Intellectual Models of Projects for the Development of Transport Infrastructure of Urban Territorial Systems

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Annotation

Intellectual models of projects for the development of transport infrastructure of urban territorial systems by means of discrete-event modeling are developed in the article. The modern trend of conducting scientific research is the use of information technologies in the process of simulation modeling at the planning stage. The peculiarities of the use of information technologies in the management of infrastructure projects are considered. The most well-known software tools for modeling transport systems are analyzed and a comparative analysis of the functionality of modeling packages is performed Infrastructure projects require detailed analysis and planning of the time characteristics, budget and WBS structure of the project. The classification and characteristics of stakeholders of the transport infrastructure project are offered. A conceptual model-scheme of the life cycle of stakeholders involved in the transport project has been developed. Stakeholders of the infrastructure project and their direct impact on the success of the implementation of set tasks for the team are taken into account. The classification of risks in the implementation of the transport infrastructure project is proposed, which aims to promote the effectiveness of risk management in the implementation of transport infrastructure projects.

Keywords 1

Simulation, information technology, infrastructure projects, stakeholders, risk management, transport infrastructure.

1. Introduction

The research of complex infrastructure projects is a quite costly, expensive and time-consuming process. Therefore, for such tasks, the modeling of critical parameters of the product of infrastructure project is used, which formalizes the object under study. During the analysis of modeling methods it was detected that an effective approach at this stage in the development of science and technology is simulation.

Simulation solves real world problems safely and intelligently. It is a convenient tool for analysis: it is clear, easy to understand and check. In various areas of business and science, simulation helps to find optimal solutions and provides a clear understanding of complex systems. Simulation modeling is an experiment on a reliable digital representation of any system. Unlike physical modeling, such as creating a model of a building, simulation modeling is based on computer technology using algorithms and equations. The simulation model can be analyzed dynamically, and animations can be viewed in 2D or 3D.

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Computer simulations are used in order to design, analyze and evaluate the operation of the facility when experiments on a real system are impossible or impractical, most often because of their cost or time. The ability to analyze a model in action distinguishes simulation from other methods such as using Excel or linear programming. The user studies the processes and makes changes to the simulation model in the course of work, which allows you to better analyze the operation of the system and quickly solve the problem. Uncertainty in the time and results of operations is easily displayed with the help of a simulation model, which allows you to assess the degree of risk and find the most reliable solutions. For example, you can get a realistic picture of an infrastructure project.

To simulate complex infrastructure projects, applied information technologies are used, which simulate the processes of the life product of the project based on intellectual models. This, in turn, allows to present the configuration of the project product, program or portfolio of projects at the planning stage. Through the project-oriented management project team realizes the customer's expectations regarding planned budget, timelines and quality of the product or service. Virtual experiments with simulation models will be much cheaper and take less time than experiments with real systems. For example, we will be able to test the effectiveness of planned infrastructure projects, avoiding unnecessary costs. A simulation model displays much more detail than an analytical model. This makes the simulation model more accurate and the predictions based on it more certain.

2. Analysis of literature

[1] The model of infection of stakeholders is presented, which is based on the understanding of the life cycle of the project manager, which is presented in the form of a curve of personal changes of the manager of projects and programs of the information system.

The works [2] considers the problems of emotional contamination of the requested infrastructure project in a crisis.

[3] The conducted a study which showed that only 11 competencies were identified by experts as a set of competencies that affect the development of creative potential.

The paper [4], an approach based on considering the process of changing information entropy as a semi-Markov process is proposed.

[5] The role of strategic audit of infrastructure projects and programs is investigated. The effective management of changes in the strategy of complex projects should be in place due to significant uncertainty and impact of external and internal factors. The relationships between strategic development of organizations and strategic audit of infrastructure projects and programs are analyzed. The adaptive model of assessment of external challenges is proposed, as well as the algorithm on the model of strategic audit of the maturity of organizations is presented.

[6] Analyzes the tasks of targeting and mission description in infrastructure projects. Effective strategies for projects implementation in a dynamic environment have been identified. Through to this, the manager is able to predict the decisions made in the short and long term perspective. Formulation of the mission and the assessment of its value are carried out by the customer and clarified with the project stakeholders for the sake of effective and productive communication. Also, this paper analyzes the feasibility of applying the contextual analysis for the complex design and interpretation of the mission of infrastructure projects and programs.

The paper [7] analyzes the current trend of using hybrid technologies in complex systems. The usage of "waterfall" and "flexible" Agile life cycle management methods for development of hybrid technology in the management of infrastructure projects, programs and project portfolios based on a convergent approach in terms of decision-making processes is investigated. The proposed models were effectively applied in construction projects and in projects for the development of information and communication systems. The deadlines were met, and the budget did not exceed planned costs. These developments should be adapted for the development of transport systems.

The works [8, 9, 10] consider the processes of safety management in complex infrastructure projects that allow to simulate critical parameters of the functioning of products of infrastructure projects.

In the scientific work [11] a study of the synthesis of project management methodology with fuzzy input parameters of the project was conducted.

In the work [12] models of management of infrastructure transport products at the conceptual stage are investigated. The relationships between stakeholder requirements, time constraints and parameters of transport infrastructure product are determined.

The work [13] considers the usage of the "Six Sigma" methodology in the context of management of system of quality (TQM) of infrastructure projects in Ukraine. The analysis of problems of implementation the system of management of quality of cluster infrastructure is carried out.

After analyzing the international standards for management of projects, programs and portfolios of PMBok, P2M projects [14, 15], we found out that the problems of assurance and planning of safety in project management are not comprehensively investigated.

The content characteristics of the interaction model and the features of stakeholder management were studied in the works of such scientists: P. Khvostenko [16], who developed new methodologies for working with stakeholders, D. Dudenkov [17], V. Gorbun [18], who proposed methods for choosing strategies for working with stakeholders, L. Gatsenko, N. Dotsenko, M. Jurgens [19, 20, 21], who studied the history of stakeholder management and proposed new tools.

Within the framework of "The Large Construction" project in Ukraine, engineering and development of transport infrastructure has been initiated. In 2021, 5,098 km of roads and 250 artificial structures were built and reconstructed. $106 billion UAH has been spent on these goals.

In 2020, 4,056 km of roads has been repaired and 158 artificial structures has been created with the cost 83 billion UAH. In 2019, 846 km of roads has been repaired and 73 artificial structures has been created with the cost 21.3 billion UAH (Figure 1).

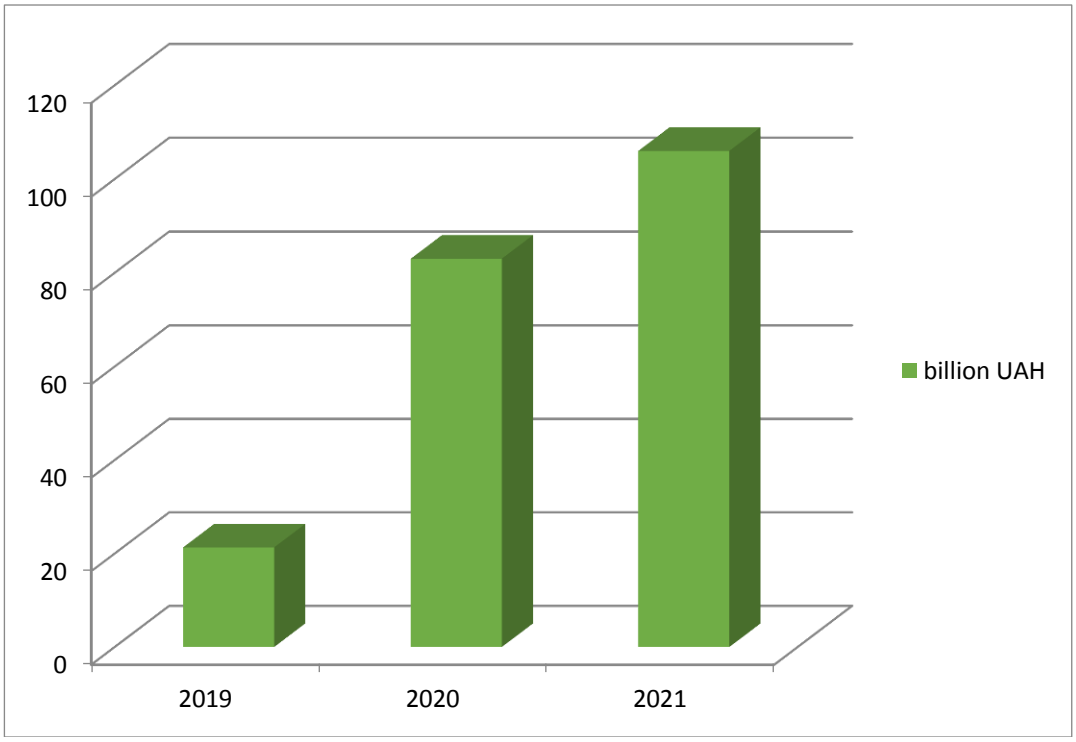

Figure 1: Road construction costs in Ukraine in the period 2019-2021.

According to the Ministry of Infrastructure [22] the cost of 1 km of road in 2019 was to 25.2 million UAH, in 2020 –20.4 million UAH, in 2021 – 20.7 million UAH. The average price of 1 km of road in 2021 increased by 1.5% and is still 18% lower than in 2019 (Figure 2).

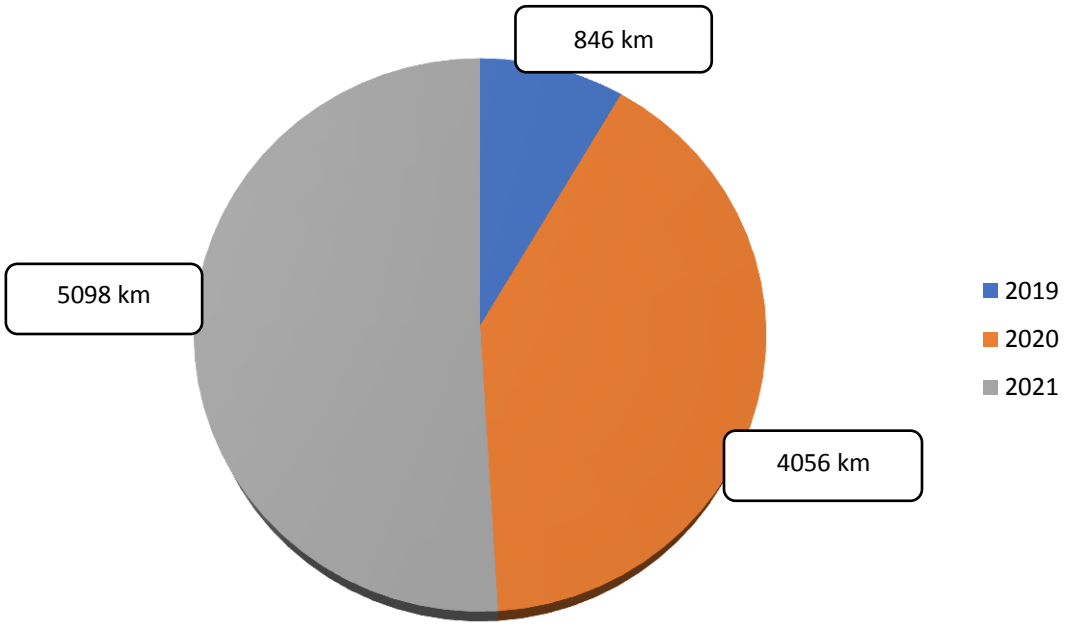

Figure 2: Diagram of new roads built in Ukraine in the period 2019-2021.

3. Research results

The most well-known software for modeling of transport systems are DRACULA, AIMSUN 2, VISSIM, CORSIM, PARAMICS (see Table 1).

The DRACULA package is designed for road modeling, which includes a microscopic model for simulating of traffic, and it simulates the process of movement of cars and their interaction regarding the transport network. An important feature of DRACULA is the animation of traffic flows, which is inseparable for understanding the traffic behavior under various criteria of planning transport networks and their managing strategies. An important advantage of DRACULA is that vehicles move in real time, and their trajectories are determined using car driving models and lane changes. This software also takes into account data about the driver's past experience and his knowledge of the network, stored in a personal history file. DRACULA makes it possible to simulate the driver's reaction to traffic jams or lane changes, which is important when studying the emergency parts of the transport network.

AIMSUN 2 software is designed to simulate a network of suburban and urban transport systems, which allows the user to use a comfortable interface that eases the construction of the model and its entire usage for imitation. This software product is based on microscopic modeling. This means that the behavior of each vehicle is constantly adjusted according to several patterns of driver behavior (following cars, changing lanes) throughout the simulation period. AIMSUN2 uses a discrete-continuous approach. This means that the model consists of elements (vehicles, detectors), the state of which changes continuously. The state of other elements (traffic light signals, entry points) changes discretely at given moments of time. This approach provides a high level of detail in traffic modeling, provides an opportunity to distinguish between types of vehicles and drivers, as well as to simulate traffic events and maneuvers.

The VISSIM package is a package for road modeling of network and traffic flows at the micro level. The VISSIM is widely used for the analysis, optimization, design and redesign of suburban, intercity and urban transport networks. The results of VISSIM are widely used to determine the optimal control of vehicles, to check the effectiveness of layouts of transport hubs, the distribution of lanes of complex crossroads, the dislocation of bus stops and parking lots for transport. VISSIM can also be used as a useful tool for various transportation tasks. Driver behavior in VISSIM is described using the R. Wiedemann model, which allows one to take into account such psychophysical properties

as decision time and driver reaction time. VISSIM allows you to collect statistics on any part of the transport network and generate relevant reports, create presentations and videos.

CORSIM is a traffic microsimulation program developed by the FHWA (Federal Highway Administration). This software product consists of two separate programs. The first program - NETSIM - was created to model urban transport networks and pedestrian crossings. The second program - FRESIM - was created for modeling and analysis of highways. CORSIM combined this software, which allowed CORSIM to model complex transport systems and analyze them. CORSIM software has been improved based on user feedback. As a result, a number of errors were detected and corrected. This software uses a micro-simulation model that allows you to assess the impact of the actions of road users on each other. The program allows you to assess the process of traffic accumulation, which is the cause of congestion in the transport network. Congestion is a fairly common problem in transport systems and can only be analyzed using microsimulation tools such as CORSIM.

PARAMICS is a micro-level road traffic simulation software that is fully scalable and designed to simulate intersections, interchanges, congested highways, and optimize traffic and control public transport routes, traffic lights, and more. This software allows you to take into account in the simulation of public transport, such as buses and trams, as well as pedestrian traffic. Each vehicle is modeled taking into account the time required to travel the road and the congestion of the road network, thus ensuring a very accurate flow of traffic. In addition to predefined vehicle classes, the user can create their own vehicle. Vehicle routing is defined by a user-defined language of rules of conduct, which makes the model more flexible and adaptable. PARAMICS is distinguished among similar systems by high-performance visualization of the modeling process and scalability of software.

In order to compare the above software products we propose to highlight the following parameters for the transport network analysis: weather conditions (1), location of parking spaces (2), unorganized parked cars (3), public transport (4), static route management (5), dynamic route management (6), autonomous vehicles (7), adaptive speed control system (8), pedestrians (9). The functionality of software products is noted in Table 1 with "+" sign. The last three factors are not implemented in existing software products, but they have a significant impact on traffic performance indicators and are offered for implementation in the simulation tool built using AnyLogic.

Table 1: Comparison of the functionality of modeling packages

Software	DRACULA	AIMSUN2	VISSIM	CORSIM	PARAMICS
1	-	+	-	-	+
2	-	-	-	+	+
3	-	-	+	+	-
4	+	+	+	+	+
5	-	+	-	-	+
6	-	+	-	-	+
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-

Stakeholders of the transport infrastructure development project should be taken into account, which have a significant impact on the stages of the life cycle: initiation, planning, implementation, monitoring and completion. The classification and characteristics of stakeholders of transport infrastructure development projects are presented in Table 2.

Table 2: Classification and characteristics of stakeholders of projects of transport infrastructure

№	Stakeholders	Characteristics	Expectations	Needs
1	2	3	4	5
1	Local population	People living in the territorial community	Satisfactory condition of the surrounding area	The desire to live among the developed transport infrastructure of the city, without threats to life and health
2	Non-governmental organizations	Represented by numerous groups of socially active citizens who pursue certain political, social or other goals.	To improve living standards. To Maintain the achieved results	To control the social processes of people's lives
4	Investors	Management of local administration, organizations that allocate loans and grants for the project	Expect to recoup their expenses	Make a profit and some benefit
5	Partner companies	Enterprises that perform various types of work on the design, construction, operation of equipment and logistics of the project	Efficiency of resource usage	To get an order for the performance of a certain type of work; To improve infrastructure parameters
6	Project team members	Specialists of the relevant organizations, deputies of local councils, members of executive committees, representatives of public organizations, scientific institutions working on the implementation of the project and representing the interests of various stakeholders of the project	Waiting for the project results, interesting work, encouraging the project leader, assistance from the management and employees of the organization	To provide an accurate understanding of the infrastructure risks caused by their activities; reduce the number of resources used in the implementation of the project;
7	Employees	Employees of local administrations who participate in the project in accordance with the range of their official duties	Waiting for profitable wages. Expectations of career growth	To meet their needs for a full life; to realize their creative and intellectual potential
8	Utilities	Enterprises that carry out their communal activities on the territory of the territorial community	Expectations to increase their competitiveness, reduce the negative consequences of its activities	Satisfy their production and financial needs; to improve the infrastructural parameters of production
9	Mass media	Cover television, radio, cinema; print media and other information resources and serve as dissemination of various information	Have permissions to freely disseminate information, without interference	To provide the population with information about everything related to the public life of the community
10	Examination bodies	Organizations that carry out public or state examination of an infrastructure project or its specific components	Waiting for compliance with the requirements of the legislation in the development of the	To get the necessary and full documentation

				project documentation
11	Environmental authorities	Department of Ecology and Natural Resources of the Regional State Administration	Compliance with the requirements of national and international regulations on environmental safety	To form an open communication policy as a basis for trust, to implement a policy ready for discussions in relations with various public groups
12	Local administration management	Heads, deputy heads and heads of departments of local administrations. Responsible for making the most important decisions for the organization	Waiting for the implementation of their ideas Expectations of career growth Waiting for profitable wages	Be sure that they have achieved their goal; Meet their needs for a full life
13	Production enterprises	Enterprises that carry out their production activities on the territory of municipal formation	Expectations to increase their competitiveness, reduce negative consequences of their activities	To meet their production and financial needs; To improve infrastucture parameters of production

For effective management of stakeholders, it is advisable to analyze the life cycle of transport infrastructure development. The map can be created at the project planning stage and applied at all subsequent stages of the project life cycle for monitoring and adjustment. An example of the dynamics of stakeholder engagement and interaction is shown in Fig. 3.

According to the PMBOK methodology, there are four main stages of the project life cycle. Suppose that at the stages of concept and planning, the same composition of stakeholders participates in the project, therefore, in Figure 3 we have three different graphs of stakeholder interaction according to the stages of the project life cycle.

At the planning stage the content of works is formed and a project plan is drawn up, which will be implemented by the team. The project team consists of: project manager, contractors, investor, local population and authorities. The model-diagram of the life cycle is presented in Fig. 3.

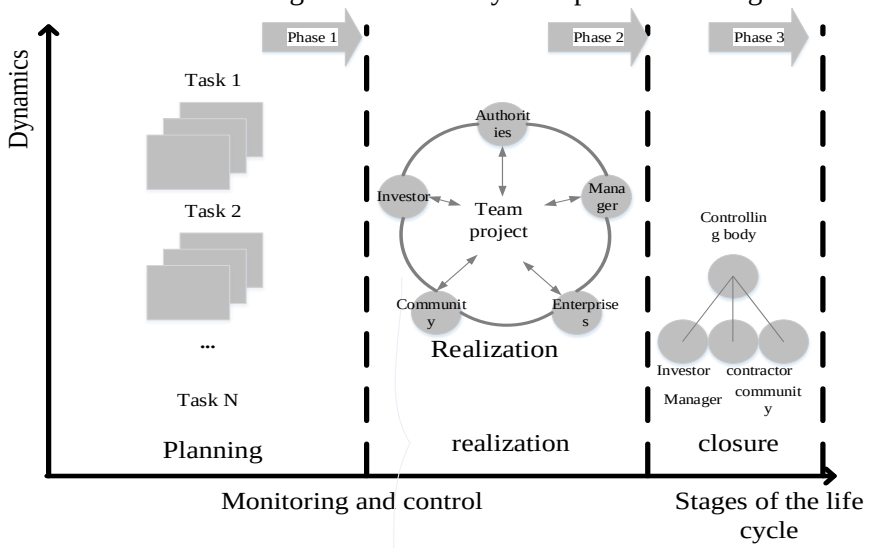

Figure 3: The life cycle of attracting stakeholders of the transport project

The definition of risks in the infrastructure project should include negative events and their size in monetary terms, which reflect them, as well as accompanying losses or losses. The considered circumstances can be provoked by mistakes in the design process, shortcomings in the process of substantiation of necessity of construction of concrete objects, and also inefficient management of the project at each of stages of a project cycle. Adhering to the definition of risk and in order to improve the efficiency of their management, it is necessary to define the essence and specify the concept of "risk factor".

In accordance with the modern concept and specifics of risk management of transport construction, risk management should be preventive in nature, ie aimed at ensuring that this risk event could not occur, or its impact was predictable and minimal. Life cycle phases, types and possible risk options are presented in table 3.

Table 3: Classification of risks in the implementation of transport infrastructure project

Project life cycle phases	Types of risks	Possible risk options
Pre investment phase	Incorrectly determined volume of traffic	Underestimation of the volume of traffic; Revaluation of the volume of traffic.
	Risk of insufficient regulatory support	Absence of actual normative legal acts operating on the territory of Ukraine;
	Project risks	The risk of obtaining a negative opinion of examinations; Insufficient level of competence of technical task developers; Insufficient level of competence of project documentation developers.
	Risks in the coordination of areas for construction	Risk of negative attitude of the population; Archaeological risks; The risk of choosing the suboptimal option as a result of opposition from landowners.
	Risk of inconsistency	The risk of underestimating the presence of "bottlenecks"; Outpacing growth in housing construction.
Investment phase	Financial risks	Underfunding risk; Risk of increased costs during construction; Bankruptcy risk of project participants.
	Political risks	Risk of withdrawal of foreign partners from the project; Occurrence of protest measures; Risk of refusal of foreign partners in the supply of materials and equipment.
	Construction risks	The risk of reducing the quality of work performed; The risk of increasing the duration of work on the project; Risk of non implementation of design decisions; Logistics risks.

Operational phase	Operational risks	Reduction of transport potential; Depreciation or absence of operating fleet.
	Risk of lack of qualified personnel	Risk of errors in forecasting the need for qualified personnel; Risk of inefficient use of qualified personnel; Reassessment of human resources.
	Environmental risks	Risk of man-made emergencies; Risk of environmental degradation.

On the example of Lviv city, a section of the road network has been selected for experimental research. Using discrete-event modeling methods, the sample of a transport network was implemented, which includes the following elements: a road part with an unregulated crossroad, which are guided by the rules of passage of unregulated crossroads and road markings, vehicles that are controlled in the simulation process using the created script in Java language. An important functionality of any software to simulate traffic is collection of information about the condition on the road during modeling. The implemented example allows to collect information about the longest length of the queue on any section of the transport network.

To conduct the experiment, a transport network has been chosen, which is represented on Figure 4. Modeling on transport networks with one and two lanes in each direction and a different number of cars was carried out, which made it possible to collect data about the maximum length of the queue in transport network.

Figure 4: Part of transport network of the infrastructure project

To demonstrate the convenience of usage of district-event modeling and the Java programming language, consider how the machine interacts with objects on the road. Using the built-in Main component –Type of agent, we receive information about all objects that are on our path, their type and distance between them. Using the following code: main, Travel time. Add (time() – Time of appearance); we can get the following information shown in Figure 5. The collected data provide a possibility to investigate the critical parameters of the transport network.

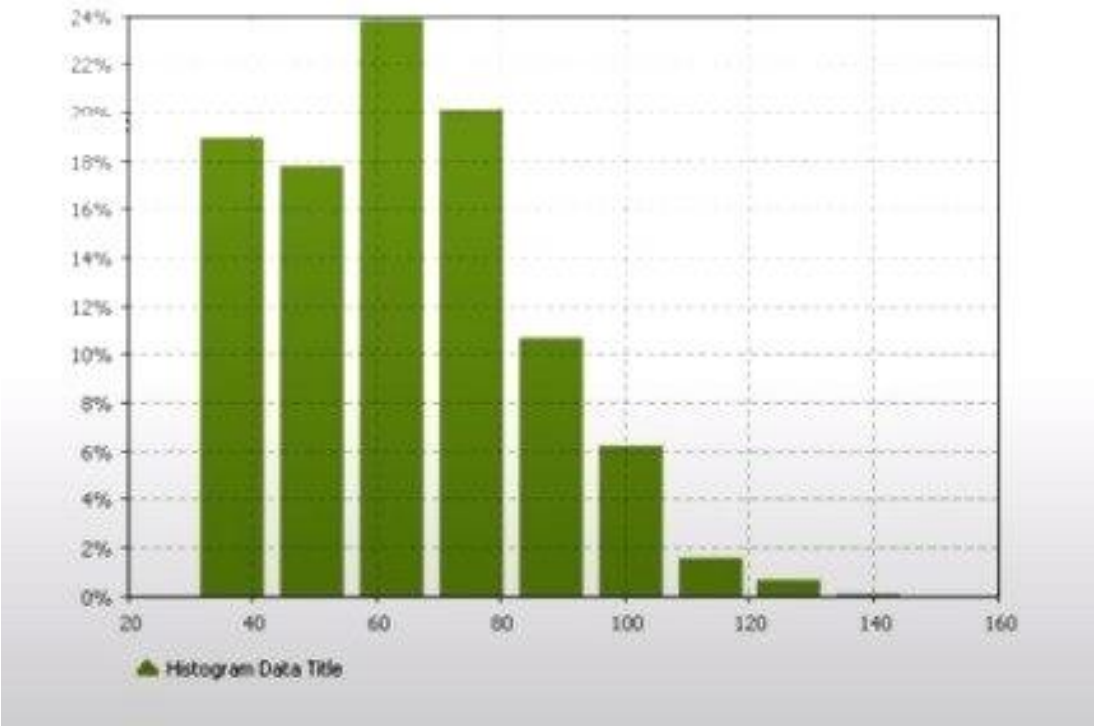

Figure 5: Modeling data of critical parameters of infrastructure project

4. Conclusion

The scientific and applied task of management of projects for the development of transport infrastructure of urban territorial systems by means of intellectual modeling are examined in the article. The state of transport infrastructure of Ukraine is analyzed. The interested participants of the project for the development of transport infrastructure and their features are classified. The model-scheme of interaction of stakeholders on different stages of the life cycle has been developed. The proposed classification aims to promote efficiency risk management in the process of implementing transport infrastructure projects. The effect will be achieved through the ability of management services to focus on specific risk factors inherent in this stage of the project. Local factors are a constant source of risks, primarily this applies to counterparties operating in supply chains. For example, research in the field of transport infrastructure project management has shown that working with contracts plays an important role in risk management. Also, external and internal factors and processes can act as sources of risk. Meanwhile, their influence is reflected in the cost and term of the project. Limiting the range of sources that trigger the emergence of critical risks will allow you to concentrate efforts on controlling their impact and choosing the best management methods. On the example of the transport infrastructure of Lviv city has been established that through to the software containing the simulation module, it is possible to effectively design infrastructure projects, programs and portfolios of projects that will adhere to the agreed deadlines, budget and scope of work at the implementation stage.

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