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Application of the integrated decision support system for scheduling of development projects

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Abstract. Introduction: A higher level of specialization in various disciplines and technologies typical for the participants of modern investment and construction (development) projects creates the need for the advanced project management models. Decision support systems and tools for communication and organization of joint activities are the mandatory components for the efficient project management. Purpose-designed information systems allow to computerize such project management function as scheduling. However, the optimum decision is still found on the basis of personal assessment by decision makers. At the same time, as competition in the construction industry increases, the need for decision support systems to optimize investment and construction activities in the environment of multi-objective optimization becomes evident. **Methods:** The findings of DSS development projects in the construction industry have been used. The studies have been based on system integration approach to engineering, method of successive concession and the procedure for a search of the satisfactory values meeting STEM criteria under given weights. **Results:** Principles of development and functioning, architecture and organization and process aspects of DSS for scheduling under multi-objective optimization. **Discussion:** Integrated DSS capable for multi-objective optimization of the schedules has been proposed.

1 Scheduling of development projects

An investment and construction project, or a development project can be defined as the complex probabilistic system where the manpower, material, financial and intellectual resources are structured and interrelated in a unique way. Business enterprises involved into implementation and/or management of the construction projects are therefore among the most complicated objects for establishment of up-to-date organizational and managerial methods as well as economic and mathematical models. Developers being the major stakeholders of a project and its driving power shall be focused on financial and economic aspects of project implementation and be interested in the overall evaluation of project-related risks. In-depth investigation of organizational problems relevant for engineering, construction and operation processes should also be performed to enhance quality of decisions being made by the developer throughout the project life cycle [1].

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New information technologies capable to integrate the individual information flows to facilitate optimized solutions provide the benefit of semi-graphical tools for decision makers. However, the majority of the existing decision support systems could not offer not-so-obvious approaches in their computing processes that relate to performance of functions that have been so far exclusively made by human users. Even the most advanced information systems for construction project management (scheduling systems) almost completely ignore the fact that the regulated and managed facilities are influenced by human factors, often not quantifiable. The previous experience and intuition successfully used by the human experts for decision making on the basis of heuristic knowledge have been neglected.

As specified in [2], in the construction industry timely commissioning of the project is in some situations more important for the client than the associated costs of construction. Besides, costs are determined by the period of construction. Unscheduled works and events could usually result in deviation from the schedule, delays of construction period and overruns that, in turn, produce a negative impact on efficiency of investments.

Developers evaluate the organization and engineering solutions for a project on the basis of their impact on investment efficiency [3]. We suggest to analyze the work schedules in the context of the model for implementation of accepted organization and engineering solutions not only as the materials, manpower and machines movement over time but also as the modelled flow of investments that are typically external, including borrowed funds. This approach to scheduling will enhance the level of responsibility of the stakeholders and provide for the more stringent plan control.

There are several promising areas for improvement of the organization and technical models of development project management, taking into account the developer's interests:

• In-depth specialization of the contractors in terms of the scope and disciplines, i.e. the optimized division of the work scope into some packages offered to the focused special companies able to perform works at high quality, competitive costs and shortened period;

• Organization and technical mechanisms providing the efficient coordination of multiple contractors responsible for construction and erection works and the suppliers of materials and equipment in order to fulfil the schedules at minimum deviation from costs and time limits specified at pre-investment phase of project engineering;

• Integrated decision support system (IDSS) for construction organization and schedule design with the benefits of semi-graphical tools and the set of well-balanced integrated indicators of the efficient implementation of a development project.

This article proposes the model for IDSS that can be applied for development project implementation on the basis of multi-objective optimization of schedules.

2 Concept of integrated decision support system for scheduling of development projects

Scheduling as part of project implementation can be characterized by multi-objective statement of tasks and problems. The results are however often determined by the background of engineering, technology and financial contractors, by their work experience, experts' intuition and other factors, whereas the conventional project management models are based only on a limited scope of formalized procedures of multi-objective optimization.

2.1 Principles for creation

The use of IDSS enabling multi-objective optimization of schedules allows for significant limitation of the biased approach to decision making, increased probability for selection of the best option of project implementation based on the rigorous mathematical analysis of project alternatives including evaluation of technical, technological and financial characteristics of project construction and further operation.

Integrated DSS can be realized on the basis of system integration approach to construction [4], by means of combination of any available scheduling system with a new subsystem of multi-objective optimization which is under development.

The difficulties for development of large complexes of interrelated software come from the fact that efficient resolution of any particular problem can usually be determined at the final stage of development when the entire system, or the major portion thereof, starts functioning. Therefore, the high-efficient software packages are difficult to create. Typically, the relatively long period of development, testing, upgrading and debugging is needed to make the system efficient.

The allowed load to the system components (i.e. amount of information to be processed per unit time) can constrain development of DSS. One of such DSS component is a human participant who is forced to make decisions during the system session under the condition of information overload.

Development of DSS can be currently performed using the experience in creation and operation of computer-aided management systems and the large software packages. The referred experience can be formulated as the set of principles which may be considered during DSS development. These principles have been extensively presented in the foreign and national literature on the subject of information systems for various applications.

In our opinion, for the purpose of development of IDSS capable to support multi-objective optimization of schedules the set of generally accepted principles should be enlarged as follows (see in Table1).

Table 1. Principles for creation and functioning of IDSS capable to support multi-objective optimization of schedules.

Principles	Description
Maximum use of off-the shelf design solutions	Use of the existing software packages that are widely accepted in construction projects for development of IDSS
Open data exchange interfaces	Maximum openness of interfaces for data exchange and system management, their generality and compatibility
Possibility for multi-objective optimization	Project designer or manager will be given the possibility of either single-criteria or multiple-criteria optimization
Principle of automated generation of input parameters	As soon as the alternative is reviewed, development of a schedule shall start automatically.
Principle of a free choice of optimization criteria by the designer	A flexible system for determination of optimization criteria
Principle of information uniformity	In all subsystems of IDSS it is required to apply terminology, symbols, ways of information presentation, etc. in accordance with the industrial standards.
Commitment to interactive mode of designing	This parameter allows for active involvement in the process, control of design progress and management of multi-objective optimization in dialogue regime.
Possibility to involve experts for decision making	Availability of the mathematical tools for processing quantitative and qualitative evaluations made by the experts
Principle of joint leadership	Decisions could be made on the principle of joint leadership, thus enabling to justify decision options based on the consolidated experts' opinion;

Integration of all tools used and division of system information among all project participants in accordance with their access rights	Data are protected against unauthorized access. Data base of standard solutions, regulations etc. is not accessible to the experts.
Consistency of objective definition	IDSS-related activities shall be focused on generation of the schedule for the investment-construction project
Automated generation of project documentation	Project documentation shall be prepared in accordance with the requirements of applicable standards.

2.2 System integration

Taking into consideration that a subsystem of multi-objective optimization shall become a component of IDSS established on the basis of the proven scheduling and project management system, we propose to take the following existing software for development of IDSS support: MS Project, Spider Project, Primavera, Gektor, 1C.

The required additions for the types of support for IDSS are characterized in Table 2:

Table 2. Required additions to IDSS support.

Type of support	Required additions
technical	Efficient tools for communication and joint work of the key decision makers
mathematical	Development of mathematical models, methods and algorithms of multi-objective optimization. The possible option of these mathematical tools is described by the author in Ref. [5].
software	Software support for the new models and algorithms. Ensure compatibility with the most popular software used for scheduling and construction management
information	Ensure information presentation in easy to use and visual graphic format
methodology	The system shall be structured based on system integration approach in construction [4]. Methodology support including description of a new subsystem of multi-objective optimization.
linguistic	Terminology and glossary for each project shall be provided to ensure the optimum level of complexity for problem setting.
organization	Organization support, similar to the mathematical tools, should be significantly updated, as man-machine interface would be drastically changed due to a new problem setting, i.e. multi-objective optimization of the schedule for the investment and construction projects. It should be also required to determine terms of reference and the scope of responsibilities for decision makers as well as the principles and operational guidelines for experts.

2.3 System development

To establish efficient operation of the system, it is of primary importance to identify the criteria and constraints for a given investment and construction project.

Development of IDSS should be focused on the following issues:

• Increase in degree of freedom for decision makers (DM) during system initialization;
• Identification of potential multiple-choice situations and elaboration of the dialogue procedures for their resolution;
• Adaptation of the computing model for the users' requirements;
• Arrangement of the interactive mode of optimization process;
• Development of the methodology of decision making under multiple-objective conditions;
• In-depth development of solutions obtained as a result of parametric optimization;
• Expanding the system service function in the dialogue mode.

Using the slightly modified definition of decision makers given by O.I.Larichev & A.B.Petrovsky in Ref. [6], in this article decision makers are understood as persons (or a group of persons) who might be interested in the analysis of the options and who are in position and willing to influence the decision.

Increased freedom of DM actions at IDSS initialization can be guaranteed by means of scheduling separation into the several procedures, each focused on the specific types of work. Depending on their background and the specific features of a task, DM may avoid performance of any separate phases of scheduling or any project procedures. For instance, the system user can be given the capability of determining the facility structure all by himself, without the use of the subsystem of multi-objective optimization. It is required to allow for setting the individual components of the schedule and for implementation of some elements of the computing model. Thus, the points of system "inlet/outlet" and its functional trend should be determined by DM.

2.4 System architecture

In accordance with the principles of development of IDSS for scheduling under the conditions of multi-objective optimization the following system architecture is proposed (Fig.1).

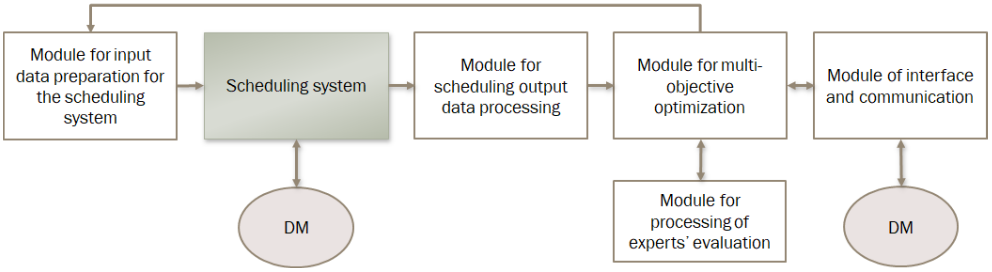

Fig. 1. Architecture of IDSS for scheduling under the conditions of multi-objective optimization

2.5 Functionality of the modules

The scheduling system shall provide implementation of the following functions:
• Generation of work schedules;
• Determination of cost parameters required for implementation of the schedule stages;
• Allocation of manpower and technical resources for implementation of the schedule;
• Quantification of materials for work performance under the schedule;
• Determination and presentation of logical relationship among works, taking into account possible delay in time and scope;
• Presenting the information on work plans in graphic way, including graphical presentation of the critical path;
• Plotting the diagrams of resource use from the works perspective and the diagrams of material use from the works perspective;

• Generation of a report on work schedule performance including the analysis of implementation and prediction of further work progress (from the perspective of a single facility under construction and also from the perspective of all facilities managed by the enterprise).
• Plotting the diagrams of manpower flow, the use of machines and mechanisms;
• Generation of a report on comparison of the schedule options with the information on costs, labor input and duration of construction and erection works.

In the author’s opinion, based on the determined principle of system structuring, to resolve the set objectives, it is possible to use any scheduling and project management system that is widely applied in the construction industry, has the standard user interface and provides the capabilities of system integration (add-in capability).

Interfacing module is intended for access authorization, information input/output; simultaneous access of several users to IDSS.

Module for scheduling output data processing is intended for transformation of output data generated by the scheduling system for their further use both by the decision maker or by the module of multi-objective optimization.

Decision makers (DM) can be understood either as a single person or a group of experts. In the latter case, it becomes possible to rely on cross-functional knowledge, background and skills of the project developers and, accordingly, to select the most justified option of the schedule.

A human being, the user of the system, is the key component of almost any decision support system. Therefore, the man-machine interface has always been in the focus of DSS development. First of all, it concerns the distribution of system functions between the operator and the computer, and, consequently, development of interactive mode of DSS functioning. Despite of the obvious trend to the higher degree of automation, the interactive mode of action remains necessary because it is still not possible to fully computerize engineering of the complex technical systems. Involvement of human operators permits to speed up decision making process for some tasks.

During development and upgrade of interactive procedures and operations for multi-objective optimization of schedules it is proposed to adopt the passive-defined dialog: using menus, filling up a form, “yes – no” requests [7, 8]. It is suggested to use terminal job processing [6], in other words, DM operation in the interactive mode (on-line).

Prediction of the construction period duration is a priority task. In case of probabilistic scheduling Monte Carlo method seems to be the universal tool. This method can be applied either directly to obtain the predicted overall duration of construction, or in combination with other methods. In the latter case the obtained result will be determined by the integrated identification of the work scope.

Module for multi-objective optimization is based on software implementation of formal-heuristic algorithms for the search of the optimum schedule option. This module is needed for determining the efficient schedule based on various economic and mathematical models of multi-objective optimization of the schedule with participation of the experts for option evaluation. As input parameters to this module it is possible to take the results of calculations performed within the scheduling system.

For instance, decision makers can appraise quality of the schedule from the construction view point (based on such criteria as continuity and regularity of construction works) or from the financial and cost-efficiency view point taking into account time value of money (net present value, NPV, and internal rate of return IRR).

It seems also very promising to use Monte Carlo method for the probabilistic scheduling as described in Ref. [9]. This method can be used in combination with other methods.

Module for processing of experts’evaluation shall be used for processing of experts’ opinions which may be presented as both quantitative and qualitative assessments of the options. It is proposed to use fuzzy logic as the tool for processing the qualitative assessments. Application of this method has been described in detail by the author in Ref.[10]. Moreover, the applicability and prospects for using fuzzy logic in the expert systems for development projects have been argued in various other studies [11, 12].

Selection of the experts and coordination of their assessments is the major concern when implementing the procedures of expert analysis. Such problems have been broadly discussed in the related publications. The following methods for expert selection have been suggested: the method of cross appraisal and self-appraisal of experts' competence, snow-ball sampling, random sampling, etc. [13-15]. The different approaches have been developed for experts' group organization to obtain information: questioning, brain-storming, appraisal scaling, modified Delphi method, etc.[14, 16, 17]. As these issues have been investigated in detail by various scientists and experts, we will not dwell on these aspects here.

2.6 IDSS application for scheduling of development projects

IDSS for scheduling is a powerful tool which cannot be used efficiently without the methodological support prescribing sequence of stages and project procedures to be applied at each stage. As each stage of scheduling by means of IDSS involves various operations with material and non-material resources, and these operations should be distributed in time and coordinated in the optimum way, it seems expedient to develop and practice the technology of CAD.

The implementation of the technology of automated preparation of schedules makes the set of the following requirements for IDSS:

- the ability to formulate the tasks in a language understood by the schedule designer;
- no rigid restrictions on the structure and volume of input data and its storage;
- fast connection with system's software of new modules and exclusion of obsolete ones;
- ability to the schedule designer to take a decision based on intermediate results for specific project task and changes in the values of individual parameters in the utilized method;
- the ability to monitor the values of the main process parameters, that indicate its effectiveness, and, depending on their values, adjust the design process;
- ensuring the compatibility of CAD and non-CAD types of scheduling;
- the possibility of using information about the design object during subsequent operation in its BIM-model.

To provide acceptable optimization time with a greater number of variants, interactive design procedures for a sequential, rationalized enumeration of variable parameters have been developed. As a basis for the development of sequential search procedures, the technology of choosing the optimal option is adopted in the "manual" formation of schedules.

Schematically, the technology of schedules generation with the help of an integrated decision support system is conventionally presented in Fig. 2.

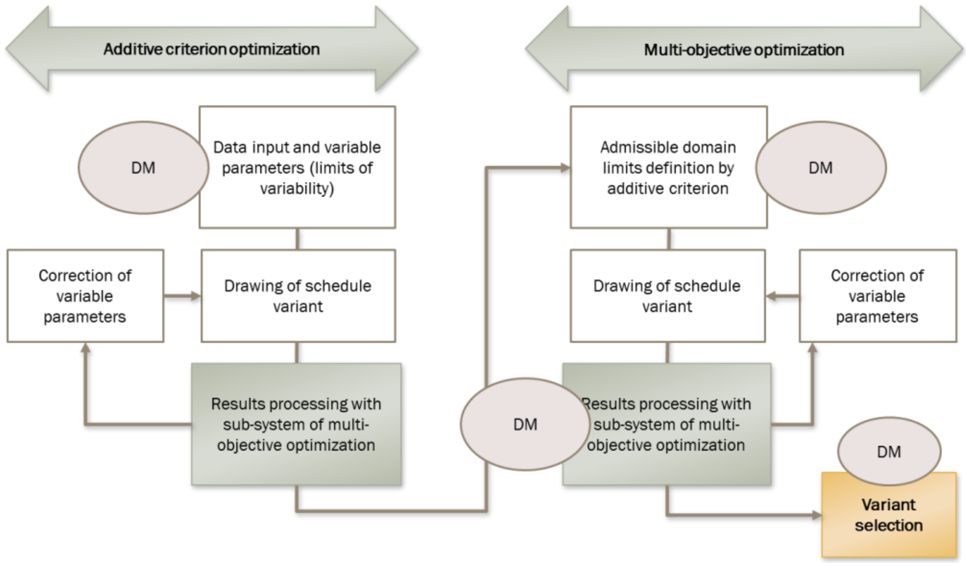

Fig. 2. Technology of schedules generation with the help of an IDSS

After selecting a prototype schedule, the optimal characteristics are determined successively. The error of decomposition can be reduced if necessary by carrying out several iterations.

Interactive procedures for sequential, streamlined enumeration allow us to solve the problem of parametric optimization quite effectively, although it is certain that obtaining a positive result depends to a large extent on the experience and intuition of the decision maker.

At the first stage, the analysis of variants of the calendar plan is carried out based on rationalized search. At the second stage, to solve the multicriteria optimization problem, an interactive procedure for narrowing the allowable range in the variable space based on the elements of the method of successive concessions [18] and the procedure for finding satisfactory values of the STEM criteria for the given weights [19].

After choosing a variant of the calendar plan, a detailed study of the variant with the help of the system of building the calendar plans is proposed. The choice of an optimal solution search strategy in the parametric optimization stage is one of the most important aspects in the development and operation of the IDSS. At present, many methods and algorithms for determining the extremum are known in mathematical programming. A lot of work has been done to study and systematize them. But universal approaches have not yet been found. Effective algorithms for optimal design are built only based on a combination of different methods taking into account the specifics of the mathematical model of the object. In connection with this, the author developed a two-stage strategy for finding the best option, combining the method of rationalized enumeration and formal heuristic algorithms.

3 Conclusions

Integrated DSS for management of a development project has been complemented by the set of organization and technological mechanisms for selecting the best option of the schedule based on multi-objective optimization. The formal algorithms used for scheduling and described above allow to consider in decision making process some factors of non-deterministic character or not represented by selected certain criteria.

The principles of structuring and functioning, the architecture of IDSS for scheduling under the conditions of multi-objective problem setting have been proposed. The technology has been developed for scheduling of development projects based on IDSS. This system can be used for evaluation of construction organization quality, also based on project financial and economic efficiency, taking into account time value of money.

The use of the proposed model of IDSS for management of development projects will allow to scale back on the subject opinions for decision making and make it more probable that the best option, in the developer's view, will be selected for project stage implementation. The model of IDSS can be generally applied as the tool for decision support when planning the investment construction projects, estimating and optimizing the schedules so as to improve the selected parameters of economic efficiency of investments.

References

1. P. G. Graboviy Construction organization and real estate development - M.: Publishing house ASV, 2018.
2. A.A. Gusakov, N.I. Ilyin, H. Edeli Expert systems in design and cunstruction managemet – M.: Stroyizdat, 1995.
3. I.I. Mazur, V.D. Shapiro Reference book for professionals "Project Management" - M.: Higher School, 2001.
4. Gusakov A.A. Sistemotekhnika [Systems engineering]. Moscow, 2002.
5. Karyakin, A.M. Interactive procedure of multi-objective optimization when drawing calendar plans / A.M. Karyakin, V.V.Berezka // Vestnik ISPU, 2013, No.2. – P.75-78.
6. Larichev, O.I. Support system of making decisions: current status and development prospects / O.V.Larichev, A.B.Petrovski // results of science and technology. - M.:– VINITI, 1987, V.21.
7. Baranov, A.N. Introduction to Applied Linguistics.- M.: MSU, 2012.
8. Dening, V. Dialogue systems "man-PC". Adaptation to the requirements of the user / V.Denning, G.Essing, C.Maas. – M.: World, 1984.
9. Predictions of Construction Duration on the Basis of Executive Calendar Schedules, Statistical and Neural Network Modeling, Bolotin Sergey Alekseevich, Dadar Aldyn-kys Khunaevna, Недвижимость: экономика, управление. 2017. No. 3. С. 59-63.
10. Karyakin A.M., Berezka V.V. Calendar planning : Fuzzy sets theory procedure for decision making, Ivanovo, Russia (2013) ;
11. E. Pagourtzi, K. Nikolopoulos, V. Assimakopoulos Architecture for a real estate analysis information system using GIS techniques integrated with fuzzy theory, Journal of Property Investment & Finance, Vol. 24 Issue: 1, pp.68-78 (2006)
12. V. Del Giudice, P. De Paola and G. Battista Cantisani Valuation of Real Estate Investments through Fuzzy Logic Italy Buildings 2017, 7 (1), 26
13. Orlov, A.V. Expert evaluation // Factory Laboratory. – 1996. – V.62, No.1. – P.54-60.
14. Orlov, A.V. Expert evaluationю – M.: IVCTE, 2002.
15. Rostegaeva, N.I. Methods of expert evaluation // Encyclopedic Sociological Dictionary / under editorship RAS G.Osipova. – M., 1995.
16. Eremeev, A.P. Expert Models and Methonds of Making Decisions. – M.: MEU publishing house, 1995.
17. Litvak, B.G. Expert evaluation and Making Decisions. – M.: Patent, 1996.
18. Batishev, D.I. Methods of optimal project work. – M.: Radio and Communication, 1984.
19. Benaiun, R. Linear Programming under Many Criteria: method of limitations / Benaiun R., Larichev O.I., Mongolfie G., Terny G. // Automatics and Telemechanics. – 1971.- No.8.- P. 108-115.