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METHODICAL FOUNDATIONS FOR MODELING THE TIMING OF MODERNIZATION OF UKRAINE'S ENERGY FACILITIES IN CONDITIONS OF LIMITED LABOR, MATERIAL AND FINANCIAL RESOURCES

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МЕТОДИЧНІ ЗАСАДИ МОДЕЛЮВАННЯ ТЕРМІНІВ МОДЕРНІЗАЦІЇ ЕНЕРГЕТИЧНИХ ОБ'ЄКТІВ УКРАЇНИ В УМОВАХ ОБМЕЖЕНОСТІ ТРУДОВИХ, МАТЕРІАЛЬНИХ І ФІНАНСОВИХ РЕСУРСІВ

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МЕТОДИЧЕСКИЕ ОСНОВЫ МОДЕЛИРОВАНИЯ СРОКОВ МОДЕРНИЗАЦИИ ОБЪЕКТОВ ЭНЕРГЕТИКИ УКРАИНЫ В УСЛОВИЯХ ОГРАНИЧЕННОСТИ ТРУДОВЫХ, МАТЕРИАЛЬНЫХ И ФИНАНСОВЫХ РЕСУРСОВ

The article devoted an adaptation of economical and mathematical models, existing in the theory of network planning and management for determination of time reserves, with the help of which both labour and material, as well as financial resources can be efficiently and rationally allocated within the set of interrelated works. The proposed approach can be used in the process of development of measures to increase the energy efficiency rate, which will involve intensification of innovation activities, more complete implementation of social and economic potential of business entities and local communities.

Keywords: *energy efficiency; network model; methods and models of project management; time reserve; heat supply.*

Fig.: 1. Table: 3. References: 15.

Стаття присвячена адаптації існуючих у теорії планування й управління мережами економіко-математичних моделей визначення резервів часу, що дозволяють раціонально та збалансовано розподіляти ресурси в межах комплексу взаємопов'язаних робіт. Пропонований підхід може застосовуватись у процесі розробки заходів, спрямованих на підвищення рівня енергоефективності, що передбачають активізацію інноваційних процесів, більш повну реалізацію соціального й економічного потенціалу суб'єктів господарської діяльності та органів місцевого самоврядування.

Ключові слова*: енергоефективність; мережева модель; методи і моделі управління проектами; резерв часу; теплопостачання.*

Рис.: 1. Табл.: 3. Бібл.: 15.

Статья посвящена адаптации существующих в теории планирования и управления сетями экономико-математических моделей определения резервов времени, что позволяют рационально и сбалансировано распределять ресурсы в пределах комплекса взаимосвязанных работ. Предлагаемый подход может применяться в процессе разработки мероприятий, направленных на повышение уровня энергоэффективности, предусматривающих активизацию инновационных процессов, более полную реализацию социального и экономического потенциала субъектов хозяйственной деятельности и органов местного самоуправления.

Ключевые слова*: энергоэффективность; сетевая модель; методы и модели управления проектами; резерв времени; теплоснабжение.*

Рис.: 1. Табл.: 3. Библ.: 15.

JEL Classification: C13, C41, Q48, R15

Relevance of the research topic. Implementation of the plan of energy efficiency operations, stimulation of energy consumption reduces, creation of transparent and competitive environment to attract investments into the industry, as well as the growth in energy efficiency of state and municipal property objects is one of the chief tasks of the Cabinet of Ministers of Ukraine defined by the Program [1]. However, the current procedure of heating energy pricing by respective authorities is based on the „out-of-cost" principle, which significantly reduces the possibility of real increase in the efficiency of central heating system [2]. The operational practice of calculation of heating tariffs at the stage of its release into the network results in the lack of financial incentives for the reconstruction of heating system, thus determining low rates of its restoration. Ukrainians are forced to pay for the heating energy, 45% of which they do not actually receive because of its loss during the transportation. In fact, nobody takes care of the quality (temperature) of the heat carrier received by consumers, as everything has been already paid.

Problem statement. Adaptation of economical and mathematical models and critical path method (CPM), Program Evaluation and Review Technique (PERT) and making decisions on stochastic GERT-networks (Graphical Evaluation and Review Technique), which are existing in the theory of network planning and management, will increase effectiveness of scheduling the implementation of works that can be substantial by their volumes, cost and time, the project management as for replacement and/or upgrade of generative points and networks for the transportation of steam, hot water and conditioned air. This foresees a large amount of interrelated works that must be executed in strict technological sequence, requiring proper timing and control in order to achieve a certain goal.

Analysis of the last researches and publications. Scientific works by P. Lazanovskyi [3], Ya. Sybal, I. Ivanytskyi, Z. Kadyuk [4], V. Sokhan [5], O. Timinskyi [6] and other researchers are devoted to the application of a method of network planning and management in various types of economic activities.

Open parts of a shared problem. Despite the considerable number of scientific works and growing attention to this problem, the task of modeling on the basis of the theory of graphs and analysis of networks in the system of technical improvement and technological upgrade of heat-power engineering objects, in order to increase the energy efficiency of energy consuming equipment, to reduce the rate of energy losses in supply networks, to minify specific costs per one unit of output (generated energy unit) and to raise the efficiency of final energy consumption is significant on a practical level and requires amplification.

Problem definition. The purpose of the article is an adaptation of economical and mathematical models, existing in the theory of network planning and management for determination of time reserves, with the help of which both labour and material, as well as financial resources can be efficiently and rationally allocated within the set of interrelated works.

Statement of the main material. When applying network methods, the minimum duration of a project is determined by the sequence of works, which form the longest (a so-called critical) path through the network, and those works creating the critical path are called critical works, so any increase in their duration or delay in their execution cause an increase in the time of project implementation as a whole. Availability of time reserves will give the users some freedom in allocating particular resources.

In today's realities of rapid development of new information and communication technologies, which form the informational society and, in particular, the informational economy, with modeling as their intellectual core [7], during the planning of projects with the use of computer technologies, together with the network models and methods, the most relevant way is the statement of a problem in the form of a „node-work" model. The difference of a „node-work" model from a „node-event" model is that the notion of an event is not introduced: various works within the network are displayed by nodes, while arcs only reflect the relation of top priority, that is the time is spent in knots, but not in arcs. Construction of the network is not a complicated task due to the introduction of only two conditional works, both having a zero duration: the first of them means a „beginning", preceding all other works, and the second of them means an „ending", following the completion of all works. Using the mathematical model there is no need to use symbols with double sub-indices, as in the case of designating any work with an arc, since all the works are uniquely linked to one particular node, one index will be enough [8, p. 309-313].

Four indicators of the time reserve for each of the works (Table 3) are calculated using the following relationships.

$TF_i = LS_i - ES_i$ or $TF_i = LF_i - EF_i$ – total time reserve. Work with a zero time reserve is on a critical path;

$FF_i = \min\limits_{X \in S_i} \left[ES_X - EF_i \right]$ – free time reserve – measures available time that does not affect the performance of subsequent work;

$IF_i = \max\limits_{X \in S_i} \begin{cases} 0, \\ \min ES_X - \left[\max\limits_{Z \in P_i} LF_Z + d_i \right] \end{cases}$ – an independent time reserve is an indicator of the possible degree of disruption of communication between the project's work and the available time in the event that the worst possible circumstances occur during the execution of the previous work;

$SF_i = LF_i - \max\limits_{Z \in P_i} \left[LF_Z + d_i \right]$ – guaranteed time reserve – allows only the delay of subsequent work, but not of the entire project.

Here d_i – the time spent on doing the i-th work, $i = \overline{1;n}$;

$P_i = \{ a \mid a << i \}$ – a lot of works that are performed immediately before work i (the previous set of works); the symbol „<<" denotes the ratio of direct precedence (foreground), for example, i << j – work i is performed immediately before work j, or work j is performed immediately after i-th work;

$S_i = \{ a \mid i << a \}$ – a lot of work that must be done immediately after work i (the subsequent set of works);

ES_i – the earliest possible start date for the i-th work;

EF_i – the earliest possible completion date for the i-th work;

LS_i – the latest allowed start date for the i-th work;

LF_i – the latest allowed date for the end of the i-th work;

T – planned completion date of the project; is necessary $T \geq EF_{ending}$, is adopted $T = EF_{ending}$;

$ES_{beginning} = EF_{beginning} = 0$ – for the conditional work „Beginning of the project",

$ES_i = \max\limits_{X \in P_i} \left[EF_X \right]$ and $EF_i = ES_i + d_i$ – for all subsequent works, and calculations must be performed from earlier to later works in such a way that each work is considered before its appearance in the immediately preceding set of another work;

$LF_{ending} = LS_{ending} = T$ – for conditional work „Ending of the project",

$LF_i = \min\limits_{X \in S_i} \left[LS_X \right]$ and $LS_i = LF_i - d_i$ – for all other works, and, as in the previous case, the movement is carried out in the opposite direction, each work is considered before its appearance in the immediately following set of other work.

Implementation of economical and mathematical models of time reserves, systematized in [9], can be carried out through the use of software products (Table 1) – comparative characteristic of their functionality has been completed in [10]. Calculations (Table 3) in accordance with the initial data from Table 2, regarding the replacement of heating network area, has been performed in MS Excel.

Table 1

The most common project management systems and tasks

Name	Developer	Official site	General characteristics
Microsoft Project	Microsoft Corp. (USA)	http://www.microsoft.com/project	It is the most widely used project management system in the world, recommended for both entry level users and professionals. In many Western companies, Microsoft Project is seen as a standard component of Microsoft Office, and even ordinary employees are able to use it for work planning. Traditionally understandable interface of Microsoft products and ease of use are supported by broad properties of building and calculating network graphs, Gantt charts, time and resource planning tools, other tools
Open Plan	Welcom Corp. (USA); distributor in Ukraine – LANIT company	http://www.projectman-agement.ru	It is a system for planning and monitoring large projects and programs. The main differences of the system are powerful resources of resource and cost planning, effective organization of multi-user work and the possibility of creating an open, scaled solution for the entire enterprise. Open Plan comes in two variants - Professional and Desktop, - each of which corresponds to different needs of executors, managers and other project participants. There is a localized version of the product
Primavera Project Planner	Primavera Systems, Inc. (USA); distributor in Russia - PMSOFT company (http://www.pmsoft.ru)	http://www.primavera.com	It is used in calendar-network planning and management, taking into account the needs for material, labor and financial resources of medium and large-scale projects in various industries, although this product has the widest distribution in the field of management of construction and engineering projects
SureTrak Project Manager	Primavera Systems, Inc. (USA); distributor in Ukraine - PMSOFT company (http://www.pmsoft.ru)	http://www.primavera.com	SureTrak is a simplified project management system for Primavera Systems. This fully Russified product is aimed at monitoring the implementation of small projects and / or parts of large projects. Can work independently or in conjunction with Primavera Project Planner in the corporate project management system
Spider Project	Spider Technologies Group (Russia)	project.ru	The system is designed taking into account the needs, features and priorities of the Russian market. It is characterized by powerful algorithms for the distribution of limited resources and a large number of additional functions. Spider Project comes in two versions - Professional and Desktop. The Spider Project package can be used as a free licensed version, designed for 40 operations
Project Expert	Pro-Invest Consulting (Russia)	http://www.pro-invest.com	It provides construction of a financial model of the enterprise, analysis of the financial efficiency of business projects, development of a strategic development plan and preparation of a business plan. The system is recommended for use by state structures of federal and regional level, as a standard tool for developing enterprise development plans
1С-Рарус: Управление проектами	1C-Rarus (Russia)	http://rarus.ru	Russian development on the platform of the accounting system „1C: Enterprise” version 8.0. It is intended for planning, organization, coordination and control of design works and resources. The standard solution is developed only by the means and methods of the „1C: Enterprise” program and is an application of the „Accounting” component of the „1C: Enterprise” program version 8.0. Project management is integrated with any configurations that use component 1C „Accounting”

Table 2

Initial data, taking into account technological and engineering features in the sequence of execution of interrelated works and duration norms for the construction of heating networks

Designation and specification of work	Immediately previous work	Duration of works, days [1]
S Preparatory operations (preparation for engineering works)	–	10
Z Preparation of the network area for disconnection (informing the consumers)	–	30
A Planning and designing works	S	2
B Arrangement of a list of materials	A	1
C Purchase of pipes	B	30
F Purchase of flanges, shut-off valves and other materials and stuff for installation works	B	45
G Manufacture of sections	C	5
I Disconnection of the network area	Z, B	1
K Digging of the canal or erection of the supports (depending on the method of laying)	B	2
O Dismantle of the old pipeline	I, K	6
P Installation of a new pipeline	O, G	6
Q Welding works	P	2
R Installation of flanges and other details	F, I, K	1
T Fitting of the pipeline and other details	R, Q	1
U Leak testing of the pipeline	T	1
W Insulation	R, Q	4
X Land management works	T, W	1
Y Cleaning of the area	U, X	1

Source: [11; 12].

Table 3

Variation in timing for execution of works on upgrading and improvement of heating networks and indicators of time reserves, days

Work (i)	Duration	The earliest possible term		The most recent deadline		Time reserves			
		beginning (ES_i)	ending (EF_i)	beginning (LS_i)	ending (LF_i)	total (TF_i)	free (FF_i)	independent (IF_i)	secured (SF_i)
Beginning of the project	0	0	0	0	0	–	–	–	–
S	10	0	10	0	10	0	0	0	0
Z	30	0	30	14	44	14	0	0	14
A	2	10	12	10	12	0	0	0	0
B	1	12	13	12	13	0	0	0	0
C	30	13	43	16	46	3	0	0	3
F	45	13	58	13	58	0	0	0	0
G	5	43	48	46	51	3	0	0	0
I	1	30	31	44	45	14	0	0	0
K	2	13	15	43	45	30	1	16	30
O	6	31	37	45	57	14	11	0	0
P	6	48	54	51	57	3	0	0	0
Q	2	54	56	57	59	3	3	0	0
R	1	58	59	58	59	0	0	0	0
T	1	59	60	62	63	3	0	0	3
U	1	60	61	63	64	3	3	0	0
W	4	59	63	59	63	0	0	0	0
X	1	63	64	63	64	0	0	0	0
Y	1	64	65	64	65	0	0	0	0
Ending of the project	0	65	65	65	65	–	–	–	–

[1] In order to minimize the time needed for the disconnection of heat supply system for consumers, the overnight works are expected.

Taking into account the methodological principles of creation, calculation of parameters and optimization of network diagrams, disclosed, as an example, in [13, p. 172-202], the „node-work" network model for the given statement of problem can be represented as follows (Figure).

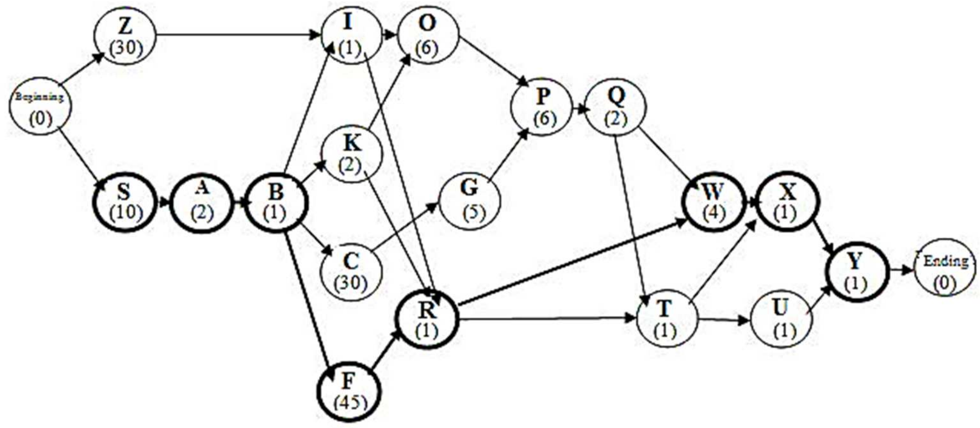

Figure. Network model of the project [2]

The total time reserve of works S, A, B, F, R, W, X, Y is equal to zero, indicating the creation of a critical path by these works precisely, and also a necessity to carefully monitor the timing of their execution. The work G, although it has a total time reserve (3 days), has no free reserves, because its delay will lead to untimely execution of the work P. The work O has a total time reserve of 14 days, but its free time reserve is only 11 days and any delay beyond 11 days will result in violation of terms for the earliest possible start of the work P. Only the work K has a non-zero independent reserve of time, while the rest of works can completely lose their time reserve due to untimely execution of previous works. Works Z, C, K and T are characterized by a non-zero secured time reserve. The following Figure shows that delay of the work C can occur due to the untimely execution of works G and P, and work K may be delayed as a result of delay of the work O. Works O, G and P will be deprived of secured time reserve due to possible delays in previous works.

Conclusions. One of the key messages of the 5th Vienna Energy Forum, organized by the United Nations Organization on Industrial Development, UNIDO, the International Institute for Applied Systems Analysis (IIASA), the Austrian government and the initiative Sustainable Energy for All (SEforALL), which in May 2017 gathered more than 1650 participants out of 128 countries, provides for energy as the most important component for the implementation of the Agenda until 2030 and the Paris Climate Agreement, and to meet the needs of the relative energy security [14]. The energy intensity of Ukraine's GDP exceeds that of the UK by 4.8 times, Turkey by 3.8 times, Poland by 3.0 times [15, p. 109], which does not contribute to increasing the competitiveness of our state to the level of the leading countries of Europe, ensuring the continuous and stable operation of the energy complex of Ukraine.

The proposed approach can be used by state authorities, business entities and investment companies in the process of development of measures to increase the energy efficiency rate at the macro-, meso- and microeconomic levels, which will involve intensification of innovation activities, more complete implementation of social and economic potential of business entities and local communities.

Management of the process of upgrading boiler stations and heating networks through the application of network methods, in particular, determination of admissible delays as a time reserve for further coordination of project implementation, will help managers to establish the

[2] In this case the final work with the execution of 0 days could not be entered, since the last work regarding the Cleaning of the area (F) and the display of conditional work „Ending" are both carried out specifically by the procedure of model constructing, in order to obtain solely initial and final nodes.

sequence and timing as for the use of limited resources throughout the entire period of project implementation, to conduct dynamic regulation of timing for the beginning of each work, to optimize rational allocation of project funds and materials due to the criterion of reducing duration of the whole project, to perform an analysis of trade-off relationships between the costs and timing of various works, with regard to the available time reserve.

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