



## Optimization of Commodity Flows: The Case of Bakery Enterprises of Ukraine

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### ARTICLE INFO

Received June 11, 2019  
Revised from July 27, 2019  
Accepted August 25, 2019  
Available online September 30, 2019

#### **JEL classification:**

O18, R41, R42.

**DOI:** 10.14254/1800-5845/2019.15-3.15

#### **Keywords:**

Logistics,  
commodity flow,  
optimization,  
logistics infrastructure,  
enterprise,  
transport task

### ABSTRACT

In the conditions of the active development of the market of logistic services, the growth of the cost of fuel and lubricants, as well as the increase of environmental requirements for the operation of the motor transport park an important reserve for improving the efficiency of enterprises and reducing the anthropogenic impact on the environment is to optimize their commodity flows. The purpose of the article is to develop a model of optimization of commodity flows of enterprises of the bakery industry, which allows to ensure timely delivery of raw materials and products with minimization of economic and environmental costs. Methodology. The methodological basis of investigation was a linear programming method adapting the transport task to the specifics of the baking industry. Authors developed the model of optimization the commodity flows of the enterprises is based on the criteria of the efficiency of the logistic using the system of indicators: economic (costs for distribution and delivery of products) and environmental (costs for reducing the anthropogenic load on the environment). It is proposed to determine the optimal sales channels of products based on the integral indicator of the efficiency of organization of commodity flows, which includes economic and environmental efficiency, weighted by the factors of importance established by expert way. Results. The developed logistic model of optimization of commodity flow has been tested on a number of bakery enterprises. As a result, an optimal plan for delivering products has been formed taking into account the economic and environmental factors. The advantage of the model is the ability to apply it to the initial flow of material flows and reverse flow (reversible logistics, or logistics of bread, bakery and flour products). The practical application of the developed model at the enterprises of the bakery industry will reduce the logistical and environmental costs, ensure the reliability of deliveries, reduce the human impact from mobile sources, meet demand, taking into account the requirements of consumers regarding the quality and environmental friendliness of products and increase its competitiveness.

## INTRODUCTION

The current problem of enterprise management is the formation of new and optimization of existing commodity flows, which cover international transport corridors, national and regional supply chains. The internationalization of the world economy, the expansion of commodity markets, the active development of electric vehicles, and the increase of consumers' demands for quality and speed of delivery of products require the improvement of commodity flows by identifying the optimal batches of goods, choosing the type of transport or carrier. Optimization of the logistic goods and transport flows of enterprises is a powerful reserve for reducing operating expenses. In 2016, the share of logistics costs in the world amounted to an average of 10.6% of GDP, including in Russia - 16.1%, Ukraine - 15.9 %, Kazakhstan - 15.1%, China - 14.5%, India - 13.0%, Poland - 11.7%, Denmark 9.6%, France - 9.5%, Germany, Great Britain - 8.8%, Japan - 8.5%, USA - 8.2% (Armstrong & Associates, 2018). From the level of logistics management, the competitiveness of enterprises in the external and internal markets depends on a significant measure. Particularly urgent is the problem of reducing operating costs by optimizing logistic for food industry enterprises. There are medium and small business entities with a high share of logistics costs in the cost of production. In 2015, the average world share of logistics costs in sales was for enterprises with an income of more than \$ 2 billion - 4.5%, from \$ 500 million - \$ 1 billion - 7.9%, \$ 100-500 million, up 8.8%, to \$ 100 million - 11.4% (The Establish Davis Database, 2015).

The global trend now is to increase the environmental requirements for the operation of vehicles, the content of harmful substances in exhaust gases of cars. Food industry enterprises produce products that require special conditions of storage, transportation, sale. The social importance of food in meeting basic public needs, the short period of their storage, the need to comply with harsh sanitary requirements, small volumes of commodity batches, require a complex logistics infrastructure to ensure timely, regular and uninterrupted commodity provision, transportation of raw materials and finished products. Thus, in Ukraine, the average annual turnover of enterprises in the bakery industry is almost 8 million ton-kilometers, and the time of stay in the tanks of one vehicle on average is more than 125 minutes per day. The volume of emissions during the transport of bakery products is almost 106 thousand tons per year, or 12% of the total emissions by mobile sources in the country (State Statistics Service of Ukraine, 2018).

In spite of the urgency and necessity of practical solution of the problem of rationalization of transportations, from the scientific point of view, more detailed researches and further elaboration of the question of complex estimation of efficiency and modeling of transport flows of enterprises on the ecological and economic grounds are needed. Inadequate study of these and other issues is complicated by the provision of ecologically-oriented commodity flows management. Thus, optimization of commodity flows is one of the important and progressive directions of scientific research, further development of the industry, reduction of their human impact on the environment, implementation of corporate social policy on sustainable ecological and economic development, as well as improving the quality of life of the population. Taking into account the above mentioned, *the purpose of the study* is to develop a model for optimizing the commodity flows of enterprises in the bakery industry, which allows timely delivery of raw materials and products with minimization of economic costs and anthropogenic impact on the environment.

## LITERATURE REVIEW

Actuality and necessity of the solution of the problem of ensuring a clear, rational organization of transport flows of economic entities, taking into account environmental factors, have caused numerous research of scientists. A critical review of the results of scientific advances in relation to the mathematical justification for optimizing commodity flows allowed to distinguish between two groups of scientists.

Scientists of the first group used mainly traditional methods for solving transport problems, taking into account the influence of external and internal factors, which have restrictive or stimulating character. This group includes A. Anikina (2013), L. N. Berkman (2002), L. D. Kiyanova (2004), A. D. Kanchaveli (2001), T. O. Zagornaya (2008), G. V. Podvalna (2012), Yu. V. Chortok (2010), O. Karpenko, A. Horbenko, Y. Vovk, O. Tson, (2017), O. Lyashuk, V. Lototska, V. Kuzmych (2016), V. Aulin et al. (2019) and others. In particular, G. V. Podvalna (2012) investigated ways to increase the revenue and efficiency of transport companies and their structural units, in particular the transport department, due to a more rational distribution of customer service time, due to this increase. According to the author, the transport task as an optimization tool in its main form should be used to find the best transport connections in a limited area, where the distance between the places of loading and unloading allows you to move within 10 hours. In particular, this may be the area of adjacent areas. In our opinion, the weak point of this approach is the consideration of a limited number of criteria- effective indicators, namely, the cost of transporting a unit of cargo and the time of transportation.

A comparative analysis of the results of the application of the methods of the north-west corner, the minimum cost, the double cost, and also the approximation of Vogel for the solution of the transport problem have made O. Ivanitsky, N.V. Roshchina and R. S. Serbul (2015) G. Kovács (2017). They found that the method of the north-west corner is the simplest, however, and the least efficient, since when filling the table for drawing up a reference plan, first satisfy the needs of consumers, and then take into account the cost of transportation. Scientists have come to the conclusion that it is best to use the reference plan of the transport task, compiled by the method of minimal cost. Based on previously obtained scientific results, in the future it is advisable to consider the peculiarities of the application of these methods taking into account the specifics of the organization of logistics activities (operation of the internal logistics department, services of 3 PL providers, external outsourcing, etc.).

Critical analysis of methodological approaches to the solution of the transport problem was carried out by R.V. Joshi (2013), and O. Velychko (2017). They analyzed three variables will be optimized to reduce transportation cost using four methods which will include: northwest corner method, least cost method, Vogel method and MODI method. This will mainly aim at finding the best and cheapest route on how supply will be used to satisfy demand at specific points. This will imply that, a variable cost of shipping products from suppliers to demand points will be considered. G. Davulis and L. Šadžius (2010) with ways of flow distribution in the transport network in order to minimize transportation costs. It describes the structure of transportation costs and principles of defining the dependence on the volumes of flow in pertinent transport modes, such as railways and road transport. It analyses classical models of flow distribution and presents a new approach to flow distribution in a transport network, based on flow optimization in individual contours or groups of contours of the network. The suggested approach is more rigorous than classical ones in mathematical terms and therefore avoids problems of heuristic nature that characterize classical approaches.

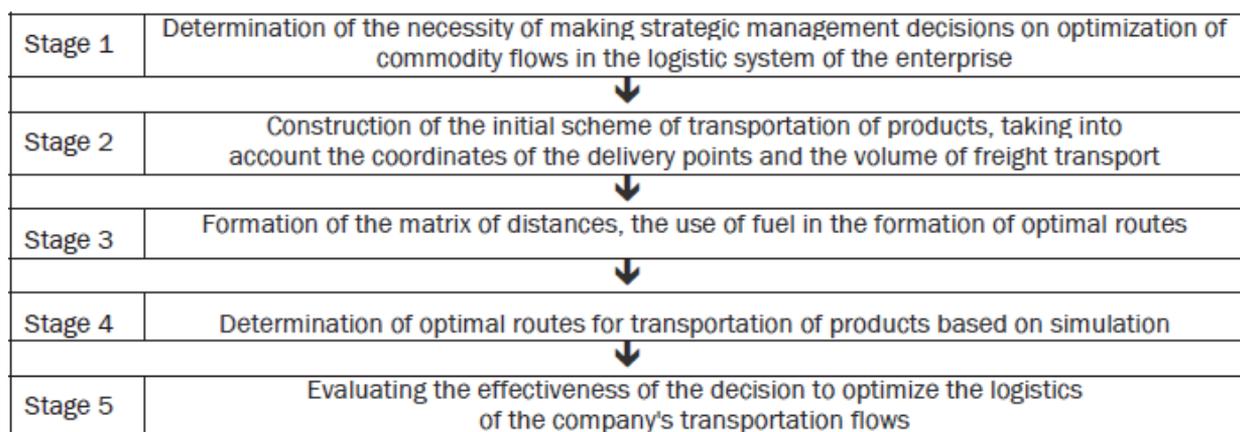
The second group scientists substantiated the directions of increasing the efficiency of organization of commodity flows taking into account industrial production, economic and environmental factors including by way of economic-mathematical modeling. Here it must be said, that T. O. Zagornaya, A. V. Poldneva (2008) developed a method for the formation and evaluation of the efficiency of the marketing policy of the enterprise to improve the system of product sales management. In the works of Ya. V. Kolodka (2014) it was considered the issue of increasing the economic efficiency of the logistics system by identifying and implementing savings reserves and / or optimizing the cost of resources. The author noted that the process of formation of efficiency involves the consideration of costs, their savings and / or optimization at all stages of the material and related financial, informational, energy and personnel flows. The modern scientific methodical approach is the justification of optimization of commodity flows taking into account environmental factors that were applied by V. Mateichik (2012), A. McKinnon (2010), E. Mishenin (2013), V. Khrutba (2014). In particular, V.

Matejchik, M. Smeshek and V. Khurutba (2014) in a study entitled "Project Management of Environmental Logistics of Transport Companies" investigated the problems of ensuring the effectiveness of environmental logistics with the use of mathematical modeling methods.

Alan McKinnon, Sharon Cullinan, Michael Browne and Anthony Whiteing (2010) in a study entitled "Green Logistics. Improvement of Environmental Sustainability of Logistics" said that the scientific analysis of approaches, methods and tools of ecological ("green") logistics, logistics of resource conservation and waste, formation of environmentally oriented strategies of behavior of logistic entities. Oksana Seroka-Stolka (2014) devoted her research to revealing and revealing the key factors that can influence the development of the concept of green logistics as a component of sustainable development. In general, without lowering the importance of the above results of scientific researches, we note that in the conditions of increasing competition, the development of logistics infrastructure, strengthening of state regulation of the operation of motor vehicles, the influence of other economic, environmental and organizational factors is increasing. In particular, the study of the impact on the efficiency of goods and transport flows of such factors as: the volume and value of goods; the number and composition of vehicles, the complexity and cost of delivery; environmental damage caused by the environment during loading, transportation and unloading of products, quality of products and delivery, environmentally friendly transport, etc.

## 2. METODOLOGY

In order to optimize the ecological and commodity flows of enterprises for the production of bread, bakery and flour products, it is necessary to take into account the peculiarities of production and use of products, as well as conditions that may influence the course of production. The sequence of the optimization procedure for the commodity flow is shown in Figure 1.



**Figure 1.** Scheme of stages of optimization of the commodity flow of enterprises of the bakery industry

We have built a model for optimizing the flow of goods for the delivery of bakery products to the enterprises of the baking industry, using the criteria of the efficiency of the logistic commodity flow (Eq. 1), which includes indicators of economic and environmental and social assessment. The following should be included in the economic categories: the volume of commodity products and their value; the number of vehicles for delivery of goods, the cost of delivery of products; the number of employees involved in delivery, and the complexity of their work.

The economic effect of logistics management is to reduce the specific aggregate costs associated with the movement of goods, the time of deliveries and ensuring their reliability. Consequently, the criterion of economic efficiency should be defined as a function

$$k_E = f(x'_{11}, x'_{12}, x'_{13}, \dots, x'_e) \quad (1)$$

where  $x'_1, \dots, x'_e$  - costs associated with the loading, transportation and unloading of products.

Environmental criteria include quantitative emission factors for the atmosphere when transporting products, waste and their recycling systems. A separate set of indicators should highlight the impact of financial and information flows on the environment. The manifestation of the ecological effect of logistics management is to reduce the specific combined effects on the environment, reduce the "ecological footprint" of the enterprise, provide resource and energy conservation. The criterion of environmental efficiency can be considered as a function

$$k_D = g(x''_{21}, x''_{22}, x''_{23}, \dots, x''_l) \quad , \quad (2)$$

where  $x''_2, \dots, x''_l$  - costs associated with damage to the environment during loading, transportation and unloading of products.

Social indicators determine the degree of consumer satisfaction, which is the main task of distribution logistics. Maximum satisfaction of consumer requests is achieved, first of all, with the minimum cost of products, subject to compliance with the requirements for the quality of bread, bakery and flour products. Consequently, the criterion of social effectiveness should be defined as a function

$$k_C = \varphi(x'''_{31}, x'''_{32}, x'''_{33}, \dots, x'''_d) \quad , \quad (3)$$

where  $x'''_3, \dots, x'''_d$  - costs associated with the quality of products and delivery, ensuring a high level of satisfaction of consumer requests, etc.

Finding an effective solution to achieve optimal effect is a multicriteria task. For its solution it is necessary to use the Pareto method, which involves the definition of the integral criterion of optimality as the sum of individual partial criteria with variable weights by obligatory participation of experts / entrepreneurs / experts. Such methodological approaches are often considered the best. The advantage is that the alternative is deliberately effective. However, there are additional assumptions that are not always justified from a mathematical point of view; the sum of partial criteria with coefficients of importance is an additive function of value. In order for it to correctly reflect the system of company benefits, it is necessary that the evaluation criteria are mutually independent.

The model of optimization of ecological and logistic commodity flows of enterprises in the bakery industry is expedient to define as an additive function with weight coefficients of indicators of ecological, economic and social efficiency:

$$K = \lambda_1 \cdot k_E + \lambda_2 \cdot k_D + \lambda_3 \cdot k_C \quad ,$$

$$\lambda_1 + \lambda_2 + \lambda_3 = 1 \quad , \quad (4)$$

where  $K$  – integral indicator of the efficiency of organization of ecological-logistic commodity flows of bakery enterprises;

$k_E$  – indicator of the economic efficiency of the system;

$k_D$  – indicator of the ecological efficiency of the logistics system;

$k_C$  – indicator of the social efficiency of the logistics system;

$\lambda_1, \lambda_2, \lambda_3$  – weighting factors of the importance of each indicator.

On the basis of the integral indicator of the efficiency of the organization of ecological- commodity flows, it is necessary to choose a channel for distribution of products. The direct distribution of bread and bakery products through its own chain of trade is expedient if a large amount of bakery products and income can balance the costs of direct sales. Such a distribution leads to the presence of a sufficient network of own facilities in the markets where the goods are sold. Direct distribution is possible at a high concentration of market and consumers in a relatively small area. It should also be used, provided that the delivery and sale of the product requires a highly specialized service or the price is constantly fluctuating, and there is a need to take into account the specifics of operation at a time. As a result of the research, it was found that for the enterprises producing bread, bakery and flour products, the intermediary services are justified when the market is horizontal, branched geographically, requires the creation of a powerful sales network, or sales require high transport costs, or the market is studied insufficiently and own funds from the producer also missing. Thus, the optimization logistic model of the distribution of the product flow for the enterprise for the production of bread, bakery and flour products, taking into account formula (5), has the form

$$\left. \begin{aligned} K &= \lambda_1 \cdot k_E + \lambda_2 \cdot k_D + \lambda_3 \cdot k_C \rightarrow \min \\ \lambda_1 + \lambda_2 + \lambda_3 &= 1 \\ k_E &= f(x'_1, \dots, x'_e) \leq a_i, i = \overline{1, h} \\ k_D &= g(x''_2, \dots, x'_l) \leq b_i, i = \overline{1, h} \\ k_C &= \varphi(x'''_3, \dots, x'_d) \leq c_j, j = \overline{1, m} \end{aligned} \right\} \quad (5)$$

where  $x'_1, \dots, x'_e, x''_2, \dots, x'_l, x'''_3, \dots, x'_d$ - valid variables (managed parameters);

?? - integral indicator of the efficiency of organization of ecological and commodity flows of enterprises of the baking industry;

$k_E$  - the indicator of the economic efficiency of the system;

$k_D$  - indicator of the ecological efficiency of the logistics system;

$k_C$  indicator of social efficiency of the logistics system;

$\lambda_1, \lambda_2, \lambda_3$ - weights of the importance of each indicator;

$a_i$  - economic costs from- $i$ -suppliers;  $h (i = \overline{1, h})$ . The number of the individual vendor

$b_i$  - environmental costs from the  $i$ -th supplier ( $i = \overline{1, h}$ )

$c_j$  - demand for products by the  $j$ -th product sales entity ( $j = \overline{1, m}$ );  $j$  - number of subjects of product sales; the number of the individual subject of product sales will be denoted by  $m (j = \overline{1, m})$ ;

$d; e; l$  - indicators that determine the peculiarities of the organization of the movement of commodity flows; environmental and economic impacts; taking into account the influence of logistics activities on the environment.

The indicator of the economic efficiency of the system  $k_E$  is defined as the function  $e$  of variables that form the cost plan  $x' = x'_1, \dots, x'_e$  for the distribution and delivery of bread, bakery and flour products. The indicator of the ecological efficiency of the logistic system  $k_D$  is a function of  $l$  parameters that formulate a cost plan  $x'' = x''_2, \dots, x'_l$ , aimed at reducing human-induced environmental impacts in the delivery of bread, bakery and flour products.

The indicator of the social efficiency of the logistics system  $k_{??}$  is a function of the  $d$  parameters that form a cost plan  $x''' = x_3''', \dots, x_d'''$ , aimed at improving the quality of delivery of bakery products.

$f(x_1', \dots, x_b')$ ,  $g(x_2'', \dots, x_l'')$ ,  $\varphi(x_3''', \dots, x_d''')$  - the corresponding functions variables  $(x_1', \dots, x_b')$ ,  $(x_2'', \dots, x_l'')$ ,  $(x_3''', \dots, x_d''')$ . Their values are limited by the values  $a_i, b_i, c_j$ . If in Eq. 5 each of the functions  $h, i = \overline{1, h, m} \quad j = \overline{1, m}$  is linear, then it is advisable to find the solution by methods of linear programming.

The target function is an additive function with weighted coefficients. It describes the effectiveness of the logistics system of bread, bakery and flour products. This solves the problem of minimizing the cost of the enterprise in the distribution of goods and transport flow of environmental and economic indicators. The optimization task of organization of ecological- commodity flows of enterprises for the production of bread, bakery and flour products is that from among all acceptable plans of transportation of products from suppliers to consumers to determine the one in which the total transport costs taking into account environmental restrictions would be the smallest.

### 3. RESEARCH RESULTS

The developed model of traffic flow optimization has been tested at the enterprises of PJSC "Kyivkhlіb". Bakery products are shipped daily to the objects of the trading network of PJSC "Kyivkhlіb", namely, M1 - supermarket, M2 - mini market, M3 - small grocery stores, M4 - private kiosks from the bakery enterprises of PJSC "Kyivkhlіb" (A1, ..., A9). The costs of transporting one batch from factories to trading platforms are given in Table 1.

**Table 1.** Transportation costs for transportation of products to the trading floors of PJSC "Kyivkhlіb", US dollars

| Production site                         | Trading platforms |                |                |                |
|---|-------------------|----------------|----------------|----------------|
|   | M <sub>1</sub>    | M <sub>2</sub> | M <sub>3</sub> | M <sub>4</sub> |
| Production shop 1 (A <sub>1</sub> )     | 88.4              | 141.5          | 53.1           | 70.7           |
| Production shop 3 (A <sub>2</sub> )     | 70.7              | 106.1          | 106.1          | 88.4           |
| Production shop 4 (A <sub>3</sub> )     | 141.5             | 123.8          | 176.9          | 106.1          |
| Production shop 7-8-9 (A <sub>4</sub> ) | 106.1             | 88.4           | 70.7           | 35.4           |
| Production shop 12 (A <sub>5</sub> )    | 17.7              | 53.1           | 35.4           | 106.1          |
| Bila Tserkva Bakery (A <sub>6</sub> )   | 38.9              | 42.4           | 67.2           | 212.2          |
| Makariv Bakery (A <sub>7</sub> )        | 49.5              | 53.1           | 60.1           | 159.2          |
| Fastiv Bakery (A <sub>8</sub> )         | 70.7              | 123.8          | 53.1           | 70.7           |
| Skvyra Bakery (A <sub>9</sub> )         | 95.5              | 159.2          | 46.0           | 88.4           |

Source: own calculation

The production capacities of the bakery are, respectively: 100 (A1), 190 (A2), 160 (A3), 108 (A4), 104 (A5), 105 (A6), 174 (A7), 170 (A8) and 108 (A9) thousand units of bakery products per year. The need for trading platforms in bakery products is 290 (M1), 320 (M2), 150 (M3) and 270 (M4) thousand units, respectively. Bread is transported in batches depending on the type of vehicle - from 1400 to 2000 units. Environmental damages for the delivery of products are calculated in accordance with Directives 2009/33 / EU of the European Parliament and the Council of the EU of April 23, 2009 on the introduction of environmentally friendly and energy efficient vehicles (Table 2).

**Table 2.** Environmental damage due to transportation of products to trading floors of PJSC "Kyivkhliv", US dollars

| Production site                    | Trading platforms |       |       |       |
|------------------------------------|-------------------|-------|-------|-------|
|                                    | $M_1$             | $M_2$ | $M_3$ | $M_4$ |
| Production shop No 1 ( $A_1$ )     | 22.13             | 24.72 | 19.34 | 5.27  |
| Production shop No 3 ( $A_2$ )     | 9.76              | 11.86 | 13.31 | 12.15 |
| Production shop No 4 ( $A_3$ )     | 10.37             | 5.27  | 13.76 | 7.12  |
| Production shop No 7-8-9 ( $A_4$ ) | 10.34             | 6.72  | 8.36  | 3.81  |
| Production shop No 12 ( $A_5$ )    | 3.24              | 7.52  | 6.18  | 13.98 |
| Bila Tserkva Bakery ( $A_6$ )      | 2.17              | 3.46  | 5.86  | 13.62 |
| Makariv Bakery ( $A_7$ )           | 7.85              | 8.73  | 8.64  | 14.14 |
| Fastiv Bakery ( $A_8$ )            | 8.83              | 9.97  | 4.61  | 4.41  |
| Skvyra Bakery ( $A_9$ )            | 5.31              | 7.20  | 3.56  | 5.00  |

It should be noted that the number of suppliers of bread of PJSC "Kyivkhliv" - production plants is 9, and the number of bread consumers - trading platforms - 4. Total production capacity of suppliers is 1219 thousand units of bread, bakery and flour products, and the demand of consumers - 1030 thousand units. Consequently, the production capacity is sufficient to ensure the existing demand, that is, the task is solved.

The choice of the final optimal delivery plan is possible by the integral indicator of the efficiency of the organization of ecological and commodity flows of the bakery enterprises (5). Weights of each indicator  $\lambda_1, \lambda_2, \lambda_3$  are determined by expert evaluation. At the same time, the most significant were economic ( $k_E$ ) and environmental ( $k_D$ ) indicators of the efficiency of the logistics system, which focuses on the applied part of this study. Due to the lack of reliable statistical information on the quality and timeliness of the delivery of bakery products, the degree of consumer satisfaction, the indicator of the social efficiency of the logistic system ( $k_C$ ), which has a qualitative characteristic for the most part, has not been taken into account as part of the integrated indicator of the efficiency of the logistics system of PJSC "Kyivkhliv".

The economic-ecological mathematical model (6) will look like a system that consists of two equations with constraints

$$\left. \begin{aligned} K &= \lambda_1 \cdot k_E + \lambda_2 \cdot k_D \rightarrow \min \\ \lambda_1 + \lambda_2 &= 1 \\ k_E &= h_i(x'_1, \dots, x'_n) \leq a_i, \quad i = \overline{1, l} \\ k_D &= g_k(x''_1, \dots, x''_n) \leq b_k, \quad k = \overline{1, p} \end{aligned} \right\} \quad (6)$$

Indications unknown  $x_{ij}$  - the volume of transportation of products (in thousands of units)

from the supplier to the consumer ( $i = \overline{1, 4}$ ;  $j = \overline{1, 9}$ );  $k_E$  - total shipping costs (US dollars) corresponding to the plan for transportation of products,  $k_D$  - the total environmental damage (US dollars) corresponding to the plan of transportation of products.

Construction of an optimal delivery plan can be done separately for economic ( $k_E$ ) and environmental ( $k_D$ ) indicators. For the indicated signs and available initial data, the task model for the economic index involves minimizing the total costs of transporting bread

$$k_E = 2.5x_{11} + 4.0x_{12} + 1.5x_{13} + 2.0x_{14} + 2.0x_{21} + 3.0x_{22} + 3.0x_{23} + 2.5x_{24} + 4.0x_{31} + 3.5x_{32} + 5.0x_{33} + 3.0x_{34} + \\ + 3.0x_{41} + 2.5x_{42} + 2.0x_{43} + 1.0x_{44} + 0.5x_{51} + 1.5x_{52} + 1.0x_{53} + 3.0x_{54} + 1.1x_{61} + 1.2x_{62} + 1.9x_{63} + 6.0x_{64} + \\ + 1.4x_{71} + 1.5x_{72} + 1.7x_{73} + 4.5x_{74} + 2.0x_{81} + 3.5x_{82} + 1.5x_{83} + 2.0x_{84} + \\ + 2.7x_{91} + 4.5x_{92} + 1.3x_{93} + 2.5x_{94} \rightarrow \min$$

The model of the task for the ecological index involves minimizing the environmental costs of transporting bread

$$k_D = 0.625x_{11} + 0.698x_{12} + 0.547x_{13} + 0.149x_{14} + 0.275x_{21} + 0.335x_{22} + 0.376x_{23} + 0.343x_{24} + \\ + 0.293x_{31} + 0.148x_{32} + 0.388x_{33} + 0.201x_{34} + 0.292x_{41} + 0.190x_{42} + 0.236x_{43} + 0.107x_{44} + \\ + 0.091x_{51} + 0.212x_{52} + 0.174x_{53} + 0.395x_{54} + 0.061x_{61} + 0.097x_{62} + 0.165x_{63} + 0.385x_{64} + \\ 0.222x_{71} + 0.246x_{72} + 0.244x_{73} + 0.399x_{74} + 0.150x_{91} + 0.203x_{92} + 0.100x_{93} + 0.141x_{94} \rightarrow \min$$

for restrictions:

a) regarding the capacity of the suppliers:

$$y_i = \sum_{j=1}^9 x_{ij}, \quad i = \overline{1, 4}$$

$$0 \leq y_1 \leq 290, \quad 0 \leq y_2 \leq 320, \quad 0 \leq y_3 \leq 150, \quad 0 \leq y_4 \leq 270;$$

b) in relation to consumer demand:

$$v_j = \sum_{i=1}^4 x_{ij}, \quad j = \overline{1, 9}$$

$$v_1 = 100, \quad v_2 = 190, \quad v_3 = 160, \quad v_4 = 108, \quad v_5 = 104, \quad v_6 = 105,$$

$$v_7 = 174, \quad v_8 = 170, \quad v_9 = 108;$$

c) on the inalienability of the main variables, which show the volume of transportation on the corresponding routes:

$$x_{ij} \geq 0 \quad (i = \overline{1, 3}; j = \overline{1, 5}).$$

The model of the task for economic and environmental indicators of the efficiency of the logistics system involves minimizing the total cost of transporting bread. The transportation plans are based on the optimization results of each model in accordance with the weighting factors of the importance of economic and environmental indicators ( $\lambda_1, \lambda_2$ ), which are determined by the experts of the enterprise depending on the tasks of the enterprise. It allows you to choose a logistic scheme for delivering finished products by an integral indicator, which is calculated optimal by economic or environmental indicators, a plan or a compromise. The recommendations for optimizing the transportation plan are presented in the Table 3.

The model is suitable for the outflow of material flows (direct logistics) and the return flow – back in the supply chain (reversible logistics, or logistics of bread, bakery and flour products). It reflects the relationship between the input flow of material flows, initial economic indicators and monetary value, taking into account the influence of logistics on the main parameters of the environment.

**Table 3.** Recommendations for enterprises of PJSC "Kyivkhliv" regarding the choice of the product delivery plan

| Condition                     | $\lambda_1$ | $\lambda_2$ | Recommendation                                     | $k_E$ , US dollars | $k_D$ , US dollars | $K$ , US dollars |
|-------------------------------|-------------|-------------|--|--------------------|--------------------|------------------|
| $\lambda_1 > \lambda_2$       | (0.6; 1)    | (0; 0.4)    | Optimum on economic indicators plan                | 55.51              | 46.26              | 78.65            |
| $\lambda_1 \approx \lambda_2$ | [0.4; 0.6]  | [0.4; 0.6]  | Compromise plan                                    | 52.11              | 52.36              | 78.29            |
| $\lambda_1 < \lambda_2$       | (0; 0.4)    | (0.6; 1)    | Optimum according to environmental indicators plan | 5.13               | 5.77               | 8.02             |

The results of the analysis of the modeling of the delivery of bread, bakery and flour products show that for the delivery of bread, bakery and flour products for trading platforms in the first zone, respectively, we developed a gravitational model, it is advisable to choose a transportation plan, optimal for economic indicators. For trading areas of the third zone it is expedient to choose the optimal delivery plan for environmental indicators. Meanwhile, for trading enterprises of the second zone, the compromise plan for the delivery of bread, bakery and flour products is optimal. This approach enables the formation of a network of distribution channels for the supply of products with a minimization of costs for enterprises, consumers and harmful environmental impacts.

#### 4. DISCUSSION

This research deepens scientific developments in managing the logistics costs of enterprises, adhering to the principles of sustainable development. The findings confirm the assertion about the role of environmental factors in the management of commodity flows of enterprises E. Mishenin (2013), V. Khrutba (2014). The empirical indicators obtained as a result of scientific research confirm that the optimization of commodity flows of enterprises is a powerful reserve for reducing operating expenses, an instrument for increasing their competitiveness on the external and internal market. Of particular relevance, the results of this study are acquired for medium and small enterprises of the bakery industry, which have important social and economic significance.

In the study, the authors proposed a methodological approach and provided arguments for the construction of an integrated indicator of estimation and modeling of commodity flows of enterprises taking into account economic and environmental factors. This allows us to apply a comprehensive system approach that will link optimization of commodity flows, reduce anthropogenic environmental impact, and increase corporate social responsibility of enterprises.

It is proved that the following indicators should be taken into account for the estimation of the efficiency of commodity flows: the volume and value of goods, the number and composition of vehicles, the complexity and cost of delivery, the environmental damage caused by the environment during the delivery of goods, the environmental friendliness of transport. Their inclusion allows us to identify new essential features of the objects under study, which were formed under conditions of national economy. A sequence of procedures for the optimization of commodity flows of enterprises in the bakery industry has been developed, which can become the basis for automation of logistic processes of enterprises, formation of providing of internal financial reporting of strategic and operational management.

Empirical evidence is presented regarding the feasibility of constructing a model for optimizing the commodity flow through the integral criterion of economic, environmental and social efficiency. The economic effect of logistics management is to reduce the specific aggregate costs associated

with the movement of goods, the time of deliveries and ensuring their reliability. The ecological effect is the reduction of the specific combined effects on the environment, the reduction of the "ecological footprint" of the enterprise, the provision of resources and energy conservation. Practical application of the developed model at the enterprises of the bakery industry will reduce the logistics costs, improve the quality of delivery of products and raw materials, and increase the efficiency of product flow management.

## CONCLUSION

Optimization of logistic systems of socially important industries, including baking, on the principles of "green" logistics requires the use of modern economic and mathematical methods of modeling. The solution to the problem of reducing the transport costs of bakery enterprises with the simultaneous reduction of their human impact on the environment contributes to the development of methodological principles for optimizing the logistic goods and transport flows of enterprises taking into account the impact of economic and environmental factors.

For modeling of commodity flows, the method of linear programming with the adaptation of the transport problem to the characteristics of the bakery industry is used. The optimization model of the transport flow of delivery of the enterprises of the bakery industry is based on the criteria of the efficiency of the commodity flow, which includes indicators of economic and environmental assessment. Taking into account the specifics of the supply of raw materials and finished products, as well as stringent sanitary and hygienic requirements for their transportation, the optimization model of the transport flow of food industry enterprises takes into account the influence of the following factors: economic - the volume of commodity products and their cost, the number of vehicles for delivery of goods, the cost of delivery of products, the number of employees involved in delivery and the complexity of their work; ecological - quantitative indicators of the emission of substances into the atmosphere during the transportation of products, waste and their recycling.

The proposed model for the formation of commodity flows of enterprises in the bakery industry is based on the evaluation of their efficiency, the mathematical expression of which is an additive function with weight coefficients of indicators of ecological, economic and social efficiency. Such a model is suitable for optimizing both the source flow of material flows (direct logistics) and the return flow - back in the supply chain (reversible logistics, or logistics of bread, bakery and flour products). It reflects the relationship between the input flow of material flows, the initial economic indicators, taking into account the influence of logistics on the main parameters of the environment.

The economic effect of the application of the developed model of formation of commodity flows of enterprises is the reduction of specific aggregate expenses for movement of goods, time of deliveries and ensuring their reliability commodity. It is advisable to reduce the specific combined environmental impacts, reduce the "ecological footprint" of the enterprise, provide resource and energy saving to the ecological effect. The implementation of the proposed methodological provisions will welcome the optimization of commodity flows of bakery enterprises and other industries on the ecological and economic basis, sustainable development of the economy.

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