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Economic and Mathematical Modeling for the Process Management of the Company's Financial Flows

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Abstract

This paper presents an analysis of existing methods and models designed to solve the problem of planning the distribution of financial flows in the operational management cycle of the enterprise; it also offers tools for process management of enterprise financial flows based on the method of dynamic programming, which allows for determining the optimal combination of factors affecting the financial flow of the enterprise, taking into account existing restrictions on changes in the influencing parameters of the model. The current study develops an innovative model that maximizes the economic efficiency of investment in the sale of food products through retail chains and the practical implementation of the developed model based on the data from the financial reports of LLC "Kraft Heinz Vostok". The theoretical and methodological basis of the research includes the works of Russian and foreign experts in the fields of methodology of economic and mathematical modeling and decision-making, dynamic programming, system analysis, information approach to the analysis of systems, process management of enterprise financial flows, and human resource management. The author's methodology makes it possible to increase the company's profitability in key clients and categories in the range of 4 to 6 million dollars and to increase the return on investment by 10–17%. The scientifically innovative aim is to develop a toolkit for process management of enterprise financial flows, characterized by a systematic combination of methods of dynamic programming, social financial technologies, and economic evaluation of investments, which allows for the creation of mechanisms for managing the development of enterprises of all organizational and legal forms and the development of model projects of decision support systems with the prospects of their incorporation into existing information and analytical systems.

Keywords:

Financial Flows;
Dynamic Programming;
Economic and Mathematical Models;
Food Products;
Key Customers;
Investment;
Economic Effect;
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1- Introduction

Among the most important tasks of modern society is to improve the system of process management of enterprises financial flows, especially those working in socially important areas of activity, such as health services, the production and sale of food products, and other sectors of the economy, which have a direct impact on the quality of life and well-being of citizens of the country. Currently, the process management of the development of both integrated corporate structures and small businesses is reaching a new level, as there is a need to mobilize the forces of society in priority areas of development, increasing welfare, expectancy, and quality of life [1, 2]. The main contradiction revealed during the study is that the existing scientific and methodological support of enterprise development management processes does not create prerequisites for improving the efficiency of their work by introducing progressive technologies of material incentives for performers and administrative and managerial staff, advanced technologies of enterprise financial flow management, and social security for employees [3–6].

The existing processes of managing the financial flows of enterprises may be characterized as inefficient since there is no coherent scientific and methodological approach integrated into the daily practice of making sound management

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decisions based on economic and mathematical methods and models. The problems of low efficiency in the processes of managing the financial resources of enterprises are related to the fragmentation and imperfection of the mathematical apparatus and tools used in practice, as well as methods of work incentives [7–10]. Attempts to create a full-fledged comprehensive system of management of financial flows, including a progressive system of incentives for employees and payments to the development fund of the enterprise, as well as effective mechanisms for managing financial resources based on the developed methodology of economic and mathematical modeling of management processes for developing medical organizations, are present in the following works [11, 12]. Yet all of them have a drawback, which is that the issues of managing investments in the development of organizations are not fully discussed, and the criteria for making informed managerial decisions aimed at organizing the interaction of patients with polyclinics and hospitals according to the categories of medical care provided are not specified.

Ambitious goals require advanced technologies and models of process management of the financial flows of enterprises and prospective systems of financing their activities. Nonlinear processes and computational methods in the management tasks of such systems are becoming increasingly relevant as the most effective tools for making management decisions and providing scientifically valid algorithms and models for the development of management objects. When managing complex systems with many interrelated parameters, it is necessary to apply algorithms and methods of nonlinear programming to achieve the best result from the set of possible values of the dependent variable within a limited range of changing influencing factors. As a rule, both the target function and each inequality of the constraint system of the optimization problem in most modern models of real process control are non-linear functions; this fact implies additional restrictions on control objects and requires special mathematical models and instrumental methods. Thus, in solving the problems of financial flow management, dynamic programming methods have proven effective [13, 14].

Thus, among the most important scientific and practical problems of the national economy are the economic and mathematical modeling of process management of enterprise financial flows, sound policy on existing and prospective customers and categories of goods, products, work, and services, the instrumental base of enterprise development management, taking into account promising and effective technologies for financing and evaluating the effectiveness of investment in their development, structural system analysis, internal and external factors, and scientifically substantiated personnel policy and motivation systems for executives and administrative and managerial staff.

The main goal of the study is to develop an economic and mathematical model that optimizes the financial flows using the methods of dynamic programming and process management and practical implementation of the developed model based on the data from the financial statements of LLC "Kraft Heinz Vostok". This paper studies the method of managing the cash flows of an enterprise for given volumes of investment and historical returns. It focuses on the modeling of the financial flows of LLC "Kraft Heinz Vostok" using methods of dynamic programming and process management.

2- Literature Review

We analyzed 87 academic articles by Russian and foreign researchers and experts that share the topic of this study; they can be divided into the following groups: Cash Flow Management (15 papers), Investment Efficiency (17 papers), Goods Safety (11 papers), Welfare and Wage Growth (13 papers), Enterprise Development (6 research papers), Dynamic Programming (11 research papers), and Business Process Management (14 papers). The relative weights of each group are shown in Figure 1.

Analysis of the data presented in Figure 1 shows that the largest share of the papers falls in the section Investment Efficiency (17 articles, or almost one fifth of all papers), followed by the problem related to Cash Flow Management, with a total of 15 articles, which is 17% of the literature review. The group of articles devoted to business process management (14 papers, or 16% of the articles) closes the top three. The smallest group of works is the section Enterprise Development, with a total of 6 articles, which is 7% of the list of the analyzed articles.

The extent of the research problem development and its analysis are presented in detail in Table 1.

Table 1. The extent of the research problem development

Direction of research	Scientists and experts contributed to the subject
Welfare and Wage Growth	[15-27]
Enterprise Development	[3-5, 28-30]
Investment Efficiency	[6, 31-44]
Goods Safety	[45-55]
Cash Flow Management	[56-69]
Dynamic Programming	[13, 14, 70-78]
Business Process Management	[7-10, 79-88]

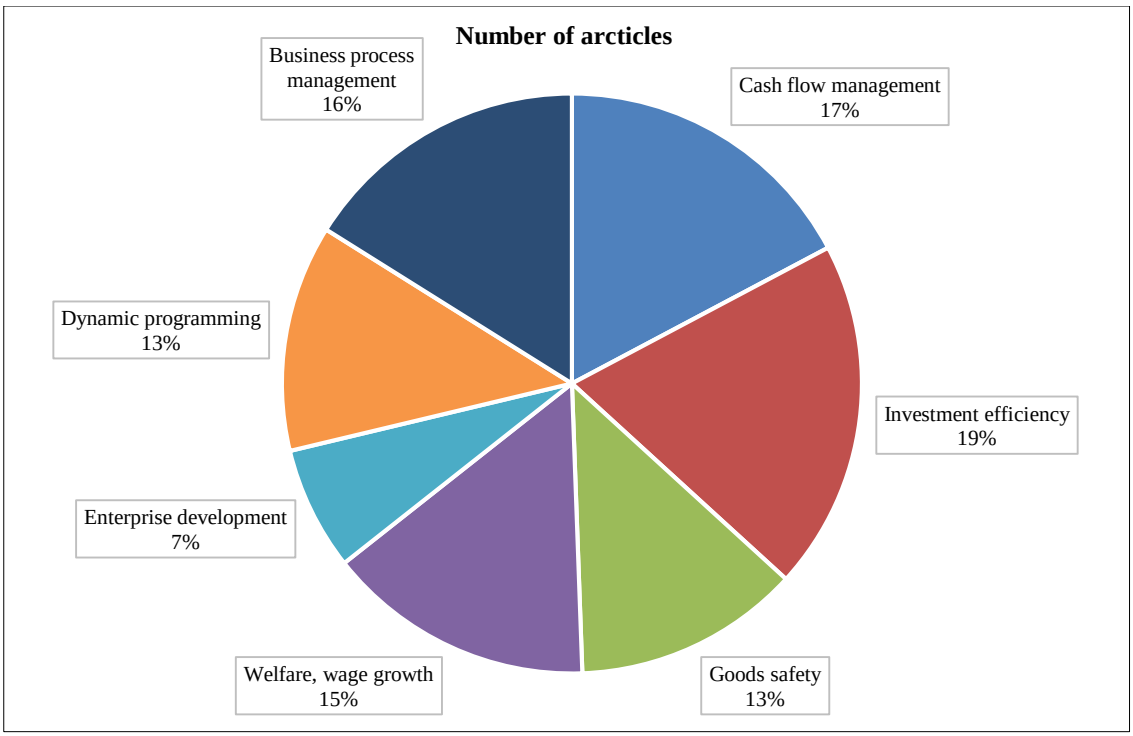

Figure 1. Distribution of articles by research topics

A comparative analysis of the research results obtained by the authors and the results of other scientists and experts dealing certain aspects of the problems raised in the article is presented in Table 2.

Table 2. Comparison with other studies and scientific incremental knowledge

N	Direction of research	Research results	Academic novelty
1	Welfare, Wage Growth	A developed economic and mathematical model of process management of company financial flows, the target function of which is to maximize the economic efficiency of investment (return on investment) in the implementation of food products through retail chains.	In contrast to the process management models used in practice [20, 25], the basis of this economic and mathematical model is a progressive system of incentives for employees of the company, which allows increasing financial incentives for employees depending on the increase in the volume of sales of food products through retail chains, taking into account the optimal distribution of investments obtained by solving the dynamic programming problem, as well as deductions for developing the company, which allows the entire team to participate in the process of management.
2	Enterprise Development	A developed comprehensive system of process management of the company's financial flows, which allows linking profits from the sale of food products through retail chains with additional remuneration of staff, investments in key partners and categories of food products, as well as allocation for developing the enterprise.	In contrast to established models of process management of companies [28-30] This approach allows for simultaneous consideration of the effectiveness of investments in key customers and food categories based on the results obtained using dynamic programming and process management techniques, which is that a comprehensive evidence-based decision is made that has synergistic effects that exceed the effectiveness of investments in key customers and food categories separately.
3	Investment Efficiency	An approach to economic evaluation of the feasibility of investment consists of making management decisions based on estimates of return on investment in key customers and categories of food products, takes into account the capacity of the market.	This approach differs from other methods of investment evaluation[32, 35, 42, 89] by the fact that the management decision is made in a three-dimensional system: return on investment in key customers and categories of food products, considering the optimal distribution of investments based on the results of the dynamic programming problem and market capacity, understood as the difference between the target value of sales of categories of food products for each retail chain and their current state. Additionally, a distinctive feature of the author's approach is that additional profits from increased sales are directed to investments, which makes such a model closed, complex, and dynamic.
4	Goods Safety	The approach to food and commodity security, the essence of which lies in the that the authors propose to load the spare capacity of retail networks and increase the sales of food products through those retail chains that have the highest return on invested capital and maximum market capacity, understood as the difference between the target sales of food products category for each retail chain and their current state, which increases their financial sustainability and competitiveness in the food market.	In contrast to the number of studies [45, 51], the proposed approach makes it possible to increase the investment attractiveness of the market of food products sold through retail chains, due to the practical application of the progressive system of staff incentives and the optimal distribution of investments between retail chains and categories of food products developed by the authors based on the basis of solving the problem of dynamic programming and using the process management of the company's financial flows.

5	Cash Flow Management	A comprehensive model for managing the cash flow of an enterprise, its revenues and expenses from the sale of products, goods, works, and services.	The proposed model differs from the used financial flow management models [57, 59, 62, 68] in that it gives the opportunity to decision-makers to coordinate investment programs and plans depending on the prices of final long products sold through retail chains, the volume and cost of these products, which contributes to the economic efficiency (profitability) of investment, material incentives for staff, and deductions to the development fund of the company.
6	Dynamic Programming	A new formulation and approach to solving the problem of dynamic programming on the allocation of investments between key customers and categories of food products.	In contrast to the works of prominent scientists devoted to solving the problem of investment distribution [70-72, 75], the author's approach uses the company budget as a source of funding, which is formed at the expense of deductions to the development fund, which depends on the performance of each employee. This approach allows the most effective redistribution of financial flows between key customers and categories of food products and provides sources of funding to equip the workplace staff and staff development and involving the entire staff in the management of the company.
7	Business Process Management	A developed economic and mathematical model of process management of company's financial and cash flow, characterized by system integration of methods of dynamic programming, economic and mathematical modelling, and process management, which allows creation tools for managing the cash flow of all organizational and legal forms and developing standard projects of support systems for managerial investment decisions with the prospects of embedding them into existing and prospective companies' information.	The developed economic and mathematical model of process management allows finding the best science-based management solution by breaking down the complex problem of allocating the investment budget between key customers and categories of food products into smaller subtasks: on the distribution of investments between key customers and on the distribution of investments between categories of food products, each of which is solved by familiar methods of dynamic programming. Then the results are integrated into a comprehensive system of management decision-making at the stage of practical implementation by using additional criteria: market capacity, the share of profits allocated to increase the material incentives for personnel, development, and investment, etc.

Thus, the literature review presented in Tables 1 and 2 shows the lack of scientific research aimed at the development and practical implementation of economic and mathematical models of management of financial flows using dynamic programming and mathematical optimization, which allow the decision-maker to ensure the relationship of financial performance of enterprises (revenues, profits, costs of goods, works, and services produced and sold) and the progressive system of material incentives for the work of citizens working in enterprises.

3- The Proposed Methods

The company's cash flow management method is a way of tracking, analyzing, and changing the way the company's financial assets circulate. The proper use of enterprise cash plays an important role in any commercial enterprise. It makes it possible to abandon unpromising areas of business development and develop the most profitable areas of free cash investments. To effectively manage the cash flows of an enterprise, it is necessary to adhere to the following principles [19]:

1) ***The Reliability of Information***: The reports used to collect the information must contain the correct data. There must be no ambiguity in the information.
2) ***Balance***: Cash flows should be relevant in terms of volume, time, and other characteristics to maintain the correctness of estimation.
3) ***Efficiency***: Each asset should be used in the most rational way to maximize the financial results of the enterprise.

Let's consider the main methods of company cash flow management.

3-1- Direct Method

The analysis is carried out with the data obtained by accounting for the current cash flow of the company. The main basis for calculations is the total revenue from the sales of goods and services. This method has peculiarities: showing the areas of use of resources and the sources of their origin; determining the level of solvency of the enterprise; showing the correlation of sales and profits for the reporting period; determining key items of expenses and profits; helping forecast cash flows for future periods; being a way to control negative and positive cash flows.

In this method, the analysis is "top-down", performed with the help of the statement of financial results. Also, the key disadvantage of the direct method is the complexity of assessing the relationship of cash flows with the financial results of the company [86].

3-2- Indirect Method

This method involves the analysis of the system of financial movement by type of activity based on reports. The basis of this method is the study of net profit from a certain type of activity. The main features of the method are: it shows the relationship between profit and cash flow; it determines the correlation between working capital and profit; it shows the problem areas in the work of the company; it helps to determine the amount of incoming cash, its sources, and methods of use; it determines cash reserves; it analyzes the solvency of the company; and it helps compare the profit target with the obtained result [88]. In this study, we used the direct method, as it was the most informative and allowed us to analyze the efficiency of the use of financial resources by the company.

For practical implementation of the direct method of a company's cash flow management, we will use the methodology of constructing dynamic programming tasks, namely, the task of distributing resources between companies (responsibility centers within the company).

Six stages (n = 6) are present. At the k stage, the volume of investment is optimized not in all centers of responsibility of the enterprise, but only from the k to the n. It is worth noting that this involves an amount of investment, B_k serving as a system position variable and acting as an investment project budget for investments in companies from k to n. At the k stage, the sum I_k representing the amount of investment in the k company acts as a management variable. This sum goes to the development of the k enterprise responsibility center or to the k company (in this study, it is to invest in the k enterprise key customer or the k category of food products). In accordance with the bellhop's optimization principle at the k stage in these conditions, the highest potential profit earned by investing in the company's responsibility centers from the k to the n should be selected. It should be considered that for financial investments in these responsibility centers, the sum B_k. Accordingly, in the process of investing financial resources in the k responsibility center of I_k sum, the final profit will be $Profit_k(I_k)k$, which, is determined by the return on investment in this responsibility center. Atthe$k$+1 stage, there is a shift to $B_{k+1} = B_k - I_k$ (state equation), which characterizes the investment budget available for distribution among the remaining companies (key customers, categories of food products, etc.) from k+ 1 to n. After this step, there will be funds of B_{k+1} [69]. And so on until the funds are invested in the responsibility centers of the company, i.e., until the entire investment budget is spent.

Thus, at the first stage of the recurrence relation, when $k = n$, the efficiency indicator represents the profit of the company when it invests in the development of the n responsibility center. Simultaneously, an amount of funds B_n can be allocated for investments in this responsibility center of the company. Accordingly, to obtain the greatest profit when investing in the development of all enterprise responsibility centers, it is necessary to direct the entire amount of financial resources [3]:

$$B_n = \sum_{k=1}^{n} I_k \quad (1)$$

In the subsequent stages of the process, to calculate the equation, it is necessary to apply the indicators obtained in the previous stages. The largest amount of profit received from the responsibility centers of the enterprise from the k to the n is [44]:

$$Profit_k(I_k) = \max_{I_k \le B_k} \{Profit_k(I_k) + Profit_{k+1}(B_k - I_k)\}, k = \overline{1,n} \quad (2)$$

The maximum value in this formula was obtained under managerial influence I_k. In the same way, it is possible to calculate the bellhop functions sequentially for all states of the system from $k = n$ to $k = 1$ (iterative process based on bellhop recurrence relations).

The target function in the bellhop optimization principle $Profit_1(I_1)$ for the problem under consideration is the maximum total profit from all responsibility centers of the organization at the optimal distribution of investments at each step (for each state of the system) I_k, which can be used to obtain the highest value of profit, is the optimal amount of investment allocated to the k responsibility center of the company [69, 85]. For all subsequent stages, the indicator characterizing the balance of funds available for allocation among the remaining responsibility centers of the enterprise is determined in accordance with the equation of states [5, 87]:

$$B_{k+1} = B_k - I_k. \quad (3)$$

Thus, considering the above considerations, economic and mathematical models of process management of the company's financial flows using methods of dynamic programming and social financial technologies [27], maximizing the economic efficiency of investment (return on investment) in the sale of food products through retail chains has the following form:

Target function:

$$R = \sum_{j=1}^{m} \sum_{k=1}^{n} \frac{Profit_{jk}}{I_{jk}} \cdot \frac{Target_{jk} - Current_{jk}}{Current_{jk}} \rightarrow max \quad (4)$$

Limitations:

$$Profit_{jk} = \max_{I_{jk} \leq B_{jk}} \{Profit_{jk} \cdot I_{jk} + Profit_{j+1,k+1} \cdot (B_{jk} - I_{jk})\}, j = \overline{1,m}, k = \overline{1,n} \quad (5)$$

$$B \geq \sum_{j=1}^{m} \sum_{k=1}^{n} I_{jk} \quad (6)$$

$$I_{jk} = \varphi_{jk} \cdot F_{jk}, \quad (7)$$

$$F_{jk} = Profit_{bjk} + (1 - \xi_{jk}) \cdot (Profit_{jk} - Profit_{bjk}) \cdot (1 - Tax_{incjk}) \quad (8)$$

$$Profit_{jk} = Inc_{jk} - V_{jk} \cdot C_{varjk} - C_{fixjk} \quad (9)$$

$$\omega_{varjk} = \frac{V_{jk} \cdot C_{varjk}}{V_{jk} \cdot C_{varjk} + C_{fixjk}} \quad (10)$$

$$\omega_{fixjk} = \frac{C_{fixjk}}{V_{jk} \cdot C_{varjk} + C_{fixjk}} \quad (11)$$

$$Sal_{ijk} = Inc_{ijk} \bullet \theta_{bijk} + \xi_{ijk} \bullet (Profit_{ijk} - Profit_{bijk}) \quad (12)$$

The economic and mathematical model (4)-(12) use the following designations:

R – economic efficiency of investment (return on investment) in the sale of all categories of food products through all retail chains, %;

m – the number of categories of food products considered by the management of the enterprise as objects of free cash investments;

n – the number of retail chains, considered by the management of the company as objects of free cash investments;

$Profit_{jk}$ – profit of the enterprise from investments in the sale of *j* type of food products through the *k* trading network, USD;

I_{jk} – investments in the sale of *j* types of food products through the *k* trading network, USD;

$Target_{jk}$ – target value of sales of the *j* category of food products through the *k* trading network, USD;

$Current_{jk}$ – the current value of sales of the *j* category of food products through the *k* trading network, USD;

$Profit_{jk}$ – profitability of investment in the sale of *j* type of food products through the *k* trading network, %;

B_{jk} – the investment budget available for distributing investments between the *k* to *n* retail chains and the *j* to *m* food product categories, USD;

B – the total investment budget of the enterprise, available for distribution among all *n* trade networks and all *m* categories of food products, USD;

φ_{jk} – the share of the company development fund allocated to invest in the sale of *j* type of food products through the *k* trade network;

F_{jk} – company development fund, formed at the expense of revenues from the sale of *j* kinds of food products through the *k* trade network, USD;

$Profit_{bjk}$ – profit of the company from the sale of *j* kind of food products through the *k* trading network before the introduction of the developed economic and mathematical model to the activities of the company, taken as a basis for comparison, USD;

ξ_{jk} – coefficient of redistribution of profit growth between the company personnel involved in the sale of *j* type of food products through the *k* trade network, and the development fund of the company;

Tax_{incjk} – corporate income tax rate from the sale of *j* type of food products through the *k* trading network;

Inc_{jk} – income of the company from the sale of *j* type of food products through the *k* trading network, USD;

V_{jk} – sales volume of *j* type of food products through the *k* trading network;

C_{varjk} – specific variable costs of the *j* type of food products sold through the *k* trade network, i.e., variable costs per unit of production, USD;

C_{fixjk} – the fixed costs of the *k* trading network associated with the sale of *j* type of food products, USD;

ω_{varjk} – share of variable costs in the structure of the cost of sales of *j* kind of food products through the *k* trading network;

ω_{fixjk} – share of fixed costs in the structure of the cost of sales of *j* kind of food products through the *k* trading network;

Sal_{ijk} – the amount of salary of the *i* employee from the sale of *j* type of food products through the *k* trading network, USD;

Inc_{ijk} – income of the *i* employee from the sale of *j* type of food products through the *k* trading network, USD;

θ_{bijk} – base percentage of income from the sale of *j* type of food products through the *k* trading network, allocated to stimulate the labor of the *i* employee;

ξ_{ijk} – coefficient of redistribution of profit growth between the *i* company's employee, engaged in the sale of *j* type of food products through the *k* trade network, and the company's development fund;

$Profit_{ijk}$ – profit of the *i* employee from the sale of *j* type of food products through the *k* trading network, USD;

$Profit_{bijk}$ – the profit of the *i* employee from the sale of *j* type of food products through the *k* retail network before the implementation of the developed economic and mathematical model in the activities of the company, taken as a basis for comparison, USD.

Algorithm of an integrated process control system for company financial flows:

Step 1: Analysis of the initial data provided by the company. At this stage, the quality, completeness, and reliability of the information provided on the historical return on investment of the company in key categories of food products and customers are evaluated. If the data received from the company meets the criteria, then we move on to the next step of the algorithm. Otherwise, we repeat step 1 until the criteria are met.

Step 2: Set up a dynamic programming problem for distributing investments among key clients. At this stage, it is necessary to solve the problem of dynamic programming on the distribution of investments among the key clients of the company and check the fulfillment of the basic assumptions and conditions of the model: the financial result from investments in one company does not depend on the financial result from investments in another company; the system in question is closed, i.e., no additional financing is provided for the whole period of investment. If the conditions are met, we proceed to the next step of the algorithm. Otherwise, repeat Step 2 until the criteria are satisfied.

Step 3: Solving the dynamic programming problem of distributing investments among the key clients in the LibreOffice Calc software environment (an analog of MS Excel in Linux). The problem is to be solved using the economic and mathematical models (4)–(12) and the integrated procedure "Solver" in LibreOffice Calc or "Solution Search" in MS Excel software.

Step 4: Setting a dynamic programming problem for distributing investments between categories of food products.

Step 5: Solving the dynamic programming problem of investment distribution among food product categories in LibreOffice Calc (analogous to MS Excel in Linux). Actions performed at Steps 4 and 5 are similar to those performed at Steps 2 and 3, respectively.

Step 6: Solving the problem of optimal distribution of food product sales through retail networks based on the analysis of relative sales growth and the results obtained in Steps 3 and 5. At this step, it is necessary to determine the most effective distribution of funds between key customers and categories of food products by evaluating the relative increase in sales of food products through retail networks, subject to the maximization of return on investment according to the target function (4) and meeting the limitations of the proposed economic and mathematical model (4)–(12). The results obtained at stages 3 and 5 of this algorithm for the complex system of process control of enterprise financial flows should be taken into account.

Step 7: Evaluating the obtained result according to the criterion of maximization of the target function (4) under constraints (5)–(12) If this condition (maximum of objective function (4)) is executed, it is necessary to analyze the received results, draw conclusions, and finish the algorithm of the complex process control system of company financial flows. Otherwise, return to step 6 of the algorithm.

Figure 2 shows a block diagram of an integrated process control system for company financial flows, which reflects in detail the main aspects and criteria for key management decisions on the investment of funds.

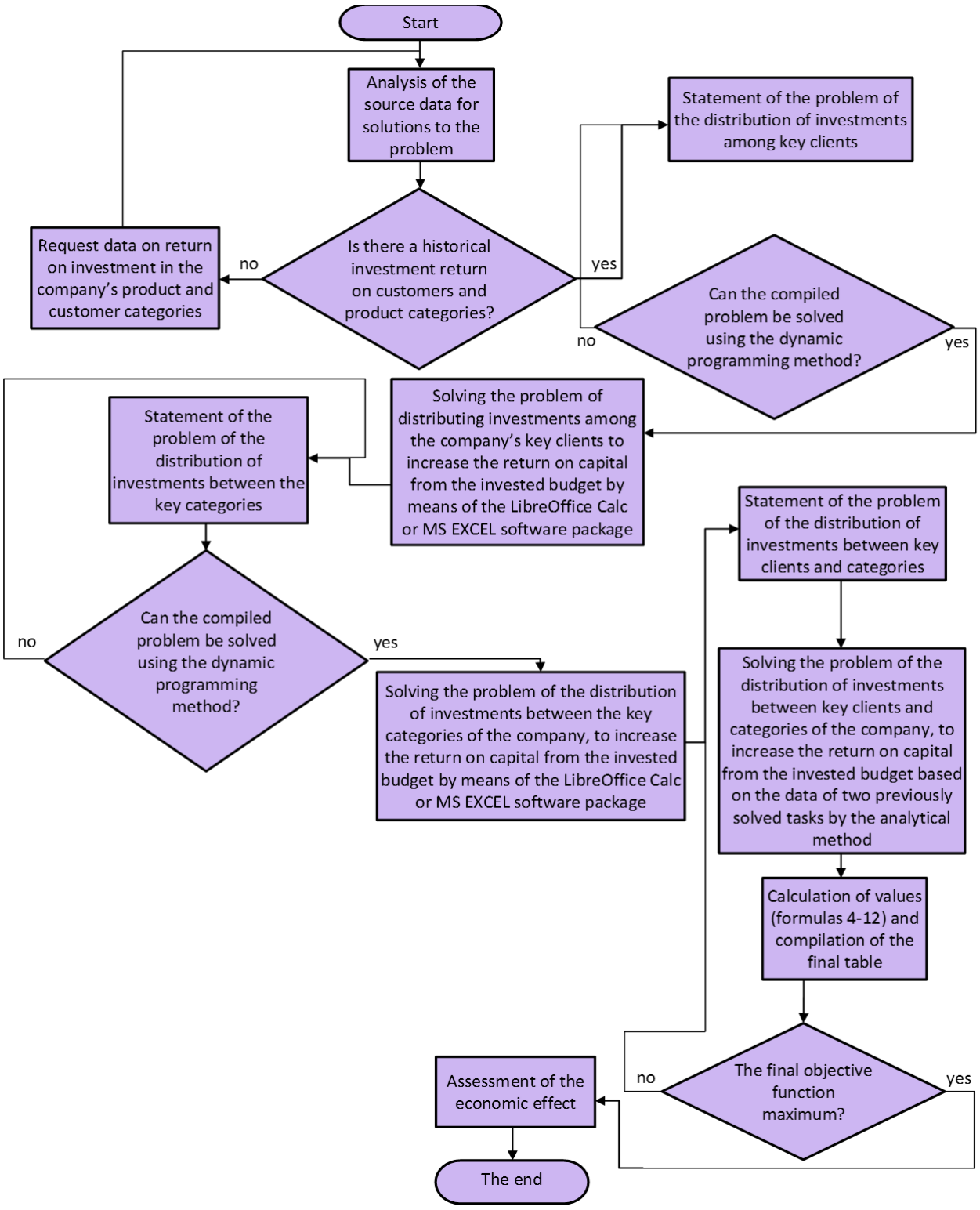

Figure 2. Block diagram of an integrated process control system for company financial flows

4- Results

Results of this research are solving the problem of distributing investments between the key customers of the company LLC "Kraft Heinz Vostok", namely, JSC Tander, LLC Auchan, LLC OK, LLC METRO Cash & Carry, LLC IKS5 Retail Group, LLC Lenta, to increase the capital return on the invested budget.

Problem Statement: it is necessary to distribute an investment budget of 5 million dollars between six above-listed companies for 2023. The data on historical profitability at different volumes of investment are shown in Table 3.

The assumptions of the model:

a) The financial result from investments in one company does not depend on the financial result from investments in another company;

b) The system under consideration is a closed system, i.e., no additional financing is provided for the whole period of investment.

Table 3 provides the initial information about the return on investment in key customers and categories of food products, provided by LLC “Kraft Heinz Vostok”.

Table 3. Return on investment of LLC “Kraft Heinz Vostok” in key customers and food categories

N	Name	Investment, million USD				
		1	2	3	4	5
		Profitability with different volume of investments				
		Key clients				
1	JSC Tander	2	3	4	3	6
2	LLC Auchan	1	3	3	5	6
3	LLC OK	2	2	4	4	7
4	LLC METRO Cash & Carry	2	4	5	5	7
5	LLC IKS5 Retail Group	3	4	5	6	8
6	LLC Lenta	1	2	2	3	4
		Food product categories				
1	Ketchup	4	5	6	9	8
2	Mayonnaise Sauce	1	3	4	5	7
3	Sauces	3	6	5	7	8
4	Canned vegetables	2	3	4	4	6
5	Baby foods	1	2	3	4	5
6	Milk porridge	2	3	1	5	4

Solving the problem using the LibreOffice Calc software. The above-considered algorithm for solving problems (4)–(12) is implemented using the LibreOffice Calc software package (an analog of MS Excel in Linux) with the "Solver" service since, under the sanctions imposed on Russian individuals and legal entities, MS Excel software is not available on all computers.

To determine the maximum value of the target function, we used the built-in LibreOffice Calc sub program "Solver": the dialog window is shown in Figure 3.

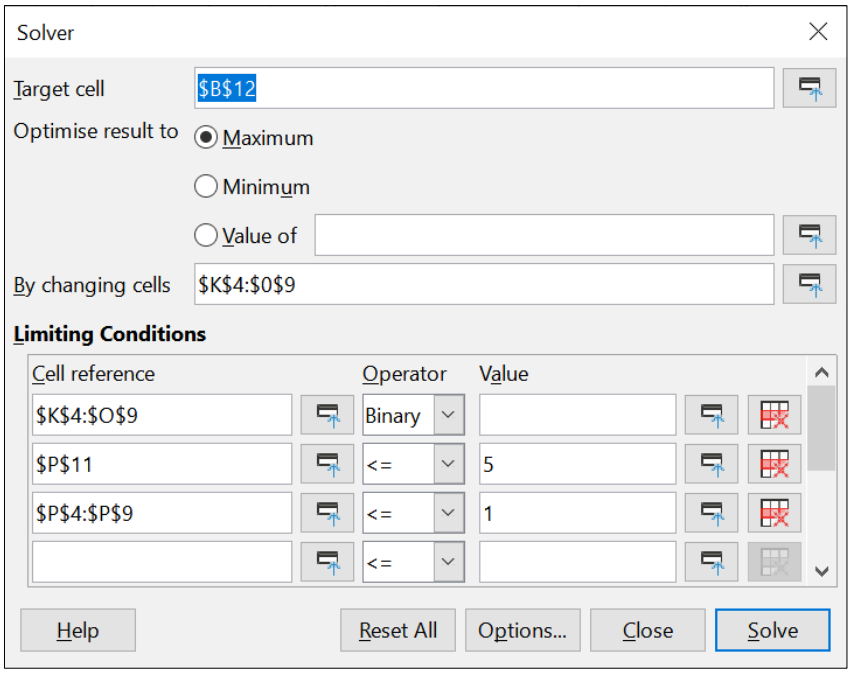

Figure 3. Dialog window of the "Solver" subprogram of LibreOffice Calc

Consider the sequence of operations in the LibreOffice Calc software to solve the problem. Create a working field on the LibreOffice Calc sheet of the same dimensionality as the original data (see Table 3). Fill out the workspace (matrix) with arbitrary values. In cells P4-P9, K10-O10 on the right and at the bottom of the table, enter the formulas SUMM(K4:O4)-SUMM(O4:O9), which are the sums of elements in each row and column of the working matrix, respectively. The values from 1 to 5 in cells K11–O11 characterize the multiplicity of investments in the company. The target function is the sum of the products of the corresponding elements of the two arrays. In the LibreOffice Calc, the entry looks like this: cell B12 = SUMPPRODUCT(C4:H9; J4:O9).

In the corresponding field of the dialog box, set the target cell $B$12 equal to the maximum value (the task of maximizing the total income from investments in enterprises). The cells $K$4:$O$9 are editable cells in the investment distribution problem in question, so specify them in the appropriate field of the dialog box. In the "Limitations" field, enter the existing restrictions on modifiable parameters (see Figure 3). The following restrictions are used in the given task:

1) Binary values of the cells to be changed are 0 or 1;
2) The sum of investments in all companies should not exceed the initial size of the investment, equal to 5 million dollars. Thus, the value in cell $P$11 is equal to the sum of products of cells K10 and K11, L10 and L11, M10, and M11, N10 and N11, O10, and O11 ($P$11 = K10 - K11 + L10 - L11 + M10 - M11 + N10 - N11 + O10 - O11);
3) Each company may either receive investment or do not receive it, which is expressed by the inequality $P$4:$P$9 < = 1.

In the Options tab of the LSolver, select "LibreOffice Linear Solver" from the drop-down list "Solver Mechanism", check the boxes "Limit Depth of Branches and Bounds" and "Accept Variables as Integer" (Figure 4). Press OK, then press "Solve".

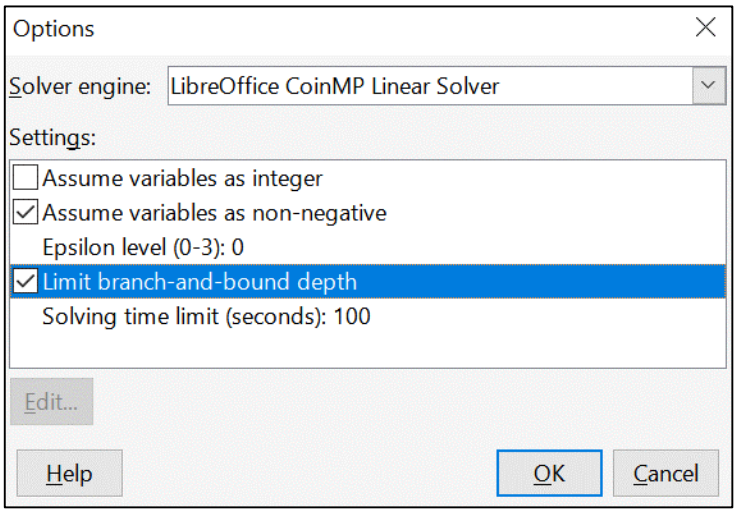

Figure 4. Options dialog window of the "Solver" subprogram

Figure 5 shows a fragment of the LibreOffice Calc workspace with the modeling results.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Initial data									Solve						
2	No.	Client	Investment, млн. USD													Column sums
3			0	1	2	3	4	5		0	1	0	0	0	0	1
4	1	Tander	0	2	3	4	3	6		0	0	0	0	0	0	0
5	2	Auchan	0	1	3	3	5	6		0	1	0	0	0	0	1
6	3	OK	0	2	2	4	4	7		0	0	1	0	0	0	1
7	4	Metro	0	2	4	5	5	7		0	1	0	0	0	0	1
8	5	X5	0	3	4	5	6	8		0	0	0	0	0	0	0
9	6	Lenta	0	1	2	2	3	4		Row sums	3	1	0	0	0	Row sums with multiplicity
10										Multiplicity	1	2	3	4	5	5
11	Maximum profit															
12	Target function	11														

Figure 5. A fragment of the working field with the results of modeling in the LibreOffice Calc software

The analysis of the data presented in Figure 5 shows that the maximum value of income from the invested funds in the amount of 5 million USD in all companies is equal to 11 million USD. To maximize profits from all companies in 2023, the following managerial decisions should be taken: 1 million USD should be invested in JSC Tander; 1 million USD should be invested in LLC OK; 2 million USD should be directed as investments to LLC METRO Cash & Carry; and 1 million USD should be directed to the LLC IKS5 Retail Group. The results of the modeling are presented in Table 4 (the profitability of companies with the optimal size of investment is highlighted in color).

Table 4. Solving the task of distributing investments among the company's key clients to increase the capital return on the invested budget

N	Name of the company	Investment, million USD				
		1	2	3	4	5
		Profitability with different volume of investments				
1	JSC Tander	2	3	4	3	6
2	LLC Auchan	1	3	3	5	6
3	LLC OK	2	2	4	4	7
4	LLC METRO Cash & Carry	2	4	5	5	7
5	LLC IKS5 Retail Group	3	4	5	6	8
6	LLC Lenta	1	2	2	3	4

Problem statement: It is necessary to distribute a production budget of $5 million between the six categories of food products: ketchup, mayonnaise, sauces, canned vegetables, baby food, and milk porridge, which will be sold through the above-mentioned trade networks. The data on the historical returns at different volumes of investment in these categories of food products is presented in Table 5. The basic assumptions and assumptions of the model are the same as in the solution to the problem of investment allocation among the key customers of LLC "Kraft Heinz Vostok" (see above).

Table 5. Solving the problem of allocating investments among the key categories of food products to increase the capital return on the invested budget

N	Food product Names	Investment, million USD				
		1	2	3	4	5
		Profitability with different volume of investments				
1	Ketchup	4	5	6	9	8
2	Mayonnaise sauce	1	3	4	5	7
3	Sauces	3	6	5	7	8
4	Canned vegetables	2	3	4	4	6
5	Baby foods	1	2	3	4	5
6	Milk porridge	2	3	1	5	4

The solution to this problem is similar to the solution to the problem of allocation of investments among the key clients of LLC "Kraft Heinz Vostok". Table 5 shows the profitability of food product sales through the retail networks of partner companies of "Kraft Heinz Vostok" with the optimal distribution of investments (the table cells corresponding to the investments that provide the maximum total return are highlighted in color).

The analysis of the data presented in Table 5 shows that the maximum value of income from investments in the sale of food products through retail chains of partner companies of LLC "Kraft Heinz Vostok" at the optimal distribution of investments is 14 million U.S. dollars. At the same time, to maximize profits from the sale of all categories of food products through the retail chains of the partner companies of LLC "Kraft Heinz Vostok" in 2023, it is necessary to take the following managerial decisions: 1 million US dollars should be invested in the realization of ketchups through the retail chains of the partner companies of LLC "Kraft Heinz Vostok", 2 million US dollars should be invested in the realization of ketchups through the retail chains of the partner companies of LLC "Kraft Heinz Vostok"; 1 million USD should be invested in the realization of sauces; 1 million USD should be invested in canned vegetables; 1 million USD should be invested in the realization of milk porridge through the trading networks of the companies-partners of LLC "Kraft Heinz Vostok".

Practical implementation of the obtained results is based on the data on the sales of food products (ketchup, mayonnaise, sauces, canned vegetables, baby food, and milk porridges) through the trading networks of LLC “Kraft Heinz Vostok” partner companies, namely, all the above-mentioned companies.

Figure 6 shows the sales volume of food products through retail chains as a percentage, corresponding to the ratio of the sales volume through the retail chain to the total sales volume of food products through all retail chains considered in the paper. The percentage indicated in Figure 6 corresponds to the share of sales of the category of food products through the point of sale in the total volume of sales of this category through all outlets presented in Figure 6. Thus, for the category of ketchup sold through the retail network of JSC Tender," the value of 12% indicates that through this outlet is sold 12% of all ketchup sold through all the above-mentioned companies together. Similarly, for the remaining values presented in Figure 6.

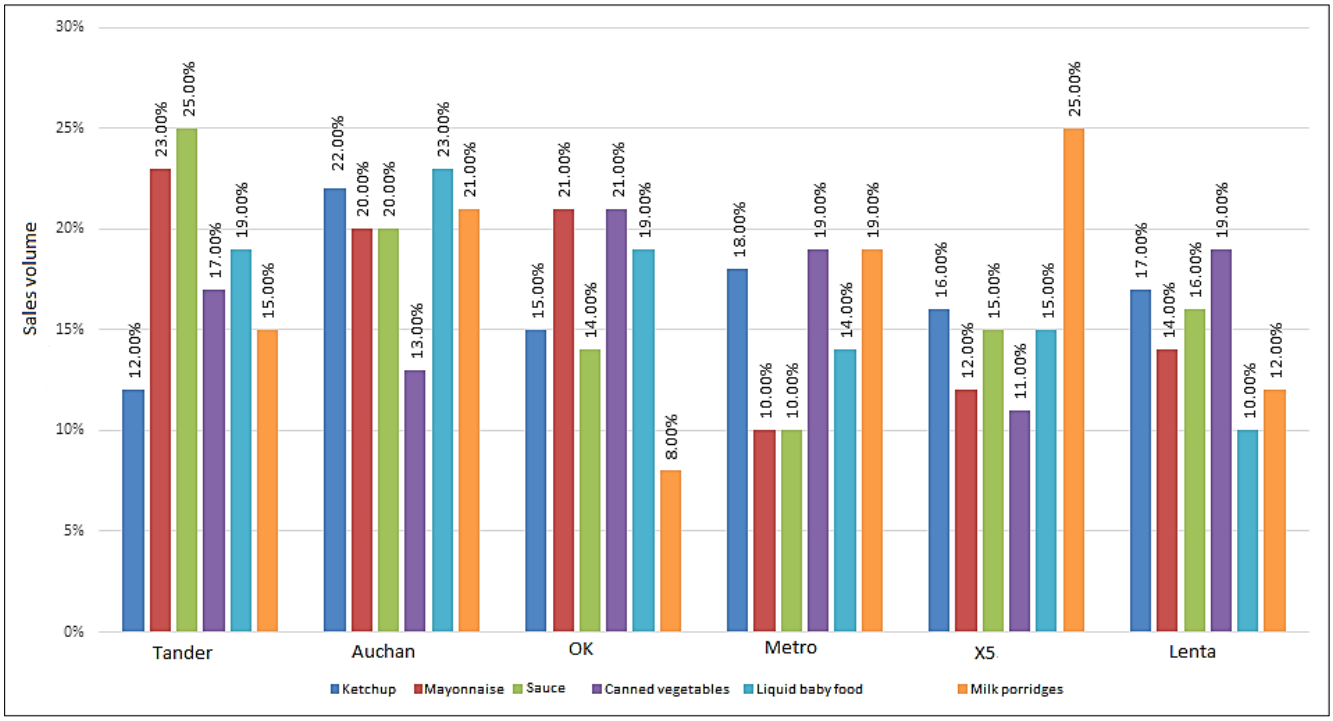

Figure 6. The volume of sales of food products through retail chains

Category sales volumes and target values for each network are in Table 6.

Table 6. Volume of sales of food products through retail chains, the main indicators and economic efficiency (profitability) of investment in the sale of food products through retail chains (The table uses points instead of commas in decimal numbers)

N	Food Products Names	Ketchup	Mayonnaise	Sauces	Canned Vegetables	Baby Food	Milk Porridge
1	Annual sales volume of the category among all retail chains, million USD	50	40	60	45	35	40
2	Target value of food category sales for each retail chain, million USD	12.00	8.00	16.00	9.95	7.00	7.20
3	Sales growth	Incentives for employees for exceeding the average annual sales rate of the store category, million USD					
4	Starting from 5%	3	-	4	5	-	8
5	Starting from 11%	6	-	5	7	-	11
6	Starting from 16%	8	-	6	9	-	13
7	Starting from 19%	11	-	7	12	-	16
8	Current sales volume of food products categories through the trade network, million USD (the highlighted cells of the table correspond to the categories of food products and networks in which it is planned to increase the volume of sales).						
9	JSC Tander	6.00	9.20	15.00	7.65	6.65	6.00
10	LLC Auchan	11.00	8.00	12.00	5.85	8.05	8.40
11	LLC OK	7.50	8.40	8.40	9.45	6.65	3.20
12	LLC METRO Cash & Carry	9.00	4.00	6.00	8.55	4.90	7.60
13	LLC IKS5 Retail Group	8.00	4.80	9.00	4.95	5.25	10.00
14	LLC Lenta	8.50	5.60	9.60	8.55	3.50	4.80
15	Increase in the company's revenue from investments in the sale of food products through retail chains, million USD	+ 6	-	+10	+5	-	+4

16	Changes in sales, %	+12%		+17%	+11%		+10%
17	Volume of one-time investments, million USD	2	-	4	2	-	2
18	Fixed costs (distributed evenly among all categories, the table shows total values for planned sales volumes), million USD	1		1	1		1
19	Variable costs (allocated based on fixed rates for each category, the table shows total values for planned sales volumes), million USD	2		4	2		2
20	Total cost price (p. 18 + p. 19), million USD	3	-	5	3	-	3
21	Percentage of income allocated to incentives for LLC Kraft Heinz Vostok employees (θ_6 in the economic and mathematical model (12)).	10%		7%	15%		13%
22	Additional income for company employees, thousand USD	600		700	750		520
23	Profitability of Investments, %	150	-	125	100	-	50
24	The enterprise development fund, formed from the proceeds from the sale of a type of food products through the trade network, million USD (formula 8)	8.26		9.67	6.44		3.94
25	Profit of the enterprise from investments in the sale of categories of food products through the trade network, million USD (formula 5 and9)	9.00		11.00	6.95		4.20
26	Share of variable costs in the structure of the cost of sales of a category of food products through the trade network (formula 10)	0.67		0.80	0.67		0.50
27	Share of fixed costs in the structure of the cost of sales of the category of food products through the trade network (formula 11)	0.33		0.20	0.33		0.50
28	The amount of employees' wages from the sale of food products through retail chains, million USD (formula 12)	0.9		1.26	0.84		0.57
29	Economic efficiency of investment in the sale of categories of food products through retail chains, % (formula 4) - the target function of the economic -mathematical model (4)-(12)	300		367	398		150

The cells highlighted in gray show the planned indicators of sales of categories of goods in retail networks. Thus, the analysis of Figure 6 allows us to conclude that the ketchup category is the least represented in the trading network of JSC Tander, as only 12% of ketchup is sold in this trading network. Table 6 shows that the total sales volume of ketchup was 50 million rubles. Therefore, the volume of sales in this category at JSC Tander is 50 × 0.12 = 6 million USD, which is indicated in row 9 and column 3 of Table 6. In addition, from the data presented in Table 6, we know the target value for each store in the ketchup category. This means that this food category must be increased by 6 million USD (12 million USD (sales target, see row 2, column 3 of Table 6) - 6 million USD (current sales, see line 9, column 3 of Table 6), which is indicated in line 15 and column 3 of Table 6. Similarly, for the remaining columns of line 15 of Table 6. Thus, the solution to the problem of dynamic programming, presented in Tables 4 and 5, as well as formula (5), suggests that an investment of 1 million USD to increase the volume of ketchup sales through the trading network of JSC Tander would bring an additional 6 million USD. Similarly, for other retail chains, and categories of food products are presented in Table 6.

The target value of sales volumes serves as a reference point for those retail chains that have a lower indicator, and those food products, investments in which are expedient and give the maximum value of the target function of the total return (see Table 6). The analysis of Figure 6 and Table 6 suggest the need to invest in the following food products sold through retail chains: 1 million USD - to increase the volume of sales of ketchup by 12% through the retail network of JSC Tander, and 2 million USD - to increase the volume of sales of ketchup through the JSC Tander retail network. We invested 2 million USD to increase our sauce sales by 16% through the LLC METRO Cash & Carry retail network, 1 million USD to increase the sales of ketchup and sauces through the JSC Tander retail network, and 2 million USD to increase the sales of sauces through the LLC METRO Cash & Carry retail network. 1 million USD should be channeled to increase sales of canned vegetables by 11% through the retail network of the LLC IKS5 Retail Group, and 1 million USD should be channeled to increase sales of canned vegetables through the retail network of LLC METRO Cash & Carry. 1 million USD should be used to increase the sales of milk porridge by 10% through the trading network of LLC OK.

The total investment budget of LLC "Kraft Heinz Vostok" available for distribution among all trading networks and all categories of food products was 10 million USD. Checking whether the condition of not exceeding the total investment budget of the enterprise according to the formula (6) of the economic-mathematical model (4)–(12) showed that the budget overrun in solving the problem of process management of financial flows of the enterprise did not occur, i.e., condition (6) is satisfied.

Let's determine the size of the development fund (F) of the company, formed by the revenues from the sale of j type of food products through the k retail network, using the example of JSC Tander and the "Ketchup" category of food products. According to the formula (8) of economic and mathematical models (4)-(12), we have: $F = 6 + (1 - 0.06) \cdot (9 - 6) \cdot (1 - 0.2) = 8.26\ million\ USD$, which is indicated in line 24, column 3 of Table 7. Here, 6 million USD is the company's profit from selling ketchup through JSC Tander before the implementation of the developed economic and

mathematical model in the company's activity, taken as a basis for comparison. The coefficient of redistribution of profit growth between enterprise personnel, involved in the realization of ketchup through JSC Tander, and company development fund, (parameter ξ_{jk} in formula (8)) is 0.06; 9 million USD is company profit from investments in the realization of ketchup through JSC Tander, and 0.2 is the profit tax rate. Similarly, for the other columns of line 24 in Table 6. Here, the enterprise profit presented in row 25, column 3 of Table 6 is determined by subtracting the total production cost from the sales target (line 2, column 3 of Table 6) (see row 20, column 3 of Table 6), i.e., 9 million USD = 12 million USD - 3 million USD (see formula (9) of economic and mathematical model (4)-(12).

The share of conditionally variable costs in the structure of the cost of sales of the category of food products through the trade network, presented in line 26 of Table 6, is determined by the formula (10). Thus, for row 26, column 3 of Table 6: $\omega_{var} = \frac{2}{2+1} = 0.67$. Similarly, for other columns of line 26 of Table 6. The share of conditionally fixed costs in the structure of the cost of sales of the category of food products through the trade network, presented in row 27 of Table 6, is determined by the formula (11). Thus, for row 27, column 3 of Table 6: $\omega_{fix} = \frac{1}{2+1} = 0.33$. Similarly, for the other columns of row 27 of Table 6.

The wages of employees from the sale of food products through retail chains are determined by the formula (12) of economic-mathematical model (4)-(12). Therefore, for the category of food products "Ketchup" and the trading network of JSC Tander, it follows: $Sal = 12 \bullet 0.06 + 0.06 \bullet (9 - 6) = 0.9\ million\ USD$. The values for other categories and retail chains are calculated similarly (see row 28 of Table 6).

Let's show the methodology of economic efficiency of investment (return on investment) in the implementation of the category of food products "Ketchup" through the trading network of JSC Tander (see formula (4) and row 29, column 3 of Table 6). $R = \frac{9}{3} \cdot \frac{12-6}{6} = 300\%$. The values for the other categories and trade networks are calculated similarly. The data are shown in the last row of Table 6, and the sum of all columns of the last row of Table 6 is the target function of the economic and mathematical models (4)-(12).

5- Conclusions

- When solving the problem of distributing investments among the company's key clients to increase the return on capital from the invested budget (see Table 6), the following results were obtained: maximizing profit from invested funds will be 11 million USD. To maximize profits for the next year (2023), it is necessary to: invest 1 million USD in JSC Tander; 1 million USD to invest in LLC OK; 2 million USD to invest in LLC METRO CASH AND CARRY; 1 million USD in the LLC IKS5 RETAIL GROUP.
- When solving the problem of distributing investments among the company's key clients to increase the return on capital from the invested budget (see Table 6), the following results were obtained: maximizing profit from invested funds will be 14 million USD; to maximize profits for the next year, it is necessary to invest 1 million USD in the production of ketchup, 2 million USD in the production of sauces, 1 million USD in canned vegetables, 1 million USD in cereals.
- Comprehensive analysis of the data presented in Table 6 allows us to draw conclusions about the optimal distribution of investments: USD 1 million should be invested in JSC Tander into the ketchup, USD 2 million should be invested in METRO Cash AND CARRY LLC in the sauces, USD 1 million should be invested in LLC IKS5 Retail Group in the canned vegetables, 1 million USD should be invested in LLC OK in the porridge.
- Analysis of line 22 of Table 6 shows that the investments calculated on the basis of the developed economic and mathematical models (4)-(12) make it possible to increase the wages of LLC “Kraft Heinz Vostok” employees by 600 thousand USD for the category of food products "Ketchup"; by 700 thousand USD - for the category "Sauces"; by 750 thousand USD - for the category "Canned vegetables" and by 520 thousand USD - for the category "Milk porridge," which is 2.570 thousand USD.

A comparison with other studies and the scientific increment of knowledge is presented in Table 2.

This study is a logical extension of a series of papers aimed at the development and practical implementation of the methodology of mathematical modeling of management processes in the development of enterprises and organizations of all forms of ownership and economic activity in Russia in general. It includes progressive methods and tools to encourage the work of executives and administrative and managerial staff and social financial technologies as a tool to increase wages of employees and the development of enterprises and the economy of the country in general [11, 12, 44, 90]. Simultaneously, the major differences in this work in contrast to the previous research is the combined application of the results of solving the problem of dynamic programming on the allocation of investments between the key categories of food products and customers based on the criterion of economic efficiency (profitability) of investment, social financial technologies aimed at increasing the material incentives for executives and administrative and managerial staff(see formula (12) of economic-mathematical model (4)-(12)), a progressive system of labor incentives and sovereign emissions as an inexpensive source of investment in the country's food security and growth of the well-being of its citizens.

Analysis of the data presented in the last line of Table 6 gives reason to believe that it is the most effective for direct investments in the food category "canned vegetables," sold through the trading network of LLC IKS5 RETAIL GROUP. The return on investment in this category of goods is estimated at 398% (see the last row, column 6, of Table 6). Then comes the category "sauces," sold through the trading network of LLC Metro CASH AND Carry with a return on investment of 367%, which is indicated in the last line of column 5 of Table 6; in the third place are investments in the food category "Ketchup," sold through the trading network of JSC Tander with a return on investment of 300%, and, finally, in the last place is the category "milk porridge," sold through the trading network of LLC "OK" (see last row 11, column 8 of Table 6). Investments in this category are 150% economically efficient (see the last row, column 8, of Table 7).

The main users of the results are the Board of Directors of the "Kraft Heinz Vostok" company. The results obtained using the economic-mathematical model (4)–(12) developed by the authors may be used to implement the company's development strategy in investment, marketing, and other related areas of activity.

The developed progressive system of personnel labor stimulation (formula (12) of the economic-mathematical model (4)–(12)) is intended for the HR-department of the "Kraft Heinz Vostok" company. Its purpose is the practical implementation of the bonus system of remuneration for employees depending on key performance indicators, namely the company's revenue, return on investment in the category of food products sold through retail chains, and the coefficient of labor involvement of the employee.

5-1- The Proposed Model's Advantages

The economic and mathematical model designed here, having a progressive system of stimulating the work of the company's employees as its basis, with the practical implementation of an integrated system for the process management of financial flows of LLC "Kraft Heinz Vostok", makes it possible for the managerial decision-maker to:

- Increase the material incentives for employees, depending on the increase in the volume of sales of food products through retail chains, by 38%, taking into account the optimal distribution of investments obtained by solving the dynamic programming problem (compare rows 28 and 22 of Table 6).
- Increase charges for developing the company by USD 28.31 million (the sum of all columns of line 24 of Table 7), which makes it possible for the entire team to participate in the management of the company and direct funds for its further development and investment in the most promising customers and categories of food products, equipping the workplace of employees, and improving their skills.

5-2- The Proposed Model's Limitations

- The financial results from the investments in one company do not depend on the financial results from investments in another company;
- The system under consideration is closed, i.e., during the whole period, no additional financing is provided;
- Quality, comprehensiveness, and reliability of data on the company's historical profitability;
- The amount of investment in key customers and categories of food products is limited and determined by the company's investment budget.

The economic and mathematical model of process management of the financial flows of companies designed here may be used to improve the accuracy, efficiency, and appropriateness of management decisions in the interests of the company's development, increasing the profitability of its activities, the growth of employee wages, and contributions to the development fund.

The results of the development of scientific and methodological apparatus and the implementation of practical tools in this study allow us to conclude that the goal of the study has been achieved. The accomplished research provides decision-makers with effective tools for process management of companies' financial flows.

Further research on these research problems may include:

- Introducing a progressive system of employees' labor stimulation in other spheres of activity, for example, providing educational services to motivate the highly effective work of scientific-pedagogical workers, increases their qualification and professional level;
- Extending the technology of setting and solving the problem of dynamic programming to prospective investors and searching for optimal (from the perspective of weighted average price) sources of financial resources to implement company investments;
- Adapting the economic and mathematical model developed in the study to the companies of all sectors of the economy;
- Including the developed economic and mathematical tools in a unified information-analytical system of company financial flow management, its interaction with widely used applied software products and others.

6- Declarations

6-1- Author Contributions

Conceptualization, E.K.; methodology, E.K.; software, D.R.; validation, E.K.; formal analysis, E.K. and D.R.; investigation, E.K. and D.R.; resources, D.R.; data curation, E.K. and D.R.; writing—original draft preparation, E.K. and D.R.; writing—review and editing, E.K. and D.R.; visualization, D.R.; supervision, E.K.; the project administration, E.K. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6-4- Institutional Review Board Statement

Not applicable.

6-5- Informed Consent Statement

Not applicable.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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