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TARGET AND SYSTEM ASPECTS OF THE TRANSPORT INFRASTRUCTURE DEVELOPMENT PROGRAM

The **subjects** of research in the article are programs and projects for the development of transport infrastructure with the allocation of the logistics system. The **purpose** is to develop a systematic representation of the process of development of a logistic transport system, taking into account the goals of the transport infrastructure development program. The following **tasks** are solved in the article: systematization of the goals and objectives of the transport infrastructure development program, analysis of the features of the logistic transport system and processes of its development management, development of a generalized formalized presentation of the logistic transport system and the process of its development. To solve these problems, we use **methods** of system analysis, set theory, hypercomplex matrices. The following **results** were obtained. The principles of sustainable development of transport infrastructure are analyzed. The article presents the systematization of the goals and objectives of the transport infrastructure development program and outlines the basic principles of its sustainable development. The tasks of development of the logistic system in the transport infrastructure of the country are considered. A logistic transport system is presented in the form of a graph, where vertices are its elements and connections are information and material flows. When determining the acceptable level of the parameter of development of the logistics transport system, such types of coordination problems arise when making management decisions, such as integral, deterministic and range. In a formalized form, the logistic transport system is presented as a set of system invariants that determine its properties: complexity, dynamism and structural. There are three phases of uncertainty change taking into account the development of the system. The hypercomplex matrix of the system allows you to define its elements and their connections. **Conclusions**: The analysis of the research subject revealed that the issues related to the choice of system concept and methodological tools for the formation of distributed logistics infrastructure remain unsettled, and the problems of transport infrastructure of Ukraine are highlighted. Based on the proposed graph analytic representation of the logistic transport system, it is possible to analyze its structure.

Keywords: transport infrastructure; sustainable development; logistics system; hypercomplex matrix; system submission; phases of development.

Introduction

Reforming the transport structure of the country requires the use of innovative mechanisms in project and program management [1], in which considerable attention is paid to change, risk, quality, resources, communications, and so on. To date, successful projects and programs in Ukraine are mostly innovative and infrastructural.

The transport sector plays an important role in the socio-economic development of the country, because a developed transport system is a prerequisite for economic growth, improving the competitiveness of the national economy and the quality of life of the population. However, the level of safety, quality and efficiency of passenger and cargo transportation, energy efficiency, man-made environmental load do not meet current requirements. There is a lag in the development of the transport network, especially in the development of public roads on the pace of motorization of the country. In particular, the development of the transport infrastructure development program of Kyiv for 2019 - 2023 is projected to increase the number of vehicles registered in the capital by 60% by 2025. The traffic and operational conditions of the roads are unsatisfactory: 51.1% do not meet the requirements for equality, 39.2% – for durability. Transport is a source of emissions of one-third of harmful substances in Ukraine. For example, in cities, 90% of the emissions of harmful substances are made by road transport.

Other problems include the following: mismatch of the transport network to the existing pass-through; unsatisfactory conditions for all road users, lack of transport efficiency of bridge crossings to the needs of residents; undeveloped rail and land transport system; poor quality of the suburban train; low average speed of public transport; lack of a unified parking space, etc. These disadvantages are caused by such external and internal current political and economic conditions; lack of developed logistics infrastructure; outdated technologies and forms of transport management.

Analysis of recent research and publications

The works of such scientists as Vinnikov V., Kotlubai O., Novikova A., Preiger D., Rybchuk A., Khakhlyuk A. and others are devoted to the study of problems of functioning of transport systems and their development. Some aspects of the functioning of the transport system of Ukraine have been analyzed.

The main methodological provisions of the development strategy development were developed and published in the works of G. Mintzberg, M. Porter and other foreign and domestic scientists [2–4]. Many domestic scholars have been engaged in scientific research on the development of economic and mathematical models of transport system development [5–9]. Modelling problems of transport systems are solved in [10, 11].

Published articles and monographs focus on solving partial, unrelated goals of transport system management [12]. In addition, there is no problem of creating a distributed logistics infrastructure and management, there is no discussion of the choice of system concept and methodological tools for solving these problems [13]. Problems of a systemic nature for substantiating the intellectual components of logistics infrastructure are considered, which will ensure that effective decisions are made [14]. When designing innovative transportation

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projects, the accumulation and use of knowledge in the form of successful past projects are not fully taken into account [15]. Due attention has not been paid to modern forms of management, such as the intellectualization and virtualization of management of socio-technical systems [16]. Little attention has been paid to the systematic integration of transport systems in the wide range of problems associated with reforming and developing the country's distributed infrastructure and making effective decisions [17].

Highlighting unresolved parts of a common problem. The goal of the work

It should be noted that the question of finding and justifying the directions of development of the potential of transport systems in Ukraine in the context of the impact of external crisis phenomena and economic development trends is still unresolved and urgent. It is necessary to create a new approach to the management of transport infrastructure development programs (TIDPs), which is based on the formation of intellectual decision-making environment, risk-oriented management methods in transport innovations, effective methods of managing virtual complex systems, which will ensure sustainable development of logistics infrastructure countries and integration into the world transport system.

The purpose of the article is to develop a systematic representation of the process of development of logistics transport system, taking into account the goals of the program of development of transport infrastructure.

The tasks are solved:

- systematization of the goals and objectives of the transport infrastructure development program,
- analysis of the features of the logistics transport system and the processes of managing its development,
- development of a generalized formalized representation of the logistics transport system and its development process.

Materials and methods

Consider defining the program in terms of project management standards. The Program [18] is a series of related projects that are coordinated to achieve the benefits and degree of manageability that are not available when managed individually. According to the P2M body of knowledge, the program is a commitment that the project team organically combines to achieve a coherent mission [19].

Individual projects are combined based on the strategic mission of the program. Structurally grouped projects need to address a range of issues related to the various tasks and methods of their implementation. However, the program has a longer duration and uncertainty than these project totals.

The basic attributes of the program include [20]: multiplicity, scalability, complexity, uncertainty. Multiplicity of the program means that its set of projects has several different goals and objectives. Callability is a hallmark of a program in size and structure. The complexity of the program arises from the interaction between projects, from the combination and overlapping of their life cycles, from the uncertainty of the conditions of implementation [18].

The term "Program Management" in notation (PMBOK Guide 5rd Edition [19]) is defined as centralized coordinated program management that aims to achieve the benefits and strategic goals of the program. Program management provides the ability of the governing body (organization) to adapt to changes in the external environment to accomplish the mission of the program, by optimizing the relationship between projects. Individual projects are grouped into a program to increase its effectiveness if they have certain characteristics that benefit from group project management [20].

The development program is the planning of the future transport infrastructure for 5 – 10 years [21]. The main goals of this development are the following [22]:

- the formation of single transport space, i.e. the creation of a transport system without "bottlenecks", which provides transport accessibility throughout the territory;
- reduction of transport costs and cost of services due to the development of the transport network, efficient logistics with the use of optimal transport schemes and the movement of freight flows;
- increase of transport mobility of the population;
- ensuring the safety of transport activities.

Note that transport infrastructure (TI) is characterized by the following [23]:

- significant impact on the socio-economic development of the territory. Developed transport infrastructure provides mobility of material and labour resources, expands trade opportunities, makes the area attractive for investment, housing and work;
- high capital consumption, especially of routes (road and rail). Public-private partnership is usually used as a tool for implementing or improving the quality of individual projects;
- long terms of creation and operation. Infrastructure projects have been developed and implemented sometimes for decades. In many cases, selecting a project option, examining it and agreeing with it, as well as making all the necessary land decisions can take longer than building the road;
- the need to take into account a set of conflicting public, public and private interests in the implementation of infrastructure projects.

To date, sustainable development principles have been formulated, which can be grouped into four categories in relation to TIDPs (table 1) [24–27].

On the basis of the development program, specific investment and business projects are developed [28]. In assessing the feasibility and decision making of the project structure, account should be taken of the uncertainty associated with the scientific and technical risk of road construction and modernization. The multiplicity of factors and the different degree of their influence in the implementation of programs causes a variation in the ways to achieve the goals of the program. As a result, there is a need to justify

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and select the "best" of some of the alternative (component projects) programs.

Table 1. *Basic principles of sustainable development of transport infrastructure*

Principle	Essence	Direction of development
Social	- promotion of socio-economic development of regions; - ensuring the freedom of people's mobility and choice of transport, taking into account a balanced tariff policy; - coordination of planning of construction of transport infrastructure objects with the general scheme of planning of the territory of Ukraine, long-term plans of land resources use and deployment of productive forces	- development of transport infrastructure and modernization of rolling stock to ensure increased mobility of the population and accelerate the movement of freight flows
Economical	- ensuring a favorable business environment for all individuals and legal entities operating in the transport services market; - ensuring the advance development of transport infrastructure; - the need for antitrust policy; - liberalization of pricing in potentially competitive markets for transport services; - attracting investment and encouraging private sector involvement on the basis of fairness, transparency and stability; - transparency of regulation of the transport system; - use of transport resources in accordance with market demand	- ensuring the competitiveness and quality of transport services for the economy; ensuring accessibility and quality of transport services to the population; - integration into the European Union and development of export of transport services
Financial	- the concentration of financial resources on the basis of determining priorities in accordance with the formulated goals and requirements for the economic efficiency of their use; - functioning of transport enterprises on the basis of self-sufficiency; - joint financing of transport infrastructure; financing investment projects on the basis of income or revenue stream from project implementation	- improving the efficiency of public administration and developing a competitive environment
Ecological	- a priority of environmental safety requirements, mandatory observance of environmental standards and standards in transport activities; - the prevention of environmental pollution and the negative impact on human health due to the intensive development of road transport; - putting into effect the economic mechanism of nature management and nature conservation activities; - adoption and implementation of international legislation on the transport of dangerous goods; - promotion of priority development of energy-saving and environmentally friendly modes of transport and intermodal technologies	- increase of environmental friendliness, the energy efficiency of transport processes and safety of transportation of passengers and cargo

The problem is the choice between different projects implemented at the expense of the budget. In this case, there is a need to choose between territories or settlements that will be serviced by new roads, and therefore receive certain socio-economic benefits or have a number of negative consequences - land alienation, environmental pollution of the surrounding territories, etc. Selection of infrastructure projects to be implemented is based on strategic goals and main development priorities, bottlenecks of existing and potential projects.

Consider the essence of TIDP, which involves the implementation of a portfolio of innovative projects. Planning for the development of transport infrastructure consists of a set of construction, technical, organizational, planning, economic and social measures [29]. In general, a planned program consists of a number of units, such as:

- design, construction, development of new ways;
- modernization and repair of existing roads;
- planning of the implementation of advanced transportation technologies;
- planning of measures for improvement of management, systems of planning and organization of traffic;
- plan for modernization and replacement of obsolete transport warehouse.

The programming documents defining the development strategy may reflect the following main measures for the implementation of this strategy [30]:

- formation of scientific and technical department and development of innovative potential in order to ensure the program's realization;
- technical re-equipment and modernization of transport in carrying out a common scientific and technological and technological policy to ensure the implementation of the program;

- improving the system and mechanism for managing the development of transport infrastructure.

Thus, in the process of TI development, it is assumed not a single, one-time transformation, but a set, a complex of changes. Development is a link to quality transformations. The main content of development is significant changes in functioning.

The structure and content of the TIDP can be described as follows:

1) conceptual framework of the program-the section reveals the methodological basis and methodological techniques of strategic planning, organizational, economic and social factors of development;

2) analytics-provides for the following tasks:

- the formulation of the mission, goals, objectives of TI;
- analysis of internal and external environment;
- risk assessment of TI development activities;

3) strategic directions and innovative projects-section includes:

- list of strategic directions of development;
- target indicators for the achievement of the TI development goals with an indication of the planned time frame for their achievement and a breakdown by possible scenarios;
- innovative project;

4) program implementation mechanism:

- information on financial and resource support of the program;
- program implementation schedule;
- comprehensive assessment of TI potential.

On the one hand, the content of the development program (goals, objectives, mechanisms) should be assessed in terms of feasibility, but on the other hand, these assessments (in the analytical section) should already be taken into account in the development of the program.

The methodology of transport infrastructure development program management includes a set of models and methods of intelligent program management, including:

- forecasting and planning of development of transport systems in conditions of incomplete certainty;
- management and implementation of innovative renewal programs of logistics infrastructure;
- distributed intelligent management and effective decision-making in the logistics of transportation;
- logistics management of cargo flows in integrated heterogeneous transport systems (road, rail, air and other modes of transport).

A reliable assessment of costs and profits on a comparative basis for all infrastructure projects will avoid inefficiencies and identify priority projects to align investment costs with available investment resources. Long-term traffic forecasts will help to identify priority components of the transport strategy, develop plans and make rational decisions. A comparative analysis of projected traffic volumes by type of cargo and infrastructure capacity will identify existing and possible long-term bottlenecks.

Table 2 gives an overview of models and methods of project management of transport infrastructure development.

Table 2. *Overview of models and methods of project management of transport infrastructure development*

Stage	Models	Methods
Strategic planning	defining the main strategies of TIDP	SWOT analysis
	models for assessing the level of competitiveness of a transport organization	probabilistic approach
	models for determining the rating of transport security of regions	cluster analysis; utility theory
Investment Planning	models of the project life cycle; a generalized model of discounting cash flows of investment projects	
Innovations Planning	modelling of assessment of the level of innovative development of regions	cluster analysis
	vehicle upgrade model	Markov chains
Risk assessment	probabilistic risk assessment models	
	models of investment project selection	linear and nonlinear programming; heuristic methods of analysis of variants
Prediction of TIDP indicators	multifactorial models	
	adaptive models	precedent theory

Results of the studies and their discussion

1. Features of logistic transport system and development management processes

The development of a logistics system in the transport infrastructure means the following tasks are solved:

1) creation (modernization) of logistical commodity distribution centres in the main directions of transportation and at the junctions, including the creation of terminal-logistics centres at the intersection of major highways, in railway junctions, in river ports, and in general the formation of an integrated system of logistics centres;

2) development and implementation of innovative intelligent transport systems with the use of navigation systems that ensure the quality of transport services. Creation of unified information services of cooperation of transport, logistic, forwarding, customs and other controlling bodies;

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3) creation of a market of competitive complex logistics services;

4) improving the legal basis for the development of logistics. Implementation of information standards and electronic document flow;

5) development of infrastructure of multimodal logistics centres for container transportation;

6) creation of competitive transport corridors on the basis of technically and technologically integrated logistics infrastructure, as well as systems of coordination of business processes in the supply chains.

The main elements of a logistic transport system (LTS) are:

- customers of transport services (*R*),
- production services (enterprises) (*P*),
- services involved in the movement of goods from the place of production to the place of consumption (*Z*), which are divided into own services (*Z′*) and third parties (*Z″*).
- consumer network (*C*).

All components are connected by direct and inverse material flows and relations in the form of information flows, i.e. graphically the supply chain can be represented as a network *S*, whose vertices are elements (*R*, *P*, *Z*, *C*), and links (*i*, *j*) between them correspond to material and information flows (fig. 1).

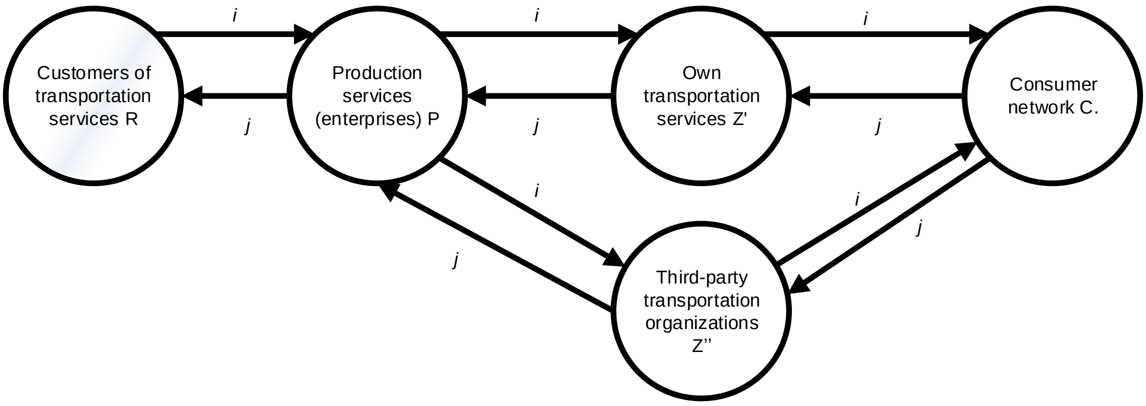

Fig. 1. Presentation of LTS elements in the form of a bidirectional graph

Thus, such an LTS representation reflects each individual transaction in cargo handling and delivery of the final product, from suppliers producing materials to a supplier of a particular enterprise, and ending with its customers.

The development of LTS can only be ensured by the joint activity of organizational elements of the system. For this, the mechanisms of interaction between all elements of the logistics chain should be taken into account. This chain can be represented as a system consisting of a set of ordered elements that perform certain functions and relationships that are regulated according to the purpose of obtaining and selling the required product or service. The main problem of this system is the regulation and coordination of processes and operations in the interactions between the elements [31].

In the transport infrastructure, the dynamics and uncertainty of the logistical process factors are important. LTS is the basis of changes in transportation processes, determines the diversity and complexity of the infrastructure and requires management development. LTS maintains correspondence between increasing market demands and logistical infrastructure activities.

At a certain stage, the functioning of the LTS increases its needs and thereby forms the goals of the TIDP, determines the ways to achieve them. A passive organizational and technical system must be considered as active and purposeful, which must be developed. Thus, LTS belonging to the class of organizational and technical systems (OTS) is a purposeful, artificial, active system.

The main properties of LTS are as follows:

- integrity – changing any element affects other elements, resulting in a change in the structure and properties of the system as a whole;
- integrative – the system has properties that are missing from its elements. But elements can also have properties that are not inherent in the system as a whole.

The current trend in OTS management is proactive (warning) management. "Being proactive is about anticipating events, initiating change, striving to hold the fate of the organization in your hands" [32].

Proactive management uses methods of forecasting, monitoring, planning, analysis, modelling of complex dynamic systems and optimization of management decisions [33].

Intelligent information technologies are used to make managerial decisions, which can help predict OTS behaviour. This requires the formation and analysis of models for the development of situations, taking into account both current and previously accumulated data.

Anticipation and prevention are the basic principles of proactive problem management. While doing this, an analysis of possible risks and errors, planning corrective actions are necessary. In addition to the prediction, proactive control is also used, the purpose of which is to detect deviations from the current state of the LTS from the predicted one. Management decisions are made based on the results of proactive control aimed at preventing adverse development of LTS.

The problem with managing the development of the system is to translate the object from some current state to desired. That is, the necessary conditions for development management are:

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- determining the quantitative and qualitative composition of the characteristics of the state space in which management is implemented;
- determination of the current and task of the desired state of the control object in this space;
- formation of managerial influence.

Thus, one of the tasks to be solved in the management of LTS development is to identify the state space and to implement methods for identifying their characteristics.

A system of indicators characterizing the status of LTS subsystems and their interconnections is needed. Indicators of Sustainable Development were developed by the Commission for Sustainable Development [34]. There is a system for evaluating organizational and technical systems using a stable functioning index, which is calculated as the sum of indices for three dimensions: economic, technological and social with appropriate weighting factors [35].

A specific list of indicators should be developed for the LTS to reflect the peculiarities of its functioning. This list is the basis for a comparative assessment of options in the strategic decision-making process for system development. The complex structure of LTS indicators makes it possible to use a flexible, adaptive model for their evaluation.

There is a challenge to manage the decisions that are made at different levels of coordination in order to be able to optimize the management of the system as a whole. Consider the following types of matching problems when determining the acceptable parameter level:

1) integrated matching – the development program specifies the planned coefficient K for a specific time period T and possible standards for resources R. So, we have:

$$\int_0^T \left[R(t) - R^* \right] dt \le K; \tag{1}$$

2) deterministic matching – a requirement for equality is set in each time interval:

$$E(t) = K \tag{2}$$

for the matched parameter E;

3) the range matching is determined by the belonging of the agreed parameter K to the specified range:

$$K(t) \in \left[K_{\min}, K_{\max} \right]. \tag{3}$$

2. Formalized presentation of the LTS development process

In terms of the LTS system approach, the system is a complex organizational and technical system and has the following features [37]:

1) complexity – the presence in the LTS of heterogeneous elements that provide the required diversity of system elements, determined by the conditions of formation;

2) dynamic – the ability of LTS elements to interact, as well as the implementation of interaction outside the system;

3) structural, integrity [36].

We define LTS as a system S that includes a set of system invariants $\{S_n\}$ that determine the properties of the system. System invariants can be obtained from the initial state of the system S_0 by the set of operators $\{P_n\}$, that is:

$$\begin{aligned} S_1 &= P_1 S_0; \\ S_2 &= P_2 S_0; \\ &\ldots\ldots\ldots\ldots \\ S_n &= P_n S_0. \end{aligned} \tag{4}$$

Denote these system properties of LTS as follows:
- complexity (S_1);
- dynamic (S_2);
- structural (S_3).

In this case, the complexity is ensured by the variety of entities that create the system (logistics centres, vehicles, management organizations, etc.):

$$S_1 = P_1 S_0 = \{a_1, a_2, \ldots, a_n\}, \tag{5}$$

where S_1 is the property of complexity; P_1 – operation of transfer and numbering; S_0 is the original representation of the LTS to which the operation P_1 is applied; a_i $(i = \overline{1, n})$ – groups of elements, varied in content.

The dynamic property reflects the processes of interaction between the elements:

$$S_2 = P_2 S_0 = \{Y_{1n}\}, \tag{6}$$

where S_2 is the dynamic realized through transport and information interaction between system elements; P_2 – identifying communication channels and their characteristics (e.g., trunk line or information channel); S_0 – initial LTS, which is considered from the point of view of interaction; Y_{ij} $(i = \overline{1, n},\ j = \overline{1, n})$ – characteristic of interaction between the *i*-th and the *j*-th elements.

We define the structural property:

$$S_3 = P_3 S_0, \tag{7}$$

where S_3 is the structure shown in the graph of the relationship of the elements of the LTS; P_3 is the operator of determining the relationships of a graph; S_0 – LTS, which is considered at a certain point in time from the standpoint of structure formation.

Therefore, system S is determined by the sequence of operations:

$$\{P_n\} = P_1 P_2 P_3. \tag{8}$$

Given (4) we obtain:

$$S = (P_1 S_0)(P_2 S_0)(P_3 S_0). \tag{9}$$

Based on the proposed graph analytic representation of the LTS model, it is possible to analyze its structure. Consider the uncertainty property of the LTS graph

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analytic model, which we will call the uncertainty of system implementation. Let uncertainty be determined by characteristic A, which is measured on a continuous scale from 0 to 1 and changes with time. The time scale reflects the process of changing the system that corresponds to the dynamic property. For example, if the system model does not display any of its properties, then the estimate A = 0, if the system with sufficient certainty reflects half of its properties, then the estimate A = 0.5, and if the system is fully displayed, then A = 1. In Fig. 2 levels A = {0,1; 0.9; 1} are selected. Horizontally we set aside time t.

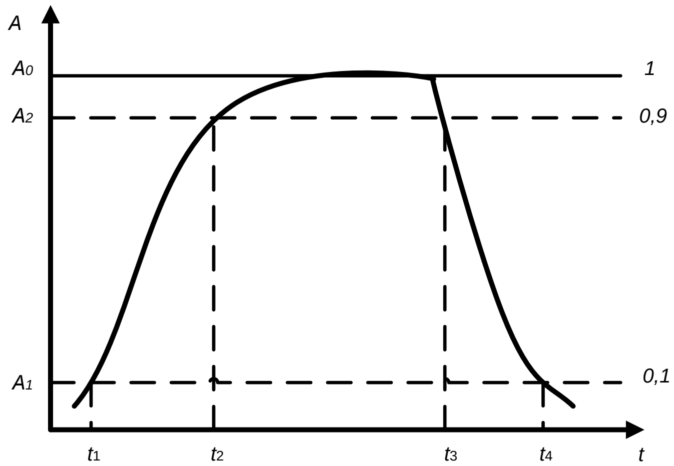

Fig. 2. Changing uncertainties with the evolution of the system

Consider the individual phases of changing the uncertainty of system implementation.

The first phase: $\Delta t_1 = (t_2 - t_1)$ – conditional start (t_1) and end (t_2) of the process of formation (development) of the system, which is determined by levels A_1 and A_2, which are close to the lower and upper thresholds of the uncertainty of system implementation. The source of uncertainty is the process of development itself, that is, at this stage the same element of the system can be displayed in different variants. Note that the level A_0 = 1, which can theoretically be achieved in an infinitely long time, corresponds to the state of complete determination of the model of the system obtained in the process of system implementation.

The second phase: $\Delta t_2 = (t_3 - t_2)$ – stationary existence of the formed system.

The third phase: $\Delta t_3 = (t_4 - t_3)$ – the destruction (decay, disintegration) of the system.

The pre-system state ($t < t_1$) reflects the properties of the system environment S_0.

The post-system state ($t > t_4$) reflects the properties of S_0 after the complete destruction of the system.

The LTS, which is considered in terms of system approach, can be reflected by a set of its individual models (system representations), which can be written in the form:

$$A \Rightarrow \lim_{\substack{t\to\infty \\ n=const}} \sum^{t} \{S_n^{(t)}\}, \tag{10}$$

where A – system (object) that is displayed; $S_n^{(t)}$ – a system model of object A at time t; n – the number of invariants in the system model.

The dynamic system can be defined in a discrete or continuous view. Since the planning of the development program is carried out for a specific period, and the change of the development indicators occurs at discrete (control) moments of time, it is more appropriate for the LTS to discrete view of the process of its development.

We will use a matrix method for describing LTS based on the use of hypercomplex matrices [37]. Let us write a hypercomplex matrix for the simplest system shown in fig. 3, where A_1 and A_2 are elements of the system and y_{12} and y_{21} are the interactions between these elements.

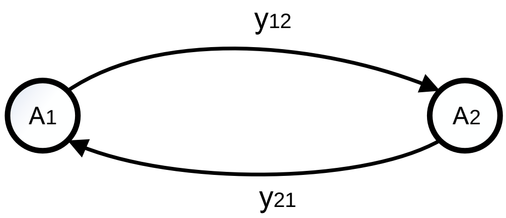

Fig. 3. The simplest connected system

We obtain a matrix of the structure of the system S:

$$|S| = \left[\frac{A_1 | y_{12}}{y_{21} | A_2}\right], \tag{11}$$

on the main diagonal of which elements reflecting the presence and properties of the elements of the system S:

$$a_{nn} = A_n(S), \tag{12}$$

where a_{nn} – a diagonal element of the matrix standing at the intersection of the n-th column and the n-th row; $A_n(S)$ – n-th element of the system S.

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To the left and to the right of the main diagonal are elements of the matrix, which reflect the interaction between the elements of the system and are determined by the rule:

$$a_{nm} = y_{nm}(S),\ n \neq m\ , \tag{13}$$

where a_{nm} – the element of the matrix that stands at the intersection of the *n*-th row and the *m*-th column; ynm – interaction of the element An with the element A_m of the system *S* in the direction from A_n to A_m.

The order of the matrix is determined by the number of elements and hierarchical levels of system *S*. In this case, the order of the matrix *N* = 2.

In dynamic LTS, the elements of the matrix *Y* depend on time, reflecting the development process:

$$\left[A_{nm} = A(t),\ y_{nm} = y(t)\right] \Rightarrow S = S(t)\ . \tag{14}$$

According to the steps of uncertainty change (Fig. 2), we write down the conditions under which the matrix *Y* will reflect the main phases of the development process:

- phase of development

$$\frac{d(S(t))}{dt} > 0\ . \tag{15}$$

Differentiation is performed by all system invariants;

- steady-state mode is defined as follows:

$$\frac{d(S(t))}{dt} = 0; \tag{16}$$

- the decay phase is defined as follows:

$$\frac{d(S(t))}{dt} < 0\ . \tag{17}$$

Analyzing the hypercomplex matrix of the system under study, it is possible to construct the system implementation process curve corresponding to this system.

Conclusions

In the article, the basic principles of sustainable development of transport infrastructure are analyzed and the description of the mathematical apparatus of formation and research of projects of development of transport infrastructure is given. The targeted aspects of the transport infrastructure development program are considered. On this basis, a systematic representation of a logistic transport system containing a set of system invariants defining its properties was proposed. A method of describing the structure of LTS based on the use of hypercomplex matrices, which allows taking into account interactions between elements of the system. In dynamic LTS, elements of a hypercomplex matrix depend on time, which reflects the main phases of the development process.

The scientific novelty of the article is a generalized formalized representation of LTS that can be used to analyze and optimize its structure. Of practical importance is the ability to form transport infrastructure within the development program by using a graphical analytical representation of the LTS, which reflects the elements and information and material links between them.

References

1. Porter, Michael. E. (2001), *Competition* / trans. from English: pos. Moscow, 495 p.
2. Mintsberg, G., Quinn, J. B. (2001), *Goshal S. Strategic process. Concept. Problems*, St. Petersburg, 688 p.
3. Drucker, P. F. (2004), *Encyclopedia of Management* / trans. from English, 432 p.
4. Gritsenko, S. I. (2009), *Transport and logistics clusters in Ukraine: ways of formation and development* : monograph, St. Petersburg, 218 p.
5. Kosenko, V., Gopejenko, V. i Persiyanova, E. (2019), "Models and applied information technology for supply logistics in the context of demand swings", *Innovative Technologies and Scientific Solutions for Industries,* No. 1 (7), P. 59–68. DOI: https://doi.org/10.30837/2522-9818.2019.7.059
6. Bludova, T. V. (2006), *Transit potential of Ukraine: formation and development,* Kyiv, 274 p.
7. Lytvynenko, D., Dorokhina, A. and Artiukh, R. (2019), "Analyzing the interests and interaction of the participants of a transport system development project", *Innovative Technologies and Scientific Solutions for Industries,* No. 1 (7), P. 69-74. DOI: https://doi.org/10.30837/2522-9818.2019.7.069
8. Bushuyev, S., Bushuiev, D. and Kozyr, B. (2019), "Development project management capability of the infrastructure program. Chernobyl case", *Innovative Technologies and Scientific Solutions for Industries,* No. 2(8), P. 15–24. DOI: https://doi.org/10.30837/2522-9818.2019.8.015
9. Shevchuk, Ya. V. (2011), *Motor transport infrastructure: theory and methods of modern regional research*: monograph. Uzhgorod, 376 p.
10. Nagurney, A., Smith, John F. (2006), *Supply Chain Network Economics: Dynamics of Prices, Flows and Profits*, Edward Elgar Publishing, Cheltenham, England, 448 p.
11. Taylor, M. A. and D’este, G. M. (2004), "Critical Infrastructure and Transport Network Vulnerability: Developing a Method for Diagnosis and Assessment", *Proceedings of the Second International Symposium on Transportation Network Reliability (INSTR), A. Nicholson and A. Dantas, editors,* Christchurch, New Zealand, P. 96–102.
12. Fan, Y, Khattak, A J, Shay, E. (2007), "Intelligent Transportation Systems: What Do Publications and Patents Tell Us?", *Journal of Intelligent Transportation Systems*, No. 11:2, P. 91–103.
13. Bereznyak, N. V, Kvasha, T. K. (2012), *Novitskaya GVProcesses of integration of information infrastructure of innovation activity: analytical review*, Kyiv, 93 p.
14. Gaykov, A. R., Baranov, O. V., Baranov, V. Yu. (2014), "Intelligent transport systems in Ukraine", *Bulletin of NTU "KPI"*, No. 9 (1052), P. 106–112.

ISSN 2522-9818 (print)
Сучасний стан наукових досліджень та технологій в промисловості. 2019. № 3 (9) ISSN 2524-2296 (online)

15. Prokofiev, D. V. (2010), "Principles and methodology of building an integrated information system for managing the functioning of logistics centers", *Logistics and supply chain management*, No. 6 (41), P. 11–23.
16. Yarkina, N. M. (2014), "Enterprise management as an economic category (theoretical aspects)", *Countries and Regions Ser. : Economics and Entrepreneurship*, No. 1 (76), P. 130–136.
17. Filatova, T. V. (2013), "Management decision making as a factor in improving the efficiency of railway transport", *Bulletin of Economics of Transport and Industry*, No. 42, P. 182–186.
18. Danchenko, O. B., Lepsky, V. V. (2017), "Modern models and methods of project management, project portfolios and programs", *Management of complex systems development*, No. 29, P. 46–54.
19. *The standard for Program Management. Global standard. PMI*. URL: http://www.pmi.org (last accessed 27.07.2019).
20. *A Guidebook of Project & Program Management for Enterprise Innovation. Volume I. Translation*. URL: http://www.pmaj.or.jp (last accessed 27.07.2019).
21. Stadnik, V. V., Yokhna, M. A. (2011), *Strategic management of enterprise innovation development*, Khmelnytsky, 332 p.
22. *On approval of the Transport Strategy of Ukraine for the period up to 2020*, URL: http://climategroup.org.ua/wp-content/uploads/2010/07/Order_KMU_Transport_strategy_UA-2020.pdf (last accessed 15.06.19).
23. Dimarchuk, S. M. (2002), "Formation of regional transport and logistics systems. Problems of rational use of socio-economic and natural-resource potential of the region", *Employment, Labor and Social Infrastructure series*, No. 3, P. 163–170.
24. Pashchenko, Yu. E., Nikiforuk, O. I. (2008), *Ukraine's transport and road complex in the processes of international integration*: monograph, Nizhyn : Aspect-Polygraph, 192 p.
25. Preiger D., Sobkevich O., Emelyanova O. *Prospective ways and mechanisms of integration of the market of transport services of Ukraine to EU countries. Analytical note*. URL: http://www.niss.gov.ua/articles/475/ (last accessed 29.05.19).
26. *Strategy for the development of railway transport for the period up to 2020. Approved by the Resolution of the Cabinet of Ministers of Ukraine dated 16.12.2009 № 1555-р*, URL: www.ugmk.info/download/1261743310 (last accessed 03.06.19).
27. *Ukraine's transport strategy for the period up to 2020*, URL: http://www.mtu.gov.ua (last accessed 03.06.19).
28. Kosenko, V. (2018), "Decision support system in planning investment projects", *Innovative Technologies and Scientific Solutions for Industries*, No. 4 (6), P. 113–119. DOI: https://doi.org/10.30837/2522-9818.2018.6.113
29. Dashchenko, N. M. *Development of logistics centers at the present stage*, URL: http://www.nbuv.gov.ua/portal/natural/Upsal/2009_6/09dnmcps.pdf (last accessed 30.06.19)
30. The main activities for the implementation of the enterprise development strategy for the medium and long term, URL: http://www.kbptula.ru/ru/about/o-predpriyatii/strategiya-razvitiya (last accessed 3.06.2019).
31. Busheyev, S. D., Kozyr, B. Yu. (2011), "Innovative mechanisms for managing programs of development of maritime transport clusters", *Management of complex systems development*, No. 7, P. 5–7.
32. Danko, M. (2007), "Reorganization of enterprises in the context of formation of corporate structures", *Ukraine economy*, No. 1, P. 64–70.
33. Daft, R. (2008), *Management* / trans. from English 6th ed. SPb. : Peter, 864 p.
34. *Indicators of Sustainable Development: Guidelines and Methodologies*, United Nations, New York, 94 p.
35. Malyuta, A. N. (1990), *Patterns of system development*, Kyiv, 136 p.
36. Bir, S. T. (2006), *Cybernetics and Management* / Per. from English V. Ya. Altayev; under the editorship of A. B. Chelyustkin, 2nd ed., Moscow, 280 p.
37. Fleishman, B. S. (1982), *Fundamentals of systemology*, Moscow, 368 p.

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ЦІЛЬОВІ ТА СИСТЕМНІ АСПЕКТИ ПРОГРАМИ РОЗВИТКУ ТРАНСПОРТНОЇ ІНФРАСТРУКТУРИ

Предметом дослідження в статті є програми та проекти розвитку транспортної інфраструктури з виділенням логістичної системи. **Мета** – розробка системного уявлення процесу розвитку логістичної транспортної системи з урахуванням цілей програми розвитку транспортної інфраструктури. В статті вирішені наступні **завдання**: систематизація цілей та завдань програми розвитку транспортної інфраструктури, проведення аналізу особливостей логістичної транспортної системи та процесів управління її розвитком, розробка узагальненого формалізованого подання логістичної транспортної системи та процесу її розвитку. Для вирішення вказаних завдань використовуються **методи** системного аналізу, теорія множин, гіперкомплексних матриць. Отримані такі **результати**. Проаналізовані принципи стійкого розвитку транспортної інфраструктури. В статті запропонована систематизація цілей та завдань програми розвитку транспортної інфраструктури та виділені основні принципи її стійкого розвитку. Розглянуто завдання розвитку логістичної системи в транспортній інфраструктурі країни. Запропоновано подання логістичної транспортної системи у виді графа, де вершинами є її елементи, а зв'язками є інформаційні й матеріальні потоки. При визначенні припустимого рівня параметра розвитку логістичної транспортної системи виникають такі види задач узгодження при прийнятті управлінських рішень, як інтегральне, детерміноване та діапазонне. У формалізованому виді логістична транспортна система подається як набір системних інваріант, які визначають її властивості: комплексності, динамічності й структурності. Визначені три фази змінення невизначеності з урахуванням розвитку системи. Гіперкомплексна матриця системи дозволяє визначити її елементи й зв'язки між ними. **Висновки**: проведений аналіз предмету дослідження показав, що залишаються невирішеними питання, пов'язані з вибором системної концепції і методологічного інструментарію для формування розподіленої логістичної інфраструктури, виділені проблеми транспортної інфраструктури України. На основі запропонованого графоаналітичного подання логістичної транспортної системи можна проводити аналіз її структури.

Ключові слова: транспортна інфраструктура; стійкий розвиток; логістична система; гіперкомплексна матриця; системне подання; фази розвитку.

ЦЕЛЕВЫЕ И СИСТЕМНЫЕ АСПЕКТЫ ПРОГРАММЫ РАЗВИТИЯ ТРАНСПОРТНОЙ ИНФРАСТРУКТУРЫ

Предметом исследования в статье являются программы и проекты развития транспортной инфраструктуры с выделением логистической системы. **Цель** – разработка системного представления процесса развития логистической транспортной системы с учетом целей программы развития транспортной инфраструктуры. В статье решены следующие **задачи**: систематизация целей и задач программы развития транспортной инфраструктуры, анализ особенностей логистической транспортной системы и процессов управления ее развитием, разработка обобщенного формализованного представления логистической транспортной системы и процесса ее развития. Для решения указанных задач используются методы системного анализа, теория множеств, гиперкомплексных матриц. Получены следующие **результаты**. Проанализированы принципы устойчивого развития транспортной инфраструктуры. В статье предложена систематизация целей и задач программы развития транспортной инфраструктуры и выделены основные принципы ее устойчивого развития. Рассмотрены задачи развития логистической системы в транспортной инфраструктуре страны. Предложено представление логистической транспортной системы в виде графа, где вершинами являются ее элементы, а связями являются информационные и материальные потоки. При определении допустимого уровня параметров развития логистической транспортной системы возникают такие виды задач согласования управленческих решений, как интегральное, детерминированное и диапазонное. В формализованном виде логистическая транспортная система представляется как набор системных инвариант, которые определяют ее свойства: комплексности, динамичности и структурности. Определены три фазы изменения неопределенности в процессе развития системы. Гиперкомплексные матрица системы позволяет определить ее элементы и связи между ними. **Выводы**: проведенный анализ объекта исследования показал, что остаются нерешенными вопросы, связанные с выбором системной концепции и методологического инструментария для формирования распределенной логистической инфраструктуры, выделены проблемы транспортной инфраструктуры Украины. На основе предложенного графоаналитического представление логистической транспортной системы можно проводить анализ ее структуры.

Ключевые слова: транспортная инфраструктура; устойчивое развитие; логистическая система; гиперкомплексные матрица системное представление; фазы развития.

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