Research of Management Processes in Complex Logistics Systems

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Abstract: The authors have proposed a project for the study of management processes in complex logistics systems. The grounds, goals, directions and research program are defined. Methodological principles and means of analysis of the global logistics system, presented in the form of a hierarchy of models for managing logistics processes at various levels, are indicated. The current results of the project development are described.

1 INTRODUCTION

The proposed article has the following objectives:

– to present to the international scientific community the program of research conducted by the authors on the management of the creation, functioning and development of complex logistics systems (CLS) on various strata of the world system of economic relations;

– to familiarize with the current results of the specified research program.

The authors propose a research program of management processes in complex production and logistics systems, which provides:

– identification and description of the main types of logistics;

– creation of a hierarchy of models of various levels of the main elements of the global logistics system as complex logistics systems;

– description of the global logistics system as a formal system object;

– creation of models of effective management of CLS, including types of support (informational, financial, service, etc.);

– creation of models of effective end-to-end procurement and supply chains, including production, transportation, warehousing, etc.;

– creation of models of interaction of CLS;

– research of CLS system parameters, including security, vulnerability, efficiency.

From the point of view of system analysis, the international logistics system assumes the formation and organization of the functioning of sustainable logistics systems linking state and business structures of various countries of the world on the basis of division of labour, cooperation and partnership in the form of agreements supported at the interstate level.

Stratification of the international logistics system can be carried out on the basis of various criteria (Ismailov, 2018).

2 RESEARCH METHODOLOGY

Let's consider the conceptual methodological principles of the study of complex logistics systems. The initial philosophical prerequisites of the study are formulated in (Platonov 1991).

The problem of studying the behavior and management of complex systems arises in various fields of human activity and is directly related to the development of system objects of various levels. There is a whole spectrum of complex systems classified by spheres of activity, applied research methods, the possibility of applying and consequences of certain control actions, ranging from a specific individual to objects of a planetary scale.

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Here the role and influence of economic instruments on social relations and, ultimately, the vital activity of each person is studied.

The proposed formalized research methodology assumes consideration of this process on the basis of integration of system-logical, structural-social and scenario approaches.

The system-logical approach involves the description and study of research objects from the standpoint of system analysis, which is based on the concept of "formal system object". This will allow us to study objects and processes from the point of view of formal logical and mathematical methods.

The structural and social approach involves the description and study of socio-economic management objects based on the definition and structuring of human activities. This should make it possible to study objects and processes in social systems at various strata of the social structure of society, identifying the main social objects, social structures and describing various social processes on this basis.

In the formalized representation of the modelling object in the proposed concept, the concept of "extended phase space" is used, which is formed depending on the purpose of the study on a certain stratum of the description field. The principal practical significance of studying various phase spaces in the process of managing various stratified descriptions is realized in the concept of "meta-laboratory of system description". This makes it possible to "end-to-end" structural and systemic description from the unified methodological positions of the noosphere as an extensive hierarchical system of jointly functioning natural and social forces.

Combining system-logical and structural-social approaches makes it possible to study human activity as the main driving cause of the development of the socio-economic system, considering it as a structured spectrum of formalized processes of changing the states of socio-economic objects and subjects of action.

The scenario approach involves the study of processes occurring in socio-economic systems based on the construction and study of behaviour scenarios (synergistic scenarios) of social actors of action and management scenarios (attractive scenarios) of social objects.

Combining system-logical, structural-social and scenario approaches make it possible to study multidimensional problems, subject scenarios to scenario analysis and synthesize scenarios of behaviour of various social actors of action, and proceed to the creation of a security system for a given social object, social structure or social process.

The proposed set of approaches, in our opinion, will allow us to classify the types of managerial influences, classifying the circumstances of their implementation. At the same time, the classification of circumstances should be considered on the basis of essential features that characterize:

– stratification areas in which the management process is carried out, since each of them is characterized by original ways of describing;

– objectives of the subjects of action;

– conditions for the implementation of the studied processes in the field of stratification,

– applied models and research methods that determine the essential conclusions about the nature of the studied processes.

2.1 Hierarchy of Models of Complex Logistics Systems

A holistic methodology for creating conceptual models focused on the study of material flows in logistics networks includes the principles of constructing the following particular models:

• models of the structure of the material flow processing system;

• models of the assortment and quantity of goods in the flows;

• models of spatial nesting of cargo, cargo carriers, vehicles and stationary cargo storage;

• time models of input flows of the system;

• models for determining the duration of technological operations;

• routing models of dynamic objects (vehicles, cargo carriers and the cargo itself);

• models for combining and separating dynamic objects;

• models of waiting queue processing strategies;

• models of inventory management strategies;

• models of resource allocation and dispatching processes.

The specified set of models includes a model of the physical (spatial) structure, models for displaying the structure of logistics objects moved and stored in the system, which together makes up a model of the process developing in the CLS.

2.2 Investigation of System Parameters

When studying CLS, presented in the form of a formal system (Uemov 1978), we use various research methods. The application of each of them is focused on identifying the properties of the system. This approach requires a certain classification, which in turn involves the formation of system-wide features. A new technique on this path is the formation, modelling and study of system parameters.

A system parameter is a characteristic of a feature, a property by which the scope of the concept "system" can be divided into classes in accordance with the rules of the logic of dividing the scope of the concept (Kononov 2016, Ponomarev 2016).

An important stage of the study is the analysis of its system parameters that characterize the effectiveness of the design, operation and development of CLS.

2.2.1 Determinability

The structure of a deterministic system correlates system elements in such a way, and the concept and set of joint characteristics of the system and the external environment are such that the status of the current internal state of the system or the transition to another internal state of the system can be predetermined with varying degrees of certainty. It is this property of the system that makes it possible to predict new states of the system.

2.2.2 Purposefulness

The most important property of the system, which many authors declare fundamental in defining the system.

The goal is the intention, the purpose of the system's activity, the integrating property, on the basis of which the system is isolated from the external environment; the system–forming factor, according to which the interacting elements of the system are combined into unity. The goal is one of the elements of human behaviour and conscious activity, which characterizes the anticipation in thinking of the result of activity and the way of its realization with the help of certain means. The goal acts as a way of integrating various human actions into a sequence or system, as one of the forms of determination of human activity. The analysis of activity as purposeful involves the identification of a discrepancy between the present life situation and the goal; the implementation of the goal is the process of overcoming this discrepancy.

2.2.3 Activity

The concept of a goal implies a description of the activity of the system. Depending on who, why and how carries out this activity, it is possible to distinguish "passive" and "active" systems. In active systems, the presence of "active" system elements is postulated, i.e., elements with "will": the ability to set goals, form ways to achieve goals and their implementation.

2.2.4 Observability

Observability in control theory is a property of a system that shows whether it is possible to completely restore information about the states of the system at the output. One of the most important characteristics that characterizes the ability to effectively monitor both the current state of the organization and the forecast of future changes.

2.2.5 Awareness

A system parameter, a property of a management system, including a manager, to have a set of data necessary for making effective decisions.

2.2.6 Manageability

One of the most important properties of the control system and the control object (machine, living organism, society, etc.), describing the ability to transfer the system from one state to another. The study of the control system for controllability is one of the important steps in the synthesis of control controllers.

In the sociology of management, manageability is a qualitative characteristic of the social environment that allows socialized subjects to set and achieve certain goals in interaction with each other

2.2.7 Durability (stability)

A system parameter that characterizes the ability to withstand disturbances, including impacts, and to function in the CRF under conditions of disturbances. The main characteristic of the stability of the system is the time when the system reaches the limit state of safety.

Perturbation is the realization of a threat that may be external to the system under study and/or arise within it. To analyse the occurrence of threats, appropriate formal threat models have been developed

2.2.8 Risk

A system parameter, a property of a control system, in particular a control system, to make decisions under conditions of uncertainty, which may entail both undesirable (dangerous) and significantly advantageous consequences.

2.2.9 Vulnerability

A system parameter that characterizes the possibility of causing damage to the described system of any nature that violates the CRF. The nature, degree and possibilities of eliminating these damages depend on the created design (structure of the system), operating conditions (operation), as well as methods and means of influence.

2.2.10 Effectiveness

A system parameter that characterizes the mechanisms and methods generated by the control system to achieve the goal. Based on a given rule for comparing strategies to achieve the goal – the criterion of efficiency, the characteristics of efficiency in various types of organization activities are determined: productivity, profitability, profitability, etc.

3 CURRENT RESEARCH RESULTS

The proposed research methodology has been tested for a number of applied projects for the development of systems of various classes and purposes. Note the following.

3.1 Scenario Study of the Vulnerability of a Complex Logistics System

To implement this task, a set of works was carried out:

– formulation of the research problem;

– building an object model;

– definition and formalization of expert-significant events;

– identification and formalization of threats;

– formalization of the scenario characteristics of the object of study;

– development of a scenario analysis program (computational experiment);

– development of algorithms and a program for calculating characteristics;

– carrying out the necessary calculations;

– the conclusions of the analysis are formulated.

When using a general methodology, it is necessary to determine a number of specific methodological conditions that need to be taken into account in scenario analysis.

Firstly, the forecast of environmental changes is carried out by studying socio-economic trends. The sooner the current development trend is determined, the more time the Company will have to adapt to it, therefore, the less acute the crisis.

Secondly, it is necessary to take into account the current mode of operation of the system, which may not always be capable of a quick change of course: the main thing here is that the functioning and development are in a balanced proportion. So, functioning tends more towards conservation with a minimum of changes, whereas accelerated development – on the contrary, to flexibility, plasticity and mobility, violating current regimes, it is able to create conditions for the transition to a qualitatively new level of development.

Modelling strategic behaviour requires awareness of a number of assumptions about the meaning of individual parameters and the relationships that exist between them. These assumptions correspond to the current state of the Russian and global conjuncture. They should be revised when trying to apply the constructed models to the study of other systems, or at other historical stages of development. Such assumptions represent the corresponding strata of the quasi-information hypothesis.

The methodology of scenario research is as follows:

– study of characteristic modes of synergistic development in the form of a set of basic scenarios of synergistic development (without explicit control):

– determination of undesirable phenomena of synergistic development;

– determination of acceptable modes of synergistic development;

– determination of permissible impulse actions to prevent undesirable phenomena of synergistic development;

– determination of acceptable scenarios of attractive development;

– determination of optimal scenarios of attractive development.

At the same time, you should:

1) to form a stratified description of the basic factors in the areas (blocks):

a) resource and technological factors: availability of resources, technologies, logistics links, etc.;

b) economic factors: labour productivity, macroeconomic risk, investments, budget, tax rates, etc.;

c) integral economic and socio-political factors: the availability of qualified personnel, external factors of development, the level of the shadow economy, etc.;

the links between the main macro indicators that determine the specifics of development are significantly different.

2) determine the target factors of development. The most important macro indicators are considered as target factors: resource and technological indicators, indicators for assessing the effectiveness of economic activity, etc. It is required that the values of these factors reach a certain, sufficiently high level and maintain their stability for a given time. However, for each type of region, other macroeconomic indicators that are essential for its functioning can act as targets.

3) identify the managed components of a dynamic development model. As manageable basic factors that can be subject to changes (impulses), we highlight the possibility of changing external factors of development through changes in external relations, tax rates, investments, etc. Changes in the structure of relations between the basic indicators of development can be considered as managed components.

4) determine the criteria for the safety of the functioning and development of the Company. Scenario analysis determines either the minimum critical values of the target indicators, or undesirable trends in their development.

When all the necessary indicators are determined, development is monitored – regular assessment of target indicators and comparison of their values with acceptable ones. During the monitoring, development trends are monitored and crisis phenomena are predicted.

Safe development is managed by influencing the managed components of the model. From them, select those on which the impact will be most effective for solving the formal task. Determine the minimum and sufficient changes to the components to get the system out of the crisis. The results are checked on a graph model. From the possible ones, such impacts are chosen that, by bringing the system out of the crisis, as far as possible, bring the trend of changes in its indicators closer to their development targets.

Such an approach will allow not only to bring the system out of crisis, but also to prevent its occurrence, manage development, adjusting the trajectory of parameter changes to effectively achieve the target result.

3.2 Expanded Model of the Transport System in the Conditions of Uncertainties

Against the background of fast development of IT technology and digitalization of economy recently, for perfecting of the international logistic activity sharp body height of containerization of freights on railway transport is observed. A basis of increase in effective management of the specified processes are the systems of support of a decision making realized in the integrated intelligent automated control systems for railway transport. At the same time, the most important component of such systems is their mathematical and methodological support developed based on system research of the considered problems.

The expanded model of a transport task considering the following principal components makes the basis of a system research of a complex of the specified tasks:

- criterion of management efficiency;
- park of load-carrying capacity of cars;
- extreme volumes of cargo departures;
- extreme volumes of cargo receiving.

The last represent volumes of the contracts signed between suppliers and consumers and their contractor – carrier.

Model 1 ("Expanded model of the transport system").

Let

$$F(C,X,\mathbf{z},\mathrm{A})=\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}(C,\mathbf{z},\mathrm{A}) \quad (1)$$

be objective function.

The formal task consists searching

$$\min_{X\in X(C,\mathbf{z},\mathrm{A})} F(C,X,\mathbf{z},\mathrm{A})= F(C,X^{*}(C,\mathbf{z},\mathrm{A}),\mathbf{z},\mathrm{A}) \quad (2)$$

under conditions

$$\sum_{j=1}^{n} \alpha_{ij}x_{ij}(C,\mathbf{z},\mathrm{A})\le a_i,\ i=1,2,\dots,m=M; \quad (3)$$

$$\sum_{i=1}^{n} \alpha_{ij}x_{ij}(C,\mathbf{z},\mathrm{A})\ge b_i,\ i=1,2,\dots,n=N. \quad (4)$$

Here

i – index of the consignor;

j – index of the consignee;

$C=\{c_{ij}\ i\in M,\ j\in N\}$ – a matrix of specific transport expenses;

$X=\{x_{ij}\ i\in M,\ j\in N\}$ – a matrix of volumes of transportation of goods (plans);

$\mathrm{A}=\{\alpha_{ij}\ i\in M,\ j\in N\}$ – a matrix of the sizes of containers in the direction ($i\rightarrow j$);

$\mathbf{a}=\{a_i\ i\in M\}$ – a vector of the extreme volumes of cargo departures;

$\mathbf{b}=\{b_j\ j\in N\}$ – a vector of the extreme volumes of cargo receiving;

$\mathbf{z}=(\mathbf{a},\mathbf{b})$ – expanded vector of the extreme volumes of cargo transportation;

$X^*(C,\mathbf{z},\mathrm{A})$ – the optimum plan of transportation at the given C, $\mathbf{z}$, A;

$F(C,X^*(C,\mathbf{z},\mathrm{A}),\mathbf{z},\mathrm{A})$ – value of a task.

Techniques of optimum scheduling of goods turnover at uncertainties of criteria of management efficiency are considered, i.e., at change of a matrix of specific transport expenses of C (Ismailov2018).

3.3 Logistics Center Functioning Model

The M^{lc} model of the functioning of the logistics center (LC) in the integrated transportation system is a model of a manufacturing enterprise, the output of which are services. The implementation of each service requires the use of certain resources.

Model 2 ("Logistics Center Problem").

Let's highlight the following components:

P^{lc} – the range of services of the logistics center;

Q^{lc} –nomenclature of resources of the logistics center;

$p^{lc}\in P^{lc}$ – number of the provided logistic center service;

$q_p^{lc}\in Q_p^{lc}\subseteq Q^{lc}$ – is the resource number for performing the service p of the logistics center;

$O_{qp}^{lc}\in Q_p^{lc}$ – the volume of the stock of the resource q_p^{lc} for performing the service p of the logistics center;

$a_{pq}^{lc}\in A^{lc}$ – technology for the production of logistics center services;

$c_p^{lc}\in \mathbf{c}^{lc}$ – the price of the p^{lc} service of the logistics center;

Π_p^{lc} –many users of the p^{lc} service of the logistics center;

$\pi_p^{lc}\in\Pi_p^{lc}$ – p^{lc} service user number of the logistics center;

C_p^{lc} – control strategies (modes of execution of tasks of the p^{lc} service of the logistics center).

The basis for the system analysis of solving complex problems of a logistics center can be formed by a model of optimal planning of production (sale of services).

We put

$$D^{lc}(\mathbf{c}^{lc},\mathbf{x}^{lc},A^{lc},\mathbf{o}^{lc})=<\mathbf{c}^{lc},\mathbf{x}^{lc}(\mathbf{c}^{lc},\mathbf{x}^{lc},A^{lc},\mathbf{o}^{lc})>^{3} \qquad (5)$$

Thus, the formal task is to find the maximum income D from the sale of services

$$\max_{\mathbf{x}} D^{lc}(\mathbf{c}^{lc},\mathbf{x}^{lc},A^{lc},\mathbf{o}^{lc}) \qquad (6)$$

under conditions

$$\sum_{qp\in Qp} a_{pq}^{lc} x_q^{lc} \leq O_{qp}^{lc},\ p\in O_p^{lc} \qquad (7)$$

In market conditions, competition, sanctions, etc. the main elements $\mu=(\mathbf{c}^{lc},A^{lc},\mathbf{o}^{lc})$ of the model can, on the one hand, change depending on the circumstances and market conditions, on the other hand, - be the subject of design and implementation of the "end-to-end" interaction process of the Participants of the logistic process.

3.4 Model of Joint Operation of a Carrier and a Logistics Center

A detailed study of the problems of the development of rail freight traffic on the New Silk Road allows us to build a general model of interaction between the logistics service of railway administrations (carrier) and managers of logistics centers (LC).

The overall interaction between the carrier and the logistics center is a complex of interrelated actions aimed at achieving compromise goals with maximum completeness, safety and reliability. As a rule, the goals of each counterparty, considered as a complex commercial system, are to carry out production activities (logistics processes) that are most efficient. Each of the subjects of interaction carries out management independently.

The system of logistics centres $S^{gc}=\{M_r^{lc}, r\in R\}$,as well as consumers $S^{gc}=\{M_\pi^{c},\pi\in\Pi\}$ of their services (carriers) is considered. The formal model of the functioning of a logistics center consists in solving problem (5)-(7). The formal model of the carrier's functioning consists in solving problem (1)-(4). In each logistics center, a number of carrier services can be performed.

Π – set of carriers;

π – carrier's index;

$P_{\pi r}^{lc}$ – the range of services of the logistics center r, provided to the carrier π;

$Q_{\pi r}^{lc}$ – the range of resources of the logistics center r, provided to the carrier π;

$p_{\pi r}^{lc}\in P_{\pi r}^{lc}$ – number of the provided services of the logistics center r provided to the carrier π;

$q_{\pi rp}^{lc}\in Q_{\pi rp}^{lc}\subseteq Q_{\pi r}^{lc}$ – the resource number for performing the service p of the logistics center r provided to the carrier π;

[3] *Scalar product of vectors.*

$O_{qp}{}^{lc} \in Q_p{}^{lc}$ – the volume of the stock of the resource $q_p{}^{lc}$ for the execution of the service p of the logistics center r provided to the carrier π;

$a_{\pi rpq}{}^{lc} \in A_{\pi r}{}^{lc}$ – the technology of production of services of the logistics center r, provided to the carrier π;

$c_{\pi rp}{}^{lc} \in \mathbf{c}_{\pi r}{}^{lc}$ – the price of the $p_{\pi r}{}^{lc}$ service of the logistics center r provided to the carrier π;

$C_{\pi rpr}{}^{lc}$ – control strategies (modes of execution of tasks of the service p of the logistics center r in the implementation of orders of the carrier π).

Their target models can represent the objectives of the functioning of the LC and the carrier. Then, under the joint mode of interaction, we mean the set of performed functions necessary for the implementation of these goals. A certain set of tools corresponds to a certain mode: configuration of hardware and software, a set of resources (including information), procedures performed, etc.

By function, we mean a set of necessary actions to perform operations along the corresponding arc of the goal tree when implementing a given mode of joint operation of the LC and the carrier. With respect to modes, we classify functions as follows:

Mandatory – functions without which the functioning of a particular mode is impossible.

Compatible – functions that can be implemented in this mode, but this is not a prerequisite.

Incompatible – functions that are prohibited in this mode.

By the regulations for the joint functioning of the carrier and the LC we mean the process of managing the implementation of goals, which is necessary to fulfil orders for the carrier's services π. To do this, you need to consider the set of clients served, the set of dedicated funds, their configurations, and the order of operation and maintenance.

In principle, the model of interaction between the carrier and the logistics center during the operation of the LC in a joint interaction mode contains the following components:

Model 3 (“Rules of joint functioning”).

$P\alpha=\{S, X, \Lambda; \Delta ta\}$,

here

S – dedicated system of carriers and logistics centres;

X – a set of allocated funds for the functioning of the regulations;

Λ – configuration of allocated funds for the functioning of the regulations;

$\Delta ta=[ta_0, tae]$ – interaction horizon.

Regulations can be classified according to various criteria:

– by used system elements,

– the duration of the performance,

– functions performed,

– criteria for the consistency of management objectives,

– criteria for management consistency,

– applied management methods, etc.

Each of the regulations simulates the implementation of a particular service provided by the logistics center to the carrier. However, as a rule, a number of services are executed concurrently, which are performed in a cooperative mode.

It is possible to define a number of characteristics of the current situation in which the interaction system S.

4 CONCLUSIONS

The paper deals with topical issues of analysis and synthesis of logistics systems, approaches and methods of design in conditions of uncertainty. The research methodology is focused on solving the following tasks: – formulation of actual problems of design and management of logistics systems; – study of the basic methods of design, analysis and synthesis of logistics systems, as well as their management systems; study of tools development of design programs, organization of their implementation and construction of appropriate control systems; development of methods and tools for obtaining an assessment of the effectiveness of design, analysis of its results and appropriate management systems; development of organizational and economic models of processes, phenomena and objects, evaluation and interpretation of results; the study of methods and tools for searching, collecting, processing, analyzing and systematizing information on the design of a complex logistics system and its management system. The results of current developments are presented. Further research is related to the scenario study of the design, effective functioning and evaluation of complex logistics systems (Shultz, 2012).

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