Models of Content Management of Infrastructure Projects Mono-Templates Under the Influence of Project Changes

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Abstract

A thorough study of the process of managing the content of infrastructure projects mono-templates under the influence of project changes was carried out. During the study, was carried out a systematic analysis of the implementation processes of infrastructure projects, programs and project portfolios. A model of formation the modification factor of changes in the content of infrastructure projects, programs and project portfolios at the planning stage was developed, which made it possible to identify the process of modification the content of the infrastructure project under the influence of changes. Based on the systematization of the dependence matrix was constructed a graph of influence dependences of modification factor of changes on different levels of projects, programs and portfolios of infrastructure projects during the life cycle. The study of the subject area allowed to expand the terminological base of project management, programs and portfolios of infrastructure projects by formalizing the concept of "changes in infrastructure projects, programs and project portfolios. The model of content management of infrastructure project mono-template under the influence of project changes is presented. The model is formed on the basis of application of DSR mono-template of infrastructure project and taking into account 5 stages of infrastructure project content management. 4 classes of deviations of infrastructure projects content under the influence of project changes at the planning stage are formed and their quantitative range of distribution is presented. The practical formalization of the developed models with the representation of the corresponding mathematical dependences was carried out.

Keywords

Infrastructure Project, Content, Modification, Mono-template, Project Changes, Project Environment

1. Introduction

Successfully implemented infrastructure projects are the cornerstone of modern society and its vital activity. They increase the efficiency of states and the welfare of citizens, are a stimulating factor in economic development. There are a large number of classifications of infrastructure projects [13], in particular by scale, scope, forms, levels, types, etc. However, non-world practice indicates that the main areas of implementation and application of infrastructure projects, programs and project portfolios are:

- Transport
- Energy
- Communication
- Water
- Waste
- Defense

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All of these industries need significant infrastructure to function effectively and efficiently. However, a completely new area is planning and implementation of IT infrastructure projects, as the number of users of the Internet and cloud technologies is growing.

The analysis of statistical data for 2019 made it possible to track trends in infrastructure quality in 100 countries based on an assessment of the complex of existing and project-implemented infrastructure. (see Table 1)

Table 1

Ranking of countries according to their quality of infrastructure in 2019 [21]

Place	Country	Indicator	Score out 100	Development index	Ambit
1	Singapore		95.4		
2	The Netherlands		94.3		
3	Hong Kong SAR		94	high	[82,63-95,4]
4	Switzerland		93.2		
5	Japan		93.2		
…	….	….	….	….	….
25	Poland		81.2	medium	[82,62 - 69,87]
57	Ukraine		70.3		
…	….	….	….	….	….
100	Bolivia		57.1	low	[69.86-57.1]

Thus, according to the obtained indicators, Ukraine with the value of the index 70.3 ranks 57th in the world and 33rd in Europe in terms of existing infrastructure and implemented projects. According to the development index, it is in the 2nd group - medium-developed infrastructure.

The main factors in obtaining such indicators include the following:

- Infrastructure projects are complex organizational and technical systems, so their implementation, in terms of time and resources, is the costliest
- There are different approaches and features to the implementation of infrastructure projects, programs and project portfolios of different types and levels
- Problems of synchronization of project management standards, programs and project portfolios with national legislation
- Constant changes that affect the content of infrastructure projects

2. Analysis of recent research and publications

Having carried out a literary analysis of scientific achievements and trends in the field of science - project management, programs and project portfolios, we can say that a special niche in this area is devoted to the study of infrastructure projects. Infrastructure projects were studied by well-known Ukrainian and foreign scientists, including S. Bushuyev, H. Tanaka, I. Chumachenko, I. Kononenko, N. Bushuyeva, I. Babayev, S. Tsiutsiura, V. Piterska, S. Chernov, V. Gogunskii, N. Kunanets, V. Pasichnyk, A. Shakhov, A. Tryhuba, D. Bushuiev and others.

The following can be considered as important results of the conducted researches of management processes of infrastructure projects, programs and project portfolios. During the COVID-19 pandemic, the features of emotional contamination of management the infrastructure projects based on rapid transformation were studied [1]. An active method of communication has been developed for energy efficiency projects [16]. The components and results of the study of the development of creative potential of project managers have been identified [19]. Are considered the basics of infrastructure project management, guided by global trends [2] and the competence of IT project

management [3], information technologies for analysis and modeling of computer networks [11]. An algorithm for simplifying the solution of discrete optimization problems and reducing the problem of discrete optimization has been formed [4, 5]. Peculiarities of transport infrastructure design taking into account the human factor and management of critical competencies in a multi-project environment are described [7, 8]. Formed proactive strategy of operations and psychological means of theoretical modeling of the optimal number of project staff [5, 9]. Presented the methodical proposals for the use of an innovative mechanism focused on risk [15] and described a method for solving the non-Markov problem of optimizing the project portfolios for the planned period [14]. A generalized information model of the object is formed [18], the coordination of configurations of complex organizational and technical systems [17] and the features of safety-oriented management of project stakeholders [10] are described. Was researched management priority of ICT projects in programme of development organization in complex dynamically varying environment, however it is not integrated it to use in infrastructure projects [22-26].

However, despite the extensive research of methods, models and processes of project management, programs and project portfolios and the obtained results, the following can be stated. Today, unresolved scientific issues are the processes of content management of infrastructure projects at the planning stage, with the use of mono-templates of such projects and under the influence of project changes. Therefore, the solution of this scientific problem is an urgent task.

Object of study. Features of the process of forming the content of infrastructure projects with the use of mono-templates and under the influence of project changes.

Subject of study. Models of content management of infrastructure projects under the influence of project changes.

The task of work. Development of models and research of the content management process with the use of infrastructure projects mono-templates under the influence of project changes. In order to solve the scientific problem should:

1. Conduct a systematic analysis of the research object, to apply in the research the methodology and tools of project management, programs and project portfolios, in particular the elements of proactive and reactive management
2. Develop a model of formation the modification factor of changes in the content of infrastructure projects, programs and project portfolios at the planning stage
3. Build a graph of the dependences of modification factor impact of changes at different levels of projects, programs and portfolios of infrastructure projects during the life cycle
4. Study the subject area and form new definitions that complement the terminology for project and program management
5. Develop a model for managing the content of infrastructure project mono-template under the influence of changes. Investigate the classes of deviations in the content of infrastructure projects under the influence of project changes at the planning stage and present their quantitative range of distribution
6. Carry out practical formalization of the developed models with representation of the corresponding dependences
7. To form directions of further research

3. The bulk of research

Implementation of infrastructure projects, programs and project portfolios according to its specifics, peculiarities of formation and implementation is a complex organizational and technical process.

The complexity of the formation and implementation of infrastructure projects are:

- Increased project requirements for the product of the infrastructure project
- The need for structural decomposition of working and organizational structures of the infrastructure project
- The need for detailed planning of the life cycle of the infrastructure project
- Taking into account the increased probability of the impact of risks on the project
- Formation of the content of the infrastructure project based on the use of mono-templates

- Taking into account the impact of changes on the content of the infrastructure project, its reactions and behavior in terms of this impact

The solution of certain difficulties in the formation and implementation of infrastructure projects, programs and project portfolios is to conduct a comprehensive study. It includes the application of the provisions of the systematic analysis of infrastructure projects. Using theoretical and practical tools for project and program management to form project structures, their decomposition and modeling of planning processes taking into account the impact of changes. A systematic analysis of the existing features of the implementation of infrastructure projects indicated that they are mostly poorly or well structured. One of the key features of the implementation of infrastructure projects, programs and project portfolios is the use of mono-templates of such projects [12, 13, 20]. This approach, it can be argued, is a guarantee of not classifying infrastructure projects as unstructured projects.

However, the relationship of infrastructure projects to the category of poorly and well-structured, and the use of their mono-templates, does not eliminate the need to study the basic elements of the impact of changes on infrastructure projects, programs and project portfolios. The application of an infrastructure project mono-template is a complex process of analysis of existing structures and content of formation and planning the infrastructure projects, their adaptation in accordance with the design requirements of each individual project. This process involves the use of tools for modeling the structures of infrastructure projects, programs and project portfolios. It is complicated by the multi-criteria of changes that affect the content of infrastructure projects throughout the project life cycle, in particular, the most significant impact is carried out at the planning stage. After conducting a detailed analysis, we formed a definition of changes in infrastructure projects, programs and project portfolios.

Changes in infrastructure projects, programs and projects portfolios – are a set of predictable and unpredictable factors that influence the content and structure of planning projects, programs and portfolios of infrastructure projects, cause reactions and modify their behavior in the process of further planning and implementation.

In turn, the modification of the content of infrastructure projects, programs and project portfolios is a behavioral response of the content to the impact of change. Based on the data of the system analysis of infrastructure projects, programs and project portfolios and using modeling tools, a model scheme of forming a modification factor of changes in the content of infrastructure projects, programs and project portfolios at the planning stage was developed (see Figure 1), where *Content (Ct) IPPo* – content of the infrastructure projects portfolio; *IPPo* – infrastructure projects portfolio; *Content (Ct) IPPo'* – modified content of the infrastructure projects portfolio; *IPPo'* – modified infrastructure projects portfolio; *Content (Ct) IPPg* – content of the infrastructure program of projects; *IPPg* – infrastructure program of projects; *IPPgn* – number of infrastructure programs of projects; *Content (Ct) IPPg'* – modified content of the infrastructure program of projects; *IPPg'* – modified infrastructure program of projects; *IPPgn'* – number of modified infrastructure programs of projects; *Content (Ct) IPPr* – content of the infrastructure project; *IPPr* – infrastructure program of projects; *IPPrn/ IPPrn+1* – number of infrastructure projects; *Content (Ct) IPPr'* – modified content of the infrastructure project; *IPPr'* – modified infrastructure project; *IPPrn'/ IPPrn+1'* – number of modified infrastructure projects; *Md1/ Md2/ Md3* – modification factors of changes in the content of infrastructure projects, programs and projects portfolio.

The model-scheme in the context of formation of infrastructure projects, programs and projects portfolio at different levels is developed: *Lpo* – level of infrastructure projects portfolio; *Lpg* – level of infrastructure projects program; *Lpr* – level of infrastructure projects, which is described by dependence (1).

$$Ip = \{Lpo; Lpg; Lpr\}, \quad (1)$$

where *Ip* – infrastructure portfolio, program, project.

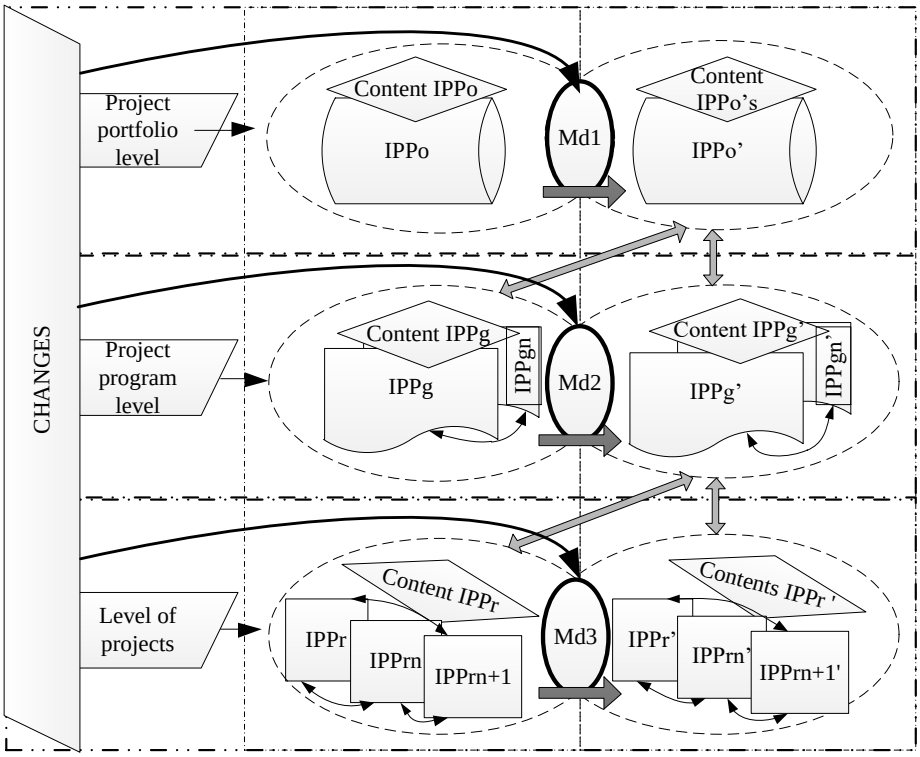

Figure 1: Model-scheme of formation the modification factor of changes in the content of infrastructure projects, programs and projects portfolio at the planning stage

Changes that occur at the level of the portfolio of infrastructure projects *Lpo* primarily affect the content of the project portfolio. They form a modification factor of changes *Md1*, which changes the structure of the portfolio, the parameters of resistance to the system of stability (portfolio hardens) and flexibility (portfolio learns to respond to changes with less consequences). We write a formalized dependence (2).

$$Cg(Lpo) = \overline{|Md1|} \Rightarrow \left\{ \left(CtIPPo \subseteq IPPo \right) \rightarrow \left(CtIPPo' \subseteq IPPo' \right)' \right\}, \qquad (2)$$

where *Cg* – the impact of changes on the infrastructure portfolio, program, project.

Changes that occur at the level of the *Lpg* infrastructure project program affect the content of the project program. We write the dependence of the formalized expression (3).

$$Cg(Lpg) = \overline{|Md2|} \Rightarrow \left\{ \begin{array}{c} \left(CtIPPg(n) \subseteq IPPg(n); \quad IPPg \in [1; n+1] \right) \\ \downarrow \\ \left(CtIPPg(n)' \subseteq IPPg(n)'; IPPg' \in [1; n+1] \right) \end{array} \right\}, \qquad (3)$$

However, at this level, the impact of changes can occur before and after the impact of the modification factor changes *Md2*. This is based on the causal links between the infrastructure projects portfolio and the project program. It is logical that the direct impact of the modified infrastructure projects portfolio of *CtIPPo'* on the modified content of *CtIPPg(n)'* and the *IPPgn'* infrastructure project program will have a positive impact on the planning of the structure and implementation parameters of infrastructure projects.

At the level of *Lpr* – the level of infrastructure projects, in addition to the impact of changes that accompany all infrastructure projects that are implemented in the context of programs and project portfolio, it is necessary to take into account their competition. Each project at this level is vulnerable

to external factors of *Md3* changes that accompany their modification. We formalize the dependence (4).

$$Cg(Lpr) = \overline{|Md3|} \Rightarrow \left\{ \begin{array}{c} \left(CtIP\ Pr(n,...,n+1) \subseteq IP\ Pr(n,...,n+1); \quad IP\ Pr \in [1; n+1] \right) \\ \downarrow \\ \left(CtIP\ Pr(n,...,n+1)' \subseteq IP\ Pr(n,...,n+1)'; IP\ Pr' \in [1; n+1] \right) \end{array} \right\}, \qquad (4)$$

Accordingly, it should be noted that the direct impact of the modified program of infrastructure projects *CtIPPg'* on the modified infrastructure projects *IPPr(n,…,n+1)'* and their content *CtIPPr(n,…,n+1)'* will have a positive impact on the planning process.

The study of the peculiarities of the distribution of impact of the modification factor according to the levels (projects, programs and portfolio of infrastructure projects) during the life cycle made it possible to build an appropriate matrix. (see Table 2).

Table 2

Matrix of the peculiarities of the distribution of impact of the modification factor according to the levels of projects, programs and portfolio of infrastructure projects during the life cycle

Level	F1	F2	F3	F4
Portfolio	+--	+--	+--	+--
Program	++-	-+-	-+-	-+-
Project	+++	--+	--+	--+

where + (influence is present), - (no influence) - the value of the influence of the modifying factor of change at different phases of the life cycle. Analyzing the matrix, we can say that the dependence of the modification factor of changes according to each level of the project will be different, and their functions will change according to the asymptotes. Thus, we constructed a graph of the dependence of the modification factor impact on changes at different levels of projects, programs and portfolio of infrastructure projects during the life cycle (see Figure 2).

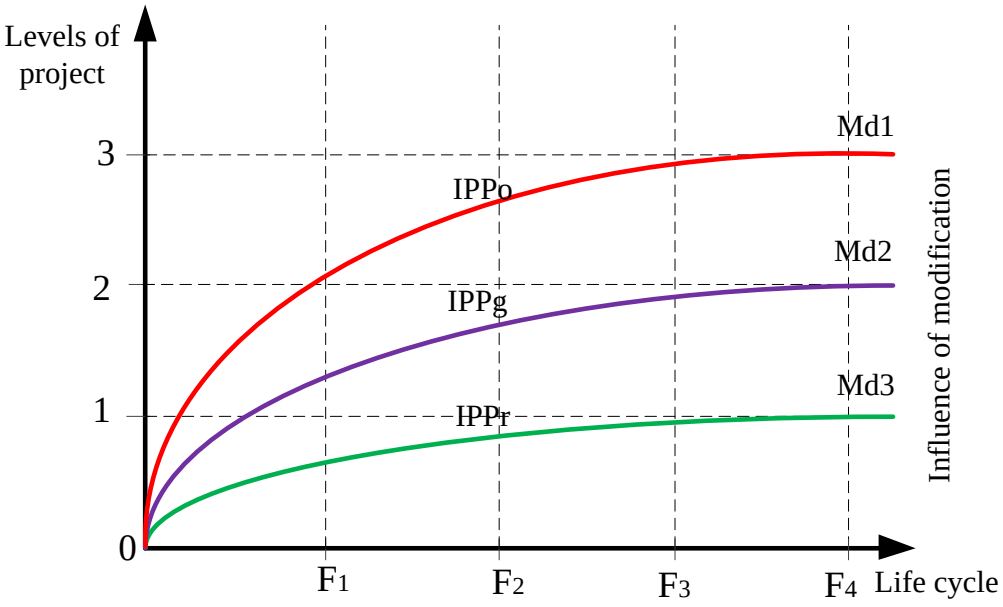

Figure 2: Graph of the dependence of the modification factor impact on changes at different levels of projects, programs and portfolio of infrastructure projects during the life cycle

where *F1* – is the initiation phase; *F2* – planning phase; *F3* – implementation phase; *F4* – completion phase.

The formed curves of dependences of modifying factor influence of changes on various levels of infrastructure projects, programs and projects portfolio can be written down by functions. For the modification factor of changes *Md1* (5).

$$Md1 = IPPo$$
$$\lim_{IPPo \to [0;3]} f\left(IPPo\right) = Md1, \quad (5)$$

For the modification factor *Md2*, the function will look like this (6).

$$Md2 = IPPo$$
$$\lim_{IPPo \to [0;2]} f\left(IPPo\right) = Md2, \quad (6)$$

For the modification factor of changes *Md3* we write down the function (7).

$$Md3 = IPPo$$
$$\lim_{IPPo \to [0;1]} f\left(IPPo\right) = Md3, \quad (7)$$

After analyzing the presented graph of dependences and matrix, we can state the following. The main impact of project changes is on the initial phases of the life cycle of projects, programs and portfolio of infrastructure projects, in particular the phases of initiation and planning. Taking into account the above and the existing practice of implementing infrastructure projects, we confirm the special importance of taking into account the impact of changes and modification factors on the project content at the planning stage of infrastructure projects, programs and projects portfolio. Since previous studies have indicated the practical feasibility of using infrastructure projects mono-templates, we have formed a model for managing the content of the infrastructure project mono-template under the influence of project changes (see Figure 3), where *Ee* – the impact of the external project environment; *Ei* – the impact of the internal project environment; *Pb* – initiation of infrastructure project changes; *Pl* – planning of infrastructure project changes; *Pw* – definition of the content of the infrastructure project; *Pc* – checking the content of the infrastructure project; *Pe* – control over the content of the infrastructure project.

The model is formed on the basis of application of *DSR* (Decomposition; Safety; Resources) of a mono-template [12] of the infrastructure project. It includes elements of content management of the infrastructure project, taking into account the impact of the project environment, dependencies and changes. The content management of the infrastructure project includes the following management units: change initiation, planning, content definition, verification and control. We write down these control blocks of expression (8).

$$CtM = \{Pb; Pl; Pw; Pc; Pe\}, \quad (8)$$

where *CtM* – content management of infrastructure project, program, project.

To verify the adequacy of the developed model, we assume that under the most favorable design conditions, the value of the project content will be equal to 1. Then, if there are changes that will affect the content of the infrastructure project, subtract their quantitative values from previously accepted. We write this solution by equation (9).

$$CtMa = 1 - \left(\Sigma Pb; Pl; Pw; Pc; Pe; Ei; Ee\right), \quad (9)$$

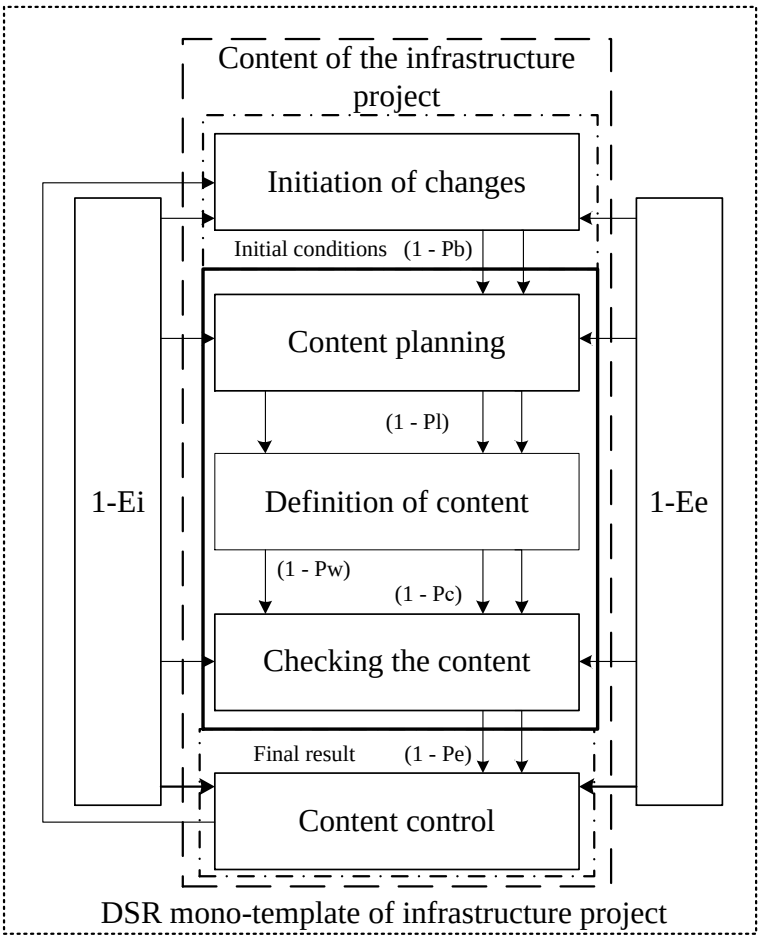

Figure 3: Model for managing the content of the infrastructure project mono-template under the influence of project changes

Assume that the results of calculating the quantitative values of changes in the content of the infrastructure project are divided into 4 classes. 1 - class – no significant deviations of the content; 2 - class – permissible deviations of the content; 3 - class – alarming deviations; 4 - class – critical deviations of the content. (see Table 3.)

Table 3

Table of values distribution of deviation the content of infrastructure project

Deviation	Range	Class
Not significant	[0.001-0.10]	1
Permissible	[0.101-0.150]	2
Alarming	[0.151-0.250]	3
Critical	[0.251-1.0]	4

Thus, we have formed 4 classes of deviations in the content of infrastructure projects under the influence of project changes at the planning stage and their quantitative range of distribution. Since there are no projects, there would be no deviations, the best option where management changes will be effective is a deviation in infrastructure projects in the ranges of class 1 "Not significant" [0.001-0.10] and class 2 "Permissible" [0.101-0.150]. In other cases, the probability of successful implementation of infrastructure projects will decrease.

4. Conclusions

A scientific study of the process of managing the content of infrastructure projects mono-templates under the influence of project changes. The research is based on the application of project

management methodology, programs and portfolios of infrastructure projects, the use of elements of system analysis of projects, modeling tools. According to the results of the study:

1. There is developed the model of formation the modification factor of changes maintenance of infrastructure projects, programs and projects portfolio at a planning stage
2. There is constructed the graph of the dependence of the modification factor impact on changes on various levels of projects, programs and portfolio of infrastructure projects during a life cycle on the basis of a matrix of dependence
3. Expanded the terminological base of project management, programs and portfolios of infrastructure projects by formalizing the concept of "changes in infrastructure projects, programs and projects portfolios"
4. Model for managing the content of the infrastructure project mono-template under the influence of project changes is developed; 4 classes of deviations of the content of infrastructure projects under the influence of project changes at a planning stage are formed and their quantitative range of distribution is presented
5. Practical formalization of the developed models with representation of the corresponding dependences is carried out;

Areas of further research include improving the methodology of managing the content of infrastructure projects with the practical implementation of the results.

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