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THE EFFICIENCY OF FOOD SUPPLY CHAIN ENGINEERING (CASE STUDY IN UKRAINE)

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Abstract:

The basic conceptual idea of logistics is the need to adapt the company to an ever-changing market situation, while spending a minimum of funds in these conditions. The concept of logistics is a system of views on the rationalization of economic activity by optimizing material flows. The paper investigates the change of the main indicators of the functioning of the supply chain, depending on the organization of distribution of the material flow. The supply systems of food products that form the consumer basket at the stage of distribution is considered. The conceptual schemes of freight flow distribution with and without distribution center is presented. The field research was conducted to determine and initial data were collected. The paper investigate the functioning of the supply chain in two cases: in a situation "proposed scenario" and in a situation "without a project". The situation "existing scenario" implies that no action to change the parameters of the supply chain during the period specified for the research does not take place. In this case, it is necessary to assess the effectiveness of the logistics chain under existing conditions. An integrated approach to evaluate the efficiency of the functioning of the logistics system and the consumer had been used. The efficiency of existing of the supply chain functioning were analysed. Also, certain measures will be implemented to improve the chain through investments and by bringing logistics infrastructure with the needs. A modelling of the supply chain was made. The effect of parameters of participants on the supply chain efficiency was analysed. The planned effect from the reorganization of distribution channels is calculated. The technological and economic feasibility of introducing a distribution center into the existing distribution channel based on modeling is calculated. The object of the research is the process of food products distribution in the supply chain. The aim of the research is to evaluate the effectiveness of the food supply chain scheme.

Keywords: *material flow, direct, channel, multilevel, supply chain, net present value*

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1. Introduction

Delivering products to the consumption sphere is one of the important trade functions that take place in commercial companies. Rational management of these processes plays an important role in the distribution of goods (Gajewska, Zimon, 2018). A logistics tools affect the choice of delivery mechanism distribution. At the current stage of development of the state's economy, the ability of one or another subject of enterprise activity to compete with national and foreign similar enterprises takes great significance. Therefore, an increasingly widespread application in practice is acquiring a logistics approach to organizing the supply chains operations, which, based on principles such as consistency, flexibility, rhythm, allows for the maximum reduction of expenses in the activities of economic entities (Chortok, Rodymchenko, 2014).

The supply chain is a system that has unique structure and links of interaction inside of system. The supply chain management considered in the form of an isosceles triangle, which represent three interconnected vertices (Lambert, Stock, Ellram, Grant, 2006):

– chain structure;
– business processes occurring in the chain;
– components of chain management.

Formation of supply chain structure means, the choice of structure option, the choice of participants at each level of the chain and the formation or adjustment of the service standards they have implemented (Almetova, Shepelev, Shepelev, 2016; Makarova, et. al., 2020). Generation of business processes of the participants in the supply chain, in turn, is the development or selection and adaptation of the logistics concept and technology that ensures the implementation of the stated standard of service (Soinio, Tanskanen, Finne, 2012). Management components formation is the creation of a supply chain controlling system (Meredith, Shafer, Mantel Jr, 2017). Simultaneously, the supply chain performs a number of functions, which also adapt to its structure. Due to this their number may vary.

Performance indicators are the most important ways to determine the quality of a supply chain. To improve them, scientists analyse each component of system, as its feature is the presence of interconnection and interdependence between its constituent elements. In this case, their changes will lead to changes in the total effect of the operations (Caputo, Mininno, 1996).

Therefore, one can distinguish traditional, vertical, horizontal and combined distribution channels (Gellynck, Kühne, 2010). Systems are often developed to match the capabilities and requirements of certain markets, mainly on the basis of internal factors and the intentions of the company (Anderson, Day, Rangan, 1997): the financial condition, stage of life cycle of the company and product.

Selection of channel directly effects speed, time, distribution efficiency and security of products during delivery from the vendor to the end-consumer (Kulińska, 2012). Specificity of modern supply channel functioning are they irregularity and seasonality due to different reasons. It gives negative effect on all supply chain processes. Thus, a variety of approaches can be used to assess the degree of efficiency, effectiveness and compliance with the expected value of interconnected and interdependent process (Mańka, Mańka, 2016). At the same time, the methods of engineering analysis using investment performance indicators are poorly assessed in the engineering of supply chain. Investment analysis of projects will solve the problem of reorganization of supply chain in the long term considering the value of money over time (Sanchez, Robert, 2010). In fact, the methods and patterns of the efficiency of distribution of freight flows and engineering decision selection are require further consideration.

The object of the research is the process of food products distribution in the supply chain.

The aim of the research is to evaluate the effectiveness of the food supply chain scheme.

To achieve the aim, the following tasks were solved:

– selecting method of research
– to analyse the process of distribution food products at supply chain;
– to investigate the project variant and it's technological changes of proposed supply chain.
– estimate the investment indicators of the supply chain patterns: existing and proposed;
– to evaluate the effectiveness of the process of distribution food products in the supply chain.

2. References review

2.1. Methods of logistics systems engineering

The process of supply chain engineering is necessary to create new and improve existing business entities, but there is no single perfect in any situation

method of evaluating alternatives. The general scheme of analysis and engineering of supply chain is presented at fig. 1.

In this process, the authors distinguish three stages (Krykavskyy, Mashchak, 2017):

1) Identifying problems and drafting a project;
2) Data collection and analysis;
3) Recommendations for project implementation.

According to the content of these steps is as follows: The task of the first stage is to identify problems through the assessment of technical and economic opportunities and planning ways for further development. It also defines the goals and limitations of the system, the criteria for the effectiveness of options, choose the method of analysis and preparation of the project task. A situational analysis of the current operating conditions is made on this stage. A conceptual scheme of possible supply chain projects is established, potential benefits are outlined, and a project task is developed. Situational analysis involves the study of internal activities of companies, assessment of the market and the competitive environment (external environment) and technological analysis. Internal analysis is a complete self-assessment, which includes in the supply chain of the enterprise and organization and covers all major types of resources: labour, equipment, economic capacity, organizational relationships and information. In particular, all the opportunities and shortcomings of the existing working conditions are assessed. The purpose of internal analysis is to identify areas where there is room for significant improvement (Halkin, et. al., 2017). The analysis of external factors is aimed at determining trends in market demand and request from the activities of the supply chain (Halkin, 2020). The assessment of external factors should include an analysis of demand trends, as well as a description of the market opportunities of the company and its competitors.

Technological analysis (Żak, Hadas, Rossi, 2017) is designed to assess the existing and potential capabilities of key technologies: transportation, warehousing, cargo handling, packaging, information support, etc. The task of technological analysis is to identify promising areas for technology improvement, which can achieve more efficient use of logistics resources (eg, transport, stocks). After compiling possible models of the supply chain, a potential assessment of the potential benefits of each design option is carried out. The benefits are usually expressed in the improvement of service, reduction and elimination of unnecessary costs. Improving service or lowering the price helps to strengthen the loyalty of existing customers and attract new customers. Expenses reduction is possible in two ways. The first is a one-time reduction in the financial or managerial resources required to operate the supply chain. The second option is to reduce variable component. The result of the analysis is the formation of existing methods and approaches to this chain engineering by the authors with the definition of the content of each approach.

Supply chain engineering, distinguishes three main stages (Goetschalckx, 2011): system analysis (identification); system formation; system implementation. An algorithm for identifying, forming and implementing a logistics system at the enterprise was described:

1) Analysis of logistical situations and the challenges and determinants of the system;
2) Development of logistics system;
3) Linking the logistics system and subsystems with other subsystems in the enterprise;
4) Implementation of the system.

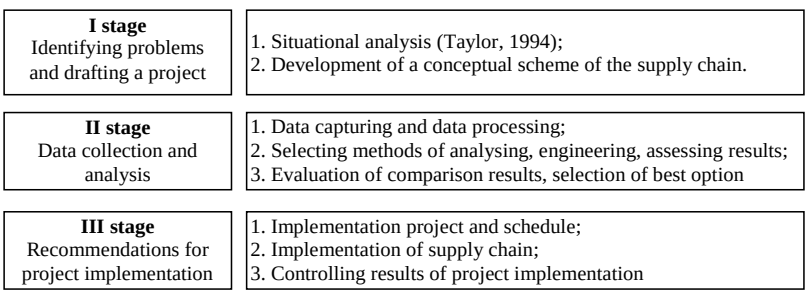

Fig.1. The stages of supply chain engineering (Krykavskyy, Mashchak, 2017)

The author also proposes the stages of system design (Sarkis, 2003):
1) Development of information engineering;
2) Structuring the supply chain;
3) Choice of conceptual framework of supply chain;
4) Development of conceptual framework of supply chain;
5) Project planning;
6) Implementation of the project.

It is proposed to divide all methods into three large groups (Agarwal, Shankar, 2002):
1) Heuristic methods based on experience of specialists: brainstorming; synetics; method of control questions; method of morphological analysis; cognitive map.
2) Methods of gradual tasks formalization: expert assessments; simulation.
3) Formalized methods of systems representation: functional-cost analysis; network planning; probability theory.

It is proposed to consider the following stages: identifying problems and planning ways to overcome them; data collection and analysis; recommendations development and project implementation plan (Dolgui, Proth, 2010). The authors consider two main engineering methods:
1) Program Evaluation And Review Technique – PERT is based on the presentation of the process in the form of a grid schedule, in which all tasks (operating) are in the order of their execution (Aziz, 2014).
2) Modelling, this includes a computer model and a series of mathematical dependencies, often expressed by a system of linear equations. The probability of modelling is provided at the maximum approximation of the model to reality (Zhong, Zhang, 2003).

The application of the algorithm for logistics systems engineering (Haralambides, Londoño-Kent, 2004): definition of goals and formalization of tasks, their achievement; choice of strategy and formation of conceptual framework; determination of system boundaries and limitation, scope, structure of functional activity and search area; information support on potential needs, technology, production, current factors, nature of material and other flow processes, etc.; data processing to identify communication and other types of connections in logistics systems; identification of hopeless situations, "bottlenecks" and shortcomings in the current economic system; forecasting and additional collection of information; development of alternative models; evaluation of the developed variants of models in order to choose the most effective; detailed development of the best version of the model.

To solve supply engineering tasks need a large amount of information (Sternad, Skrucany, Jereb, 2018). The complexity is due to the fact that the value of total logistics costs is influenced by a wide range of factors, and the decision has to choose from many alternatives. A large array of data is required to evaluate logistical alternatives. Typical analysis of information should include alternative forms of service, cost characteristics, technology. Analysis aimed at solving logistical problems requires careful structuring and selection of the most appropriate research methods. General scheme of the research process used for analysis and design of most logistics systems.

Modern theoretical and methodological approaches to engineering supply chains are marked by significant shortcomings, including the use of only normative methods, mechanical transfer of some organizational forms to other conditions, narrow interpretation of factors forming organizational structures, functional orientation, strict regulation and others. The presence of these shortcomings necessitates research aimed at the engineering modelling of logistics process with invest indicators modelling and practical cases. Moreover, there are existing scientific developments not enough to dramatically improve the situation with methodological support of the management process projects in logistics, which would be taken into consideration features of logistics infrastructure, such as distribution centers.

2.2. Modelling distribution system

To study the operating of the supply chain, it is necessary to determine the boundaries, participants and their links and interaction. This paper considers the logistics chain at the stage of distribution, which is formed by independent market participants of pure competition: the wholesaler, retailers and the transport participant in the area of the wholesaler - retail network. Transport service is carried out by road. The supply chain is formed by independent participants of the market of pure competition at the distribution stage, namely: Vendor, wholesaler, retailers and transport operator on section: Vendor - wholesaler and wholesaler - retail chain. The

engineering models of the functioning of the participants and the supply chain reflect the transport-technological and economic features of their interaction, consider the tax component and the conditions for attracting financial resources (Kucera, 2019). To study the current state of the supply chain, it is necessary to build a mathematical model of its operation, which is based on the methodology of project analysis.

As a criterion for evaluating the key performance indicators of the supply chain proposed net present value (NPV), which characterizes the excess of total expenses in the supply chain (Tavassoli, Faramarzi & Saen, 2015; Kush, et. al., 2018). Since it is planned to use the methodology of project analysis when building a model of the supply chain, the choice of efficiency criteria should be made among the main criteria of commercial efficiency of investment projects. For the conditions of the system under consideration, the most adequate indicator can be considered the indicator of net present value. This figure is absolute, characterizing the excess of total cash inflows over total project costs - NPV (Galkin, 2017):

$$NPV_{sys} = F(NPV_{tpm}, NPV_{dc}, NPV_{tpdc}, NPV_r) \to \max, \quad (1)$$

where $NPV_{tpm}, NPV_{dc}, NPV_{tpdc}, NPV_r$ – respectively, the net present value of the all participant of distribution channel, UAH.

An analysis of the existing state of sites is carried out using a model that is based on the determination of a net cash flow (Halkin, et. al, 2016):

$$NPV_{sys} = \sum_{t=1}^{k} \frac{NCF_{sys}}{(1+i)^t}, \quad (2)$$

where NCF_{sys} – net cash flow at selected intervals of the total calculation period *t*; *i* – discount rate; *k* – total calculation period.

The paper investigate the functioning of the supply chain in two cases: in a situation "with a project" and in a situation "without a project". The situation "without a project" implies no action to change the parameters of the supply chain during the period specified for the study does not take place. In this case, it is necessary to assess the effectiveness of the logistics chain under existing conditions.

The situation "with the project" involves changes in certain parameters of any of the participants in the chain, which will have an impact on the technology of their operations. Improving the efficiency of the considering system is expected due to the investment and organizational component, therefore all the proposed measures should be reflected in the form of investment, or changes in current operating costs of chain participants.

In the general case, net cash flow is defined as the difference between all cash inflows during the project and all types of their costs. Taking into account the peculiarities of the formation of income and expenditure parts of each participant of the studied system, we note that the methods of calculating the net cash flow for each participant will be slightly different. Investment costs within this study are investments in the project of each participant. The discount rate is conditionally accepted at the level of 10 percent.

The total calculation period depends on many factors, and for each project is determined individually. The analysis of literature sources on this issue made it possible to establish the average age of a supply chain, which are similar to the study, without significant changes. This period is 3-5 years (based on Kush Ye. et. al., 2020; Galkin, 2017). According to this conclusion, the service life of the project of the studied system is proposed to be equal to 5 years.

On the basis of the constructed mathematical model of functioning of a supply chain in these section questions of research of system effect of system and its components, definition of tendencies and laws of work of transport and warehouse participants of investigated system are considered.

The values of the factors of the mathematical model of a supply chain were established through surveys of experts working in the field of distribution of consumer goods. Microsoft's Excel software product was used to automate the calculations of the model indicators. Automation of calculations allows to determine the value of the criterion of efficiency of the system and its individual participants, as well as to monitor other parameters of the model.

The number of intermediate levels between the producer and the end-consumer characterizes distribution channels of goods. In fact, they consist of independent participants are mutually collaborating. Each participant is a separate unit that seeks to secure their own maximum profit. This approach contradicts the system approach, since none of the channel participants has full or sufficient control over the

activities of the rest of the participants. Fig. 2 presents the conceptual schemes of freight flow distribution, which will be considered in the paper.

Analysing of fig. 2 allocate two technologies of freight distribution scheme:

1)Without the use of a Distribution Center (existing scenario).

2)Using the Distribution Center in the distribution scheme - proposed scenario.

Let us describe the participants of the distribution schemes:

– Retail Network: retailers, hotels, restaurants and catering, etc .; their choice is related to replenishment (frequency and size of delivery); their main interest is to receive the cargo at the lowest price;

– Transport and Logistics Operators: they are formed by independent participants of the market of pure competition: the distribution center, the transport operator providing transportation of freights on sites:

1) The Vendors – the Retail Network and the Distribution Center – the retail network;

2) The Vendors – the Distribution Center. It is considered that the section «The Vendors – Distribution Center» is served by heavy vehicles, and the remaining sections are «The Vendors – Retail Network» and «Distribution Center – Retail Network».

According to (Litomin, Tolmachov, Galkin, 2016; Taylor, 1994), the main purpose of using the services of intermediaries - to expand markets for goods and reduce expenses. In cases of territorial "scattering" of the market of goods, according to (Shepelev, et. al., 2018), the company - the vendor may be inefficient to supply material flow through direct links with consumers, due to significant expenses for the sale of its products. In such cases, distribution centers can be used. The distribution center, accumulates incoming goods of different nomenclature, sells them, receiving part of the profits from joint sales. As a result of such organization of sales of goods, suppliers are able to sell their products to a wider range of consumers. Logistics channels for a single material flow delivered to different regions may be own. The possibility of the existence of several distribution channels simultaneously raises the issue of the synergistic effect in their maintenance. Maintenance of several logistics channels will allow to use vehicles more efficiently and to share fixed expenses: drivers' salaries, overhead expenses, vehicle repair and maintenance expenses, credit expenses between all logistics channels. Products from vendors arrive at the territorial logistics center, where they are either distributed through the retail network, or remain for short-term storage until the demand. This organization of delivery allows the retail chain to reduce the cost of product delivery by coordinating the actions of all retailers. All products are assembled at a distribution center owned by the vendors and located in the region of production. It coordinates and distributes products to consumers in the region. However, it often happens that the vendor itself participates in the sale of its products to the end-consumer. Transportation can be carried out both by the vendor (or its subsidiaries) and retailers independently or with the involvement of third parties.

3. Results

3.1. Research of the distribution system

The object under consideration is a retailer. The supermarket, located in Kharkiv, is part of a retail chain consisting of five supermarkets in Kharkiv. In this paper, it is proposed to consider not a supermarket as an independent entity, but a part of the chain, the initial link of which is Vendors. Freight flows in individual areas relative to the object being examined, are depicted in Figure 3. In this case, two separate sections of the existing system within the city are being investigated, namely the «Distribution center» in Kharkiv (Ukraine) – Limited Liability Company «Rost» and Vendor of groccery (manufacturer) in Kharkiv (Figure 4).

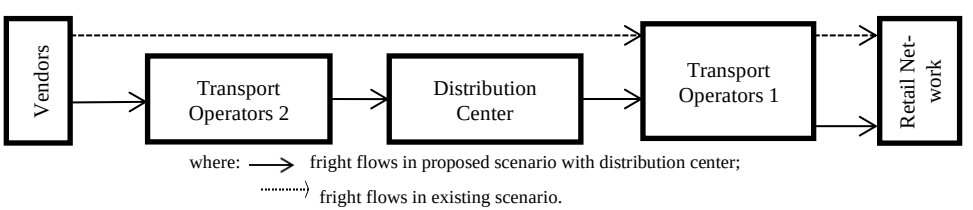

Fig. 2. Schemes of freight flow promotion

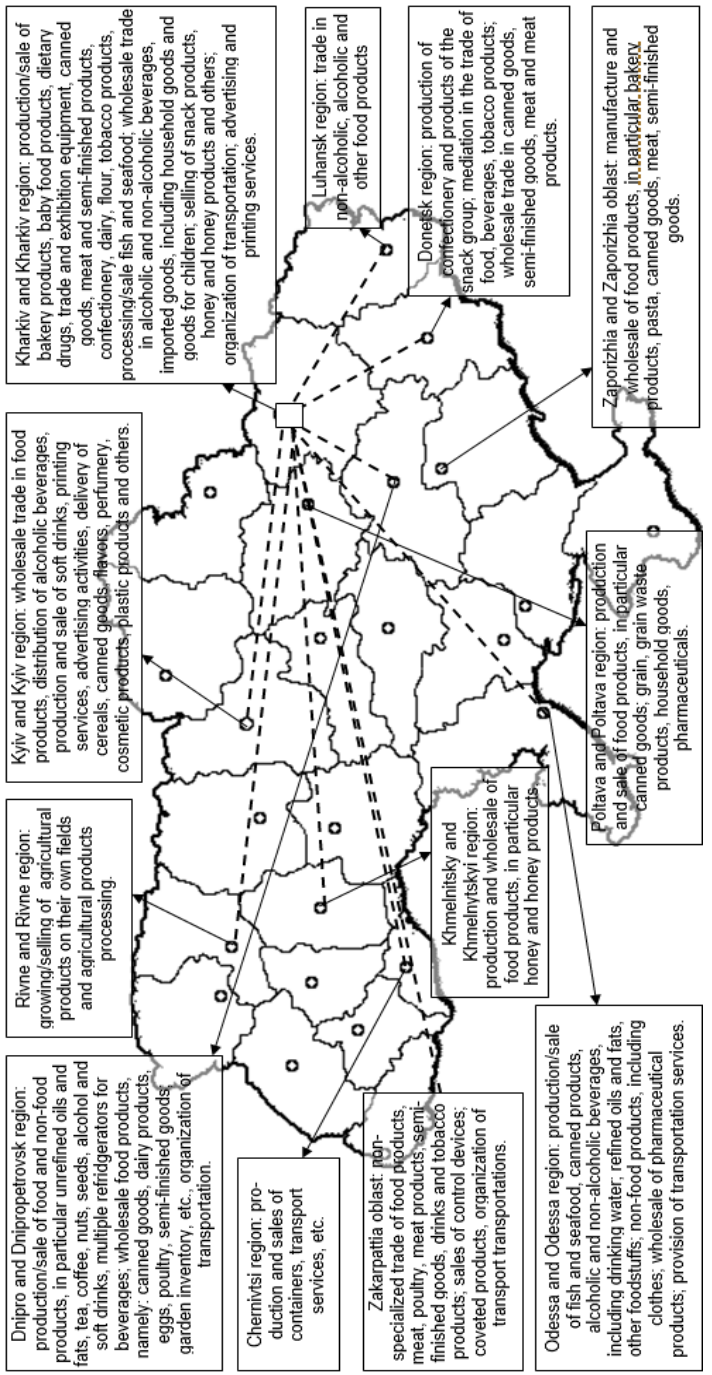

Fig. 3. Existing organized of supply chain (Kush Ye. et. al., 2020)

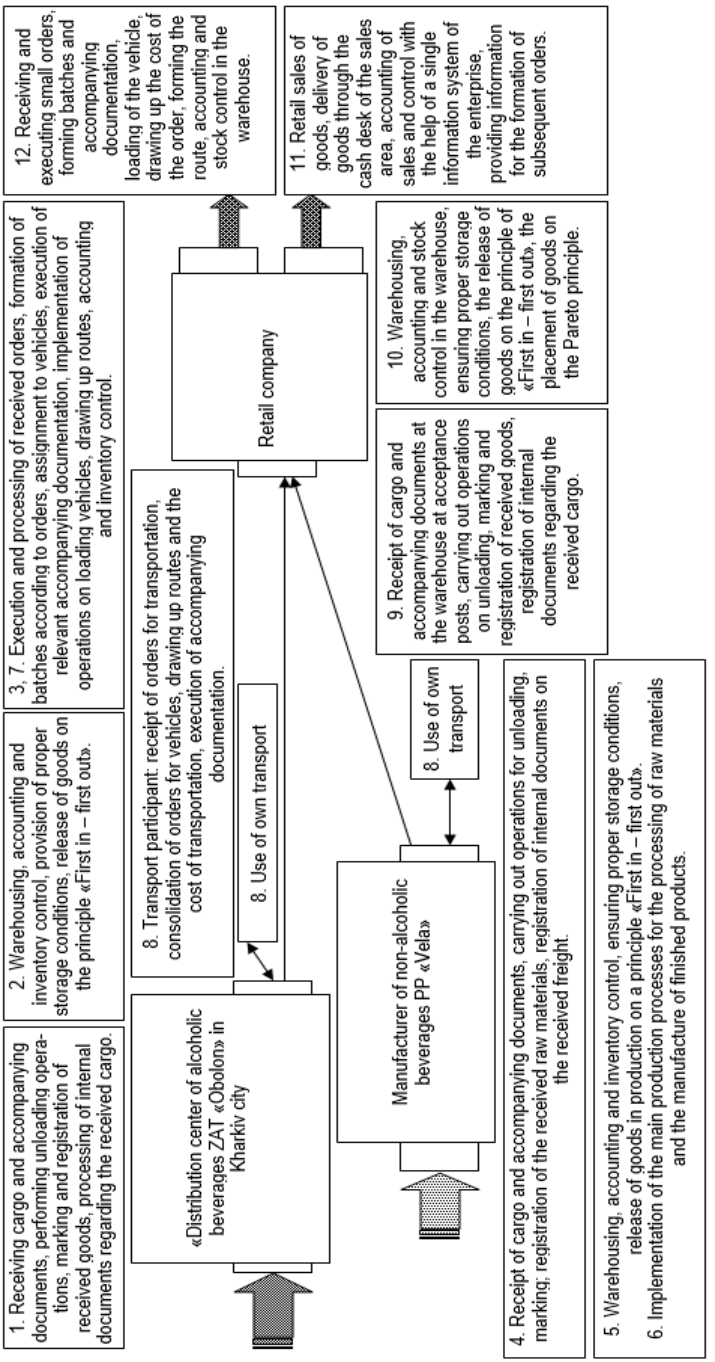

Fig. 4. Description of the distribution of products flows (Kush Ye., 2020)

The total area of the supermarket, including the parking area, is approximately 10,000 square meters. The total area set aside for construction is approximately 5,000 square meters. The area of the supermarket premises, including the administrative building, warehouses, is approximately 8,500 square meters. The supermarket is essentially a warehouse-store, most of all products are stored directly in the premises of the trading hall, the rest - in warehouses. It was obtained according economic-planning department and logistics department of considering supply chain.

3.2. Modelling distribution system operations

The technology of each participant's operation and the expenses associated with its implementation are determined by certain parameters. Among the many factors that determine the formation of benefits and costs of work in the system under study, personal attention requires a factor such as the volume of material flow.

The models of distribution of martials flows which characterize technologies of operating in supply chain «The Vendors – Transport operator 2 – Distribution center – Transport operator 1 – Retail network» is present in table 2.

The process of freight management is based on the processing of information (technological, technical, economic), ie a set of different information about the operation of objects that can be recorded, transmitted, converted and used to implement management functions such as planning, accounting, analysis, regulation and others. When solving various logistics tasks for freight management, it is important to systematically evaluate the obtained results (information) within the entire logistics chain. Given that the volume of traffic is directly related to the volume of material flow, we determine the value of the latter in the calculation horizon.

The technological process of transport operation at the site of the distribution center - retail network is significantly different from the technology of transport at the site of the manufacturer - the distribution center. Accordingly, the characteristics of vehicles used in these areas also differ. Averaging the data obtained during surveys of transport companies providing cargo transportation services in Kharkiv.

Table 1. Scheme of costs of participants in the supply chain for the existing organization of the system

№	Name of factor	Units of measurements	Value
1	The average value of the daily sales volume of the enterprise of production is 1 (distribution center)	tonn	0,08
2	The average value of the daily sales volume of the enterprise products - 2 (manufacturer)	tonn	0,048
3	Proportion of products - 1 (distribution center), which is considered, in the total sales of products by the enterprise	%	0,075
4	The share of production - 2 (manufacturer), which is considered, in the total sales of products by the enterprise	%	0,029
5	The value of the area's retail network storage	m^2	425
6	The value of space by retail chain	m^2	6050
7	The average height of storage space among members of the retail network	m	5,5
8	The average value of the bulk cargo	ton/ m^3	0,7
9	Number of days a retailer works in a month	unit	30
10	Average markup for retailer products	%	34
11	The average markup on the products of the distribution center	%	40
12	Average cost of production of one tonne of material flow 1 (distribution center) at manufacturer's selling price	UAH	3600
13	Average cost of production of one ton of material flow 2 (manufacturer) at the manufacturer's selling price	UAH	3200
14	The total number of staff required for a retail network participant, as required by the approved staffing schedule	units	483
15	Average monthly salary per unit of retailer's staff according to staffing	UAH	11960
16	Rate of deductions for repair and maintenance of equipment and maintenance of premises of the retail participant	%	2
17	Income tax rate	%	25
18	Value added tax rate	%	20
19	Discount rate, to adjust net cash flow	%	17

Table 2. Modelling distribution system operations

Name of characteristics	Equation	
Loading time of single vehicle in the distribution center warehouse	$t_n^{рц} = \frac{\frac{\overline{Q}_{пк} \cdot n_э}{q_{n1}^{DC} \cdot \gamma_{c1}^{DC}} \cdot T_ц^{DC-RN}}{X_{n1n}^{DC-RN}} + k_{пзр}$	(3)
The maximum daily demand of freight flow in the section «Distribution Center – Retail Network»	$Q_d^{DC-RN} = N_p^м \cdot \overline{Q}_{пк}$	(4)
The number of loaders in the distribution center	$X_n^{DC-RN} = CEILING\left(\frac{k_{дoб} \cdot N_p^м \cdot \overline{Q}_{пк} \cdot T_{cl}^{DC-RN}}{T_{рп}^{DC} \cdot q_{n1}^{DC} \cdot \gamma_{c1}^{DC} \cdot k_{вн}}\right)$	(5)
The required number of loading bays for the Distribution Center	$X_{n1n}^{DC-RN} = \frac{X_n^{DC-RN}}{N_{bay}^{DC-RN}}$	(6)
Downtime under unloading when servicing the Retail Network	$t_p^{RN} = \overline{Q}_{пк} \cdot n_э \cdot \bar{t}_{рр}$	(7)
The required number of vehicles is determined as follows	$A_c^{mc} = CEILING\left(\frac{k_{дoб} \cdot N_p^м \cdot \overline{Q}_{пк}}{n_{cl}^d \cdot q_н \cdot \gamma_c^{TO}}\right)$	(8)
The maximum possible number of operating circles per day of single vehicle	$n_{об}^d = INT\left(\frac{T_p^{TO}}{\overline{T}_{cl}^{TO}}\right)$	(9)
The required number of loaders in the area "Vendor - Distribution Center"	$X_n^{V-DC} = INT\left(\frac{\overline{Q_м} \cdot T_{cl}^{V-DC}}{n_{bay}^V \cdot T_p^{DC} \cdot q_{п2}^{DC} \cdot \gamma_{c2}^{DC} \cdot k_{вн}}\right)$	(10)
Required number of loading bays for The Distribution Center in the area «Vendor – Distribution Center»	$N_{bay}^{V-DC} = INT\left(\frac{X_n^{V-DC}}{X_м^{DC}}\right)$	(11)
The number of loaders in the Distribution Center at the service area of the retail network	$X_{n1n}^{V-DC} = \frac{X_n^{V-DC}}{N_{bay}^{V-DC}}$	(12)
The required area of the Distribution Center	$S_{DC} = INT\left(\frac{R^{DC} \cdot k_{кр}}{f_1 \cdot z}\right)$	(13)
The monthly need for the number of storage spaces in the racks for the distribution center	$R^{DC} = INT\left(\frac{\overline{Q}_м \cdot k_{сэ}^{DC}}{n_{bay}^V \cdot \overline{m}_{во}}\right)$	(14)
Number of drivers working in the distribution center	$N_{imp}^{DC} = INT\left(2 + Q_м \cdot K_{imp}^{DC}\right)$	(15)

where:

$\overline{Q}_{пк}$ - average amount of delivery to the participant of retail network, t;

q_{n1}^{DC} - nominal load capacity of the loader in the Distribution Center at the service area of the retail network, t;

γ_{c1}^{DC} - utilization factor of loading capacity of a loader in A Distribution Center at a retail network service site;

$T_ц^{DC-RN}$ - loader cycle time In The Distribution Center warehouse at the retail network service area, hours;

X_{n1n}^{DC-RN} - the number of loaders in The Distribution Center at the service area of the Retail Network,

which simultaneously serve single load bay, units;

$k_{пзр}$ - constant, taking into account the time spent on preparatory and final operating during loading and unloading, h.

T_{pn}^{DC} - operation time of the Distribution Center per day, h.;

$k_{вп}$ - factor of use operation time hours per shift;

k_d - factor that characterizes the maximum possible amount of participants whose needs must be met within a day.

$X_{м}^{DC}$ - the maximum possible amount of loaders serving single bay of the Distribution Center, units.

$\bar{t}_{pp}$ - average time for unloading 1 ton of piece cargo, h;

$n_э$ - number participants of retail network, un.;

n_{cl}^{d} - the maximum possible number of operating circles per day, units

T_{p}^{mc} - service time of the section «Distribution center – Retail network», h.

$k_{сз}^{DC}$ - factor that takes into account the share of insurance stock in the total storage in the Distribution Center;

$\overline{m}_{вo}$ - average weight of a cargo unit, t;

n_{bay}^{V} - monthly number of deliveries made by the Vendor, units.

$k_{кр}$ - factor considering the amount of operation on picking at the distribution center;

f_1 - specific quantity of pallets placed on 1 sq.m. storage space, taking into consideration the aisles when stored in one tier in height;

z - number of storage tiers by height, units.

K_{imp}^{DC} - factor characterizing the dependence of the number of engineering and technical workers on the monthly demand of the distribution center.

According to the obtained results, the proposed changes provide for the introduction to the warehouse distribution center of 1 loader on the service area of Vendor and 118 additional storage places in the racks; 1 additional car to the transport operator on the section «Distribution center – Retail network».

Table 3. Modelling Capital investments, Barrow Capital and Taxes of supply chain engineering project

Capital investments		
Capital investment for transport operator	$K_0^{TO} = K_{const}^{TO} \cdot A_{сн} + (A_{сн}^{TO} \cdot P_c) \cdot (1 - H_{vat}^{'}) \cdot \alpha_{ob}$	(16)
The cost of purchasing new vehicles	$K_з^{TO} = A_{сн}^{TO} \cdot P_c$	(17)
The capital investment for the rack in the distribution center	$K_r^{DC} = R_н^{DC} \cdot g \cdot K_m$	(18)
The capital investment for the pallets in the distribution center	$K_{pallet}^{DC} = f_p \cdot R_н^{DC} \cdot P_{pallet}$	(19)
The capital investment for the loaders in the distribution center	$K_{load}^{DC} = X_{нн}^{DC} \cdot P_{load}^{DC}$	(20)
Barrow Capital		
Payments on borrowed capital	$P_t = P_{body\_t} + P_{\%t}$	(21)
The amount of payments of the loan body	$P_{body\_t} = K_b / m$	(22)
The annual interest rate for the use of credit	$P_{\%t} = \dfrac{K_b \cdot I_p}{m}$	(23)
Taxes		
The value added tax	$H_{vat-t} = (D_t - U_{pt} - U_{nnt} - U_{at} - k_{зг} \cdot U_{згt} - P_{body\_t}) \cdot H_{vat}^{'}$	(24)
The book value of equipment in accordance with the group of fixed assets	$BV_{об} = DV_{\text{int}}^{i} + K_p \cdot (1 - H_{VAT}^{'})$	(25)
The income submitted for taxation	$П_{ont} = D_t - U_t - H_{vat\_t} - A_t - P_{\%t} - K_0^{mc}$	(26)

where:

K_{const}^{TO} - permanent component of costs associated with the registration of vehicles, UAH;

$A_{cн}^{TO}$ - required number of vehicles, units;

$P_c^{'}$ - purchase cost of single vehicle, UAH;

$H_{vat}^{'}$ - the value that determines the part of VAT in the total value of purchased values;

α_{ob} - interest rate, taking into account the cost of banking operations in the registration of vehicles, %.

$R_н^{DC}$ - required number of storage places in racks in the warehouse of the distribution center, units;

g - metal consumption of racks per one cargo unit, t;

K_m - cost of metal structures of racks, UAH/t.

f_p - factor that takes into account the reserve of pallets in delivery turnover;

P_{pallet}^{Dx} - the cost of single pallet, UAH.

$X_{пн}^{DC}$ - the required number of loaders in the distribution center at the service area of Vendor, units;

P_{load}^{Dc} - the cost of single loader, taking into account the cost of delivery at the service area of Vendor, UAH.

P_{body_t} - the amount of payments of the loan body in the period, UAH;

$P_{\%t}$ - the amount of interest payments for the use of credit funds, UAH.

K_b - the amount of borrowed capital, UAH;

m - term for which the funds are borrowed;

I_p - annual interest rate for the use of credit, %;

BV_{int} - initial book value, UAH;

K_p - size of investments of the participant of the supply chain, UAH.

Deciding on the choice of route traffic demands from the driver of comparison options, based on the experience of management, psycho-physiological state, personality characteristics. Conducted research showed that the probability of selecting the *i*-th route driver for transportation can be formalized as follows:

$$Ver_i = f(V_i/V_{krat}, L_i/L_{krat}), \quad (27)$$

where V_i/V_{krat} – the ratio of the speed of movement along the i-th route to the speed of movement along the shortest route; L_i/L_{krat} – the ratio of the length of the *i*-th route to the length of the shortest route.

Investments in the distribution center in this case are directed to the racking system and pallets and loading posts. The proposed measures are reflected in the change of technology of interaction with other participants in the logistics chain and in capital expenditures. The implementation of the proposed measures will lead to a change in certain technological parameters, which are compared with the situation that existed from the beginning. To analyse the economic efficiency of the proposed measures, we make appropriate changes to the mathematical model of the supply chain.

3.3 Comparison scheme of distribution

The collaborative approach allows its participants to gain more profit, operate based on equal partnership and in a high degree of trust, delegate powers and delegate responsibilities, co-solve problems, and focus their attention and strength not on their own operations, but on existing and potential consumers. In this case, the terms of contracts are more flexible. In this case, the horizontal collaboration of two separate supply chains, which are considered in the second section of the research, is examined. Thus, the following scheme is proposed for organizing the movement of material flows (Figure 6) in comparison with the existing one (Figure 5).

The terms of such an organization are the change in the direction of the material flow distribution, which will cause the corresponding changes in the main operational and economic indicators in the efforts of participants. Other source data remain unchanged. Thus, the total damand of products serviced by the latter is increased by 431.8 tons and is 1280.8 tons.

Determination of the main key performance indicators for the retail participant, distribution center and transport operator in the section «Distribution center – Retail network» is carried out according to the model presented in section 3.2 of the operating, considering the following changes: retail network consists of 304 participants; average amount of delivery to one participant – 2.1 tons, the total amount of products sold by the distribution center per month – 1280.8 tons. The average amount of deliveries to single participant per month remains unchanged

Table 4 shows the calculated by formulas (3) - (15) performance indicators of the distribution center and the transport participant in the area «Distribution center - Retail network».

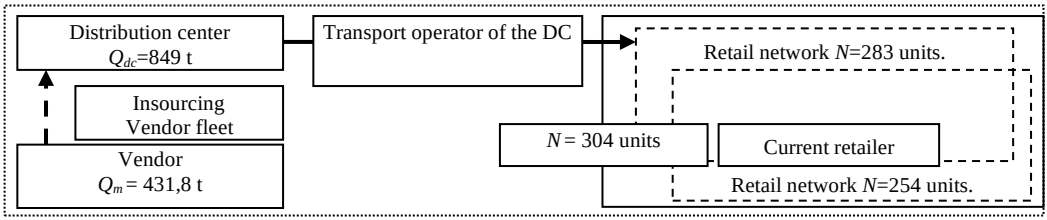

Fig. 5. Existing scheme of distribution of material flows

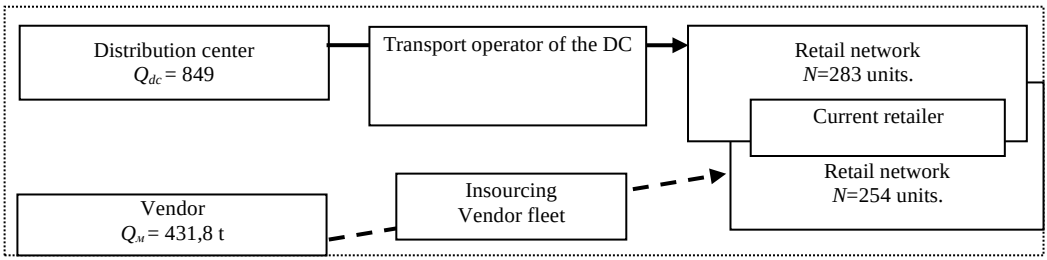

Fig. 6. Proposed scheme of distribution of material flows

Table 4. Results of calculations performed and comparison with existing ones

№	Indicator	Value		Difference
		Existing scenario	The proposed changes scenario	
1	Average bulk of single delivery, tons	1,5	2,1	0,6
2	Number of circle operations, units	189	304	115
3	Number of delivery bays on the route, units	3	2	-1
4	Average circle operation time of vehicle, h	3,72	3,37	-0,35
5	Average length of the route, km	35,2	32,2	-3
6	Loading time of single vehicle of the distribution center, h.	0,94	0,91	-0,03
7	Number of loaders in the distribution center in the retail network operating area, units.	2	2	-
8	Maximum daily demand at the section «Distribution center - Retail network», tons	424,5	638,4	213,9
9	The required number of loading bays of the distribution center at the retail network operation area, units.	1	1	-
10	The number of loaders in the distribution center in the service area of the retail network, which simultaneously serves 1 post load, units.	2	2	-
11	Idle time during unloading of the vehicle when servicing the retail network, h.	1,35	1,26	-0,09
12	Number of vehicles, units	10	11	1
13	Maximum number of circle operations per day by single vehicle, units.	4	4	-
14	Number of truck drivers in the distribution center, units.	8	10	2
15	Number of engineering and technical workers of the distribution center, units	18	27	9
16	Number of drivers of vehicles, units.	6	9	3
17	Number of engineering and technical workers of the transport operator, units	6	6	-
18	The average number of retail participants serviced per day, units	19	21	2
19	The required number of loaders in the distribution center of vendor, units	2	3	1
20	The required number of loading bays for the distribution center of the vendor, units	1	1	-
21	The number of loaders in the distribution center at the operation area of the vendor, which simultaneously serves single loading bay, units.	2	3	-

For a transport operator in the section «Vendor – Distribution Center» the model for calculation of the main indicators of functioning was changed. Table 5 show the calculated performance of the distribution center and transport operator in the section «Distribution Center – Retail Network».

Table 5. Calculated indicators of the monthly demand for the number of storage places in the racks and the required area of the warehouse of the distribution center

Monthly need for storage places in the racks for a distribution center, units.		
The monthly amount of the main products of the distribution center, 849 tons.	233	351
Monthly production amount of the Vendor involved, 431,8 tons	118	
Required area of the distribution center, sq. m.		
The monthly amount of the main products of the distribution center, 849 tons.	203	306
Monthly production amount of the Vendor involved, 431,8 tons.	103	

The calculated amounts of required capital investments for the distribution center and the transport participant in the section «Distribution center – Retail network» are entered in the table (Table 6).

Table 6. Values of investments for participants

№	Name of indicator	Value
For the distribution center, UAH:		
1	The amount of investment in the rack	472000,00
2	The amount of investment in pallets	8425,20
3	The amount of investment in the loader in the warehouse of the distribution center	87560,00
4	The amount of investment in the posts of loading work	0,00
Total amount of investments of the participant, UAH:		567985,20
For the transport participant on the section «Distribution center – Retail network», UAH:		
5	Costs associated with registration of vehicles	6279,17
6	The amount of investment in vehicles	80000,00
Total amount of investments of the participant, UAH:		86279,17

Thus, the total amount of borrowed capital for the distribution center is 567985.20 UAH., For the transport participant in the area under consideration – 8000.00 UAH.

For the transport operator in the section «Vendor – Distribution Center», which is part of the Vendor, the procedure for determining the main performance indicators is given below. The results of calculations according to the above formulas (16) - (26) are presented in Table. 7. According to the obtained results, the proposed changes provide for the introduction of 1 loader into the distribution center to the service area for Vendor and 118 additional storage locations in the racks; An additional vehicle to the Transport operator in the section «Distribution center - Retail network». The results of the calculations are presented in Table. 7.

Table 7. Comparison of the received indicators of the proposed organization of the transport operator at the section «Vendor - Distribution Center» with the existing ones

№	Name of the indicator	Existing scenario	Proposed Scenario
1	Monthly sales flow, tons	431,8	431,8
2	Load time of single vehicle at the Vendor, h.	0,71	0,93
3	Idle time under unloading at the distribution center warehouse on section «Vendor - Distribution Center», h.	0,71	1,53
4	Vehicle fleet, units	2	4
5	The maximum possible quantity of operating circles of the vehicle per month, units	286	90
6	The duration of the return trips at the site «Vendor - Distribution Center», days, h.	0,10	4,73
8	Total number of drivers, units	3	5
9	Number of engineering staff, units	2	3

The proposed changes to this supply chain participant contribute to the reduction of indicators that characterize its capacity, in particular, the reduction of the average length of the route to 10 km and the supply to single customer allows reducing the number of existing vehicles to 2 units, which in turn will affect the traffic of the site, the cost of servicing vehicles, including key employees, and the amount of depreciation deductions by reducing the value of vehicles.

The emergence of a DC on the way of promoting the Vendor's products to the retail network caused changes in the main performance indicators of each of the participants in the system under study. Such redistribution was reflected in the figures for the total NPV of each participant in such an organization (Table 8).

Table 8. Comparison of the obtained indicators of *NPV* for 5 years, UAH

Participant	NPV for existing scenario, UAH	NPV for proposed scenario, UAH
Vendor	X	« + 715108,45 »
Insourcing Vendor fleet	556924,32	230324,36
Distribution center	10468392,36	11454077,86
Transport operator at the section «Distribution Center – Retail Network»	1051385,59	1690495,94
Total *NPV* of the system (excluding the relevant indicator of the retailer being considered)	12076702,28	14090006,61
Retail participant	28696355,47	28685298,53

In Figure 7 and Figure 8 graphically according to Figure 5 and Figure 6 are presented the existing system and system with considering the proposed changes in the organization, indicating the NPV indicators of each of the participants.

Provided, the distribution center and the Vendor are use their own vehicles for the transportation. Therefore, the income of Transport operator constitutes the corresponding item of expenditure in their operation. In the case of the Vendor, a brand new organization of the material flow assignment allows to reduce costs. Since the main means of generating income for a distribution center and a retailer is an additional charge per sales unit, an increase its value by single participant requires a fall in the corresponding for another. This dependence is presented graphically at (Figures 9, 10).

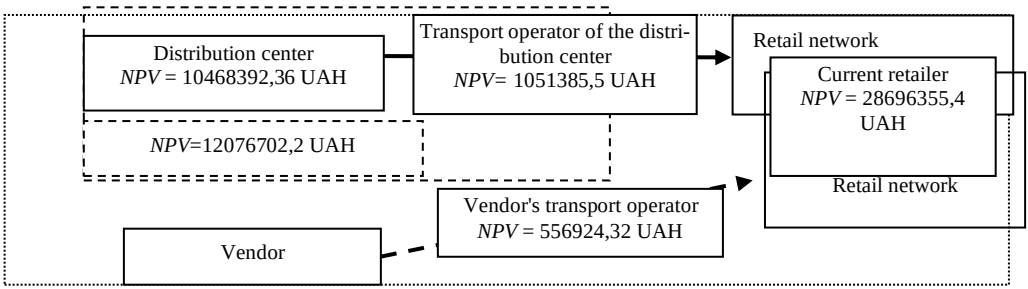

Fig. 7. Existing scheme of organization of movement of material flows

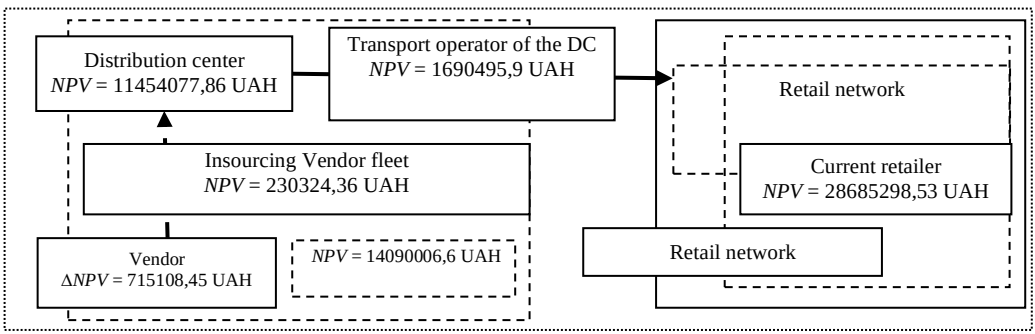

Fig. 8. Proposed scheme of organization of movement of material flows

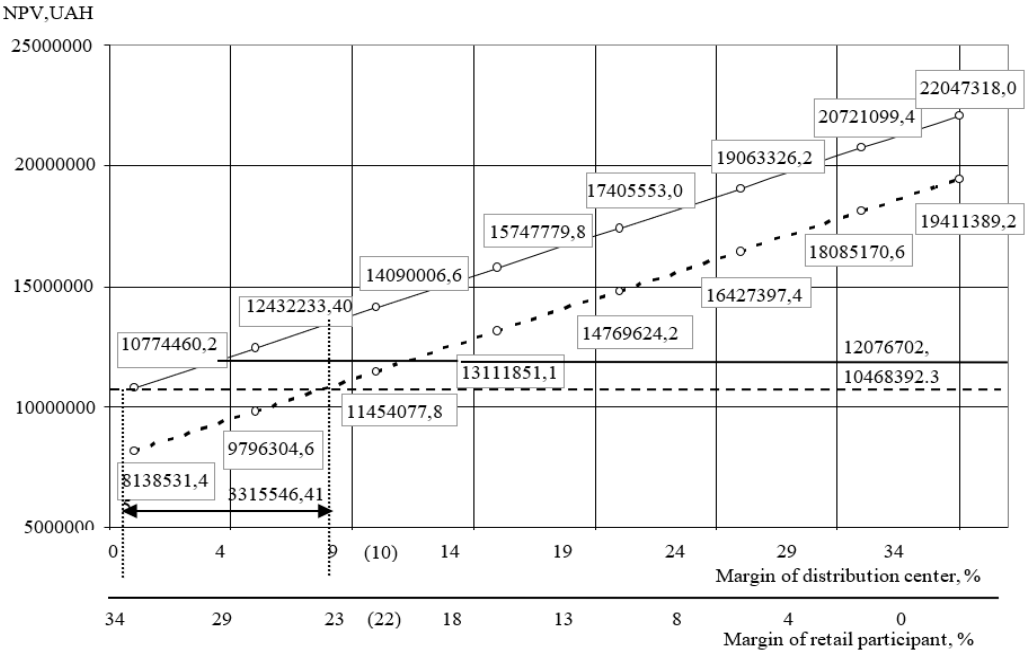

Fig. 9. Dependence of the *NPV* of the DC and the system depending on the change in the margin of the DC in the price of the unit of material flow considered without the *NPV* of the retail network: - - ○ - - - *NPV* of the considered system; ——— - *NPV* of the distribution center; —○— - *NPV* of the considered system under the existing working conditions (direct channel); - - - - *NPV* of the distribution center under the existing operating conditions.

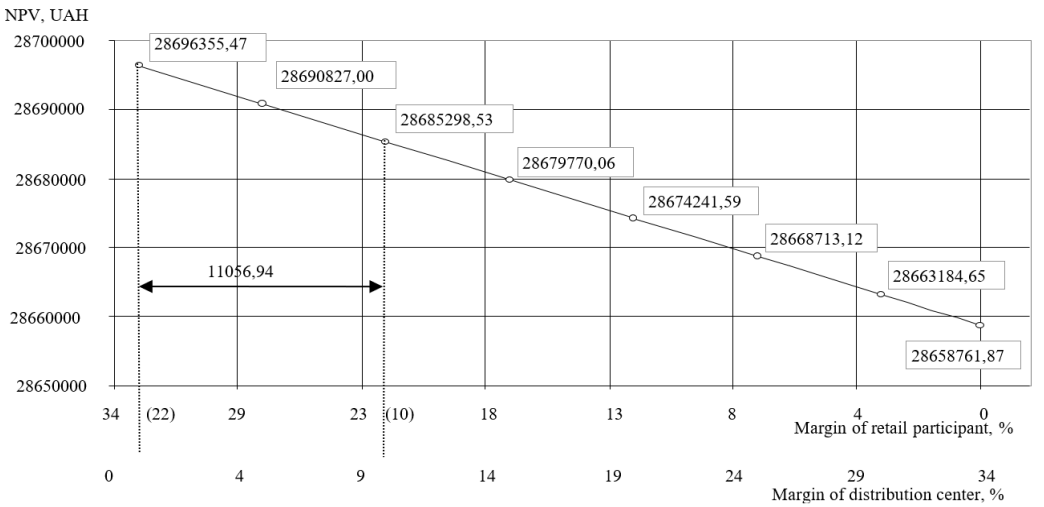

Fig.10. The dependence of the *NPV* of the retail participant depending on the change in the margin of the distribution center in the unit price: —○— - *NPV* of the retail participant.

Comparison of the costs of the existing and proposed organization of the movement of material flow is carried out using Figures 11-13, where: «1» is the sum of the profits of the enterprise, «2» is the sum of depreciation deductions, «3» – the total sum of taxes from the participant, «4» – current expenses. The average amount of profit per unit of current member's expenses under the existing organization of the system is UAH 0,36, in the conditions of the proposed organization – UAH 0,50. The indicator of profitability of the participant under the existing organization of the system under consideration is UAH 0,30. per unit of current expenses for the calculated period, under the conditions of the proposed organization – 0,29.

For a Transport operator, the average amount of profit per unit of current expenses of a participant for an existing organization in the accounting period is UAH 0,27, under the conditions of the proposed organization – UAH 0,14. Changing the organization of the movement of material flow requires the appropriate costs from the parties to ensure its promotion in the supply chain.

The sales flow of non-alcoholic products of the Vendor, the total amount of loss for the entire retail network is 8290560.00 UAH in the form of income, 3315546.41 UAH – in the form of NPV. That is, on average, in such an organization, single member of the retail network loses 211 UAH profit per month.

In the case of a Vendor, a change in the trajectory of its products allows to release funds in the amount of 715,108.45 UAH in the form of profit for the billing period due to the drop of freight transportation flows. Thus, it is possible to reduce the mark-up of the considered producer to 47.4% and increase the average mark-up in the retail network by 2%. In this case, single representative of the retail network loses on average about 165 UAH, which is much less than the previous result.

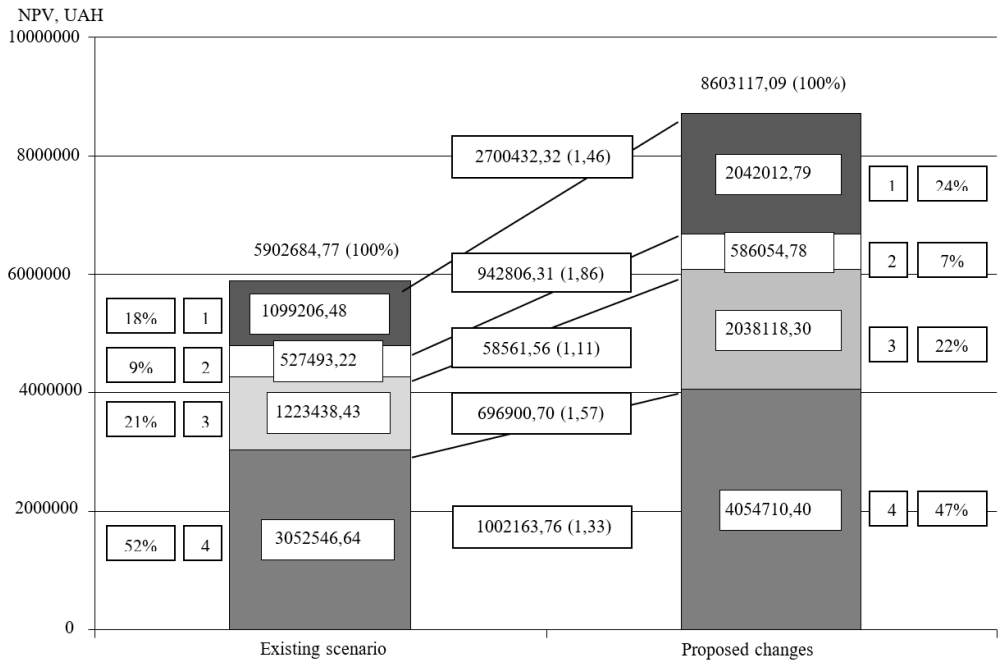

Fig.11. Income components of revenue for a Transport operator in the existing organization of the system and considering the proposed changes

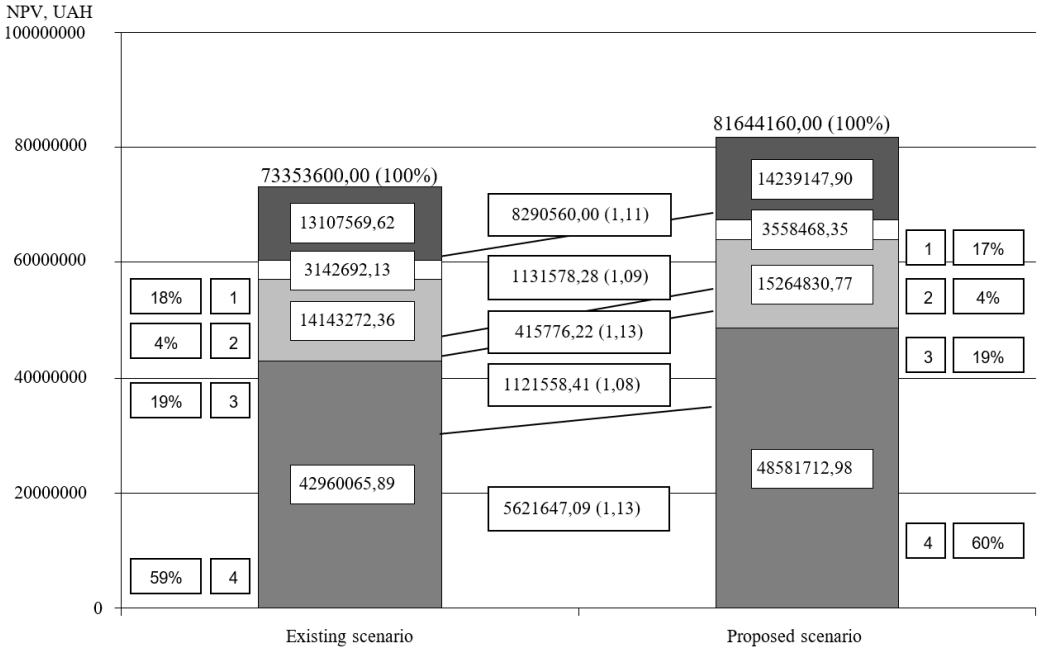

Fig.12. Income components of revenue for distribution center in the existing organization of the system and considering the proposed changes

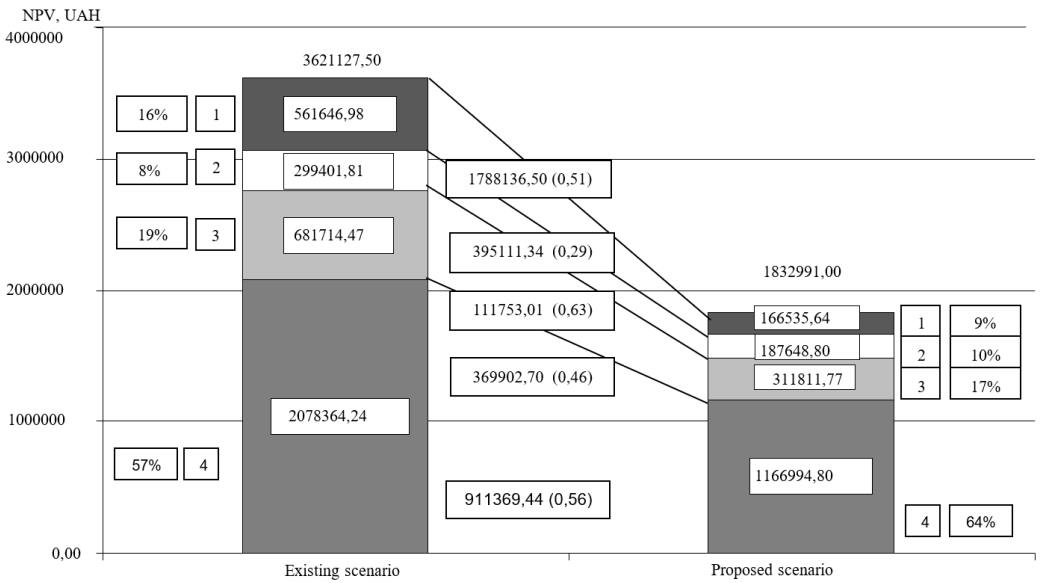

Fig. 13. Income components of revenue for a Transport operator from the Vendor in the existing organization of the system and considering the proposed changes in the distribution center into scheme

According to the calculations performed under the current operating conditions of the system under consideration, the net present value for: the distribution center is UAH 10468392,36 (at current expenses UAH 42960065,89, the total amount of income for the estimated period is UAH 73353600,00), for TP in the section «Distribution Center – Retail Network» – UAH 1051385,59 (at current expenses UAH 3052546,64, total amount of income for the estimated period – UAH 5902684,77), for TP in the section «Manufacturer – Distribution Center» – UAH 556924,32 (at current expenses UAH 2078364,24, the total amount of income for the estimated period is UAH 3621127,50), for the retail participant is UAH 28696355,47. As a result, a larger indicator of the total net present value for the system is obtained, minus the corresponding for the retail network. Profitability of a transport operator in the link «Distribution Center – Retail Network» has been increased from UAH 0,36 per unit incurred expenses up to UAH 0,50, profitability of the distribution center reduced by 1%, profitability of the TP included in the manufacturer – reduced by 13% due to reduction of work volume. At the same time, in such an organization, in the conditions of the constant retail price for the retail network for end users, each of the participants in the retail network on average loses UAH 211 profit in a month due to the appearance of an additional link in the channel of promotion of the material flow of the manufacturer under consideration.

4. Conclusion

The idea of supply chain management is to adapt to an varying market, while investing a minimum funds. Taking into consideration demand on food products at the vendor, the total amount of loss for the entire retail network is 8290560,00 UAH in the form of income, 3315546,41 UAH – in the form of NPV. That is, on average, one member of a retail network loses 211 UAH profit in a month per such organization. In the case of a vendor, changing supply chain allow free up 715108,45 UAH yerly funds in due to a decrease in the workload of transport. Thus, the possible reduction of the vendor's margin is up to 47,4% and the increase in the average retail margin by 2%. In this case, one representative of the retail network, on average, loses about UAH 165, which is significantly lower than the previous result.

The article improves the method for evaluating the effectiveness of product distribution channels, which is based on net present value. Based on a real example, the implementation of a distribution center, the effect for all participants in the supply chain channels separately and the overall effects for the channel are calculated. The results indicate the advisability of introducing such a system of promotion of goods. In case of a change in cargo turnover and changes in other factors (change in the supplier, change in transport and warehouse tariffs, etc.), it is necessary to separately assess the feasibility the rational scope of using direct and multilevel supply channels for material flow distribution.

The ranges of variations of factors of mathematical model of a logistic chain established on the basis of data of experts in the field of distribution of consumer goods allow to carry out research of influence of parameters of transport and warehouse participants on efficiency of work of the investigated system. The positive or negative impact for an individual participant in the supply chain does not unambiguously affect other participants and the chain entirety.

However, the supply schemes may differ in the quantity of participants (Żak, Hadas, Rossi, 2017) and their location relative to the shippers and demand (Litomin, Tolmachov, Galkin, 2016), the urban surrounding (Galkin, 2017), service functions (Kush, et. al, 2018), and others. Various conceptual schemes of supply consideration with variation of parameters showed a general trend in engineering supply chain and selecting necessary participants. An increase of the demand would move scheme from existing scenario to proposed (with use of distribution center), according to operation expenses minimizing. However, engineering the freight distribution system in the service sector, it is not enough to consider only total operating costs, since they do not reflect the results of the overall supply chain functioning. Therefore, its necessary to involved capital invests costs, taxes and borrow capital expenses.

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