Iryna Fedotova
E-mail: irina7vf@gmail.com
Associate Professor
Kharkiv National Automobile and Highway University
ORCID ID:*0000-0002-3277-0224*
Kharkiv, Ukraine
Nadiia Bocharova
E-mail: bocharova.n.a.xnadu@gmail.com
Associate Professor
Kharkiv National Automobile and Highway University
ORCID ID: *0000-0003-4371-0187*
Kharkiv, Ukraine
https://doi.org/10.46361/2449-2604.10.1.2023.130-151

A SYSTEMIC APPROACH TO THE FORMATION OF MULTI-LEVEL SUPPLY CHAIN MODEL BASED ON CYBERNETIC MODELING OF VIABLE SYSTEMS

The article discusses the structure and levels of supply chain formation as a logistics system from a systemic approach perspective. Research on the formation of logistics systems is important both theoretically and practically. The goal of the research is to improve the theoretical foundations of the formation of a multi-level supply chain model based on the concept of modeling viable systems. A supply chain model based on the methodological apparatus of cybernetic modeling of viable systems is proposed. The supply chain model is presented in the form of a subject (metasystem) and an object of management (operational element), which is proposed in the form of links-elements of the supply chain. This allows coordinating material and other flows in the supply chain, providing viable means of development and maintaining long-term business relationships, and achieving synergistic effects from the interaction between system links. Flows in this system are formed into a logistics chain, which generally combines producers, intermediaries, carriers, and consumers. Based on the structural-level and metasystemic approaches, the main levels and structure of the supply chain are defined. To form a multi-level supply chain model, a differentiation criterion for levels is proposed, which allows, in accordance with the metasystemic approach, to identify five levels of the supply chain - element, component, subsystem, system and metasystem. The multi-level model of an integrated supply chain requires the integration of various functional areas and their participants at all levels within a single supply chain for its optimization and can be applied to any enterprises. The proposed theoretical foundations make it possible to coordinate such management objects in the logistics system as interaction between chain participants, logistics functions, business processes, and create their specific structure and determine integration levels. The structure of the mechanism for forming the supply chain is proposed, which is based on five functions: planning, procurement, production, sales, returns. The feature of the proposed mechanism is that special attention is paid to information support. Generalizing the structure of the supply chain mechanism will improve the effectiveness of establishing logistics links for the enterprise.

Keywords: *supply chain, logistics system, systemic approach, multi-level model, cybernetic modeling, integration levels, logistics functions*

JEL classification: *L14, L23, L91, M11*

ირინა ფედოტოვა
E-mail: irina7vf@gmail.com
ასოცირებული პროფესორი,
ხარკოვის ეროვნული საავტომობილო საგზაო უნივერსიტეტი
ORCID ID:*0000-0002-3277-0224*
ხარკოვი, უკრაინა
ნადია ბოჩაროვა
E-mail: bocharova.n.a.xnadu@gmail.com
ასოცირებული პროფესორი,
ხარკოვის ეროვნული საავტომობილო საგზაო უნივერსიტეტი
ORCID ID: *0000-0003-4371-0187*
ხარკოვი, უკრაინა

სისტემური მიდგომა სიცოცხლისუნარიანი სისტემების კიბერნეტიკურ მოდელირებაზე დაფუძნებული მრავალდონიანი მიწოდების ჯაჭვის მოდელის ფორმირებასთან დაკავშირებით

სტატიაში განხილულია მიწოდების ჯაჭვის, როგორც ლოგისტიკური სისტემის ფორმირების სტრუქტურა და დონეები სისტემური მიდგომის პერსპექტივიდან. ლოგისტიკური სისტემების ფორმირების კვლევა მნიშვნელოვანია როგორც თეორიულად, ასევე პრაქტიკულად. კვლევის მიზანია სიცოცხლისუნარიანი სისტემების მოდელირების კონცეფციის საფუძველზე მრავალდონიანი მიწოდების ჯაჭვის მოდელის ფორმირების თეორიული საფუძვლების გაუმჯობესება. შემოთავაზებულია მიწოდების ჯაჭვის მოდელი სიცოცხლისუნარიანი სისტემების კიბერნეტიკური მოდელირების მეთოდოლოგიურ აპარატზე დაფუძნებული. მიწოდების ჯაჭვის მოდელი წარმოდგენილია სუბიექტის (მეტასისტემის) და მართვის ობიექტის (ოპერაციული ელემენტის) სახით, რომელიც შემოთავაზებულია მიწოდების ჯაჭვის რგოლ-ელემენტების სახით. ეს საშუალებას იძლევა კოორდინირება მოახდინოს მატერიალური და სხვა ნაკადების მიწოდების ჯაჭვში, უზრუნველყოს განვითარების ეფექტური საშუალებები და გრძელვადიანი საქმიანი ურთიერთობების შენარჩუნება და სინერგიული ეფექტის მიღწევა სისტემურ კავშირებს შორის ურთიერთქმედებიდან.

ამ სისტემაში ნაკადები ყალიბდება ლოგისტიკურ ჯაჭვად, რომელიც ზოგადად აერთიანებს მწარმოებლებს, შუამავლებს, გადამზიდავებსა და მომხმარებლებს. სტრუქტურულ-დონეზე და მეტასისტემური მიდგომებიდან გამომდინარე, განისაზღვრება მიწოდების ჯაჭვის ძირითადი დონეები და სტრუქტურა. მრავალდონიანი მიწოდების ჯაჭვის მოდელის ფორმირებისთვის, შემოთავაზებულია დონეების დიფერენციაციის კრიტერიუმი, რომელიც საშუალებას იძლევა, მეტასისტემური მიდგომის შესაბამისად, გამოავლინოს მიწოდების ჯაჭვის ხუთი დონე - ელემენტი, კომპონენტი, ქვესისტემა, სისტემა და მეტასისტემა. ინტეგრირებული მიწოდების ჯაჭვის მრავალდონიანი მოდელი მოითხოვს სხვადასხვა ფუნქციური სფეროების და მათი მონაწილეების ინტეგრაციას ყველა დონეზე ერთი მიწოდების ჯაჭვის ფარგლებში მისი ოპტიმიზაციისთვის და შეიძლება გამოყენებულ იქნას ნებისმიერ საწარმოში. შემოთავაზებული თეორიული საფუძვლები შესაძლებელს ხდის ლოჯისტიკურ სისტემაში ისეთი მართვის ობიექტების კოორდინაციას, როგორიცაა ჯაჭვის მონაწილეებს შორის ურთიერთქმედება, ლოგისტიკური ფუნქციები, ბიზნეს პროცესები და მათი სპეციფიკური სტრუქტურის შექმნა და ინტეგრაციის დონის განსაზღვრა. შემოთავაზებულია მიწოდების ჯაჭვის

ფორმირების მექანიზმის სტრუქტურა, რომელიც ეფუძნება ხუთ ფუნქციას: დაგეგმვა, შესყიდვა, წარმოება, გაყიდვები, ანაზღაურება. შემოთავაზებული მექანიზმის თავისებურება ის არის, რომ განსაკუთრებული ყურადღება ეთმობა ინფორმაციის მხარდაჭერას. მიწოდების ჯაჭვის მექანიზმის სტრუქტურის განზოგადება გააუმჯობესებს საწარმოსთვის ლოგისტიკური კავშირების დამყარების ეფექტურობას.

საკვანძო სიტყვები: *მიწოდების ჯაჭვი, ლოგისტიკური სისტემა, სისტემური მიდგომა, მრავალ დონის მოდელი, კიბერნეტიკური მოდელირება, ინტეგრაციის დონეები, ლოჯისტიკური ფუნქციები.*

JEL კლასიფიკაცია: *L14, L23, L91, M11*

Introduction and review of literature

The modern acceleration of economic development in the country is largely attributed to the development of information, marketing, and logistics technologies, which has led to a change in the subject of competition within most economic activities. Due to the influence of globalization and the rapid development of scientific and technological progress, the composition of market participants is continuously changing, making their mechanisms of operation more complex. This has created a demand for new approaches to managing physical movement processes of goods in various industries, which has broadened the scope of logistics application.

The main potential of logistics lies in the rationalization of managing material, information, energy, and financial flows. Logistics designs harmonious and coordinated logistics systems with predetermined material flow parameters at the output. These systems have a high degree of coordination of logistics links to manage cross-functional material flows.

In the markets of industrial products, participants who use distribution channels with levels above zero (i.e., involving logistics intermediaries of trade and functional nature) now compete not as individual enterprises but as integrated entities known as "value delivery systems" - supply chains. As a result, manufacturers, intermediaries, and consumers involved in these integrated entities are increasingly interested in the methodology of supply chain formation and management. Thus, there is a need to formulate the structure of the mechanism for forming a supply chain that will determine the functions, information support, implementation of each function, and decision-making regarding the formation of a specific supply chain.

A supply chain can be viewed as a complex logistics system, where each element of the chain is an important component. From a systems approach, a supply chain is a system that has a complex structure and interaction among its component parts. The logistics system is aimed at providing the necessary goods and services at the right time and place, at the optimal cost. The supply chain consists of various stages such as production, transportation, storage, and delivery of goods, which interact with each other and with external factors.

The concept of a logistics system is one of the fundamental concepts of logistics. There are various systems that ensure the functioning of the economic mechanism, so it is necessary to identify logistics systems for their analysis and improvement. The supply chain represents a broader category that encompasses the production and circulation of material resources, management of material and related flows, and aimed at optimizing logistics functions and operations to increase the efficiency of organization and management of the trade process [1].

According to the widely accepted definition, a logistics system is an adaptive feedback system that performs logistics functions. Typically, it consists of several subsystems and has developed connections with the external environment [2-4]. This generalized definition enables us to represent a logistics system as interconnected subsystems that perform specific logistics functions.

From a systems approach to business organization, authors view a logistics system from the perspective of interacting subsystems (links) that require management. Let's consider some of them. A logistics system is a relatively stable set of links (structural/functional departments of a company, as well as suppliers, customers, and logistics intermediaries) that are interrelated and united by a single management of the corporate strategy of business organization [5, p. 28]. A logistics system is a set of logistics network and administration system that a company forms to implement its logistics strategy (tactics) [5, p. 29]. A logistics system is a complex, organized (structured) economic system consisting of link elements (subsystems) interrelated in a single process of managing material and related flows, whose aggregate, boundaries, and functional operation tasks are combined by internal business organization goals and external goals [6]. Most authors view a logistics system as a collection of link elements between which certain functional relationships and connections are established, as well as a single process of managing material and other flows. However, authors do not have a consensus on the structure of the logistics system, its elements and levels, the model of formation and management of it.

The study of the supply chain as a logistics system in modern market conditions becomes particularly relevant and significant since their state is currently characterized by dynamics, a complex mechanism for forming and coordinating links, and a high level of uncertainty.

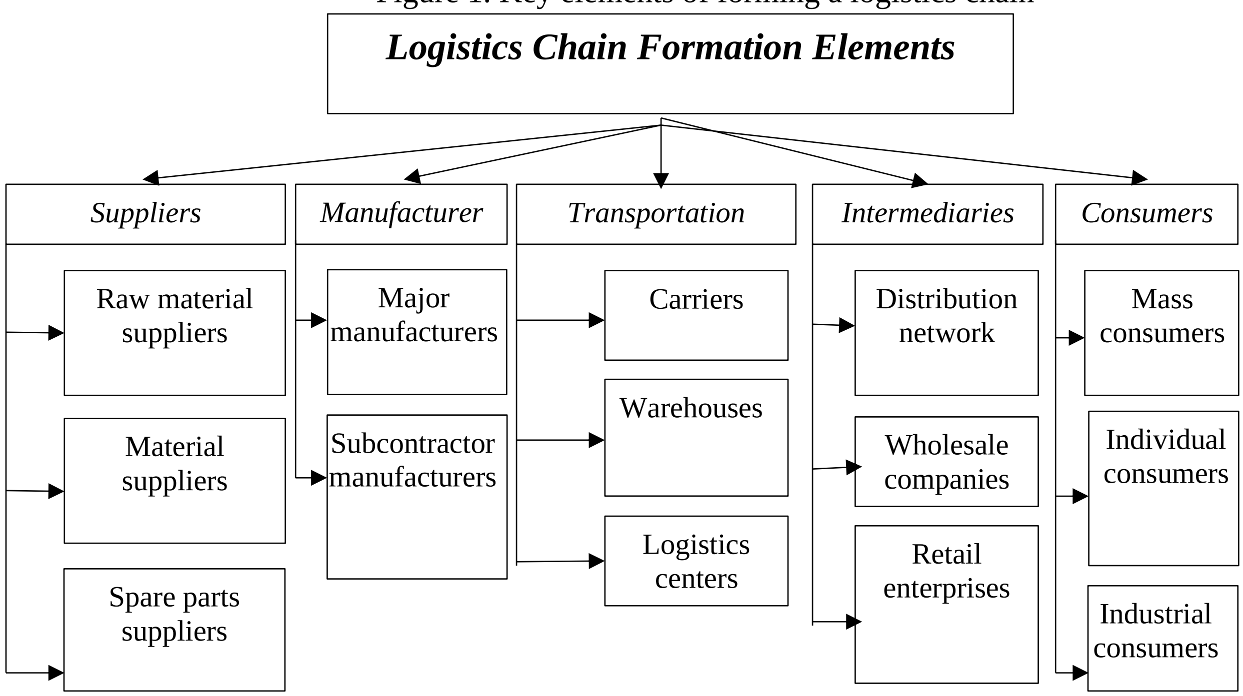
Recently, much attention has been given to the formation and management of supply chains in the economic literature, with particular emphasis on their study from a logistics perspective by both domestic and foreign scholars such as K.M. Afanasyev [7], T.A. Workut [8], A.N. Granin [9], Ye.A. Yeryomina [10], A. Zhymonik [11], D.A. Ivanov [12], M.V. Kindiy [13], T.O. Kolodiziyeva [14], D.V. Kochubey [15], M. Kristofer [16], Ye.G. Kuzmenko [17], G.S. Ovcharenko [18], I.V. Palamarchuk [19], A.V. Selivanov [20], J.R. Stok [21], D. Waters [22], and N.I. Chukhray [23].

In both foreign and domestic literature, as well as in the practice of managing integrated economic entities, the concept of "supply chain" is defined as "a set (sequence) of processes that are performed in bringing products from a particular manufacturer to the consumer/group of consumers (market segment), as well as a linearly ordered set of participants (links) performing the aforementioned processes" [18, p. 138].

The works of foreign and domestic scholars often contain different, sometimes contradictory, approaches to defining the structure of the supply chain and the basic principles of its management. In order to develop a multi-level model of the supply chain, it is necessary to first understand how different authors have viewed the essence and structure of the supply chain and define its levels.

The main elements of supply chain formation include raw material/materials and purchased parts suppliers, manufacturers and subcontractors, carriers, warehouse companies, logistics centers, intermediaries, distribution network enterprises, wholesale companies, retail companies, and consumers. This is illustrated in Figure 1.

Figure 1. Key elements of forming a logistics chain



Recognized SCM experts present supply chain management as the interaction of three elements: chain structure; business processes occurring in the chain; and chain management components [21]. Taking into account the aforementioned stages of the process of forming integrated economic entities (supply chains), the structure is understood as "a set of system elements (objects that interact with a specific purpose), obtained on the basis of establishing the presence of links between these elements" [18, p. 140].

Planning, organizing, and controlling supply chains are provided by the SCM system. Supply chain management largely determines the effectiveness of a company's performance results. To ensure profitability in the face of global crisis and intense competition, it is necessary to constantly track and reduce transportation and distribution costs, optimize prices, minimize stocks of poorly realized goods, and reduce storage costs.

Based on the works of foreign scientists, Ovcharenko G.S. formulates the following stages of forming a supply chain [18, p. 140]:

1. PLAN. Determining the volumes of raw materials and finished products supply, and production volumes.
2. SOURCE. Procurement, acquisition, and storage of inventory.
3. MAKE. Determining production procedures and cycles.
4. DELIVER. Managing orders, inventory, and transportation.
5. RETURN. Defining structural elements of product returns.

Yeryomina EA believes that supply chain management (SCM) is a process of planning, execution, and control with a view to reducing costs of raw materials, unfinished products, finished products, services, and related information from the point of origin of the request to the point of consumption [10, p.71]. The SCM process consists of stages such as planning, procurement, production, delivery, and returns. According to the scholar, improving performance often requires changes in existing logistics chains.

Kolodiziyeva T.O. believes that "the general algorithm of supply chain management consists of implementing such functions as planning (strategic, tactical, operational); organizing flow processes and interaction between elements of the logistics system; regulation (decision-making); coordination (interfunctional and interorganizational); analysis; audit (internal and external); controlling; pricing (budgeting)" [14, p.54]. Planning supply chains is "a form of regulation and management of processes that occur within a particular supply chain by developing temporary parameters of these processes that indicate how and when they should be performed" [14, p.54]. The scholar also identifies the following key elements of supply chain optimization:

– Configuration of the logistics network, planning, and design of supply chains.
– Integration into the supply chain and strategic partnerships.
– Inventory management in supply chains.
– Contracts and supply bases.
– Outsourcing and procurement and distribution strategies.
– Decision support systems.

Palamarchuk I.V. relies on the opinion of the Polish scholar Andriy Zhymonik in his research. Zhymonik insists that "managing the parameters of the supply chain is a continuous process and must take into account the action of external and internal factors" [11, p.46].

Each supply chain is characterized by its unique configuration and features, and their optimization requires careful analysis, planning, and implementation of appropriate strategies.

The most common view of the supply chain model is the list of subsystems that form the logistics system's properties and relationships, oriented towards the company's activities. Most authors consider the company as a certain logistics system, without considering the hierarchy of its levels.

For example, Anikin B.A., Sumets O.M., and Babenkova T.Yu. [25, 26] propose to consider the classical logistics system (LS) as a set of main subsystems (Ms elements): M1 - procurement, M2 - warehouses (warehouse management), M3 - inventory, M4 - transportation, M5 - production, M6 - distribution, M7 - sales, M8 - information, M9 - personnel. These subsystems are interconnected through the material flow. The fundamental scheme of the enterprise's logistics system proposed in the work of Gadzhinskiy A.M. [27] shows that all processes are interconnected and occupy a certain level in the logistics system where operations related to a specific stage of production activity take place. The LS includes the following processes: procurement of raw materials, production of products, distribution of finished products, after-sales service, disposal of products, and personnel, information, production, financial-credit, transport-expeditionary services. The disadvantage of these approaches is that the management of existing enterprise flows is not reflected, and interaction with the external environment is not considered. In addition, the hierarchy of the LS formation is practically not considered.

A broader scheme of the enterprise's logistics system is presented in [27], which takes into account entities from the external environment. This system includes three LS links: supplier, enterprise, and consumer. The logistics system of the enterprise has the following elements: procurement, warehousing, processing, finance, and sales, which are interconnected with each other through material and financial flows. A positive aspect is that the LS model includes both the external and internal levels of the system. However, the management of material flows between the links is not fully covered, and there is a lack of a clear hierarchy of LS formation.

Some authors attempted to introduce logistic management into the model of the logistics system of the enterprise. For example, Valkova N.V. [28] proposed a three-level model of logistic system management. The LS model is presented in both horizontal and vertical dimensions. In the horizontal dimension, the author highlights the stages of supply, production, and sales, as well as transportation and warehousing services. The author writes that for the basis of the vertical division of the logistic system into subsystems of logistic management, a three-level gradation should be carried out at the strategic, tactical, and operational levels. It should also pertain to long-term, medium-term, and short-term tasks, and be localized with respect to specific logistic decisions in a particular phase of production [29]. The disadvantage of this LS model of the enterprise is the absence of a systemic approach to building the model.

Development of Logistic System Model based on a System Approach as a Management System has been studied by Shinkarenko V.G. [30]. The author proposes to represent the logistic system of an enterprise as a system of any type of enterprise activity consisting of a controlled and controlling subsystem. The latter is intended to provide for the processes of formation and movement of material resources, unfinished production, and finished products from the supplier to the end consumer. The controlled subsystem is designed to optimize the flow of these processes in the provision of the delivery of the material flow in the required assortment, quantity, and quality, at the required place and time with a minimum of resource costs. The controlling subsystem forms managerial influence at three levels - strategic, tactical, and operational. The controlled subsystem reflects the process of formation and movement of the material flow, which involves the following operations: procurement logistics, distribution logistics, sales logistics, transport logistics, inventory logistics, and warehouse logistics. However, the proposed logistics system only relates to the formation and management of the material flow of the enterprise. The author does not consider the possibility of constructing a multilevel LS that takes into account the interrelationships not only within the enterprise but also in the external environment when forming a logistics chain.

In logistics, when constructing logistic systems, there is often a combination of different functional areas and their participants at the meta-, macro-, meso-, and micro-levels within a single logistics system to optimize it [31-33]. Logistics levels were identified according to the scale and depending on the level of the subjects involved in the supply chain.

A micrologistic system encompasses the sphere of activity of an individual enterprise, built from the standpoint of the firm's strategic goals and the optimization of basic operational processes, providing solutions to local issues within individual functional elements of logistic systems.

The mesologistic system is created through the joint efforts of counterparties linked by commercial contracts. Like the macrological systems, individual organizations are elements of mesologistic systems. The mesologistic system ensures the promotion of specific product flows through a chain of organizations linked by specific contracts.

The macrologistic system is a large material flow management system that encompasses enterprises and organizations in the industry, intermediaries, trading, and transport organizations of various departments located in different regions of the country or in different countries. The macrologistic system represents a certain infrastructure of the economy of the region, country, or group of countries.

Metalogistic systems only emerge from an understanding of the global economy as a business system that creates value-added elements distributed across different countries. The scale of their activities covers several countries connected by a single network of flows and common infrastructure, such as the logistics formation of the European Union.

Thus, the logistics system is represented as a set of logistics links connected by material and other flows. A link in the logistics system is a certain economically and/or functionally isolated object that is not subject to further decomposition within the framework of the task of analysis or construction of the logistics system and performs its local purpose related to certain logistics operations or functions [5]. However, these systems are mostly considered in the form of certain classifications, and logistic system models from a systems approach are practically absent.

Other authors, Nagorny Y.V., Naumov B.C., and Ivanchenko A.V. [34], proposed to represent the functioning model of logistics systems (LS) in the form of a cybernetic model. In a cybernetic model, indicators describing input factors (controlled parameters), a group of output indicators (target functions), and a group of indicators describing random external environment influences on the system are typically distinguished. Accordingly, three types of flows circulating in the system are identified: material, financial, and informational. When considering LS for international freight delivery, the authors proposed to identify two subsystems: a logistics subsystem that represents a set of transport, trading, and intermediary organizations in one country, as well as a corresponding logistics subsystem of enterprises in another country. The following elements of LS were identified:

- Cargo owners: two subgroups can be distinguished - cargo senders and cargo recipients;
- Carriers: two subgroups can be distinguished - regional and international carriers;
- Freight terminals (3PL logistics operators): provide their own infrastructure for implementing the process of material flow promotion;
- Freight forwarders (4PL logistics operators): are organizers of the material flow promotion process, forming logistics chains and optimizing the delivery process;
- Customs checkpoints: are a type of element that is characteristic of LS for freight delivery in international communication.

According to this LS model, the authors consider many links of different interacting logistics systems, but it is unclear how they are interconnected with each other and how flow management takes place at the levels of each logistics subsystem.

For a more detailed study of the supply chain, authors [35-37] propose to consider its structure and decomposition into levels, which can be presented as a set of certain elements and connections that ensure the integrity of the logistics system and its interaction with the external environment. In scientific literature [35, 36], object-oriented decomposition of logistic systems is being formed from the perspective of two approaches. According to the first approach, a logistic system consists of subsystems, links, and elements. The second approach identifies the following levels of LS: network, channel, chain. These approaches allow us to consider the logistic system from the point of view of hierarchical levels of formation.

Thus, the logistic system can be represented as a hierarchical structure: the first level of decomposition - subsystems and modules, the second - logistic technologies, the third - business processes, further - logistic functions and the lowest level - logistic operations [36]. The positive aspect of these developments is the consideration of hierarchical levels of LS formation, but all models are too generalized, and the use of a systemic approach is missing.

Authors Kanke A.A. and Koshevaya I.P. [37] consider LS as a multi-level system. The first level - logistic subsystems are divided into two directions: functional subsystem and providing subsystem. Functional subsystems include supply, production, and distribution (transportation, warehousing, cargo handling, packaging, inventory management, etc.). The providing subsystem traditionally includes organizational, economic, legal, and information and computer support, environmental and ergonomic support for logistics. At the second level, links of the supply chain are highlighted, which in most cases are associated with the presence in the organizational structure of functionally isolated units regarding the main and related flows, as well as partners and counterparts in the logistics organization of the company. The identification of logistic elements is determined by the lower level of supply chain decomposition and is driven by the need to separate operations or their aggregates in order to optimize resources, build an enterprise or its structural units model, simulate business processes, assign a particular executor or device to an operation, and establish a system of logistics plan accounting, control, and monitoring. Although the proposed model is interesting, it is generalized and lacks interconnections between subsystems, and the management of various flows is not considered.

Another group of authors [38] expanded the structure of the logistic system, which, in a detailed form, contains the following components: infrastructure of logistic processes, logistic flows, logistic chains, logistic management, legal, informational, personnel, and other provisions.

The subjects of economic activity and the departments of enterprises through which the logistic flow passes sequentially constitute a logistic chain, and the totality of chains is a logistic network. Thus, the authors suggest including not only management but also logistic infrastructure in the system. However, there is no clearly defined proposed model of the logistic system, and its multilevel structure is not considered.

Analysis of literary sources has shown that various scientists consider the structure of the logistic system from the point of view of the chosen research object, the level of the logistic system, and the definition of the essence of this concept regarding the functional division of logistics. In addition, most definitions of this concept emphasize the need to manage flows, but many researchers do not take management into account when modeling logistic systems. Therefore, there is no unanimity in the literature regarding the composition, structure, management, and levels of the supply chain. Unfortunately, there is also no consensus on the formation of the supply chain mechanism structure. Various scientists argue that there is an objective need to create a universal software solution available to every logistician. The complexity lies in the processing and analysis of large amounts of data, which requires a significant amount of computing resources and expertise.

Methodology

The lack of a unified approach to supply chain modeling in the works under consideration [1-38] highlights the need for further investigation of this issue from the perspective of logistics system management. It can be concluded that there is a necessity to coordinate such management objects in an integrated logistics system, such as the links of the supply chain, logistics functions, business processes, flows, and create a certain structure, determine interaction and integration levels.

The globalization of economic development and the transition of companies to a new type of network relationships determine the need for the development of a logistics management model aimed at coordinating the activities of all links and flows between them. These changes determine the need for the formation of a new system of general logistics management, which would connect the entire complex of LS elements at different levels.

The imperfection of existing approaches to forming LS models highlights the need to improve the theoretical foundations for forming a multi-level supply chain model. After determining the LS structure, it is necessary to form a logistics management system in such a way as to take into account the different levels of its structure, both within the enterprise and in the external environment. The absence of a systemic approach to forming a multi-level LS model does not allow for the full use of their capabilities to organize effective interaction of all system links.

A systemic approach is a methodology for scientific knowledge, based on the consideration of objects as systems, which allows one to see the studied object as a complex of interrelated subsystems united by a common goal, to reveal its integration properties, as well as internal and external relationships. According to the methodology of the systemic approach, each system is an integrated whole, even when it consists of separate disconnected subsystems.

Logistic systems are included in the commonly accepted concept of "systems" as they consist of system-forming elements that are closely interrelated and interdependent, with ordered connections and forming a certain structure with predetermined characteristics. These systems are distinguished by a high degree of consistency among the links to manage material and other types of flows.

Complex management systems are characterized by an obvious hierarchy, and at the upper levels, they inevitably lead to a set of local management systems. As a form of reflection of the interdependence and interrelatedness of system objects, the concept of structural levels allows for a more profound and organic reflection of the relationship between the processes of systematization and development, as well as the genesis of the studied object with its organization. Such a feature of the concept of structural levels is realized in its direction towards the study of the internal differentiation of the system, the identification of qualitatively diverse connections and interactions, which are one of the moments of the mechanism of the functioning and development of the studied object.

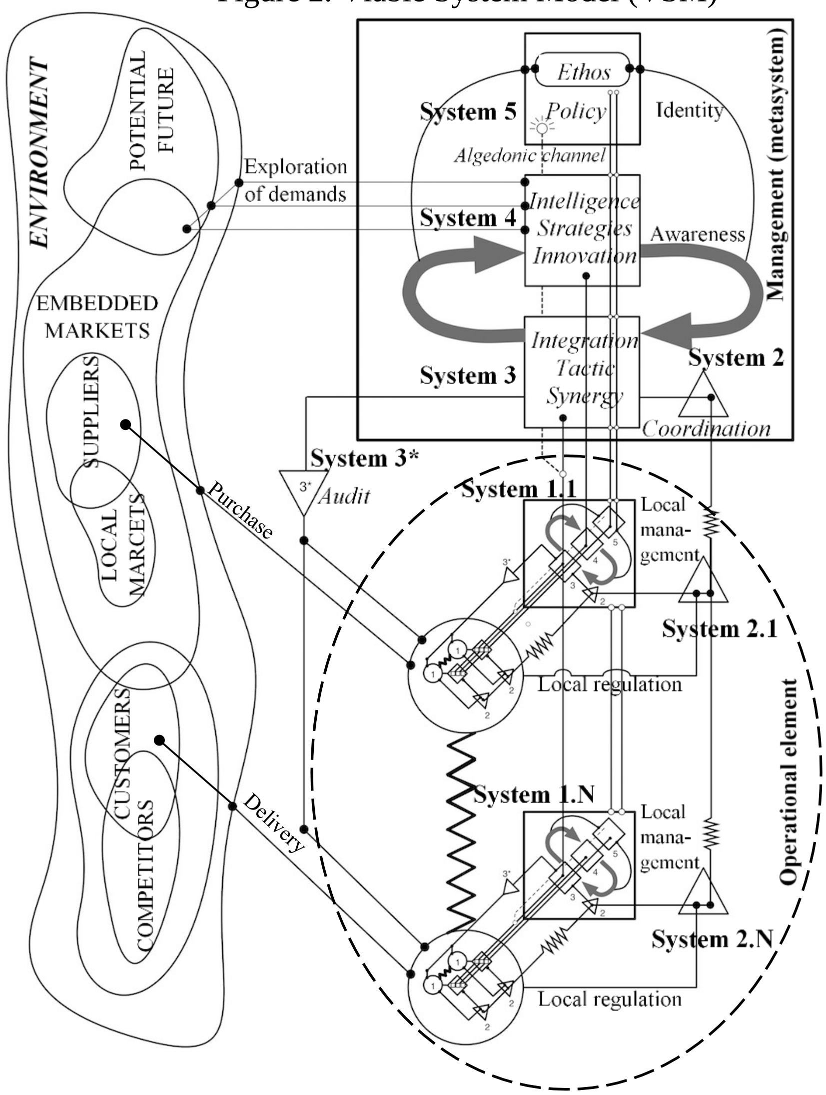
At the same time, the task of fully implementing a structural-level approach to the supply chain model is still far from being resolved. This task will enable the development of a principle of a structural-level system approach to the supply chain.

The purpose of this article is to improve the theoretical foundations of the multi-level supply chain model formation based on the concepts of modeling viable systems, structural-level and system approaches. The study examines the key aspects and justifies the fundamental elements of the mechanism for forming a supply chain.

In the conditions of constant changes in the external environment, special attention should be paid to building a multi-level viable supply chain based on the principles of self-organization. Adherence to this principle allows for the implementation of the concept of a viable system.

One of the most promising cybernetic approaches to developing a multi-level supply chain model is the use of the Viable System Model (VSM) by Stafford Beer [39]. Beer proposed a model for the organizational structure of any viable organism or autonomous system. A viable system is any system organized in such a way as to meet the requirements for survival in a changing environment. The VSM model offers the possibility of scientifically designing any organization as a system with regulating, learning, and adaptive capabilities necessary to ensure its survival in the face of changes that may occur in its environment over time, although they were not predicted in its design. To achieve this viability, the VSM proposes an invariant system structure based on the definition of five functions, so-called systems, which are considered necessary and sufficient conditions to cope with the complexity of the environment in which the overall system operates. The Viable System Model of an enterprise is shown in Figure 2.

Figure 2. Viable System Model (VSM)



A viable system consists of five interacting subsystems that can be reflected as aspects of the organizational structure. System 1 in the VSM model represents the operational (autonomous) units that manage various production elements. Each System 1 is first and foremost a viable system according to the recursive nature of the system. System 2 plays an important role in coordinating other subsystems, providing information channels and organs that allow subsystems in System 1 to communicate with each other and with System 3. System 3 is responsible for monitoring the performance level of each operational unit, determining directives, allocating resources, rights and responsibilities of System 1 units, as well as identifying potential synergy and ensuring interaction with Systems 4 and 5. Next to System 3 is System 3*, which is responsible for performing auditing activities in the operational units of System 1.

The governing bodies within System 4 are responsible for monitoring the external environment, predicting future trends, and identifying potential risks in order to control how the organization must adapt to remain viable. Ultimately, System 5 formulates principles and entire systems, playing a key role in preserving its identity and making political decisions within the organization as a whole to balance the needs and demands of various parts of the organization and management overall.

A whole viable system can be represented as part of a larger viable system (parts that make up operations or System 1). Any viable system is part of an even larger viable system. Recursion offers a new way of manifesting the organization. Vertical deployment of the system supports recursion of operational units into smaller subsystems. The goal is to reduce the diversity that each part of the system faces (complexity of the system decreases).

The model of the viable system consists of three groups of elements: operational elements, metasystem, and environment. Each system has certain contractual powers over its autonomy and operates within its competence. Information flows from the bottom up, smoothly filtering out unnecessary details. Systems and management levels come into operation depending on the need. If a certain level of management does not find a solution to the problem, the upper level begins to work.

The work of the authors [40] using the concept of the viable system (VSM) to manage the supply chain (Supply Chain Management) is intriguing. The authors included the manufacturer, wholesaler, distributor, and retailer as operational elements in the supply chain (management object). Each operational element in the chain represents a separate recursive system, so it is possible to further define previous (countries, continents, etc.) and subsequent (departments, production lines, etc.) levels of recursion (vertical deployment). However, the proposed model does not include all links in the supply chain, and it does not reflect the main flows between the systems, the hierarchy and recursion of the system are superficially considered.

Results

When forming a supply chain model based on the concept of viable systems, it is advisable to start with the basic elements of the supply chain. The links of the enterprise's supply chain are divided into internal (its own departments) and external (supplier companies, intermediaries, transportation companies, etc.) [37, 38].

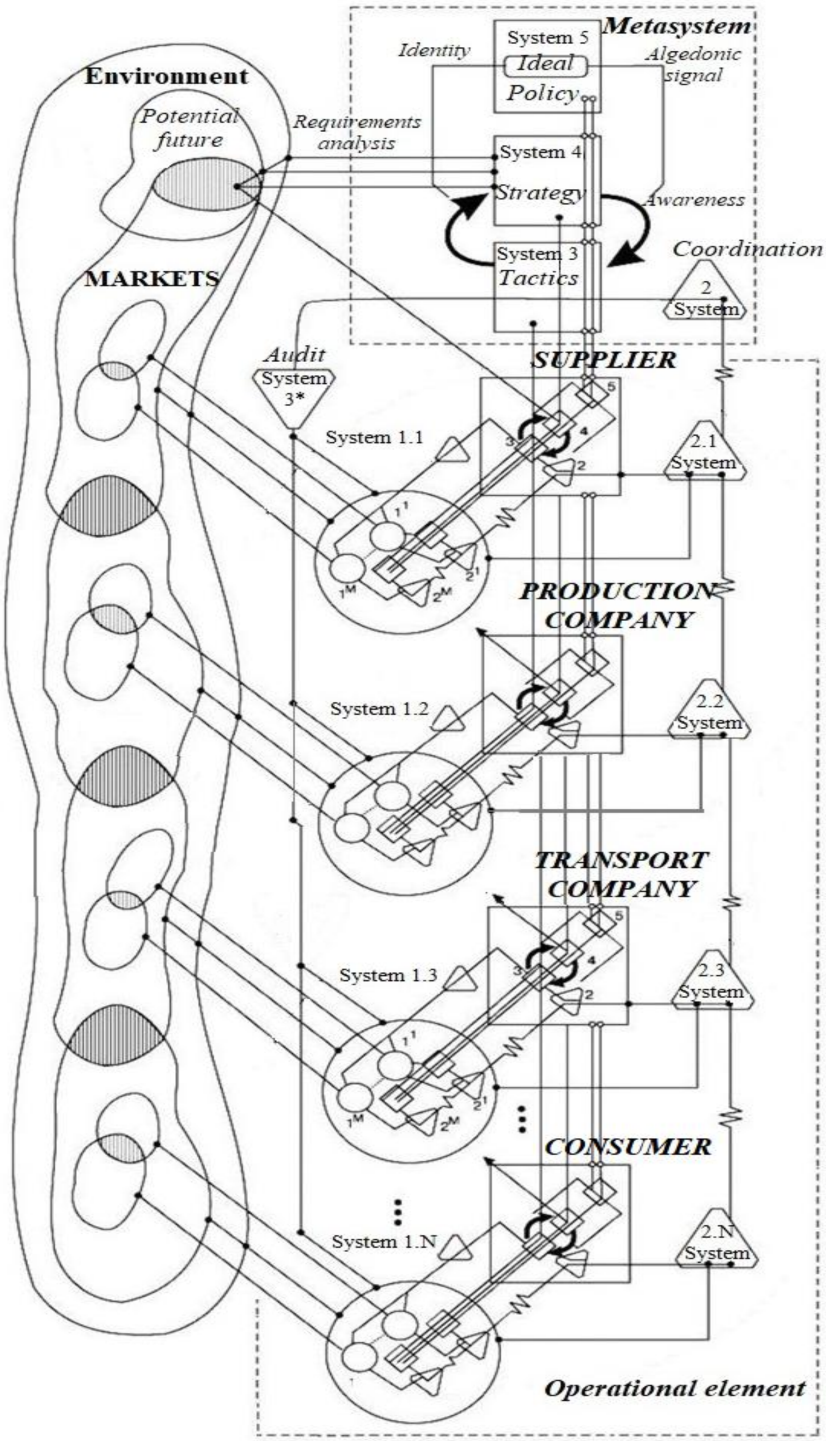
Let's first consider the logistics system consisting of external links of the logistics system, i.e. a supply chain model reflecting the elements of the logistics chain or network.

When modeling a viable supply chain, a graphical method is used to visualize the model more cohesively (Fig. 3). The diagram presents three elements: the environment, the operational element, and the metasystem, as well as various connections (interactions) between them.

The operational element is represented by systems 1.1 through 1.N, presented as links - separate enterprises forming the supply chain. The links of the supply chain consist of suppliers of material resources, production enterprises and their units, intermediary organizations of different levels, sales, trading, transportation and expeditionary enterprises, exchanges, banks and other financial institutions, insurance companies, information technology and communication enterprises, etc. For example, four enterprises are presented in Figure 3, but the actual number depends on the configuration of the supply chain. System 1 is responsible for distributing and promoting material, financial, and information flows between the enterprises of the supply chain.

The metasystem consists of five systems (Systems 2-5) that provide management of the operational element. The VSM model identifies the main links of the supply chain, determines the relationships between these links and the four supporting management functions: coordination, control, planning, and policy formulation. The task of the metasystem is to ensure unity, interaction, optimization, stability, and adaptation of the supply chain to the dynamic environment. It is in the metasystem where the supply chain policy, strategy, and tactics are formed. The main role of System 2 is to ensure the harmonious functioning of the links of the operational element, which make up System 1. Each of the Systems 2.1 - 2.N coordinates the activities of the enterprises of the supply chain (respectively, Systems 1.1, ..., 1.N) and provides information channels between them. In order to maintain viability and fulfill its purpose, the supply chain must maintain its integrity and optimize the work of its elements from the perspective of a common goal.

Figure 3. Model of a viable supply chain



System 3 is responsible for managing current activities, developing tactics, controlling flow distribution, and optimizing the functioning of all links that are part of System 1, as well as providing interaction with Systems 4 and 5. System 3* is responsible for auditing the activities of the elements in System 1. System 4 is responsible for monitoring the external environment, determining its requirements, anticipating future changes, and forming various strategies for the LS depending on possible scenarios to remain viable. System 5 formulates the principles and goals of the LS, is responsible for the implemented policy and general decisions that correspond to the ideal vision of LS development. Communication channels allow all systems to interact with each other and with the external environment. The hedonic signal provides feedback and plays a critical role in collecting and transmitting information to System 5, which is vital to the viability of the LS.

The presence of the external environment reflects the scope of the system in the model, without which it is impossible to consider the base of internal interactions within the supply chain. The environment is represented by various entities of the supply chain interaction, grouped into consumer markets, suppliers, intermediaries, and others. Each supply chain enterprise constantly interacts with them through its operational elements, determines market requirements, and forecasts potential futures with the help of the meta-system.

In Figure 3, we can see that the operational element also has a structure in the form of certain logistical links (systems 1.1, …1.N), similar to a whole viable system. Any viable system is a part of an even larger viable system. This illustrates the principle of recursion, where systems consist of smaller viable systems that are included in a larger viable system. In the links of the supply chain (systems 1.1 – 1.N), material and other accompanying flows can converge, diverge, split, change their content, parameters, intensity, etc. Links in the supply chain can be of three types: generating, transforming, and absorbing.

Due to their autonomy, LS links can do whatever they please, subject to one constraint: they must maintain their affiliation with the LS (i.e., work according to the goal of the entire LS, act within the coordination framework of Systems 2, 3* and be subject to the management of System 3).

Flows in this system are formed in a supply chain (logistics chain), which generally combines the manufacturer, intermediaries, transporters, and consumers. The logistics chain is a system of flow business processes implemented in a system of relationships of interacting partner enterprises integrated in the direction of the flow from raw material sources to the end consumer. In connection with this, supply chain management has become increasingly important in recent years. Supply chain management means managing the global flow (materials, goods, services) and ensuring effective integration and coordination of suppliers, producers, logistics, trade companies, and consumers. Systems 1.1 – 1.N use certain resources in the process of activity, interact with different parts of the material flow and the environment, so the operational connection between them is shown in the "accordion" diagram.

In modern practice, there are four main classes of logistics operators:

- The first class is narrow-functional logistics intermediaries such as transportation companies, freight forwarders, shared warehouses, freight terminals, and the like. They occupy the classic logistics service market area, providing transportation, cargo handling, and storage services.
- The second class is 3PL providers (third party logistics), which offer comprehensive logistics services by combining several (or the majority) of logistics functions and coordinating them under a single operator to expand the range of services for the client.
- The third class is 4PL providers (fourth party logistics), which take a systematic approach to managing key logistics business processes, integrating and coordinating the actions of supply chain participants, including the formation of an effective supply chain and data exchange between supply chain counterparts in real-time using modern information systems and technologies.
- The fourth class is 5PL providers (fifth party logistics), which are virtual integrated logistics operators that emerged due to changes in e-business logistics.

The main directions of integration and system-forming processes are seen in the lines of interaction between economic entities - potential links in the supply chain. Vertical integration is determined by the economic feasibility of ensuring the integrity of technological processes. Its opposite is horizontal integration, which is economically feasible for carrying out auxiliary and servicing operations in support of the main technological process. Horizontal integration of several autonomous technological processes is also possible.

The integrative qualities of logistics systems are provided through the implementation of a coordination function of management - the harmonization of logistics processes, the ordering of operations, and the synchronization of logistics flows.

To reflect the recursive nature of the proposed supply chain model, it is necessary to consider the decomposition of logistics systems at different structural levels. Complex management systems are characterized by an obvious hierarchy and inevitably divide into many local management systems at the upper levels. Each management level has its specific relationships.

For management, research, and design purposes, a logistics system can be divided into subsystems, links, and elements [36]. A logistics subsystem is a part of the supply chain that is identified according to the organizational structure to solve management tasks as a logistics system of the entire supply chain or a complex of logistics functions in a separate business area of the enterprise.

A link in the logistics system is an economically and/or functionally separate object (a company unit or a legally independent enterprise) that performs its local goal related to the implementation of one or several types of logistics activities. The links of one logistics system in the supply chain should have unified logistics management. Examples of links in the supply chain include suppliers, consumers, and logistics intermediaries. Industrial or commercial enterprises are often referred to as the central company, with suppliers and consumers being the first and second parties, respectively, and logistics intermediaries being the third party.

An element of the logistics system is an indivisible part of the link of the supply chain (subsystem) in terms of the management or design task. The identification of an element is determined by the lowest level of the supply chain decomposition and is caused by the need to isolate operations or their combination to optimize resources, build a model of the enterprise or its structural units, model business processes, assign a specific performer or technical device (such as an automated workplace), and form a logistics plan accounting, control, and monitoring system.

The current division of logistics systems into three hierarchical levels does not fully disclose the potential levels of recursion within the proposed recursive model of the supply chain (Fig. 3). Attempts to consider the levels of the viable system hierarchy from the standpoint of a separate organization have already been made in the literature [41]. The deployment of the Viable System Model (VSM) in both horizontal and vertical directions is suggested. In the horizontal dimension, the system can have various levels at which the organization unfolds in the external environment. For example, a certain level should include a designated share of the external environment and a specific organizational unit acting within it. In the vertical dimension, the organization unfolds into specific parts - smaller structural units. Each higher-level structural unit is divided into several lower-level units, which fully corresponds to the different levels of system recursion.

The Viable Supply Chain Model requires clarification of its structural-level organization. The most suitable approach for this purpose is the systems approach, which is gradually transforming into a meta-systemic approach [42]. The meta-systemic approach involves a different understanding of the interaction between the system and the meta-system. From the standpoint of the meta-systemic approach, the content of the system may have a level that simultaneously acts as both a level that goes beyond its boundaries (meta-level) and its own level, meaning it has dual localization - both outside and inside the system.

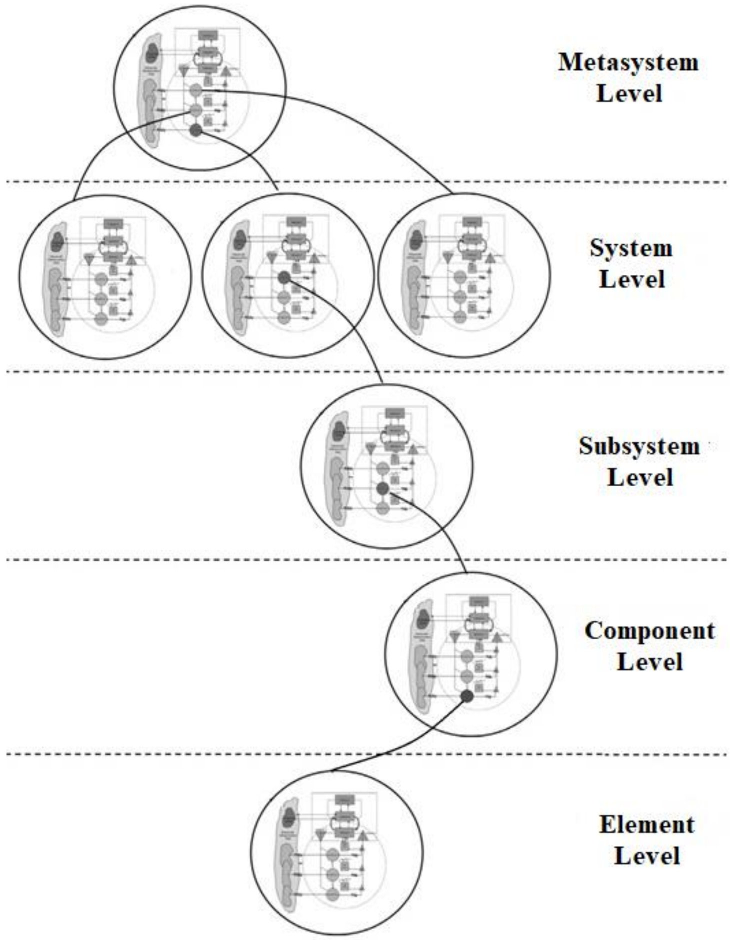
To determine the levels of logistics systems, it is suggested to use the criterion of differentiation of levels in accordance with the meta-systemic approach [42]. According to this approach, the integrative levels of logistics systems are identified in the structure of a complex whole: element, component, subsystem, system, and meta-system. This distribution of logistics systems into five levels has already been proposed by Fedotova I.V. in her work [43], where she examined the levels of integrated logistics.

Let us consider the structural-level model of the supply chain based on the recursive representation of the concept of viable systems. Each level of recursion represents a viable system that is a constituent part of the viable system at a higher level.

When deploying the vertical complexity of the supply chain, less complex levels of organization interact with corresponding parts of the external environment. In other words, the external environment is divided into subsystems that represent specific logistic links. Vertical deployment will determine the type of subsystem that the logistic link encounters and forms relationships with.

Figure 4 illustrates the vertical deployment of the supply chain and the distribution of its structural levels, which are levels of recursion in the VSM model.

Figure 4. Recursive structural-level model of the supply chain.



Let us examine in more detail the proposed levels of the supply chain from bottom to top:

- the Element Level of the supply chain is considered to be the lowest level of recursion. At this level, the logistical operation serves as the operational element, which cannot be further decomposed. In other words, it encompasses a series of actions aimed at transforming material, financial, and information flows. Logistic operations may include collecting, storing, and transmitting information about the material flow, receiving and transmitting orders through information channels, calculating with suppliers, buyers of goods, and logistics intermediaries, cargo insurance, customs clearance, loading or unloading of vehicles, packaging, labeling, storage, and others. The organizers of this level can be workers who perform specific logistic operations, and interaction is formed between individual performers of specific operations or actions, both within a particular enterprise and with the personnel of partners;
- the Component Level of the supply chain represents a set of components consisting of elements that possess specific properties of this system. Components may include certain structural units of an individual enterprise that perform various logistic functions or business processes. The logistic function is a larger group of logistic operations aimed at achieving the goals of the supply chain. This level integrates individual operations into logistic functions for planning, production, sales, and supply, as well as for transport, warehousing, loading and unloading, and other work within the enterprise. The following links of the supply chain can be identified at this level: the composition of material resources, production units, warehouses for finished products, etc. For example, if the warehouse is considered as a link in the supply chain, then zones for assembly, reception, palletizing, and shipment are elements of the supply chain. The organizers of this level can be the leaders of certain structural units of the enterprise;
- the Subsystem Level represents the logistic system of a particular enterprise. Components are combined into subsystems, as constituent parts of the system, and they can become independent systems. At this level, the

integration of structural units, logistic functions, types of activities, and flows of various types of resources is formed within the supply chain of an individual enterprise, i.e., into intra-logistics activities that can function as an independent open system. At this level of supply chain recursion, the chain is divided into larger systems such as warehouses, production lines, logistics centers, and so on. Each subsystem can be optimized to improve the efficiency and productivity of the entire supply chain. At this level, it is important to establish connections between subsystems and determine which subsystems are most critical to the uninterrupted operation of the supply chain. The following processes responsible for forming and moving the resources of the enterprise flow are the operational elements, and they are combined into a single logistics complex: procurement, distribution, sales, transport, warehousing, and so on;

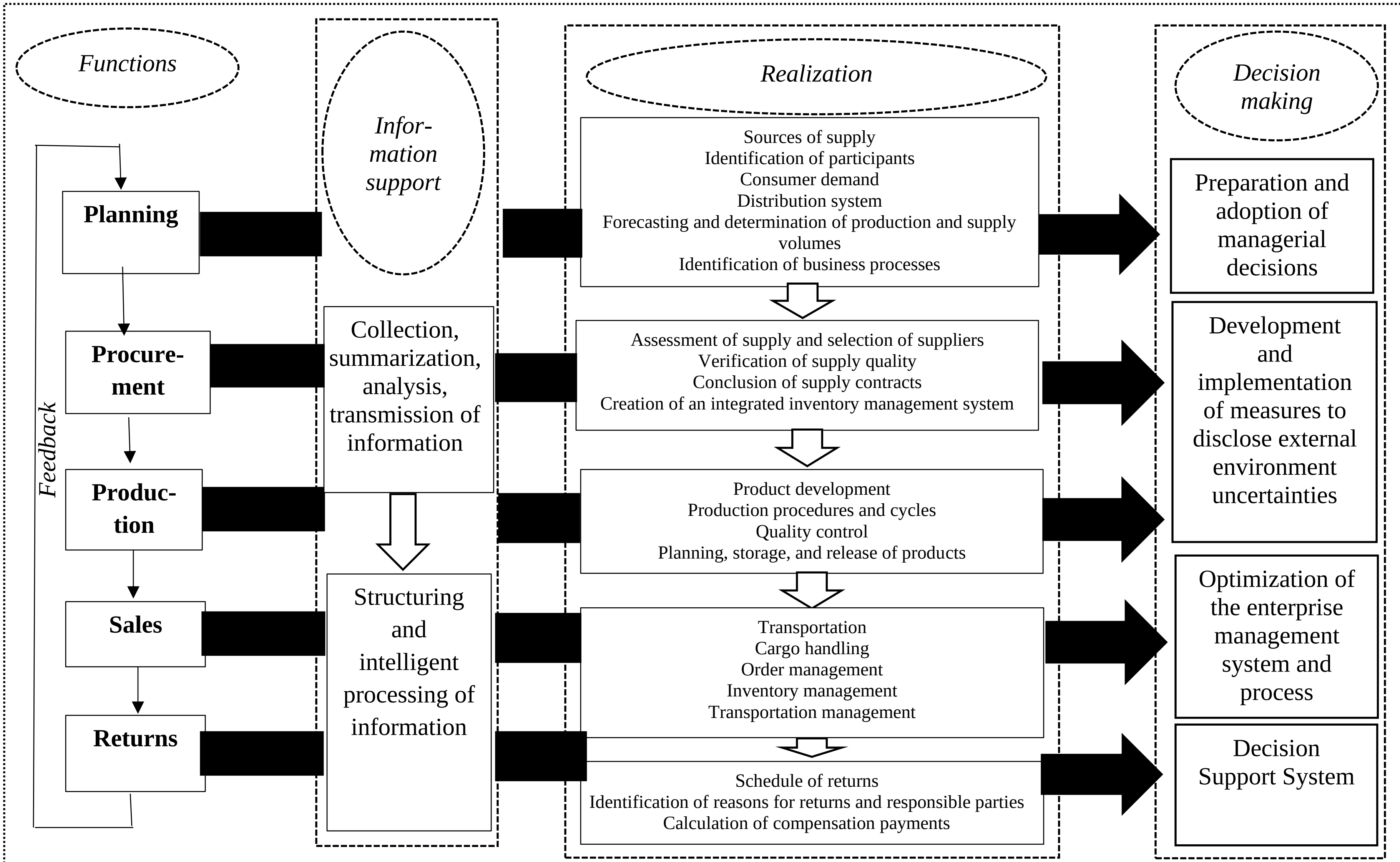
- the System Level represents a complex logistical system that is formed within the framework of a supply chain, channel, or network (of various integration forms). At this level of recursion, the supply chain is viewed as a unified system that must function as a whole. It is important to define the overall goals and objectives of the supply chain, establish connections between its elements and components, and organize resource management, production process planning, and quality control. The supply chain is realized within a system of relations between interacting partner enterprises that are integrated in the direction of flow from raw material sources to end consumers. Logistics chains and channels are integral parts of the logistics network, which is usually constructed by the central company - the "owner" of the logistics process or the customer of the logistics system. An example of a supply chain at this level is shown in Figure 3. The System Level forms an extensive material flow management system that encompasses enterprises and organizations, territorial-production complexes, intermediaries, commercial and transport organizations of different departments, and the infrastructural structure. Flows in this system are formed into a logistics chain, which, in the most general case, unites the producer, intermediaries, carriers, and consumers. In the logistics system, stable connections are formed between enterprises that are united to achieve common goals. Thus, at this level, the interaction between subsystems - enterprises of the logistics chain, channel, or network (customers, suppliers, intermediaries, and others) - is represented. The organizer of this level may be a logistics operator or another central focus company or customer of the logistics system. In addition, the system level may include tasks related to monitoring and analyzing the market, industry trends, consumer needs, etc. Based on this data, development strategies and plans can be devised that ensure competitiveness and market success;
- the Metasystem Level is reached by a global logistics system when it manifests itself against the background of the action of extracting, processing, transport, and other economic systems, united for more efficient distribution of world resources and management of integrated business, or interaction of different logistics networks on an international scale. The Metasystem Level allows for solving current and long-term tasks of harmonizing the entire set of relationships of logistics chains with each other, united into logistics networks, gradually transitioning into logistics systems of higher levels between industry sectors of the country, different countries at the national and international levels. For example, the management of networks of global logistics systems of transnational corporations (TNCs), as well as international global logistics projects and programs. This means creating a single informational, legal, transport and logistics, and expeditionary space for all participants in the transit cargo flow process. The organizers of this level can be government institutions, international enterprises, associations, TNCs, and other structures at the territorial and international levels.

Overall, the metasystem level is crucial for ensuring the effectiveness and efficiency of the entire supply chain. It allows for the management of all aspects of production and distribution, as well as the development of the business in accordance with changing market requirements and consumer needs. It is important to understand how the supply chain fits into the overall economic system, how it interacts with other supply chains, and how its activities affect the environment. At this level of recursion, decisions are made about how to allocate resources among different systems in order to achieve the best overall result. In addition, global standards and regulatory policies aimed at sustainable development of the economy and the environment can be developed at the meta-system level.

Based on a study of the element and component levels of supply chain formation in enterprises, the authors propose the components of the supply chain formation mechanism. Drawing on an analysis of scientific literature, it is suggested that the structure of the supply chain formation mechanism should include functions such as planning, inventory procurement, production, sales, and returns. The implementation of each function must be examined. It is also essential to justify decision-making at each stage of implementing the established structure of the mechanism. To achieve this, it is necessary to have and process sufficiently large volumes of information. Otherwise, inaccuracies and difficulties may arise in implementing the management decisions taken. The structure of the supply chain formation mechanism is presented in Figure 5.

Figure 5 depicts the structure of the supply chain formation mechanism. This diagram illustrates the components and functions necessary for the successful formation and management of a supply chain. The mechanism consists of various stages, including planning, procurement, production, sales, and returns. Each stage is crucial for the effective functioning of the supply chain, and it is necessary to examine the implementation of each function to ensure optimal results. The proper implementation of the supply chain formation mechanism requires the processing of significant amounts of information and data to ensure accurate decision-making at every stage of the process. The successful implementation of this mechanism can lead to the development of a highly efficient and profitable supply chain that can meet the needs and demands of both suppliers and consumers.

Figure 5. The Structure of Supply Chain Formation Mechanism



As for the initial information, it should be presented in a user-friendly format and contain information on the optimal:

- amount of raw materials that can be obtained from each of the suppliers;
- location and capacity of new facilities;
- level of material flow from suppliers to facilities;
- level of resources used at each facility;
- servicing of semi-finished products in the supply chain;
- level of material flow of finished products to end consumers;
- level of logistical support for end consumers.

According to Figure 5, the implementation of each function is as follows:

1. Planning. This process involves identifying sources of supply, taking into account consumer demand, prioritizing consumer demand, planning inventory, determining basic requirements for the distribution system, as well as determining the volume of raw materials, materials, and finished products to be supplied. It is also necessary to determine production volumes during this stage.

2. Procurement. During this stage, key supply chain management elements are identified, suppliers are selected and evaluated, quality of supplies is monitored at all stages, and contracts are entered into with suppliers. The main processes related to the acquisition of raw materials and materials are: acquisition, receipt, transportation, control, storage prior to receipt and profitability. In addition, actions related to the management of goods and services procurement should correspond to the planned or current demand.

3. Production. At this stage, the main attention is paid to the main structural elements, as well as the control of technological changes, management of production capacity, production cycles, production quality, and the schedule of production changes. Specific production procedures are also determined, including production procedures and cycles, storage and release of products, quality control, and packaging. All components of the process of transforming input products into finished products must correspond to the planned or current demand.

4. Sales. The main elements of this process are order management, inventory and transportation management. Order management includes creating and registering orders, determining the cost, choosing the product configuration, creating and maintaining a customer base, and maintaining a database of products and prices. Inventory management involves a series of actions, including picking and assembling orders, packaging, creating special packaging and labels for customers, and shipping products. The transportation and delivery management infrastructure involves managing channel and order rules, regulating product flows for delivery, and managing delivery quality.

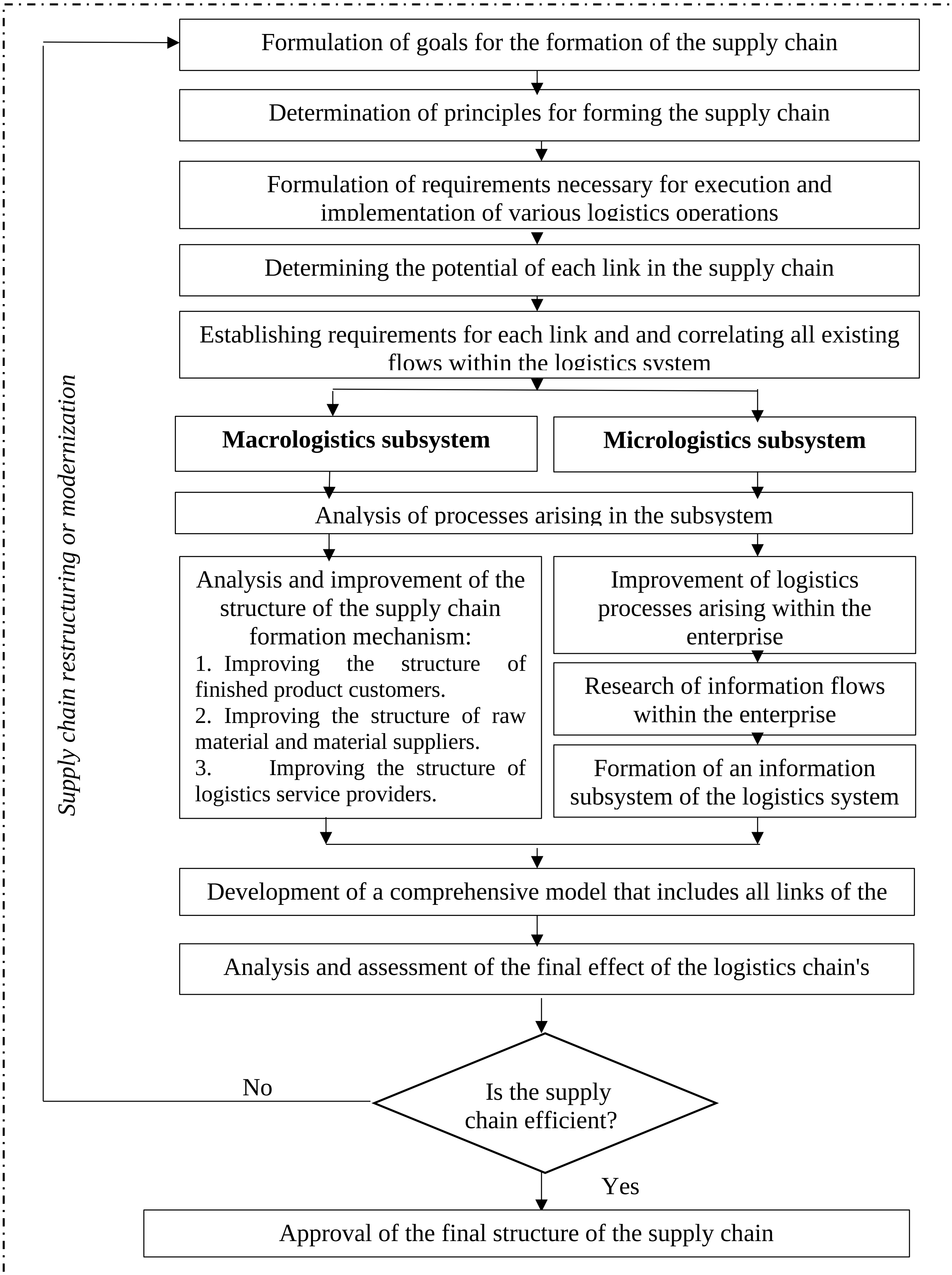
5. Returns. In the context of this process, the structural elements of defective product returns are determined, including determining the condition of the product, its placement, requesting authorization for returns, identifying responsible parties and issuing refunds as necessary, creating a schedule for returns, and directing products for destruction or recycling.

One of the key components in the mechanism of management is the decision-making block, which holds a significant place. It is crucial to make accurate decisions for each function considered. Therefore, decision-making preparation is necessary, which entails considering the impact of both external and internal factors, as well as utilizing decision support systems. This process enables the optimization of the system and the management process of the enterprise.

To develop and implement the proposed supply chain formation mechanism, an algorithm for its approval and implementation is required. The organizational and economic mechanism of the formation and efficient functioning of the logistics system of the forestry enterprise, proposed by Shishlo S.V. [24, p.247], serves as the basis for this algorithm.

The algorithm for the implementation of the proposed mechanism's structure is depicted in Fig. 6.

Figure 6. Algorithm for the implementation of the supply chain formation mechanism



In order to establish an effective supply chain, it is essential to first determine the objectives of each individual supply chain and establish the principles for its formation. The endorsement of these principles will facilitate the identification of requirements necessary for the execution of various sets of logistical operations. Following this, the potential of each link in the supply chain is determined, and requirements for each link and the relationship between all existing flows within the logistics system are established. The links are described in detail in the implementation of the supply chain formation mechanism functions, depicted in Figure 5.

The next stage involves dividing the algorithm into macro- and micro logistical subsystems. An analysis of processes is carried out for each subsystem. For the macro logistical subsystem, improvements to the structure of the purchasers of finished products, the structure of raw material and material suppliers, and the structure of logistics service suppliers are proposed. At the level of the micro logistical subsystem, logistics processes within each of the enterprises involved in the supply chain must be improved, information flows must be investigated, and an information subsystem of the logistics system must be formed.

Following this, a comprehensive model encompassing all links of the logistics chain is developed for both subsystems. The effectiveness of the proposed logistics chain is then evaluated, and a decision is made regarding its implementation in the case of satisfaction with the final result. Otherwise, restructuring or modification of the supply chain is necessary.

Based on the analysis results, it is proposed to determine the effectiveness of the proposed supply chain formation mechanism structure. If it proves to be effective, the proposed structure should be implemented. Otherwise, it is necessary to refine and improve it for each supply chain.

Conclusions

Based on a metasystemic approach, the main levels and structure of the supply chain are defined. The larger and stronger the supply chain is, with more elements, links, and interdependencies, the more complex relationships it forms and rises to higher levels of recursion. The elemental, component, and subsystem levels primarily reflect the internal logistical system of individual enterprises within the supply chain. Other levels of the supply chain are more oriented towards the formation of the supply chain in the external environment from the perspective of enterprises. The proposed multi-level model of the supply chain, developed using the principles of building viable systems, allows for the comparison of the needs and capabilities of the supply chain and the realization of its potential, ensuring the stability of functioning and adaptation to changing external conditions. Furthermore, based on a structural-level and metasystemic approach, the main recursion levels of the supply chain are determined.

A proposed structure and algorithm for implementing a supply chain mechanism are also presented. Their application allows for the subordination and standardization of the process of raw materials and materials delivery, organization of planning, production and transportation of finished products, as well as effective decision-making by obtaining timely information on the movement of goods. With the use of SCM, the coordination, planning and management of the processes of supply, production, warehousing and delivery of goods and services are solved.

References

1. Buhtiyarova, T.I. & Fedorova, E.V. (2012). Approaches and principles of logistics system trading company. *Modern problems of science and education*, 5. Retrieved from: http://www.science-education.ru/ru/article/view?id=7170.
2. Albekov, A.U. & Mitko, O.A. (2002). *Commercial Logistics*. Rostov-na-Donu: Feniks.
3. Mirotin, L.B. & Tashbaev, I.E. (2002). *Logistics for an entrepreneur: basic concepts, regulations, procedures*. M.: INFRA-M.
4. Kalchenko, A.H. (2004). *Logistics*. Kyiv: KNEU.
5. Sergeev, V.I. (Eds.) (2005). *Corporate logistics. The 300 answers to the questions of professionals*. M.: INFRA-M.
6. Smirnov, I.G. (2003). Problems and methods of effective inventory control in logistics systems. *Distribution and logistics*, 4, 6-22.
7. Afanasyev, K.M. (2017). The model of optimization of supply chain management system. *Market infrastructure*, 6, 250-253.

8. Workut, T.A., Bilonoh, O.YE., Dmytrychenko, A.M., Trenytrychenko, Yu.O. (2016). *Supply Chain Management: Logistics Aspect*. Kyiv: NTU.
9. Granin, A.N. (2013). *Packaging in logistics systems*. Minsk: Mezhdunar. un-t «MITSO».
10. Yeryomina, Ye.A. (2012). Tools for assessing the effectiveness of supply chain management. *Polzunovsky messenger*, 2/1, 70-73.
11. Zhymonik, A. (2010). *Logistyka i zarządzanie łańcuchem dostaw*. Warszawa.
12. Ivanov, D.A. (2009). *Chain management*. SPb.: SPbGPU.
13. Kindiy, M. V., Malysh, Ya. V., Pryyma, L. P. (2015). Management of chains of deliveries of trading networks on the basis of categorical management. *Bulletin of the National University "Lviv Polytechnic". Logistics*, 833, 143-152.
14. Kolodiziyeva, T.O. (2016). *Supply Chain Management*. KHNEU named S. Kuznets.
15. Kochubey, D. V. & Hryhorenko, T.M. Features of the formation of retail supply chain. *Business-Inform*, 10, 264-268.
16. Kristofer, M. (2004). *Logistics and Supply Chain Management*. SPb.: Piter.
17. Kuzmenko, Ye.G., Okolnishnikova, I.Yu., Stukalov, D.V., Kalenteyev, S.V., Katochkov, V.M. (2018). Development of warehouse logistics in the regional market: problem statement. *Bulletin of the Altai Academy of Economics and Law*, 6, 102-110.
18. Ovcharenko, G. S. & Rudkivskyy, O. A. (2011). Management of the supply chain of the enterprise on the basis of the SCM system. *Bulletin of the Khmelnytsky National University. Series: Economic Sciences*, 3, Ch. 1, 138-142.
19. Palamarchuk, I.V. & Artyukh, N.A. (2017) Supply Chain Management and Logistics Infrastructure Utilization. *Bulletin of the Economy of Transport and Industry*, 60, 101-107.
20. Selivanov, A.V. & Shamlitskiy, Ya.I. (2013) Warehouse logistics production system engineering enterprise. *Bulletin of SibSAU*, № 2(48), 260-265.
21. Stok, J. R. & Lambert, D.M. (2005). *Strategic logistics management*. M: INFRA-M.
22. Waters, D. (2003). *Logistika. Supply Chain Management*. M: YUNITI DANA.
23. Chukhray, N. I. (2006). *Logistic service*. Lviv: Lvivska politekhnika.
24. Shishlo, S.V. (2010) Formation of efficiently functioning logistics systems in forestry enterprises. *Works BSTU. Series 5: Economics and Management*, 7, 245-249.
25. Anikin, B.A. (2013). *Logistics*. Moscow: Prospekt.
26. Sumets, O.M. & Babenkova, T.Yu. (2012). *Logistics systems and supply chains*. Kyiv: Khai-Tek-Pres.
27. Gadzhinskiy, A.M. (1995). *Basics of logistics*. M.: Marketing.
28. Anikin, B.A. (2007). *Logistic*. M.: Velbi; Prospekt.
29. Valkova, N.V. (2015). Logistic systems: definition, classification and role at different levels of management. *Young scientist*, 2 (17), 146-150.
30. Shinkarenko, V.G. (2018). Management of logistics systems at the enterprise. *Economics of the transport complex*, 31, 5-26. DOI: https://doi.org/10.30977/ETK.2225-2304.2018.31.0.5
31. Kuzmenko, Yu.G. (2014). *Methodology of logistic integration of trading service systems.* Extended abstract of Doctor’s thesis. Ekaterinburg.
32. Demchenko, A.I. (2014). On coordination of the categories “flow" and “process" in logistic management. *Bulletin of South Ural State University. Series “Economics and Management”*, 2, 161-166.
33. Bykovskiy, V.V. (2015). Causes and conditions for the integration of micro-, meta- and mesologistic systems in macrologistic infrasystems. *Successes of modern science and education*, 1, 20-25.
34. Nahornyi, Ye.V., Naumov, B.C. & Ivanchenko, A.V. (2011). The model of logistics system of cargo delivery in international traffic. *Automobile Transport*, 29, 258-263.
35. Sergeev, V.I. (2014). *Corporate logistics in questions and answers*. M.: INFRA-M.
36. Sergeev, V.I. (2001). *Logistics in business*. M.: INFRA-M.
37. Kanke, A.A. & Koshevaya, I.P. (2015). *Logistics*. M.: ID FORUM: NITs INFRA-M.
38. Tiurina, N.M., Hoi, I.V. & Babii, I.V. (2015). *Logistics*. Kyiv: Tsentr uchbovoi literatury.
39. Beer, S. (2005). *The Brain of the Firm*. M.: URSS.

40.Puche, J., Ponte Blanco, B., Costas, J., Pino, R. & de la Fuente, D. (2016). Systemic approach to supply chain management through the viable system model and the theory of constraints. *Production Planning & Control*, 27 (5), 421-430.

41.Rios, J.P. (2010). Models of organizational cybernetics for diagnosis and design. *Kybernetes*, 39, 9/10, 1529-1550.

42.Karpov, A.V. (2011). *Psychology of consciousness: Metasystem approach*. M.: RAO.

43. Fedotova, I.V. (2017). Conceptual bases of integrated logistics. *Economics of the transport complex*, 30, 15-32. DOI: https://doi.org/10.30977/ETK.2225-2304.2017.30.0.15