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MARKETING RESEARCHES IN THE FORMATION OF PRICING AND LOGISTICS POLICY OF THE ENTERPRISE

Introduction. *Marketing researches are the main means of adapting to changes in the market environment, which are based on complete, reliable and timely information. In the works of scientists, the question of the role of marketing researches in the formation of pricing and logistics policy of the enterprise remains insufficiently covered.*

Purpose. *Presentation of theoretical and practical positions about the main tools of marketing and determination of the place of marketing researches in the formation of pricing and logistics policy of the enterprise.*

Results. *It is analyzed that the purpose of marketing researches is identifying market opportunities of the enterprise. They allow the enterprise to get the advantage over competitors, reduce risk, timely determine changes in the marketing environment, namely it is the collecting and processing of marketing information. Exactly in the analysis of the collected marketing information a set of statistical indicators and statistical methods is used. Based on this, the relationship between marketing researches, pricing and logistics policy is revealed, without which the effective functioning of the enterprise is impossible. The analysis of time series of average prices for cereals and legumes sold by enterprises of Poltava region is performed. The analysis of the level of wholesale turnover of wholesale enterprises by districts and cities of Poltava region and further forecast of this indicator with the use of trend models is performed. It is revealed that for research and forecasting the level of wholesale turnover of wholesale enterprises by districts and cities with the help of trend models it is advisable to use a linear trend model, as this model more precisely shows and compares actual and theoretical values of the level of wholesale turnover of wholesale enterprises.*

Originality. *It is substantiated that an important factor in the interaction of logistics and pricing policy in marketing researches is the product range. It is revealed that the purpose of marketing researches is identifying market opportunities of the enterprise, which allow the enterprise to get the advantage over competitors, reduce risk, timely determine changes in the marketing environment, namely it is the collecting and processing of marketing information. With the help of available information and trend models, the expediency of marketing researches of the pricing policy of the enterprise is revealed and the expediency of a linear trend as a model that more precisely shows and compares actual and theoretical values of the level of wholesale turnover of enterprises is revealed. A scheme of the relationship between pricing, logistics policy and marketing researches, showing the relationship and expediency of their conducting with the help of chains of interdependence between them was made.*

Conclusion. *It is revealed that marketing researches in the system of the enterprise is one of the levers of ensuring its competitiveness, by studying the subsystems of pricing and logistics policy that will directly affect its economic efficiency. Since the use of marketing researches in the formation of pricing and logistics policy has certain problems, it is necessary to more carefully study the open niches of marketing researches for the effective formation and operation of the enterprise.*

Keywords: *marketing, marketing researches, price, marketing pricing policy, logistics, enterprise, logistics policy, product promotion.*

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РОЗВИТОК РЕГІОНІВ, ГАЛУЗЕЙ ТА ВИДІВ ЕКОНОМІЧНОЇ ДІЯЛЬНОСТІ

DEVELOPMENT OF REGIONS, INDUSTRIES AND TYPES OF ECONOMIC ACTIVITY

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INTEGRATED TECHNOLOGICAL MANAGEMENT SYSTEMS IN AGRICULTURAL PRODUCTION DEPENDING ON THE TIME OF OPERATIONS

The integrated systems of control of technological processes implementation in agricultural production, which depend on the initial and final moments of their operation time, are substantiated. In order to optimize the management processes of these systems, a generalization of the results of researches of the influence of various factors on the efficiency of crop production has been carried out. The most important technological, technical and organizational criteria of the quality work of agricultural machines are determined along with their level of influence on the final result - the magnitude of the harvested yield, as well as the possible level of efficiency of the application of the corresponding technical means of mechanization with a controlled effect on the quality of the actual performance of the technological operations itself.

Key words*: integrated control systems, technological processes, agricultural production, dependence, initial and final moments of functioning/operation.*

Introduction. It is known that integrated systems of automatic control of the technological processes implementation in agricultural production are the most promising. They should ensure the creation of qualitatively new technologies (innovative technologies), which have the latest economic, social and environmental indicators.

It is clear that in order to generalize the results of previous studies concerning the level of influence of various factors on the efficiency of crop production, it is necessary to identify the main technological (application rate, depth of cultivation, etc.), technical (speed, engine load, etc.) and organizational (terms of execution, machine-tractor unit (MTU) loading) criteria for the quality work of agricultural machines, the importance of the influence of these factors on the size of the harvested yield (the final result), as well as the probability (possible) level of efficiency of the applied relevant technical mechanical means with controlled impact on the quality of technological operations.

According to the authors' of this study opinion, it is necessary to consider a specific class of managed systems that depend on the initial and final state and which adequately simulate integrated systems of automatic control of the technological processes implementation in agricultural production, including crop production. The tasks of managing such systems are somewhat different from the traditional tasks of management (including optimal) and are primarily related to the planning of the work of each of these systems.

It is clear that the simulation of such systems, methods of optimal management of them are relevant studies of the present and require further in-depth study.

Literature review. The authors of the works [1-7] consider and comprehensively explore various aspects of the management of finite-dimensional linear objects, various problems of the theory of motion control, automatic control of linear (nonlinear) systems. However, the management of the system, which depends on the start and finish, in the opinion of the authors of this study, require further thorough study.

It should be noted that the results of the above quoted works will be used in this study.

The purpose of this work is to substantiate the approach to the solution of the main problems of the theory of system management, depending on the start and finish, as well as the problem of complete control of such systems in optimizing management.

Results and discussion. Let's consider that it is a question of growing some crops, such as corn. On the starting date, let us take January 1. The state of plants at any given time *t*, $t \succ 0$ can be characterized by a set of parameters $x_1(t),..., x_n(t)$. The rate of growth and maturation of plants depends on many factors. We will indicate only some of them: the quality of seeds at the time $t = t_0$ when grains enter the soil, the quality of soil, the quality of vegetation care, the time when harvesting is taking place, and so on. Considering the quality of seeds and soil predetermined and constant, one can study the dependence of the development of the plant on other factors. If we take into account that the rate of development of a plant at an arbitrary time *t* depends on the initial moment of time, when the grain enters the soil, the quality of the plant care at a given time *t*, from the state of the plant at the current time, then the process can be described by a system of equations:

$$\dot{x}_i = f_i(t, t_0, x, u), \ i = 1,..., n, \tag{1}$$

where the vector $x = \{x_1,..., x_n\}$ characterizes the state of the plant, and $u = \{u_1,..., u_n\}$ - the care of the plant. The initial state of the system can be considered as given:

$$x(t_0) = x^0 \tag{2}$$

If this process is considered to be controlled, then the in the right part of the system (1) the function $u_k = u_k(t, t_0, T)$, $k = 1,.., r$, should be introduced, where *T*- the end of the plant care process (i.e. harvesting), the choice of which depends not only on the optimality of the system, but also on the t_0 and *T*. Substituting such a control into equation (1), we have a level system that depends on t_0 and *T*.

The following should be noted:

1. Managed movements of the system, depending on the start and finish, in some cases can be considered as multi-step processes, described by the equations of the form:

$$x_i(n+1) = f_i(t_0, T, t, n, x(n), u), \ i = 1,..., m, \ n = 1,..., N, \tag{3}$$

where *n*- segment number when dividing $(T - t_0)$ into *N* parts.

2. In tasks that should take into account continuously variable time, processes in systems that are dependent on start and finish can be described by differential levels of the form:

$$\dot{x}_i = f_i(t, t_0, T, x, u), \ t_0 \le t \le T, \ i = 1,..., n \tag{4}$$

Similarly, we can consider systems with distributed parameters, depending on the start and finish.

3. For this type of systems, the main problems of the theory of management remain the natural ones (controllability, observation, optimality, etc.). However, now they acquire some new shades because the right-hand sides of the equations of motion can be continuous coordinates *t*, *x* and *u*, but to

be discontinued at t_0 and T. This last fact can significantly affect the content, respectively, in each particular task of the theory of management.

As it is shown below, in these cases, the method used to solve a problem may be considerably complicated.

Controllability. First, let us consider the system

$$\dot{x} = A(t) \cdot x + B(t)\,,\ t_0 \le t \le T, \tag{5}$$

In which $A(t)$ is a continuous matrix of order n, and $B(t)$ a continuous matrix of dimension $[n \times m]$, $x \in E^n$, $u \in E^m$. Admissible control is considered to be piecewise-continuous functions $u = u(t)$ with values in the whole space E^n.

It is known that the system of equations (5) is called controlled, as for a given t_0 and any one $x^0 \in E^n$, $x' \in E^n$, it is possible to specify $T(t_0)$, $T \succ t_0$, and the permissible control $u = u(t, t_0, T, x^0, x')$ such, that there $x = x(t)$ is a solution of the equation:

$$\dot{x} = A(t) \cdot x + B(t) \cdot u(t, t_0, T, x^0, x^1)\,,\ x(T) = x^1, \tag{6}$$

with the initial condition (2).

If t_0 and T are given, then the system is called controlled by a segment $[t_0, T]$. We know the conditions for controllability, for example [1-3]. Here we present them in a convenient formula for further analysis [4]. To do this, we write a Cauchy matrix $W(t, s)$ of a homogeneous equation:

$$\dot{y} = A(t) \cdot y \tag{7}$$

If now indicate $h_i(t, T)$ the i-th column of the matrix $B^*(t)W^*(t)$, then the condition of control is that, for a given t_0 vector-function $h_1(t, T),..., h_n(t, T)$ are linearly independent on a certain segment $[t_0, T]$. This condition remains fair in the case when the matrices $A(t)$ and $B(t)$ are piecewise and continuous.

In the case when the linear control system is considered, depending on the start and the finish, the process is described by the equation:

$$\dot{X} = A(t, t_0, T) \cdot x + B(t, t_0, T) \cdot u\,,\ t_0 \prec t \prec T\,. \tag{8}$$

We will assume that $A(t, t_0, T)$ and $B(t, t_0, T)$ are continuous on t in any segment $[t_0, T]$ and piecewise-continuous in t_0 and T.

It is clear that in the problem of controllability of the system (8) on a given segment no new features arise in comparison with the same problem for the system (7). In the case when t_0 and T the columns of the matrix $B^*(t, t_0, T) \cdot W\ \ (T, t; t_0 T)$ and T, then the linear dependence or independence of the vector of the function:

$$h_1(t, t_0, T),..., h_n(t, t_0, T) \tag{9}$$

is determined not only by the variable t, but by the parameters t_0 and T. As it is shown in the following example, in this case there may not be quite normal situations.

Example 1. Consider the managed system:

$$\dot{x}_1 = x_2 + \alpha(t, T)u_2\,,\ \dot{x}_2 = u_1\,,\ \dot{x}_3 = x_4 + (t-1)u_2\,,\ \dot{x}_4 = u_1 + \beta(t, t_0)u_2\,, \tag{10}$$

in which

$$\alpha(t, T) = (t-1) \cdot \Theta(T-2) = \begin{cases} 0\_\,при\_\,t_0 \le t \le T \le 2, \\ t-1\_\,при\_\,t_0 \le t \le T, T \succ 2 \end{cases}, \tag{11}$$

$$\beta(t, t_0) = \Theta(t_0 - 1) = \begin{cases} 0\_\,при\_\,t_0 \le t \le T, t_0 \le 1, \\ 1\_\,при\_\,t_0 \le t \le T, t \succ 2 \end{cases}. \tag{12}$$

If the system (10) is rewritten in the form (8), then we will have:

$$A(t.t_0,T)=\begin{bmatrix}0&1&0&0\\0&0&0&0\\0&0&0&1\\0&0&0&0\end{bmatrix},\ B(t.t_0,T)=\begin{bmatrix}0&\alpha(t,T)\\1&0\\0&t-1\\1&\beta(t,t_0)\end{bmatrix}, \tag{13}$$

$$W(t.s)=\begin{bmatrix}1&t-s&0&0\\0&1&0&0\\0&0&1&t-s\\0&1&0&1\end{bmatrix}. \tag{14}$$

Expression (14) is a Cauchy matrix, and the vector functions (9) have the form:

$$\begin{cases} h_1(t,t_0,T)=\begin{bmatrix}T-t\\ \alpha(t,T)\end{bmatrix}, h_2(t,t_0,T)=\begin{pmatrix}1\\0\end{pmatrix}\\ h_3(t,t_0,T)=\begin{bmatrix}T-t\\ t-1+\beta(t,t_0)\cdot(T-t)\end{bmatrix}, h_4(t,t_0,T)=\begin{bmatrix}1\\ \beta(t,t_0\end{bmatrix}\end{cases}. \tag{15}$$

From the definition of the function $\alpha(t,T)$ and $\beta(t,t_0)$ (see (11) and (12)), it follows that these vectors are linearly independent only under the condition of $t_0 \succ 1,\ T \succ 2$ or $t_0 \succ 1,\ T \le 2$.

In these cases, the system under consideration is controlled. In other cases ($t_0 \le 1$, $T \succ 2$; $t_0 \le 1$, $T \le 2$), the function vectors h_1, h_2, h_3 and h_4 are linearly dependent, and system (10) is not controlled in a segment $[t_0, T]$.

It is appropriate to pay attention to the following interesting facts. The system (10) is controlled on a small segment $[t_0, T]$ at $t_0 \succ 1$, $T \le 2$ and uncontrolled on a large segment $[t_0,]T$, at $t_0 \prec 1$, $T \succ 2$

Identity and visibility. We will consider the system of equations of management:

$$\begin{cases} x = A(t,t_0,T)\cdot x + B(t,t_0,T)\cdot u\\ y = C(t,t_0,T)\cdot x\end{cases}, \tag{16}$$

in which the matrices *A* and *B* are the same as in the system (8), and $C(t,t_0,T)$ is continuous at *t* and piecewise continuous at t_0 and *T* matrix with dimensionality $[n \times m]$.

When fixed t_0 and *T* this system can be presented as:

$$\begin{cases} x = A(t)\cdot\alpha + B(t)\cdot u\\ y = C(t)\cdot x\end{cases} \tag{17}$$

As it is known, the task of observation is the task of a definite state of the x^r system at the time *r* of the input and output signals, which will be measured in the future, that is, according to the data of the control $u(t)$ and the signal $y(t)$ at $t \ge r$. The task of identity of a system is to evaluate the state of the system x^r at a time *r* with data about $u(t)$ and $y(t)$ at $t \le r$.

A point (r, x^r) is called an event for the characteristic of which we introduce the following two concepts. An event (r, x^r) is called unidentified, if $y(t,r,x^r,u)\big|_{u=0} = 0$ for every $t \ge r$. In accordance with these concepts, the following characteristic of the system is given (17).

This system is called the observed (identified) at the time $t = r$, unless any event (r, x^r) is not observable (unidentified), with the exception of an event $(0, r)$. The known criterion for unidentified of a system (for example, [1]) can be formulated as follows.

In order for the event (r, x^r) of the system (17) to be unidentified, it is necessary and sufficient that the vector x^r belongs to the matrix kernel:

$$M(t_0,r)=\int_{t_0}^{r} W^*(t,t_0)\cdot C^*(t)\cdot C(t)\cdot W(t,t_0)dt\,,\ t_0 \prec t \prec q\cdot T\,, \tag{18}$$

In the same way, the criterion of unobservability is formed.

In order for the event (t_0,x^0) system (17) to be unobservable for a time interval $t_0 \prec t \prec T$, it is necessary and sufficient that the vector x^0 belongs to the matrix kernel:

$$N(t_0,r)=\int_{t_0}^{T} W^*(t,t_0)\cdot C^*(t)\cdot C(t)\cdot W(t,t_0)dt \tag{19}$$

In the case of the system (16), which depends on the start and the finish, the quantities t_0 and T are variable, therefore, the matrices $M(t_0,r)$ $N(t_0,r)$ are not constant and their rank can vary depending on the variables t_0 and T. As a result, the structure of unobservable and unidentified systems will vary depending on t_0 and T.

Example 2. Consider the system:

$$\begin{cases} \dot{x}=x_2,\dot{x}_2=u_1,\dot{x}_3=x_4,\dot{x}_4=u_1+u_2 \\ y=x_2+x_4,y_2=\alpha(t,T)\cdot x_1+(1-t)\cdot x_3+\beta\cdot(t,t_0)\cdot x_4 \end{cases} \tag{20}$$

In which $\alpha(t,T)$ and $\beta(t,t_0)$ are determined by formulas (11) and (12), then by means of direct calculations we find that the matrix $M(t_0,r)$ is a Gram matrix:

$$\Gamma=\begin{vmatrix} q_{11} & q_{12} & q_{13} & q_{14} \\ q_{21} & q_{22} & q_{23} & q_{24} \\ q_{31} & q_{32} & q_{33} & q_{34} \\ q_{41} & q_{42} & q_{43} & q_{44} \end{vmatrix}, \tag{21}$$

of vectors of functions

$$q_1(t,T)=\begin{vmatrix} 0 \\ \alpha(t,T) \end{vmatrix},\ q_2(t,t_0,T)=\begin{vmatrix} 1 \\ (t-t_0)\cdot\alpha(t,T) \end{vmatrix},\ q_3(t,T)=\begin{vmatrix} 0 \\ (t-1) \end{vmatrix},\ q_4(t,t_0)=\begin{vmatrix} 1 \\ (t-t_0)\cdot(t-1)+\beta\cdot(t,t_0) \end{vmatrix}, \tag{22}$$

where the scalar product is determined by the formula:

$$(q_i,q_k)=\int_{t_0}^{r} q_i^*\cdot q_k dt\,. \tag{23}$$

It is known that the rank Γ of such a matrix is equal to the number of linearly independent vectors-functions in the system q_1, q_2, q_3, and q_4.

We find that by direct computation at which values of the parameters t_0, r and T the rank of the matrix can not be equal to four. Only the following partial cases are possible:

$$\begin{gathered} Rank\ \ \Gamma=3 \text{ if } \ t_0 \succ 1,\ T\le 2, \\ Rank\ \ \Gamma=3 \text{ if } \ t_0 \le 1,\ T\le 2, \\ Rank\ \ \Gamma=3 \text{ if } \ t_0 \succ 1,\ T\succ 2, \\ Rank\ \ \Gamma=3 \text{ if } t_0 \le 1,\ T\succ 2\ . \end{gathered} \tag{24}$$

Thus, in the first three cases, the set of unidentified events (r,x^r) forms an one-dimensional space, that is, the general solution of the equation:

$$\Gamma_{\rm X}=0 \tag{25}$$

depends on one arbitrary constant. In the fourth case, the set of unidentified events forms a two-dimensional space.

Similarly, one can consider the dependence on t_0 and T of the matrix $N(t_0.T)$, which defines the unobserved initial states.

Optimal control. When considering the problem of optimal control of the system (5) depending on the start and finish, it is formally possible to proceed from the fact that these systems depend on two parameters t_0 and T. As it is known, systems dependent on the parameters began to be considered in the mathematical theory of optimal processes at the dawn of its development (for example, [5]). The necessary optimality conditions for them were formulated in the form of a maximum limit.

It seemed that these results could be used without any additional conditions and in the analysis of a system that depends on the start and the finish. However, this approach in the case under consideration does not provide an exhaustive answer, because here the value of the parameters t_0 and T affect the area of definition of functions f_i in the variable t. Such a dependence is not foreseen in the classical problems of optimal processes with parameters. Therefore, various features are possible here.

The results of the analysis of Example 1 show that the solution of the problem of the complete controllability of the system of the form (5) can essentially depend on t_0 and T. Therefore, when studying the problems of optimal management it is expedient to consider individual situations, when the system is completely guided in a segment $t_0 \le t \le T$, sometimes such control is not present. This analysis is necessary regardless of whether the length of the process $(T - t_0)$ is fixed or not (for example, as in problems with optimal performance).

Example 3. Consider the problem of optimal performance in the system (10) under initial conditions:

$$x_i(t_0) = x_i^o, \ i = 1,...,4, \tag{26}$$

where the vector $x^0 = (x_1^0, x_2^0, x_3^0, x_4^0)$ is assigned.

It is necessary to transfer the system to a state:

$$x_i(T) = x_i^1, \ i = 1,...,4, \tag{27}$$

for the shortest period of time $(T - t_0 = \min)$ with additional restrictions on permissible control:

$$J(u) = \int_{t_0}^{T} u^*(t) \cdot u(t)dt = \int_{t_0}^{T} \left[u_1^2(t) + u_2^2(t)\right]dt \le \nu^2, \tag{28}$$

where ν - given constant. At the same time, the start time t_0 of the system is not specified.

Assuming that the vectors x^o and x^1 do not undergo any additional condition, then the problem must be solved with the same values t_0 and T, under which the system is fully controlled. In this case, the function vectors h_1, h_2, h_3 and h_4 (see example 1) must be linearly independent of T.

First, in accordance with the known method (for example, [2,4]) the solution of the problem of speedwork, we fix t_0 and T and solve the problem of control with minimal energy. First and foremost, we write out the condition that the solution $x = x(t)$ of the equations (10) to the initial conditions (26) must satisfy the condition (27). This requirement leads to moment proportions:

$$\int_{t_0}^{T} h_i^*(t,t_0,T) \cdot u(t)dt = C_i, \ i = 1,...,4, \tag{29}$$

where C_i, $i = 1,...,4$ is the component of the vector $C = x^1 - W(T,t_0;\mathrm{t}_0,T) \cdot x^0$.

With linear independence of vectors-functions h_i, $i = 1,...,4$, (this case we are considering now) control with minimal energy can be presented as:

$$u^0 = \sum_{i=1}^{4} \gamma_i \cdot h_i(t,t_0,T), \tag{30}$$

where $\gamma_i = \gamma_i(t_0,T)$ is uniquely determined by a system of equations

$$\sum_{л=1}^{4} \gamma_k \int_{t_0}^{T} h_i^*(t,t_0,T) h_k(t,t_0,T)dt = C_i(t_0,T), \ i = 1,...,4. \tag{31}$$

If equation (30) is substituted on the left side of the relation (28) and the equation (31) is taken into account then we have:

$$\varphi(t_0,T)=\int_{t_0}^{T}u^*(t,t_0,T)dt=\sum_{i=1}^{4}\gamma_i\cdot C_i\,, \tag{32}$$

here $\varphi(t_0,T)$ is the minimum value of the functional J of equation (28).

The solution of systems (31) can be presented as:

$$\gamma_k=\frac{1}{\Delta(t_0,T)}\cdot\sum_{i=1}^{4}\Delta_{kj}(t_0,T)\cdot C_j\,,\ k=1,...,4\,, \tag{33}$$

Where Δ is the determinant of the system, and Δ_{kj} is the algebraic complement of the element, which stands at the intersection of the *k*-th row and *j*-th column.

Therefore, we can write:

$$\varphi(t_0,T)=\sum_{k=1}^{4}\sum_{i=1}^{4}C_k\cdot C_i\,\frac{\Delta(t_0,T)}{\Delta(t_0,T)} \tag{34}$$

Consider now t_0 and T as variables (where $t_0 \prec T$), we have the problem of optimal speedwork, which can be formulated as follows.

You need to know t_0 and T such that:

$$t_0 \prec T\,,\ \varphi(\mathrm{t}_0,T)=\nu^2\,,\ T-t_0=\min\ .$$

Since we consider the case of complete controllability of the system (10), then, in addition, one more condition must be fulfilled (see example 1): $t_0 \succ 1,\ T \succ 2,\ t_0 \succ 1,\ T \le 2$.

The optimal problem is the non-linear programming problem, in which the area of variables t_0 and T is not complete. It follows that it may not have solutions.

Let us now consider the problem of optimal speedwork in one of the cases when the system (10) is not controlled.

Let, for example, $t_0 \le 1,\ T \succ 2$. In this case (see example 1):

$$h_1=h_3=\begin{pmatrix}T-t\\ t-1\end{pmatrix},\ h_2=h\ =\begin{pmatrix}0\\ 1\end{pmatrix}. \tag{35}$$

Accordingly, in system $h_1,\ h_2,\ h_3$ and h_4 it is possible to receive only two linearly independent vector-functions. Let it be h_1 and h_2.

Since the relations (35) are executed, then the constant $C_1,\ i=1,...,4$, at the time of the correlations (29) must follow the condition:

$$C_1=C_3\,,\ C_2=C_4\,. \tag{36}$$

According to the ratio vector $C=\{C_1,C_2,C_3,C_4\}$ is determined by the formula:

$$C_1=X^1-W(T,t_0)\cdot x^0\,.$$

Therefore equalities (36) can be presented as:

$$x_1^1-x_1^0-(T-t_0)\cdot x_2^0=x_3^1-x_3^0-(T-t_0)\cdot x_4^0 \tag{37}$$

$$x_2^1-x\cdot x_2^0=x_4^1-x_4^0 \tag{38}$$

Condition (38) does not depend on t_0 and T. Therefore, it can be characterized as a "severe restriction" to the state of the system at the initial and final moment of time. The content of the restriction (37) is slightly different. It connects the points $x^0,\ x^1$ and the duration $T-t_0$ of the process under consideration. Therefore, if the points are given, then this condition determines the length of the process, taking into account the limitation $t_0 \le 1,\ T \succ 2$. It remains to build a control. To find it, we have moment correlations (29) and restrictions (28). At the same time t_0 and T are not fixed, but only the difference is known $T - t_0$. Such a task is solved by the known methods.

The agro enterprise has mastered the production of several types of agricultural products, such as four assortments (rye B_1, corn B_2, rape B_3, wheat B_4), which annually an agricultural enterprise can produce in limited quantities (because it is a resource!). Annual income of the necessary raw materials A_i, $i = \overline{(1,4)}$, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q is shown in the table 1.

Table 1

Annual income of the necessary raw materials, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q

Type of raw material	Annual raw material flow, c	Consumption of raw materials per center			
		B_1	B_2	B_3	B_4
A_1	1260	2	4	6	8
A_2	900	2	2	0	6
A_3	530	0	1	1	2
A_4	210	1	0	1	0
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4
Profit from sales, c.u./ha		8	10	12	18

$$\begin{cases} 2 \cdot X_1 + 4 \cdot X_2 + 6 \cdot X_3 + 8 \cdot X_4 \le 1260; \\ 2 \cdot X_1 + 2 \cdot X_2 + 0 \cdot X_3 + 6 \cdot X_4 \le 900; \\ 0 \cdot X_1 + 1 \cdot X_2 + 1 \cdot X_3 + 2 \cdot X_4 \le 530; \\ 1 \cdot X_1 + 0 \cdot X_2 + 1 \cdot X_3 + 0 \cdot X_4 \le 210. \end{cases} \quad (1)$$

$$X_1 \ge 0; \; X_2 \ge 0; \; X_3 \ge 0; \; X_4 \ge 0. \quad (2)$$

Profit from sales, c.u./ha:

$$Z = 8 \cdot X_1 + 10 \cdot X_2 + 12 \cdot X_3 + 18 \cdot X_4 \to \max \quad (3)$$

This is a classic linear programming problem:

$$\text{PROFIT = INCOME - EXPENDITURE} \quad (4)$$

$$\text{EXPENDITURE}\downarrow \quad \to \quad \text{PROFIT}\uparrow \quad (5)$$

Rewrite the problem of linear programming in our case. Let the cost of information (annual) about the possible yield is I_{Σ}. The coefficients k_1, $k_2, \ldots, k_n$ give the value Z of each type of product, at an increment per 1 hectare $I_1 = k_1 \cdot I_{\Sigma}$; $I_2 = k_2 \cdot I_{\Sigma}$; ...; $I_8 = k_8 \cdot I_{\Sigma}$. Then the table 2 will be the same, but the raw material needs to be transferred into Z:

$$\sum_{i=1}^{8} k_i = 1 \; . \quad (6)$$

Table 2

Mathematical model with data of annual income of the necessary raw materials, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q

Type of raw material / information	Annual supply of raw materials in Z, c/ A_i, $i=\overline{(1,4)}$, I_i, $i=\overline{(1,8)}$	Consumption of raw materials per center			
		B_1	B_2	B_3	B_4
A_1	3000	12	14	16	18
A_2	1000	20	20	0	60
A_3	500	0	10	10	20
A_4	200	10	0	10	0
$I_1(k_1)$	400	11	15	16	17
$I_2(k_2)$	5000	17	18	19	20
$I_3(k_3)$	700	16	20	21	23
$I_4(k_4)$	1400	18	33	32	40
$I_5(k_5)$	800	19	45	44	15
$I_6(k_6)$	900	22	22	14	19
$I_7(k_7)$	1200	13	17	34	8
$I_8(k_8)$	1400	14	9	0	16
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4
Profit from sales, c.u./ha		$X_1 \geq 8$ 15	$X_2 \geq 10$ 12	$X_3 \geq 12$ 14	$X_4 \geq 18$ 19

$$\begin{cases} 12\cdot X_1 + 14\cdot X_2 + 16\cdot X_3 + 18\cdot X_4 \leq 3000; \\ 20\cdot X_1 + 20\cdot X_2 + 0\cdot X_3 + 60\cdot X_4 \leq 1000; \\ 0\cdot X_1 + 10\cdot X_2 + 10\cdot X_3 + 20\cdot X_4 \leq 500; \\ 10\cdot X_1 + 0\cdot X_2 + 10\cdot X_3 + 0\cdot X_4 \leq 200; \\ 11\cdot X_1 + 15\cdot X_2 + 16\cdot X_3 + 17\cdot X_4 \leq 400; \\ 17\cdot X_1 + 18\cdot X_2 + 19\cdot X_3 + 20\cdot X_4 \leq 500; \\ 16\cdot X_1 + 20\cdot X_2 + 21\cdot X_3 + 23\cdot X_4 \leq 700; \\ 18\cdot X_1 + 33\cdot X_2 + 32\cdot X_3 + 40\cdot X_4 \leq 1400; \\ 19\cdot X_1 + 45\cdot X_2 + 44\cdot X_3 + 15\cdot X_4 \leq 800; \\ 22\cdot X_1 + 22\cdot X_2 + 14\cdot X_3 + 19\cdot X_4 \leq 900; \\ 13\cdot X_1 + 17\cdot X_2 + 34\cdot X_3 + 8\cdot X_4 \leq 1200; \\ 14\cdot X_1 + 9\cdot X_2 + 0\cdot X_3 + 16\cdot X_4 \leq 1400. \end{cases} \quad (7)$$

$$X_1 \geq 0;\ X_2 \geq 0;\ X_3 \geq 0;\ X_4 \geq 0. \quad (8)$$

Profit from sales, c.u./ ha:

$$Z = 15\cdot X_1 + 12\cdot X_2 + 14\cdot X_3 + 19\cdot X_4 \rightarrow \max \quad (9)$$

Specify how much we will get a profit compared to a task when there is no information.

Conclusion. Based on the results of research, we formulate a mathematical model of the difference in the rate of application depending on the agro-biological state of the soil environment. The agro enterprise has mastered the production of several types of agricultural products, such as four assortments (rye B_1, corn B_2, rape B_3, wheat B_4), which annually the agricultural enterprise can produce in limited quantities (because it is a resource!). Annual income of the necessary raw materials A_i, $i=\overline{(1,4)}$, raw material costs per unit (per 1 c) of each type of product, the profit from the sale of 1 c is shown in the table 3.

Table 3

Mathematical model of annual income of the necessary raw materials, raw material costs per unit (per 1 c) of each type of product, the profit from the sale of 1 c

Type of raw material	Annual raw material flow, c	Consumption of raw materials per center					
		B_1	B_2	B_3	B_4	…	B_n
A_1	W_1	a_{11}	a_{12}	a_{13}	a_{14}	…	a_{1j}
A_2	W_2	a_{21}	a_{22}	a_{23}	a_{24}	…	a_{2j}
A_3	W_3	a_{31}	a_{32}	a_{33}	a_{34}	…	a_{3j}
A_4	W_4	a_{41}	a_{42}	a_{43}	a_{44}	…	a_{4j}
…..	….	…	…	…	…	…	…
A_n	W_n	a_{i1}	a_{i2}	a_{i3}	a_{i4}	…	a_{ij}
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4	…	X_n
Profit from sales, c.u./ha		Y_1	Y_2	Y_3	Y_4	…	Y_n

$$\begin{cases} a_{11}\cdot X_1+a_{12}\cdot X_2+a_{13}\cdot X_3+a_{14}\cdot X_4+...+a_{1j}\cdot X_n\le W_1; \\ a_{21}\cdot X_1+a_{22}\cdot X_2+a_{23}\cdot X_3+a_{24}\cdot X_4+...+a_{2j}\cdot X_n\le W_2; \\ a_{31}\cdot X_1+a_{32}\cdot X_2+a_{33}\cdot X_3+a_{34}\cdot X_4+...+a_{3j}\cdot X_n\le W_3; \\ a_{41}\cdot X_1+a_{42}\cdot X_2+a_{43}\cdot X_3+a_{44}\cdot X_4+...+a_{4j}\cdot X_n\le W_4; \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots \\ a_{i1}\cdot X_1+a_{i2}\cdot X_2+a_{i3}\cdot X_3+a_{i4}\cdot X_{i4}+...+a_{ij}\cdot X_n\le W_n. \end{cases} \tag{1}$$

$$X_1\ge 0;\ X_2\ge 0;\ X_3\ge 0;\ X_4\ge 0\ \dots.\ X_n\ge 0 \tag{2}$$

Profit from sales, c.u./ ha:

$$Z=Y_1\cdot X_1+Y_2\cdot X_2+Y_3\cdot X_3+Y_4\cdot X_4+...+Y_n\cdot X_n\to \max \tag{3}$$

This is a classic linear programming problem:

PROFIT = INCOME - EXPENDITURE (4)

EXPENDITURE↓ → PROFIT↑ (5)

Rewrite the problem of linear programming in our case. Let the cost of information (annual) about the possible yield is $I_{\sum}$. The coefficients k_1, $k_2,\dots,k_n$ provide added value Z of each type of product, at an increment per 1 hectare $I_1=k_1\cdot I_{\sum}$; $I_2=k_2\cdot I_{\sum}$;…;$I_8=k_8\cdot I_{\sum}$. Then the table 4 will be the same, but the raw material needs to be transferred into Z:

$$\sum_{i=1}^{8}k_i=1\ . \tag{6}$$

Table 4

Mathematical model of annual income of the necessary raw materials, raw material costs per unit (per 1 c) of each type of product, the profit from the sale of 1 c when the raw material needs to be transferred into *Z*

Type of raw material / information	Annual supply of raw materials in Z, c/ A_i, $i=\overline{(1,4)}$, I_i, $i=\overline{(1,8)}$	Consumption of raw materials per center					
		B_1	B_2	B_3	B_4	…	B_n
A_1	W_1^A	a_{11}	a_{12}	a_{13}	a_{14}	…	a_{1j}
A_2	W_2^A	a_{21}	a_{22}	a_{23}	a_{24}	…	a_{2j}
A_3	W_3^A	a_{31}	a_{32}	a_{33}	a_{34}	…	a_{3j}
A_4	W_4^A	a_{41}	a_{42}	a_{43}	a_{44}	…	a_{4j}
…..	….	…	…	…	…	…	…
A_n	W_n^A	a_{i1}	a_{i2}	a_{i3}	a_{i4}	…	a_{ij}
$I_1(k_1)$	W_1^I	b_{11}	b_{12}	b_{13}	b_{14}	…	b_{1j}
$I_2(k_2)$	W_2^I	b_{21}	b_{22}	b_{23}	b_{24}	…	b_{2j}
$I_3(k_3)$	W_3^I	b_{31}	b_{32}	b_{33}	b_{34}	…	b_{3j}
$I_4(k_4)$	W_4^I	b_{41}	b_{42}	b_{43}	b_{44}	…	b_{4j}
…..	….	…	…	…	…	…	…
$I_n(k_n)$	W_n^I	b_{i1}	b_{i2}	b_{i3}	b_{i4}	…	b_{ij}
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4	…	X_n
Profit from sales, c.u./ha		Y_1	Y_2	Y_3	Y_4	…	Y_n

$$\begin{cases}
a_{11}\cdot X_1 + a_{12}\cdot X_2 + a_{13}\cdot X_3 + a_{14}\cdot X_4 + \ldots + a_{1j}\cdot X_n \le W_1^A;\\
a_{21}\cdot X_1 + a_{22}\cdot X_2 + a_{23}\cdot X_3 + a_{24}\cdot X_4 + \ldots + a_{2j}\cdot X_n \le W_2^A;\\
a_{31}\cdot X_1 + a_{32}\cdot X_2 + a_{33}\cdot X_3 + a_{34}\cdot X_4 + \ldots + a_{3j}\cdot X_n \le W_3^A;\\
a_{41}\cdot X_1 + a_{42}\cdot X_2 + a_{43}\cdot X_3 + a_{44}\cdot X_4 + \ldots + a_{4j}\cdot X_n \le W_4^A;\\
\ldots\\
a_{i1}\cdot X_1 + a_{i2}\cdot X_2 + a_{i3}\cdot X_3 + a_{i4}\cdot X_{i4} + \ldots + a_{ij}\cdot X_n \le W_n^A;\\
\mathrm{b}_{11}\cdot X_1 + b_{12}\cdot X_2 + b_{13}\cdot X_3 + b_{14}\cdot X_4 + \ldots + b_{1j}\cdot X_n \le W_1^I;\\
\mathrm{b}_{21}\cdot X_1 + b_{22}\cdot X_2 + b_{23}\cdot X_3 + b_{24}\cdot X_4 + \ldots + b_{2j}\cdot X_n \le W_2^I;\\
\mathrm{b}_{31}\cdot X_1 + b_{32}\cdot X_2 + b_{33}\cdot X_3 + b_{34}\cdot X_4 + \ldots + b_{3j}\cdot X_n \le W_3^I;\\
\mathrm{b}_{41}\cdot X_1 + b_{42}\cdot X_2 + b_{43}\cdot X_3 + b_{44}\cdot X_4 + \ldots + b_{4j}\cdot X_n \le W_4^I;\\
\ldots.\\
b_{i1}\cdot X_1 + b_{i2}\cdot X_2 + b_{i3}\cdot X_3 + b_{i4}\cdot X_{i4} + \ldots + b_{ij}\cdot X_n \le W_n^I.
\end{cases} \quad (7)$$

$$X_1 \ge 0;\ X_2 \ge 0;\ X_3 \ge 0;\ X_4 \ge 0. \quad (8)$$

Profit from sales, c.u./ha:

$$Z = Y_1\cdot X_1 + Y_2\cdot X_2 + Y_3\cdot X_3 + Y_4\cdot X_4 + \ldots + Y_n\cdot X_n \to \max \quad (9)$$

Specify how much we will get a profit compared to a task when there is no information.

Mathematical model of the difference of the rate of application depending on the agro-biological state of the soil environment (our option)

The agro enterprise has mastered the production of agricultural products of A type on a certain agricultural field. Taking into account the content of a certain type of nutrients in the soil c_1, c_2, c_3, c_4, $\ldots, c_j$, we obtain the quantity of products with the cost that annually the agro-company can produce in a limited amount (as it is a resource!), taking into account the nutrient content in the soil from this area.

To get the planned yield b_1, b_2, b_3, $b_4, \ldots, b_i$, it is necessary to apply, accordingly, certain dozes of nutrients a_{11}, a_{12}, a_{13}, $a_{14}, \ldots, a_{1j}$; a_{21}, a_{22}, a_{23}, $a_{24}, \ldots, a_{2j}$; a_{31}, a_{32}, a_{33}, $a_{34}, \ldots, a_{3j}$; a_{41}, a_{42}, a_{43}, $a_{44}, \ldots, a_{4j}$; $\ldots$; a_{i1}, a_{i2}, a_{i3}, $a_{i4}, \ldots, a_{ij}$ for a certain type of yield A_c, A_1, A_2, A_3, A_4, $\ldots$, A_i respectively, the profit from the application of which is Y_1, Y_2, Y_3, Y_4, $\ldots$, Y_i (Table 5).

Table 5

Expenditures of nutrients are needed to obtain a planned yield

Type of raw material	Profit from sales, c.u. / ha	Cost of products received, c.u. / ha	Expenditures of nutrients kg / ha					
			X_1	X_2	X_3	X_4	…	X_j
A_c	Z	b_0	c_1	c_2	c_3	c_4	…	c_j
A_1	Y_1	b_1	a_{11}	a_{12}	a_{13}	a_{14}	…	a_{1j}
A_2	Y_2	b_2	a_{21}	a_{22}	a_{23}	a_{24}	…	a_{2j}
A_3	Y_3	b_3	a_{31}	a_{32}	a_{33}	a_{34}	…	a_{3j}
A_4	Y_4	b_4	a_{41}	a_{42}	a_{43}	a_{44}	…	a_{4j}
…..	…	….	…	…	…	…	…	…
A_i	Y_i	b_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	…	a_{ij}

This is a classic linear programming problem:

PROFIT = INCOME - EXPENDITURE (4)

EXPENDITURE↓ → PROFIT↑ (5)

$$\begin{cases} Z = b_0 - (c_1 \cdot X_1 + c_2 \cdot X_2 + c_3 \cdot X_3 + c_4 \cdot X_4 + \ldots + c_n \cdot X_j) \to \max; \\ b_1 - (a_{11} \cdot X_1 + a_{12} \cdot X_2 + a_{13} \cdot X_3 + a_{14} \cdot X_4 + \ldots + a_{1j} \cdot X_j) = Y_1; \\ b_2 - (a_{21} \cdot X_1 + a_{22} \cdot X_2 + a_{23} \cdot X_3 + a_{24} \cdot X_4 + \ldots + a_{2j} \cdot X_j) = Y_2; \\ b_3 - (a_{31} \cdot X_1 + a_{32} \cdot X_2 + a_{33} \cdot X_3 + a_{34} \cdot X_4 + \ldots + a_{3j} \cdot X_j) = Y_3; \\ b_4 - (a_{41} \cdot X_1 + a_{42} \cdot X_2 + a_{43} \cdot X_3 + a_{44} \cdot X_4 + \ldots + a_{4j} \cdot X_j) = Y_4; \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ b_i - (a_{i1} \cdot X_1 + a_{i2} \cdot X_2 + a_{i3} \cdot X_3 + a_{i4} \cdot X_{i4} + \ldots + a_{ij} \cdot X_j) = Y_i. \end{cases} \quad (1)$$

$$X_1 \geq 0;\ X_2 \geq 0;\ X_3 \geq 0;\ X_4 \geq 0 \ldots.\ X_j \geq 0 \quad (2)$$

Profit from sales, c.u./ha:

$$Z = b_0 + c_1 \cdot X_1 + c_2 \cdot X_2 + c_3 \cdot X_3 + c_4 \cdot X_4 + \ldots + c_n \cdot X_j \to \max \quad (3)$$

In order to receive the planned yield b_1, b_2, b_3, $b_4, \ldots, b_i$ taking into account the received operational information about the agro-biological state of agricultural lands with the value of k_0, k_1, k_2, k_3, $k_4, \ldots, k_i$, it is necessary to apply, accordingly, certain dozes of nutrients a_{11}, a_{12}, a_{13}, $a_{14}, \ldots,$

a_{1j}; a_{21}, a_{22}, a_{23}, $a_{24}, \ldots, a_{2j}$; a_{31}, a_{32}, a_{33}, $a_{34}, \ldots, a_{3j}$; a_{41}, a_{42}, a_{43}, $a_{44}, \ldots, a_{4j}$; …; a_{i1}, a_{i2}, a_{i3}, $a_{i4}, \ldots,$ a_{ij} for a certain yield A_c, A_1, A_2, A_3, A_4, …, A_i respectively, based on the data on the agro-biological state of the soil environment, the profit from the implementation of which is Y_1^k, Y_2^k, Y_3^k, Y_4^k, … , Y_i^k (Table 6).

Table 6

Planning of profit from the sale of the planned yield with the introduction of nutrients, based on data on the agrobiological state of the soil environment

Type of raw material	Profit from sales, c.u. / ha	Cost of products received, c.u. / ha (depending on yield, c/ha)	Value of information on nutrients' content, c.u. / ha	Cost of consumed nutrients, c.u. / ha					
				X_1	X_2	X_3	X_4	…	X_j
A_c	Z^k	b_0	k_0	c_1	c_2	c_3	c_4	…	c_j
A_1	Y_1^k	b_1	k_1	a_{11}	a_{12}	a_{13}	a_{14}	…	a_{1j}
A_2	Y_2^k	b_2	k_2	a_{21}	a_{22}	a_{23}	a_{24}	…	a_{2j}
A_3	Y_3^k	b_3	k_3	a_{31}	a_{32}	a_{33}	a_{34}	…	a_{3j}
A_4	Y_4^k	b_4	k_4	a_{41}	a_{42}	a_{43}	a_{44}	…	a_{4j}
…..	…	….	….	…	…	…	…	…	…
A_i	Y_i^k	b_i	k_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	…	a_{ij}

Let the value of information (annual) about a possible application of nutrients in the soil is k_1, k_2, k_3, $k_4, \ldots, k_i$, which allows for more productivity, which affects the final yield b_1, b_2, b_3, $b_4, \ldots,$ b_i and, accordingly, the income Y_1^k, Y_2^k, Y_3^k, $Y_4^k, \ldots,$ Y_i^k.

Then the table will be the same:

$$\begin{cases} Z^k = b_0 - k_0 - (c_1 \cdot X_1 + c_2 \cdot X_2 + c_3 \cdot X_3 + c_4 \cdot X_4 + \ldots + c_n \cdot X_i) \to \max \\ b_1 - k_1 - (a_{11} \cdot X_1 + a_{12} \cdot X_2 + a_{13} \cdot X_3 + a_{14} \cdot X_4 + \ldots + a_{1j} \cdot X_i) = Y_1^k; \\ b_2 - k_2 - (a_{21} \cdot X_1 + a_{22} \cdot X_2 + a_{23} \cdot X_3 + a_{24} \cdot X_4 + \ldots + a_{2j} \cdot X_i) = Y_2^k; \\ b_3 - k_3 - (a_{31} \cdot X_1 + a_{32} \cdot X_2 + a_{33} \cdot X_3 + a_{34} \cdot X_4 + \ldots + a_{3j} \cdot X_i) = Y_3^k; \\ b_4 - k_4 - (a_{41} \cdot X_1 + a_{42} \cdot X_2 + a_{43} \cdot X_3 + a_{44} \cdot X_4 + \ldots + a_{4j} \cdot X_i) = Y_4^k; \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_j - k_j - (a_{i1} \cdot X_1 + a_{i2} \cdot X_2 + a_{i3} \cdot X_3 + a_{i4} \cdot X_{i4} + \ldots + a_{ij} \cdot X_i) = Y_j^k. \end{cases} \tag{7}$$

$$X_1 \geq 0;\ X_2 \geq 0;\ X_3 \geq 0;\ X_4 \geq 0 \ldots.\ X_j \geq 0 \tag{8}$$

Cost of the received product, c.u./ha:

$$b_n = S_n \cdot U_n,$$

where S_n - the cost of one center of agricultural products of the species, c.u. / c;

U_n - productivity of agricultural products, c / ha.

Profit from sales of products (c.u. / ha):

$$Z^k = b_0 + k_0 + c_1 \cdot X_1 + c_2 \cdot X_2 + c_3 \cdot X_3 + c_4 \cdot X_4 + \ldots + c_n \cdot X_i \to \max \tag{9}$$

Specify how much we will get a profit compared to a task when there is no information.

$$\Delta Z = Z^k - Z \tag{10}$$

To compare the expedient standard of agricultural land cultivation it is necessary:

$$\Delta Z \geq Y_i$$

Data that satisfy this requirement should be used in terms of agricultural production.

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