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Classification, Digitalization and Structure of Integrated Logistics Chains

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ABSTRACT

Objective: Effective management of integrated logistics chains requires structuring them at a lower level, down to indi-vidual performers, and establishing clear relations between them. Addressing this problem will significantly reduce lost profits in these chains and increase their competitiveness. The purpose of this article is to develop a structure for integrated logistics chain that includes value, demand and supply chains, as well as providing recommendations for managing these chains.

Methods: To achieve the purpose of the study, terminological analysis, descriptive and faceted methods were used to identify, structure, formalize, combine, model and digitize objects and components of integrated logistics chain, thereby creating the prerequisites for the creation of artificial intelligence operating with non-physical management objects of this chain.

Results: The article develops a classification of integrated logistics chains according to the attributes of "management objects", which include enterprises, relationships, processes and flows, as well as "management components, such as values, novelties, demands and a products or services. Based on this classification, typical structures of integrated logistics chain are received. For each typical chain structure of this type, variants of focus enterprises are proposed that make it possible to design logistics channels and further integrated logistics chains adequate to a specific management situation.

Conclusion: The results obtained make it possible to create a methodology for designing integrated logistics chains and a digital twin for managing these chains. This is based on consumer values, chain management systems of various types, environmental factors, and integrated logistics chain management decisions and options for structuring and adjusting them during implementation.

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Introduction

A set of logically justified, interrelated and time-distributed impacts of an entity: a person making managerial decisions on linearly ordered objects, such as enterprises, relationships, processes and flows to create a management component in demand on the market: values, novelties, demands, products and/or services, hereinafter referred to as “logistics chain management” (Tyapukhin, 2022), is an extremely complex activity.

Today, depending on the management component, there are at least three types of logistics chains: value chains, demand chains and supply chains (e.g., Kannegiesser, 2008). These chains, in one combination or another, form integrated logistics chains. The management of these chains involves the development and implementation of a variety of consistent decisions made by formally independent management entities. The author’s approach to defining the essence of an integrated logistics chain differs significantly from the traditional understanding of the term “supply chain”, which states that “a supply chain is a single process from raw materials to finished goods distribution” (CSCMP, 2013).

Logistics chain management, primarily supply chain, as noted earlier, involves impact on several management objects, such as enterprises (Coyle et al., 2013), relationships (Christopher, 2011), processes (Wisner et al., 2012) and flows (Blackhurst et al., 2012). These objects undergo changes when influenced by management entities. Firstly, when creating management components, the values of end users of products and services are taken into account. Secondly, when responding to current and/or potential threats and opportunities created by environmental factors.

Each link in the logistics chain is characterized by a unique combination of management entities that form an organizational structure. This structure is supported by an original management system, which includes goals, objectives, approaches, principles, functions, and methods. (Tyapukhin, 2022). In addition, in logistics chains, management entities pursue not only collective goals, but also individual ones. (e.g., Rosko, 2016; Howe and Jin, 2022). This aspect significantly complicates the process of making consistent management decisions for various types of chains. In addition, the quality of decisions made by different management entities is affected by the uncertainty, transience, and mobility of environmental factors. (e.g., Koç et al., 2022; Acero et al., 2022). Therefore, it is nearly impossible to prevent the occurrence of bottlenecks, the growth of lost profit, and conflicts within the logistics chain. (e.g., Fawcett et al., 2008; Akın Ateş et al., 2022).

The specifics and complexity of integrated logistics chain management negatively affect the performance of management entities and objects and therefore can provoke dissatisfaction and outflow of end consumers of products and services (e.g., Priem, 2007). The solution to this problem can be achieved through a comprehensive digitalization of the values of consumer data; entities and management systems; logistics chains in statics and dynamics (Tyapukhin, 2022); environmental factors; and organizational structures for managing links and chains.

However, in solving this problem, it is necessary to overcome a number of related problems related to the identification of real entities, objects and components of the logistics chain management; their structuring, formalization, standardization, digitalization and modeling. In addition, it should be borne in mind that the entities, objects, and management components studied are described not only by quantitative parameters, the methodology for measuring and processing which is well known, but also by qualitative attributes. These attributes vary in a wide range, changing the form and content of entities, objects, and components of management. They are difficult to measure, and accordingly, reduce the effectiveness and efficiency of management decisions. This leads to lost profits.

The problems outlined above are reflected in the concept of Industry 5.0. This concept focuses on human beings, sustainability and resilience (Bregue et al., 2021). Industry 5.0 focuses on collaboration between humans and machines (Adel, 2012), including in management. At the same time, issues of practical implementation of the results of this collaboration remain outside the field of vision of the developers of the concept. This concept provides not only for the development of complex management solutions using information technology but also for their structuring along scalar chains and levels of organizational management structures (e.g., Fayoumi, 2016; Holschbach and Tank, 2016). In addition, given that a human being is a biological organism and a machine is a technological device, the process of creating and implementing management decisions differs significantly for each. In other words, the theory and methodology of logistics chain management developed to date, which is intended for humans as entities of management, cannot be adequately applied to machines, such as digital twins of logistics chains.

The novelty of this study lies in the results of structuring and combining objects and management components into an integrated logistics chain. These objects and components are characterized by a minimum required measurement accuracy, connectivity using relevant classification attributes, and dichotomies. The approach to digitization is simple, and there is a possibility of switching between variants of objects or management components vertically and horizontally, depending on changes in specific qualitative attributes or dichotomies.

These aspects of scientific novelty allow us to design algorithms that include stages and stages of decision-making development, as well as points of bifurcation that prompt artificial intelligence to sequentially justify these decisions, considering the specifics of qualitative attributes and dichotomies of objects and management components, as well as environmental factors. Furthermore, these algorithms can either lead to the selection of a typical or well-known management decision, or the decision can be developed using the artificial intelligence of a digital twin for integrated logistics chain management.

The hypothesis of the study is an assumption about the possibility of creating and using a universal software product of a new generation, first in the form of a prototype, and then a digital twin aggregate (Grieves and Vickers, 2017) for managing the integrated logistics chain. It is assumed that this product will allow you to identify, measure, structure, formalize, standardize, digitize and model the following objects as their complexity increases: a link in the logistics chain or a focal enterprise; any of the links in this chain, including the supplier and consumer of the focus enterprise; their entities, objects and components; relations between them; local logistics chains in statics and dynamics; integrated chains and, finally, business networks based on them.

Within this study, the following tasks must be solved: the development of classifications for logistics chains based on the attributes of “management object” (enterprises, relationships, processes, and flows) and “management component” (value, novelty, demand, product, or service); formation of a typical sequence for logistics chains to create value for end consumers of products and services; determination of characteristic features of management objects, depending on components of logistics chain management; justification of the structure of integrated logistics chains in dynamics, for subsequent development of their variants and virtual standards necessary to create and use a digital twin for logistics chain management.

The structure of the study is presented in the following way. Based on a pairwise comparison of objects and management components, variants of the logistics chain are justified. Considering the typical stages of creating value desired by the end consumer, two types of integrated logistics chains are formed. By using a set of relevant qualitative attributes and dichotomies that characterize local logistics chains, main forms of focus enterprises are identified. Depending on the stage of value creation or the form of focus enterprise corresponding to it, characteristic features of integrated logistics management objects are defined. Taking into account these features, a typical structure of an integrated logistics chain in dynamics is developed.

Literature review

A preliminary analysis of the problem allowed us to determine that most experts consider the logistics chain to be a supply chain, which consists primarily of processes (CSCMP, 2013). Therefore, we used the internet to search for and select literary sources related to our research topic using keywords such as “integrated”, “chain”, and “supply”.

At the first stage, we identified the most reputable publishing houses of the world's leading companies, which include distribution of scientific literature. According to information published on Publishersglobal.com, there are currently at least 470 such publishers. After reviewing the content of their online libraries, we selected 13 publishers as a basis for our research.

At the second stage, we used keywords in the online libraries of these publishers to search for information related to our research topic. We did not restrict the search by date of publication or type of literature source. In total, we identified 585 publications (books and journals). The largest share was from IGI Global Publishing (22.0%), followed by Elsevier (17.4%). Wiley and Inderscience each had 11.5% of the total, containing 1,456 articles and chapters relevant to our study. However, the majority of articles and chapters were published by Elsevier (28.4%), followed by Taylor & Francis (19.6%) and Indersciences (14.0%).

Since, when searching for literature, the keywords "chain" and “supply” give out the information that is irrelevant for this study, on the third floor, articles and book chapters corresponding to the term “integrated supply chain” were selected, the number of which was 178. Moreover, most of them also account for Elsevier publishers (25.8%), Taylor and Francis (18.0%), as well as Inderscience (12.9%).

At the fourth stage, a task was set to determine more or less accurately the research areas corresponding to the chosen term. The results of this are presented in Table 2.

It follows from the contents of this table that:

Firstly, some literary sources, primarily books (18 titles listed in Table 1) which cover a wide range of areas studied in integrated supply chains, had to be excluded from the analysis.

Secondly, in the study of the integrated supply chain, the authors give priority attention to areas such as inventory and the structure of this chain (13.8%), as well as modeling and design (12.5%), and analysis, forecasting, and planning (10%).

Thirdly, in most cases, the authors used economic-mathematical or quantitative methods to obtain results. Only one article out of 178, by Mingers (2011), indicates that “there are many situations, or perhaps aspects of situations, that could not be adequately represented by mathematical or computer-based modeling… This led to the development of several new “softer” methods that took the human or subjective dimension of problem situations seriously, while still being rigorous and systemic”.

Fourth, 22 articles focus on the structure, elements, and relationships of integrated supply chains (Nasiri et al., 2014; Zhang et al., 2015), or the processes (Dotoli et al., 2005; Zamarripa et al., 2013). However, there is a part of the objects and components of logistics chain management that is ignored for some reason.

Fifthly, only two out of 178 articles were consumer-oriented. This means that such a complex management object as the "value chain" still remains outside the field of view of researchers. By the way, this is why the concept of supply chain management is rightly criticized. (Rain bird, 2004; Jüttner et al., 2007; Lu and Swaminathan, 2015).

After studying the literature presented in Tables 1 and 2, the three main aspects of integrated supply chains included in the title of this article remained insufficiently developed.

Table 1. Results of the search for information about the research object "Integrated supply chain" according to online libraries

Publisher	Number of journals and books matching the request		Number of articles and chapters on the key words: "integrated", "supply", and chain"		Number of articles and chapters corresponding to the request	
	in total	%	in total	%	in total	%
Springer	19	3.3	23	1.6	5	2.8
Taylor and Francis	76	13.0	286	19.6	32	18.0
Elsevier	102	17.4	413	28,4	46	25.8
Wiley	67	11.5	167	11.5	14	7.9
SAGE	18	3.0	28	1.9	2	1.1
Inderscience	67	11.5	204	14.0	23	12.9
Emerald	42	7.2	131	9.0	16	9.0
Brill	3	0.5	4	0.3	2	1.1
SCIRP	9	1.5	16	1.1	3	1.7
IGI Global Publishing	129	22.0	129	8.8	(18)	(10.2)
Hindawi	7	1.2	7	0.5	4	2.2
IEEE	28	4.8	28	1.9	11	6.2
World Scientific	18	3.1	20	1.4	2	1.1
Total:	585	100	1456	100	178	100

Table 2. Research areas corresponding to the term "integrated supply chain"

Research area	Distribution of research areas	
	Number of articles and chapters	%
Inventory	22	13.8
Information technology	14	8.7
Sustainability and risk management	12	7.5
Flexibility	8	5.0
Analysis, forecasting and planning	16	10.0
Quality management	9	5.6
Relationships	8	5.0
Ecology	12	7.5
Cost and efficiency	15	9.4
Structure (elements and relations)	22	13.8
Modeling and design	20	12.5
Consumer orientation	2	1.2
Total:	160	100

One of the most widespread classifications of business systems today is the classification of management objects: enterprises, relationships, processes and flows according to the qualitative attribute "type of movement of processed resources" and dichotomies: sequential and parallel-sequential movement. The use of this attribute and dichotomies allows us to distinguish two types of business systems, respectively, business chains (e.g., Oliver and Weber, 1982) and business networks (e.g., Lazzarini et al., 2001). Since network research is accompanied by significant difficulties, there is a tendency to transfer the results of business chain research to business networks (e.g., Pohja, 2004; Braziotis et al., 2013). To simplify the transition from business chains to business networks, it is advisable to use the qualitative attribute: "stability of parameters and characteristics of the flow of processed resources" and dichotomies: stable and unstable parameters and characteristics. In this case, the following types of business systems can be distinguished: channel, chain, front and echelon (Tyapukhin, 2023). This study is intended to explore channels and chains focused on managing the flow of material, information, financial and human resources. In other words, the objects of this study are logistics channels and chains (Bowersox et al., 2000).

Another common classification of options, but already components of business systems management, is a classification using the qualitative attribute "type of transformable management component", which made it possible to identify values, demands and supplies (e.g., Kannegiesser, 2008). However, since value creation is initiated not only by the consumer of products and services, but also by their supplier (Vargo and Lusch, 2008), it is advisable to add to these components the "novelty" component offered by the supplier to its potential consumers, using the qualitative attribute "type of management situation" and dichotomies: standard and non-standard management situations (Tyapukhin, 2022).

Considering the possibility of different combinations of objects and management components, researchers: firstly, they use parallel terms such as "supply chain" (e.g., Ayers, 2001) and "supply network" (Harland, 1996), "value chain" (Ramsey, 2005), and "value network (Ericsson, D., 2003), "demand chain (Selen and Soliman, 2002), and demand network (Kaipia et al, 2006); and secondly, they attempt to integrate various types of business chain objects and components: supply chain and value chain (Feller et al., 2006), demand chain and value chains (Walters and Rainbird, 2004), demand chains and supply chains (Walts, 2007), supply chains, demand chains, and value chains. (Singh and Power, 2010).

In other words, there is an effort to move from local business systems to integrated systems by combining objects and components of management.

This approach to classifying options for objects and components of the logistics chain management is not entirely accurate. If researchers identify four objects and four components of management, at least two groups of logistics chains with different structures can be formed based on these. The first group is oriented towards the consumer (management components), while the second takes into account the interests of the supplier (management objects). Based on these groups, numerous variants of integrated logistics chains can be generated and a methodology for their digitization using relevant quantitative parameters and qualitative characteristics of their component entities, objects, and components of management can be developed.

If you select its links (enterprise objects) as the basis for designing an integrated logistics chain, then these links will solve various tasks and perform functions not only within local logistics chains but also within integrated logistics chains. In other words, when creating value for the end consumer of products and / or services, the enterprise changes its form and assumes one or another role involving one or more divisions or chains of divisions to solve current problems. Under these conditions, the problem of classification, formalization, and digitization of logistics chain links (enterprises) arises, a solution to which has not been found yet. As an example, we can cite the well-known forms of enterprises that in the SCOR model (Supply Chain Council, 2012) are presented as "supplier's supplier", "supplier", "your organization", "customer", and "customer's customer". At the same time, in accordance with this model, many processes take place at the enterprise, and it becomes problematic to choose a unique form of a particular enterprise at a certain point in time. This significantly complicates its identification and, consequently, digitalization. Additionally, a large number of concurrent processes carried out by the enterprise lead to lost profits, which increases significantly in an integrated logistics chain.

If we consider that an enterprise is a management object that forms several logistics chains, each of which creates many values for consumers in various market segments, then the requirements for the organizational structure of the management of not only the enterprise, but also the logistics chain, are seriously increased. On the one hand, this must be unique, (e.g., Ahmadya et al., 2016) and, on the other hand, it has standard interfaces for establishing relationships with many adjacent links in the logistics chain (Peck and Jüttner, 2000; Seguel et al., 2014). This aspect of the research confirms the validity of using the term "organizational structure of logistics chain management" (e.g., Holschbach and Tank, 2016), which is adapted to create specific values for the end consumer of products and/or services. It can be assumed that this type of structure is formed from the divisions of various links in the logistics chain, which are connected in certain relationships and perform required processes coordinated in time and space, managing flows of materials, information, finance, and human resources. Depending on the form and role of the enterprise, their number and quality may vary widely, but they can be effectively managed using digitalization and further software and computer support for managerial activities.

One of the paradoxes in the research of logistics chains, mainly supply chains, is the attempt to form a theory and methodology for managing business networks without considering the intermediate stage of management: the management of logistics channels, which includes the previous and subsequent links in the flow of resources, with constant quantitative parameters and qualitative characteristics for their objects (Tyapukhin, 2023). However, there are two possible ways to move from managing an object or component to business network management: (a) management object or component → logistics channel → *logistics chain* → logistics echelon → business network, and (b) management object or component → logistics channel → *logistics front* → logistics echelon → business network.

Thus, depending on the value life cycle stage (e.g., Potra and Izvercian, 2015), the priority role of the focal enterprise in the logistics chain is determined. Then, this enterprise is selected, and inputs and outputs are specified within it (Hammer and Champy, 1993), or options for creating value are determined. Logistics business systems are designed and formed consistently at the micro level after this problem has been solved. After this, you should proceed to designing and forming macro-level logistics business systems by starting with logistics channels and finishing with a business network that can complete the required stages of the value lifecycle created for the end consumer.

Literature study allowed us to establish that today:

Firstly, the results of research on the integration of logistics chains, particularly supply chains, are well known (for example, Bask and Juga, 2001; Fawcett and Magnan, 2002; Fabbe-Cos and Jahre, 2007; Liao et al. 2022; Zighan et al., 2023, etc.). Most research on this topic focuses on the study of internal and external factors that contribute to the creation of business systems that achieve the final result in a more efficient way through coordinated actions by their links. However, issues related to the management of business systems and the digitalization of their components remain outside the focus of researchers.

Secondly, studies on the creation of integrated logistics chains and networks (e.g., Nordmark et al., 2012; Lee et al., 2013; Hart, 2017, etc.) are mostly subjective in nature, based on empirical methods and aimed at finding optimal structures for these chains and networks. The objects of research are typically transport, warehouses, stocks, or physical objects that are relatively easy to optimize and digitize. However, the need to implement the tools of the new business concept "Industry 5.0" (Breque et al., 2021) necessitates a change in approaches to the creation of these integrated logistics chains and networks.

Thirdly, authors explore the problems of digitalizing supply chains (e.g., Seyedghorban et al., 2020; Durach et al., 2021; Toorajipour et al., 2021) and value chains (Bauer et al., 2018; Johns, 2021; López et al., 2021) to a lesser extent but not managing them.

Fourthly, despite the fact that entities, objects, and components of management of logistics chains, when creating value for the end consumer of products and/or services, are constantly changing their form and content, i.e., they are in a dynamic state. Existing approaches to digitalization do not allow tracking the logic of these changes. Consequently, there are currently no prerequisites for introducing artificial intelligence and other software products to effectively manage logistics chains using digital twins.

Fifth, the main focus of the research is on the digitalization of physical objects in logistics chains and/or objects that are measured by quantitative parameters (e.g., Marmolejo-Saucedo, 2020). The research does not explore the issues of digitalizing non-physical objects in these chains, such as values, management systems, relationships, organizational culture, options for managerial decisions, staff points of view, and behavior, etc.

Sixth, attempts are made to adapt existing information products and technologies such as artificial intelligence (e.g., Min, 2010), robotics (e.g., Yong and Khor, 2018), IoT (Simchenko et al., 2019), 3D printing (e.g., Laplume et al., 2016), autonomous machines (Bechtsis et al., 2008), blockchain technologies (e.g., Treiblmaier, 2018), etc., to optimize local logistics chains. However, the prospects for their use, especially in managing integrated logistics chains, are not well understood.

Seventh, existing software products adapted to the specifics of logistics chains, such as the SCOR Reference Model (Supply Chain Council, 2012) and the Design Chain Operations Reference Model (APICS, 2014), do not take into account all the objects and components of logistics chain management. It is worth noting that efforts are currently underway to create a Customer Chain Operations Reference model (for example, Chen and Pai, 2014). This model, however, poorly takes into account the digitalization specifics of entities, objects, and components within the logistics chain.

Thus, an analysis of the literature on the study problem has shown that there is currently no holistic methodology for designing, forming and optimizing integrated logistics chains, including value, demand and suppy chains, including:

(a) the terminology of chain management of various types is insufficiently developed, which does not allow to properly identify its non-physical objects and establish unambiguous relations between them in a specific management situation;

(b) methods for measuring and formalizing objects of this type have not been developed, taking into account the fact that they can change their shape and content. As a result, it is impossible to establish the logic of their transformation, which prevents the creation of artificial intelligence operating with non-physical management objects of integrated logistics chains;

(c) when optimizing logistics chains of various types, the main criterion for the effectiveness of managing these chains is mostly ignored, namely, lost profits, which constitute the main reserve for increasing the competitiveness of their chainss; and

(d) the mechanism of justification and structuring of management decisions both vertically (scalar chains) and horizontally (levels of these chains), as well as their adjustment and restructuring depending on environmental factors, is poorly developed.

Thus, the following research questions can be formulated:

RQ1: What types of logistics chains can be created using objects and components of management?

RQ2: How are the typical structures of an integrated logistics chain formed?

RQ3: How can we identify the main forms of enterprises as objects of integrated logistics chain management?

RQ4: What characteristic attributes of the value, demand, and supply chain objects can be justified?

RQ5: What does the structure of a digital integrated logistics chain look like, including not only objects, but also components of the management of this chain?

Methodology

When researching and optimizing entities, objects and components of logistics chain management, described mostly by qualitative attributes, it is necessary:

First, to study the terminology of this type of management, and more specifically, the qualitative attributes used in the content of the terms under study. For example, when studying 176 terms “supply chain management”, “supply chain”, and “SCM” Stock and Boyer (2009) highlighted three major themes: activities, benefits, constituents/components; and six sub-themes: flows; networks of relationships; value creation; creates efficiencies; customer satisfaction; and constituents or component parts. Despite the fact that this classification needs additional comments, it allows us to draw a number of the following conclusions: (a) it confirms three of the four previously presented management objects: flows, relationships and activities (or processes), as well as one of the management components: value; (b) the classification contains elements of statics and dynamics, for example, constituents or component parts and value creation; and (c) the themes and sub-themes highlighted by the authors create prerequisites for their measurement in the simplest case using dichotomies in three main variants: (i) quantitative parameters of the type “more” or “less”; (ii) states of the object of study: “state 1” or “state 2”; and (iii) stages of the process: “stage 1” or “stage 2”.

Secondly, to substantiate and select qualitative attributes of real objects and mnanagement components and measure them using dichotomies and the symbols “0” and “1”. In this case, it is recommended to use a descriptive research method (e.g., Yin, 2009) based on the analysis of not only terminology, but also literary sources in retrospect (e.g., Marshall and Rossman, 2016) or on the results of current sociological surveys of specialists (e.g., Mertens, 2010). Since there can be many such attributes and dichotomies, it is advisable to divide them into relevant and irrelevant ones. For example, if you are trying to uniquely identify a specific person from among more than 8 billion people on the planet Earth, using dichotomies, you would need 2^x= 8,000,000,000 (or 33) relevant classification attributes in order to solve the problem. In the case of solving a specific research problem, the quantity and quality of these attributes can be clarified (vertically), supplemented (horizontally), and even standardized. Unfortunately, insufficient attention has been paid to this aspect of the methodology of qualitative research in the literature (Bailey, 1994; Creswell and Creswell, 2018); and

Thirdly, to determine rational combinations of these attributes in two, three or more using a faceted method (Sneath and Sokal, 1973). This makes it possible to identify various options for entities, objects, and components of the logistics chain management process located in cells of binary matrices. For example, combining two classification attributes can yield 4 possible entities, object, component, or management options. Using three attributes simultaneously contributes to justifying 8 of these variants, etc.

Descriptive and faceted methods of qualitative research create prerequisites for the subsequent use of methods for identifying entities, objects and components of management; their structuring, formalization, standardization, digitalization and modeling, allowing to create virtual and real integrated logistics chains and manage them using digital twins.

The methods of qualitative research mentioned above form the so-called matrix approach, which solves many theoretical, methodological, and practical problems in supply chain management in the context of digitalization. This aspect of the study is particularly significant, as specialists may be under the impression that the apparent simplicity of this approach is overshadowed by the opportunities presented to researchers by powerful digital tools such as algorithms trained on large language models (LLM) and big data.

In the context of implementing the priorities of Industry 5.0 and future supply chain management, the proposed matrix approach offers:

First, to introduce a systematic approach to improving the terminology in supply chain management by clarifying classification attributes, forming logical relations between terms and eliminating their duplication and possible ambiguity.

Secondly, not only to properly digitize the already published memoirs of well-known specialists in the field of management (we are not talking about simply transferring their booming variants to a digital environment), but also to create conditions for the digitalization of future memoirs, allowing to continuously form a base of standard management decisions used by digital twins of SCM.

Thirdly, to enhance the skills of managers by rebuilding their competencies in line with the capabilities provided by current and future information technologies. This involves encouraging them to think in a “computer-based” manner, that is, operating not only with images and variations of management objects but also with their categorical attributes, dichotomies, and binary codes.

Fourthly, to achieve a reasonable adjustment of the information technology and digital tools market by moving from the “supplier market” to the “consumer market” in accordance with the modern marketing concept. This means that future users of technologies and tools should be able to solve supply chain management problems, and based on this, form requirements for future software products, which their future developers or suppliers should fulfill, not vice versa.

Fifthly, to create the necessary conditions not only for the development of efficient digital management solutions, but also for their structuring and formalizing at different levels and across the organizational structure of the supply chain, as well as for their implementation with minimal loss of profit. This means effectively performing those management functions that are beyond the competence of the IT developer or supplier.

Sixthly, clearly identify, rank and formalize the required supply chain management objects both in their current and future states. And only then, make the necessary adjustments to mostly impersonal information technologies and digital tools that are also available to competing supply chains. It should be remembered that, in any case, final management decisions are made by the users, who should be able to “computer-wisely” speculate and refine the alternatives offered by these digital decisions, and

Seventhly, to ensure the creation and implementation of artificial intelligence for managing non-physical SCM objects, which, under certain conditions, could lead to the development of innovative management decisions and their adjustment with the help of currently unavailable “sensors” and feedback. (To be continued.)

Results

The main prerequisites of the study include:

(a) the problem of improving the management efficiency of complex socio-economic systems such as value, demand and supply chains and the integrated logistics chains created on their basis;

(b) lack of methodology for designing and managing various types of chains;

(c) the insufficiently developed potential of qualitative research methods, such as terminological analysis, descriptive and faceted methods;

(d) ignoring the possibility of creating identification series for the subsequent digitization of non-physical management objects of the integrated logistics chain, such as values, demands, ideas, plans, strategies, relationships, environmental factors, management decisions, organizational management structure, etc.; and

(e) the absence of attempts to create a digital twin of integrated logistics chain management, which is based on artificial intelligence operating with non-physical management objects.

Classification of local logistics chains and determination of the structure of typical integrated logistics chain

The solution of these tasks is fundamentally important from the point of view of creating a digital twin of integrated logistics chain management, because: firstly, each variant of the logistics chain is formed on the basis of relevant qualitative characteristics and differs from their other variants either by attributes or dichotomies. Thus, the possibility of a subjective approach to the classification of non-physical entities, objects and management components is excluded; secondly, a logically justified transition from one entity, object or component to another entity, object or management component of the logistics chain is ensured; and, thirdly, a kind of reserve of etities, objects and management components of the logistics chain is formed for future research, which can be identified, structured, formalized, integrated, applied as models and digitized.

If you designate a group of management components with the symbol “0” and a group of management objects with the symbol “1”, then in the corresponding group (binary matrix) each component or object will receive a three-digit code. Group “0” includes product or service: “000”, demand: “001”, novelty: “010”, and value: “011” (Table 3); and group “1” contains enterprises: “100”, processes: “101”, relationships: “110”, and flows: “111” (Table 4).

Tables 3 and 4 are formed as follows. The horizontal and vertical lines of these tables indicate, respectively, the components and management objects of the integrated logistics system. At the intersection of columns and rows of these tables, pairs of components and management objects are formed, allowing you to determine a variant of the local logistics chain. For example, the combination of the components “demand”, code “001” and “novelty”, code “10”, allows you to select a “chain of contacts”, code “010001” (Table 3). Accordingly, the management objects: “enterprise”, code “100”, and “flow”, code “111”, are the basis for creating a “chain of routes”, code “100111”" (Table 4).

The information in Table 1 allows us to conclude that, using the pair-wise combination of management components (group “0”), 6 variants of homogeneous logistics chains can be obtained:

Table 3. Classification of logistics chains based on the attribute “management component”

Logistics chain options (group “0”)				
	Value (011)	**Novelty (010)**	**Demand (001)**	**Product or service (000)**
Value (011)	X	Chain of desires (chain of initiatives) (011010)	Chain of agreements (011001)	Chain of consumption (011000)
Novelty (010)	-	X	Chain of contacts (010001)	Chain of innovations (010000)
Demand (001)	-	-	X	Chain of orders (chain of possibilities) (001000)
Product or service (000)	-	-	-	X

Table 4. Classification of logistics chains based on the attribute "management object"

Logistics chain options (group "1")				
	Enterprise (100)	**Relationships (110)**	**Process (101)**	**Flow (111)**
Enterprise (100)	X	Chain of specialization (chain in static) (100110)	Chain of technologies (100101)	Chain of routes (100111)
Relationships (110)	-	X	Chain of responsibilities (110101)	Chain of communications (110111)
Process (101)	-	-	X	Chain of resources (chain in dynamic) (101111)
Flow (111)	-	-	-	X

(1) chain of desires (consumer) or chain of initiatives (supplier), code "011010", characteristic of desired end consumer value or concept of value chain management, as well as novelty chain management;

(2) chain of contacts, code "010001", chain of approvals, code "11010", chain of orders (consumer) or chain of possibilities (supplier), code "00110";

(3) chain of innovations, code "010000", specific to value carrier (product or service), or for supply chain management concept; and

(4) chain of consumption, code "011000", characteristic of perceived value, or for value chain management concept (paragraph 1).

These types of local logistics chains form typical sequence of homogeneous logistics chains (group "0") or chains of management components (Fig. 1).

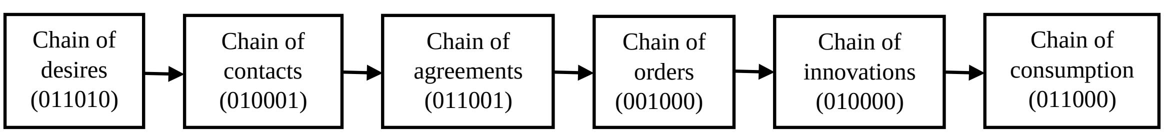

Fig. 1. Sequence of logistics chain management (chains of management components)

Similarly, information in Table 2 allows us to conclude that, based on the pair-wise combination of management objects (group "1"), 6 variants of homogeneous logistics chains can be obtained:

(1) chain of specializations or chain in statics, with code "100110", chain of technologies with code "100101", typical for the concept of manufacturing management;

(2) chain of communication, code "110111", chain of responsibilities, code "010001", typical for the concept of information management; and

(3) chain of routes, code "100111", chain of resources or dynamic chain, code "101111", typical for logistics management concept.

These types of local logistics chains form a typical sequence of homogeneous logistics chains (group "1") or chains of management objects (Fig. 2).

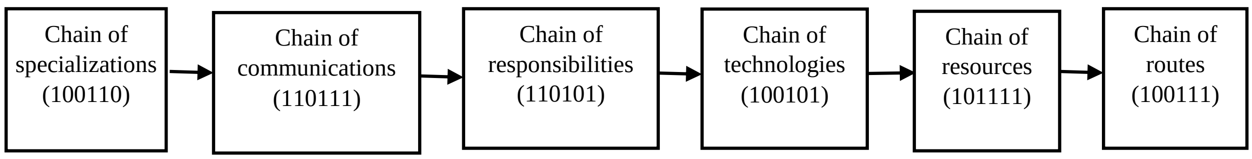

Fig. 2. Sequence of logistics chain management (chains of management objects)

Typical structures of the integrated logistics chain

There are interconnections between chains of management components (Fig. 1) and management objects (Fig. 2), which allow for the creation of the integrated supply chain, as well as the business network in two main configurations: for local management (Fig. 3) and for global management of supply chains (Fig 4).

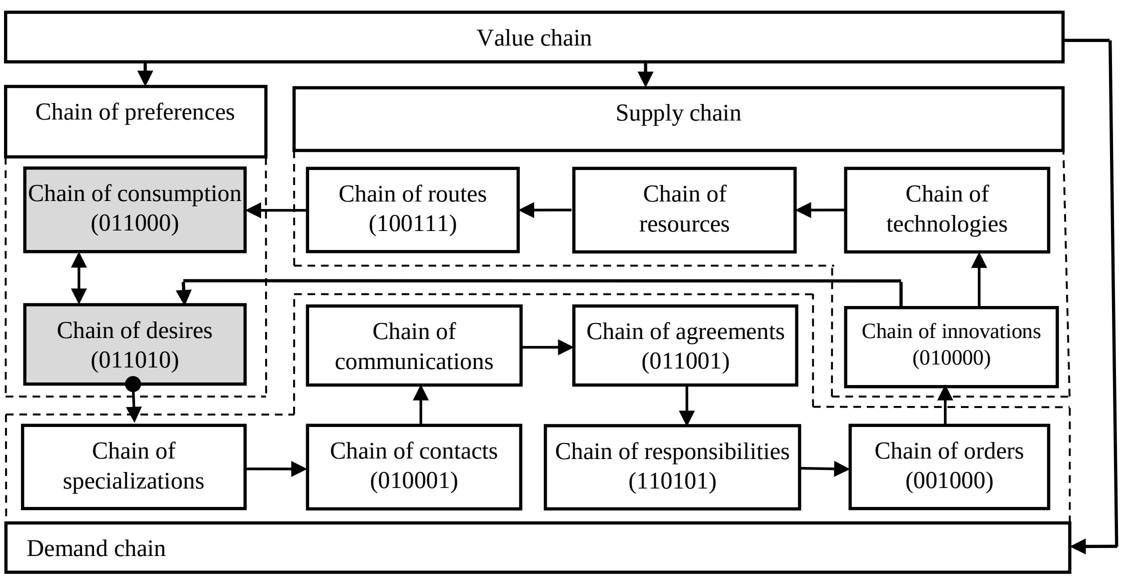

Fig. 3. Integrated logistics chain management sequence (local or sequential version)

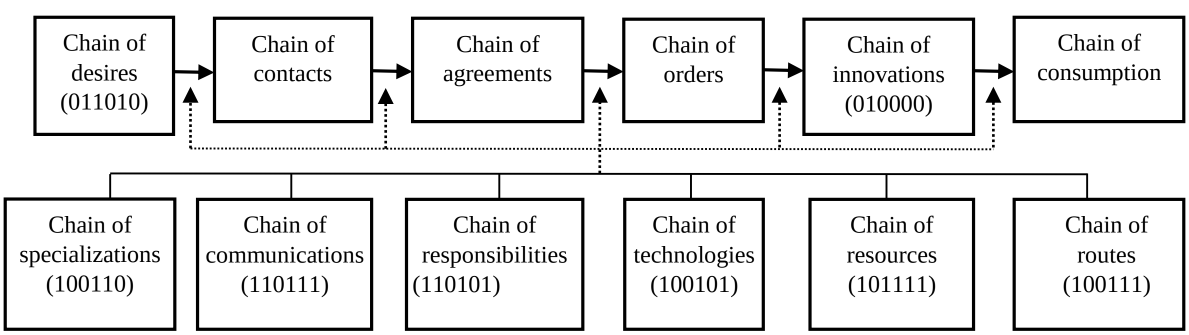

Fig. 4. Integrated logistics chain management sequence (global or parallel version)

The local or sequential option (Fig. 3) is advisable for forming logistics channels such as “consumer - focal enterprise” and “focal enterprise – supplier” or three-link logistics chain. In this case, a cycle of “chain of desires - demand chain - supply chain - chain of consumption” is formed, and the chain of desires and consumption form the chain of preferences, which, together with the demand and supply chains, form the logistics chain known as the value chain. The global or parallel option (Fig. 4) is typical of the creation of logistics networks formed by the focal enterprise and requiring the establishment of relationships between that enterprise and various counterparties.

In this scenario, priority is given to the logistics chains created based on the classification attribute of “management component” (group “0”), which are focused on consumers. At the same time, the group of logistics chains established based on the classification attribute of “management object” (group “1”) is used at the junctions between logistics networks of group “0”.

Classification of the main forms of a focus enterprise as an object of integrated logistics chain management

The enterprise, code “100”, including the focus enterprise, is the basic object of logistics chain management. It establishes relationships with other enterprises (code “110”), performs required processes (code “101”), and manages resource flows (code “111”). Since the design of the integrated logistics chain involves designing logistics channels that contain at least two enterprises at the initial stage, creating value for the end consumer of products and/or services requires constant changes in the quantity and quality of the management objects listed above as well as the organizational structure of the logistics channel management. This aspect of the research involves creating virtual standards for logistics channels used in modeling the organizational structure of the integrated logistics chain and forming the theoretical and methodological basis for creating not only the digital twin of this chain, but also the digital twin for managing it. The solution to this problem is provided on the basis of such the qualitative attribute as “form of focus enterprise as the object of logistics channel management”, which, in turn, implies orientation towards the components of logistics channel management and the relevant qualitative attributes and dichotomies presented in Table 5.

Table 5. Qualitative attributes and dichotomies are used to justify the form of enterprise as an object of a logistics channel.

Component of management	Type of business chain	Classification attribute	Dichotomies (states, processes)
Value (novelty)	Chain of preferences	Form of manifestation of insufficiency of something	Feeling
			Elimination
		Type of consumer value	Value carrier
			Value prototype
Demand	Demand chain	Object of discussion or contract	Interaction
			Product and service
		Type of relationships function in the business channel	Communication (discussion)
			Conclusion and execution of the contract
Product or service	Supply chain	Type of created values	Intangible
			Tangible
		Type of business channel link function	Resource management
			Order fulfillment

The information presented in Table 5 allows us to not only substantiate the main forms of focus enterprise, but also designate them using binary codes, the basis of which is the code “100” (enterprise, Table 4). The results of this stage of the research are presented in Figs. 5-7.

Form of manifestation of insufficiency of something \ **Type of consumer value**	Value carrier (0)	Value prototype (1)
Feeling (0)	Tester (100.0000)	Performer (100.0001)
Elimination (1)	Developer (100.0010)	Consumer (100.0011)

Fig. 5. Main forms of focus enterprise (100) in logistics chains of preferences (option 00)

Type of relationships function in the logistics channel \ **Object of discussion or contract**	Interaction (0)	Product and service (1)
Communication (discussion) (0)	Negotiator (100.1000)	Counterparty (100.1001)
Conclusion and execution of contract (1)	Plaintiff or defendant (100.1110)	Professional (100.1111)

Fig. 6. Main forms of focus enterprise (100) in logistics demand chains (option 10)

Type of logistics channel link function \ **Type of value created**	Intangible (0)	Tangible (1)
Resource management (0)	Partner (100.0100)	Owner (100.0101)
Order fulfillment (1)	Logistician (100.0110)	Technologist (100.0111)

Fig. 7. Basic forms of focus enterprise (100) in logistics supply chains (option 01)

These Figures allow us to conclude that the main forms of focus enterprise are:

(a) in preference chains: tester (code “100.0000”), performer (code “100.0001”), developer (code “100.0010”), and consumer (code “100.0011”);

(b) in demand chains: negotiator (code “100.1000”), counterparty (code “100.1001”), plaintiff or defendant (code “100.1110”), and professional (code “100.1111”); and

(c) in supply chains: partner (code “100.0100”), owner (code “100.0101”), logistician (code “100.0110”) and technologist (code “100.0111”).

If we take as the basis the focus enterprise in any form, then we can establish relationships between this enterprise and counterparties or other enterprises in 12 different forms shown in Figs. 5-7 (Fig. 8).

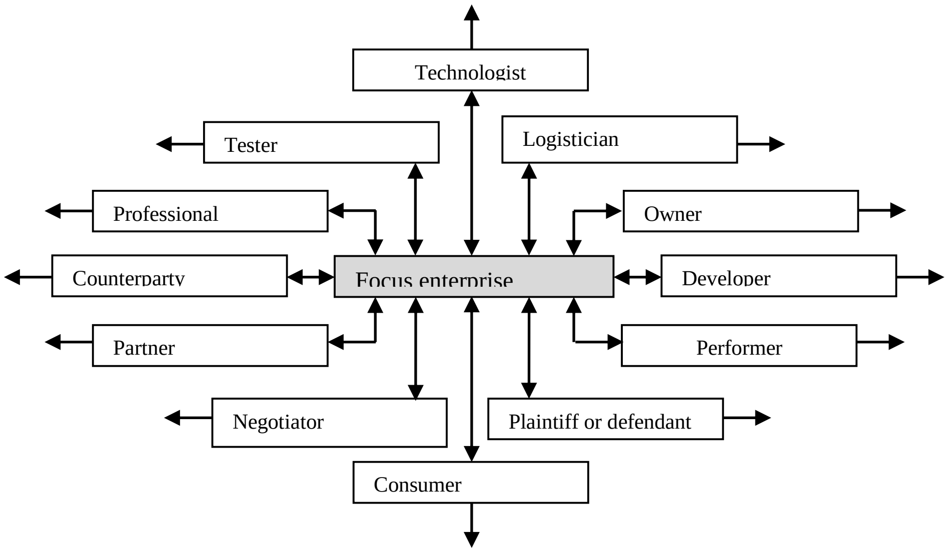

Fig. 8. Relations of forms of focus enterprise in the design of logistics channels

Moreover, each of these 12 forms involves transition to three-link logistics chains, with the possibility of creating "n" - link chains and/or to logistics fronts of the focal enterprise taken as a basis, with the subsequent possibility of creation of logistics echelons based on these. Moreover, each form presented above involves the creation of virtual standards for logistics channels using standardized relationships, code "110", performing standardized processes, code "101" and managing standardized flows, code "111".

Characteristic features of integrated logistics chain management objects

It is possible to identify and systematize all possible options for typical logistics channels, which create prerequisites for designing business networks based on their digitalization and creating digital twins for managing these business networks. However, first, based on the objects of logistics channel management, we should determine the content of typical logistics chains (Figs. 1 and 2), a solution to this problem is presented in Table 6, the feature of which is the concretization of these objects into the following variants: "form of focus enterprise", "aspect of counterparty relationships", "main process" and "flow elements".

These options allow you to create virtual standards for logistics chains, each of which requires the use of typical computer-aided design techniques using 7-digit binary codes for focus enterprise forms and 9-digit binary codes for the objects in these logistics chains. For example, the chain of desires is created on the basis of the focus enterprise such as the consumer, with the code "100.0011", which implies clarification of the desired value with the code "100.0011.00", using formalization with the code "100.0011.01" operating with flows of preferences and prototypes coded as "100.0011.10". Similarly, virtual standards for other logistics chains are created, creating the prerequisites for designing the integrated logistics chain that is most suitable for creating value for the end consumer of products and services.

Structure of an integrated digital logistics chain

It should be recalled that the design of any object or management component involves a number of stages, which can be determined based on the following qualitative attributes and dichotomies: "stage of creation of an object or component of management": search, symbol "0", and visualization, symbol "1", as well as "management function of the object or component": planning, symbol "0", and design, symbol "1". The joint use of these attributes and dichotomies makes it possible to justify and digitalize the following stages of design of objects or components of management: study, code "100", divergence, code "110", convergence, code "111", and formalization, "101" (Fig. 9).

Table 6. Prototypes of typical logistics chains

Types of logistics chains	**Characteristic attributes of logistics chain management objects**			
	Form of a focus enterprise	**Aspect of relationships**	**Main process**	**Flow elements**
1	2	3	4	5
Chain of preferences (creation of desired and perceived value)				
Desires	Consumer (100.0011)	Clarifying the value (100.0011.00)	Formalization of value (100.0011.01)	Preferences, prototypes (100.0011.10)
Consumption	Tester (100.0000)	Getting value (100.0000.00)	Maintenance of consumption (100.0000.01)	Feelings, Impressions (100.0000.10)
Demand chain (value prototyping)				
Specializations	Professional (100.1111)	Purchases (100.1111.00)	Exploring the database (100.1111.01)	Information about suppliers (100.1111.10)
Contacts	Counterparty (100.1001)	Choice (100.0100.00)	Attracting a supplier (100.0100.01)	Proposals for cooperation (100.0100.10)
Communications	Partner (100.0100)	Opportunity (100.1001.00)	Communication and discussion (100.1001.01)	Messages (100.1001.10)
Agreements	Negotiator (100.1000)	Compromise (100.1000.00)	Decision making (100.1000.01)	Approvals (100.1000.10)
Responsibilities	Plaintiff or defendant (100.1110)	Compensation (100.1110.00)	Corrections and mprovements (100.1110.01)	Special conditions (100.1110.10)
Orders	Performer (100.0001)	Contract (100.0001.00)	Registration of the order (100.0001.01)	Documentation (100.0001.10)
Supply chain (creating a value carrier)				
Innovations	Developer (100.0010)	Project (100.0010.00)	Product (service) development (100.0010.01)	Ideas (100.0010.10)
Continuation of the Table 6				
1	2	3	4	5
Resources	Owner (100.0101)	Access to resources (100.0101.00)	Acquisition of resources (100.0101.01)	Raw materials, materials, semi-finished products (100.0101.10)
Routes	Logistician (100.0110)	Movement (100.0110.00)	Resource delivery (100.0110.01)	Transport, packaging, equipment (100.0110.10)
Technologies	Technologist (100.0111)	Operations (100.0111.00)	Manufacturing of a product (service) (100.0111.01)	Tooling, energy, etc. (100.0111.10)

Object or component management function	**Stage of creating an object or component of management:** Search (0)	Visualization (1)
Planning (0)	Study (100)	Formalization (101)
Design (1)	Divergence (110)	Convergence (111)

Fig. 9. Classification of the stages in creating an object or component in logistics chain management

These stages are typical not only for the design of objects and components of management, but also for any type of business system using their corresponding digital twins. First, they are based on prototypes developed by the customer (future user) and then instances created by the performer based on a technical specification. In either case, the digital twin of a business network and its management is an aggregate of digital twins (Grieves and Vickers, 2017), which includes many hierarchically organized instances, the creation of which will be an extremely difficult task in the distant future.

Using information from Table 6, it is possible to create a structure for the integrated logistics digital chain (Fig. 10) that includes a set of logistics channels taking into account the shapes of its links (Figs. 5-7). The initiator of the creation of this chain is a consumer experiencing a shortage of something (Table 5) presented as a desired value.

Since "value is always intangible, heterogeneously tested, co-created, and potentially perishable" (Vargo and Lusch, 2008), it should be specified or its prototype. In some cases, this prototype may be presented as flows of products and/or services that create local value or several different desired values for consumers. To solve this problem, it is advisable to establish a "consumer ↔ professional" logistics channel, which requires the establishment and, perhaps, clarification of relationships between counterparties, allowing: (a) consumers, through a "formalization" process, to determine which products and services in quantity and quality are required at a particular time, and (b) potential suppliers to effectively manage the necessary resources and supplies.

Having received information about potential suppliers, consumers, possibly with the help of a counterparty, select suppliers involved in cooperation and send them appropriate proposals focusing on the creation of logistics channels "consumer ↔ professional". At the same time, not all professional suppliers involved in the cooperation have the opportunity to establish relationships with this consumer. Therefore, some professionals are eliminated in the future, and their remaining part becomes partners of the consumer of products and/or services. Communicating and discussing options for possible cooperation, including on the basis of various kinds of compromise (in this case, the partner acts as a negotiator), decisions are made to establish relationships and draw up agreements, including specific conditions, based on which it is possible in the future to create a logistics channel "plaintiff ↔ defendant". This channel is especially relevant in the event of inevitable corrections and improvements to earlier agreements, providing compensation for the costs and time associated with this logistics channel's links. After the conclusion of a cooperation agreement and the establishment of relationships, the "consumer ↔ provider" channel is formed, which involves fulfilling orders for products and/or services requested by the consumer and providing the necessary documentation for their implementation. Innovative solutions or ideas are needed to create desired value for consumers, so performers can form a "performer-developer" logistics channel, whose task is to develop products and/or services based on corresponding projects. This project requires the involvement of resources and the creation of many types of logistics channels, such as "performer - owner". These channels are necessary for the purchase of raw materials, components, and semi-finished products, for which "performer – logistician" channels are used to involve transport, containers, lifting, and transportation equipment. Further, logistics channels "performer → technologist" are formed, designed to create value carriers (products and/or services) using personnel, machinery, technological equipment, various types of energy, etc. The values created in these logistics channels are verified for compliance with the desired value in "performer – tester" logistics channels with appropriate support from the performer. At the same time, the tester, who may be a consumer, experiences sensations and chats that allow him to compare the desired and perceived values, gain necessary experience and decide on the possible continuation of cooperation with known counterparties.

The structure of the integrated digital logistics chain, shown in Fig. 10, can: (a) be digitized using the codes shown in Table 4; (b) contain a set of ordered logistics channels, such as "performer ↔ owner", "performer ↔ technologist", etc.; (c) have numerous options depending on the specific management situation; and (d) be transformed into business fronts and business echelons whose structure depends on the goals and objectives of the particular focal enterprise.

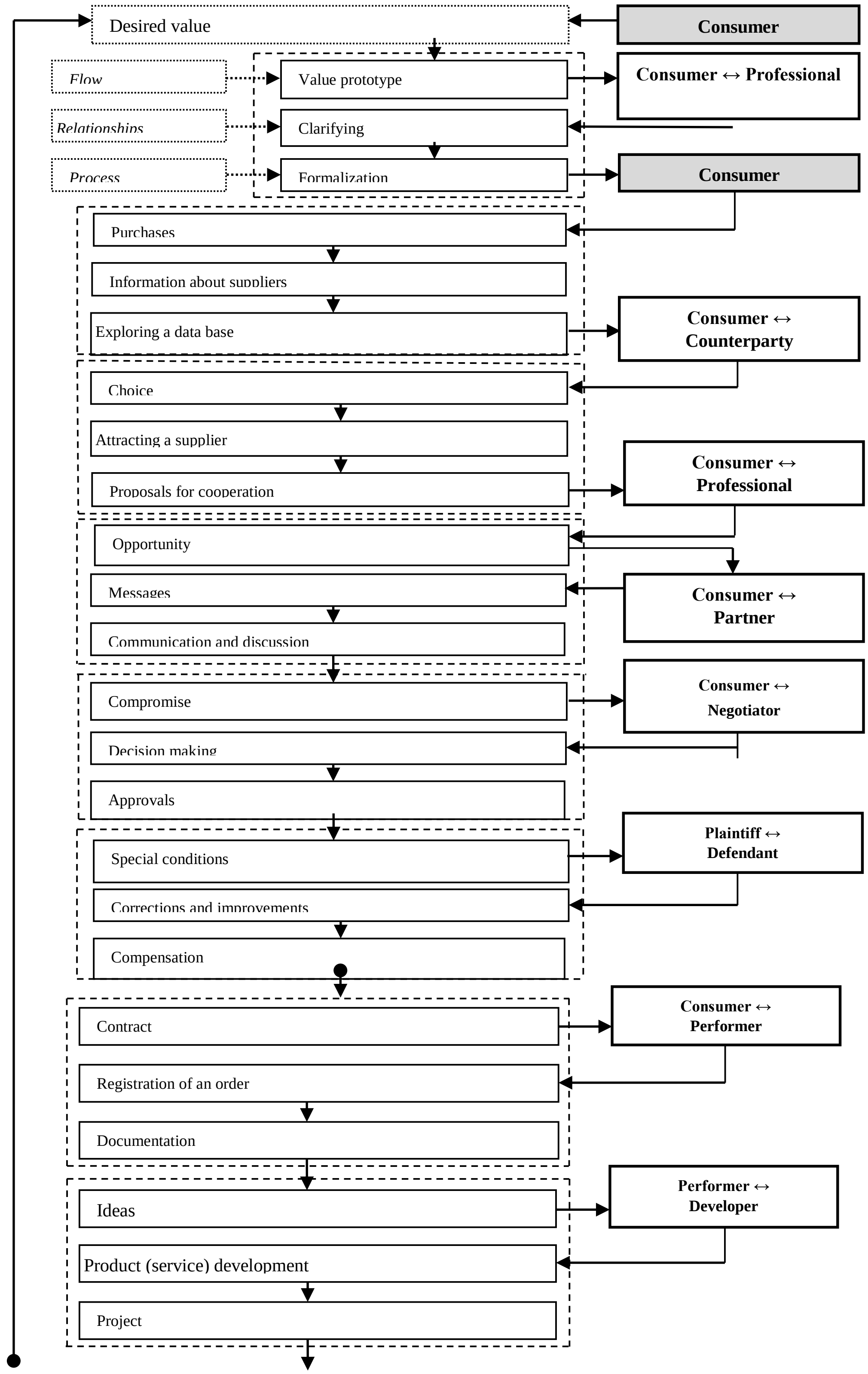

Fig. 10. Structure of a digital integrated logistics chain (beginniing)

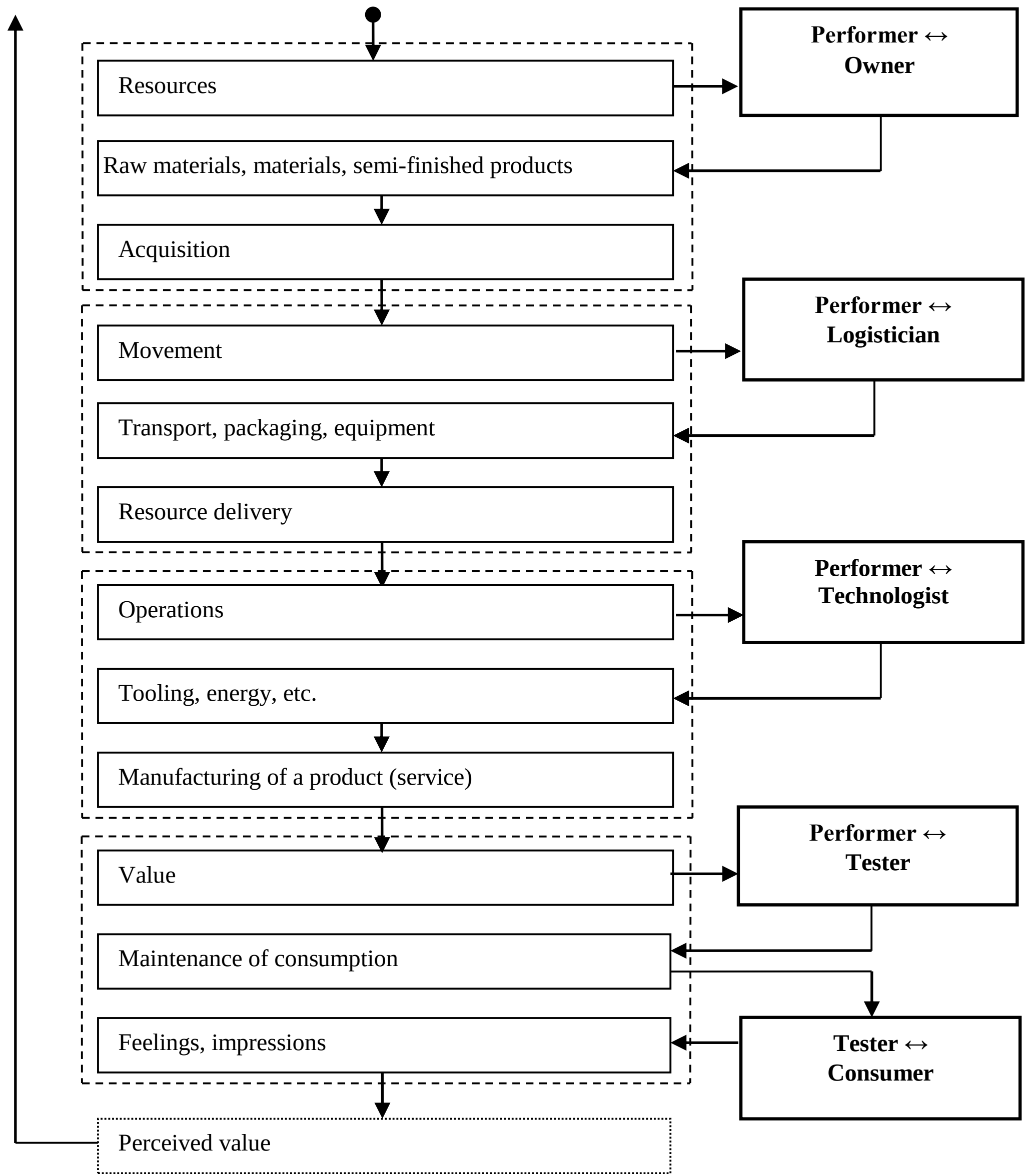

Fig. 10. Structure of a digital integrated logistics chain (ending)

Discussion

In the context of continuous changes in the external environment, the problem of developing and implementing effective management decisions in integrated logistics chains using information technology is becoming more and more urgent. When solving this problem, not only physical, but also non-physical entities, objects and management components should be taken into account and, accordingly, quantitative and qualitative research methods should be used together. To do this, it is necessary: firstly, to continuously improve the multi-methodology of integrated logistics chain management, which includes, among other things, soft systems methodology, cognitive mapping, strategic choice analysis, and strategic assumption surfacing and testing (SAST), strategic assumption surfacing and testing, strategic choice approach, critical systems heuristics, etc. (Mingers, 2011); secondly, to substantiate the set of classifications, primarily based on qualitative attributes of values of consumers, entities and objects of management relevant at the specific time of the research; thirdly, to identify and define objects and components of management and their elements and relations; fourth, to develop a scale for measuring classification attributes and determine what should be included in this scale (dichotomies, object states, process stages, etc.) and what accuracy of measurement should be used; fifth, to change the content of business system management terminology dictionaries so that they can become an effective tool for digitalization; sixth, to create virtual standards for values of consumers, entities, objects, and management components, as well as relations that allow not only identifying them but also adapting them to real analogs; seventh, to overcome conflicts between goals of business systems and links, eliminating the possibility of opportunistic behavior (Williamson, 1998); and eighth, providing for the possibility of forecasting strategies and behavioral options for competing business systems.

These aspects of the problem of developing effective management solutions in integrated logistics chains are fundamentally new for specialists and, accordingly, are subject to discussion, the results of which suggest the creation of a prototype concept of a digital twin of this type of chain management.

Conclusion

In this article, the following results with signs of scientific novelty have been obtained: classifications of logistics chains were developed according to the attributes of “management object” (enterprises, relationships, processes, and flows) and “management component” (value, novelty, demand, and product or service). A typical sequence of logistics chain has been created to create value for the end consumer of products and services. The typical structure of an integrated logistics digital chain has also been justified.

In the future, it is planned to address the following tasks in designing logistics business systems: developing a methodology for designing virtual standards for entities, objects, and components of management as well as relations between them; clarifying the structure and content of an integrated logistics management system, which includes goals, objectives, principles, functions, approaches, and methods; justifying an approach to determining the modes of operation for integrated logistics chains based on environmental factors; clarifying structures for prototypes of digital twins for entities, object, and component of management in the logistics chain, and preparing recommendations for the development of technical specifications for designing instances and aggregates for digital twins in logistics chains and managing these chains.

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