j* state	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0	64	95	127	188	196	234	281	283	298	315	330	336	348	371	405	416	447	455	464	487	517
2		0								234				284						400	423	453
3			0	32							220	235		253	276		321	352	360	369		422
4				0		69					188			221					328	337		390
5					0	8	46	93	95	110	127	142	148	160		217	228	259	267	276	299	329
6						0				102	119		140	152		209	220		259	268	291	321
7							0	47		15	17	15		12		34	11	31	8	9	23	30
8								0		17		49		67				166	174	183	206	236
9									0		32	47		65			133	164	172	181		234
10										0				50							189	219
11											0			33					140	149		202
12												0		12				31	8	9		30
13													0			69			119	128	151	
14														0						116		169
15															0		45		84	93		146
16																0			50	59	82	
17																	0			48		
18																		0	8	17		
19																			0	9		
20																				0		
21																					0	
22																						0

Table 8. Probability of transition from state to state (R_{ij})

To j / From i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.05	0.2	0.1	0.055	0.075	0.07	0.055	0.05	0.025	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.025	0.02	0.025	0.05	0.02	0.02
2		0.1								0.3				0.2						0.2	0.1	0.1
3			0.05	0.25							0.1	0.05		0.05	0.04		0.04	0.025	0.2	0.17		0.025
4				0.05		0.25					0.15			0.25					0.2	0.05		0.05
5					0.05	0.2	0.1	0.0	0.05	0.05	0.15	0.025	0.025	0.05		0.02	0.02	0.01	0.05	0.05	0.05	0.05
6						0.05				0.2	0.15		0.1	0.1		0.15	0.05		0.05	0.05	0.05	0.05
7							0.05	0.25		0.05	0.05	0.1		0.1		0.1	0.05	0.05	0.04	0.06	0.05	0.05
8								0.05		0.14		0.2		0.2				0.1	0.01	0.1	0.1	0.1
9									0.05		0.3	0.15		0.15			0.1	0.05	0.05	0.05		0.1
10										0.5				0.3							0.15	0.05
11											0.4			0.2					0.25	0.1		0.05
12												0.4		0.25				0.2	0.05	0.05		0.05
13													0.35			0.25			0.15	0.2	0.05	
14														0.4						0.35		0.25
15															0.5		0.25		0.1	0.05		0.1
16																0.35			0.3	0.25	0.1	
17																	0.7			0.3		
18																		0.4	0.35	0.25		
19																			0.6	0.4		
20																				1		
21																					1	
22																						1