***

Adowan G. A global method for solution of complex systems. *Mathematical modeling.* Vol.5. 1984. Pp. 251-263.

Cao S.G., Rees N.W., Feng G.Analysis and design for a class of complex control systems Part I: Fuzzy modelling and identification. Volume 33. Issue 6. June 1997. Pages 1017-1028

Chimshir V., Chimshir A. (2014) Method of choice of a technical system for project implementation basing upon situational efficiency criterion. *Electronic Scientific Journal.* Retrieved from http://www.wspolczesnagospodarka.pl/?p=764

Chymshyr V. System's technical condition assessment method and determination of its operation timeframe in uncertainty conditions. *Scientific development and achievements.* Volume 5. London: «Sciemcee Publishing», 2018. Pp. 182-195.

Donald V. Steward (1981) Transactions on Engineering Management. Volume: EM-28. Issue: 3. Pp.71-74

Игнатьева А.В. Исследование систем управления [Текст]. М.: ЮНИТИ-ДАНА, 2000. 157с.

Кокин А.Г. Имитационное моделирование систем: Учебное пособие. Курган: Изд-во Курганского гос. ун-та, 2011. 98 с.

Кузьмин Е.А. Неопределенность и определенность в управлении организационно-экономическими системами [Текст]:[Монография]. Екатеринбург : Институт экономики УрО РАН. 2012. 184 с.

Липаев В.В. Методы обеспечения качества крупномасштабных программных средств. М., 2003. 520 с.

Проектно-ориентированное управление жизненным циклом ремонтопригодных технических систем: дис. докотра технических наук: 05.13.22 АВ Шахов. Одеса: Феникс, 2006. 238 с.

Растригин Л.А. Адаптация сложных систем. Рига: Зинатне, 1981. 375 с.

Урбанович П. П. Информационная безопасность и надежность систем [Текст]. Минск : БГТУ. 2007. 90 с.

Чимшир В.И. Разработка метода количественной оценки социального эффекта при реализации социотехнических проектов [Текст]. *Журн. Восточно-Европейский журнал передовых технологий.* Харьков: УКЖТ. 2016. № 2/3 (80). С. 56-62.

Valentyn CHIMSHIR

Doctor of technical Sciences, Professor, Director of the Danube Institute of the national University «Odessa Maritime Academy».

Author of 137 scientific works.

He has been studying at Izmail State University of Humanities from 1994 till 1998 years.

Research interests: complex systems management processes; project and program management; modern concepts for improving the energy efficiency of ship systems and complexes.

E-mail: chimshir@ukr.net

TIME PROCESSES COMBINATION IN THE COMPLEX SYSTEMS

The presented work researches a possibility to compose temporal processes to reduce complicated system operation expenditures. It is established, that temporal processes are classified into three categories in view of their influence on a system's functional state. They are single (1), repeating (2) and cyclic (3). It is also established, that presence of large number of temporal processes within a system requires an individual approach to their control.

Key words: *Temporal Processes, Complicated System, Lifecycle, Costs, Optimization, Recovery, Forecast, Time Span.*

The emergence of new technologies in the field of information processing has opened up new opportunities for inventing new methods for optimizing processes in the life cycle of

complex systems. One of these problems is the problem of optimal integration of temporary processes in complex systems**.**

A complex system in the course of its life cycle combines many temporary processes and can be in two opposite states relative to them: regular and non-standard. Under the normal state, we understand the entire set of states in which the system performs its functions for its main purpose. Accordingly, the freelance state of the system is characterized by a state in which the system cannot perform some or all of its functions related to its main purpose.

This study will examine the temporary processes that are aimed at returning the system from a non-standard state to a regular one.

As a rule, when studying complex systems, there is a problem of uncertainty of a number of its states. Uncertainty characterizes the state of the system in relation to the ideal conditions of its operation. E. A. Kuzmin's research *(Adowan: 1984, 251-263)* systematized aspects of uncertainty in relation to complex systems, among which the information component plays a key role.

Thus, the uncertainty measure plays the key role in obtaining the results of modeling the system states.

If the optimization is based on reducing the cost of restoring the functional state of complex systems by combining temporary processes, the primary tasks can be defined as follows:

1. Classification of temporary processes based on their impact on the functional state of the system and the cost of its recovery.
2. Defining parameters that affect the integration of temporary processes.
3. Development of the method for combining temporary processes.
4. Development of an algorithm for combining temporary processes.

Analyzing the conclusions of many scientists who have devoted their works to the study of time processes, it can be noted that time processes are represented by a sequence of planned events at a certain level of system management, which are characterized by a number of parameters: structure, duration and speed. Poorly managed temporary processes can generate new processes that require separate management.

Temporary processes, respectively, before they appear in the life cycle of the system, can be divided into three classes: single, repetitive and cyclic.

Single processes in the system of lifecycle are usually executed once. They are well structured, can have different duration and, as the practice shows, have an average speed of execution.

Recurring temporary processes are processes that do not have a rigid periodicity, depend on the processes of the external environment in which the system operates, and have a high speed of execution.

Cyclical time processes are characterized by cyclical execution, rather good structure, and the speed of their execution varies from low to medium.

The presence of a large number of temporary processes in the system requires a separate approach to their management *(Cao: 1997, 1017-1028)*. One of these approaches is the approach of combining processes. The nature of the Association is very complex and requires consideration of many parameters. One of the main parameters is the choice of the merge time.

When choosing the time of merging processes, the following considerations are mainly guided *(Chimshir: 2014)*:

– first, these are planned processes, that is, after some time has elapsed, the process

must be started regardless of the system state at the previous time;

– secondly, if the system condition deteriorates, which affects the quality of its operation or the failure of some of its functions, but the system is in a working state, that is, it can actually function;

– third, when the system is in an inoperable state, that is, the loss of the system's function does not allow it to continue functioning.

The formalization of this task, in general, involves a description of all the important factors that affect the achievement of the desired state of the system and their interaction, taking into account the limiting conditions and criteria for evaluating the quality of combining processes *(Chimshir: 2016, 56-62)*.

Thus, the goal of the optimization problem, both practical and theoretical, is to choose the «best» (acceptable or optimal) configuration with alternatives to achieve a certain task *(Chymshyr: 2018, 182-195)*.

None of these reasons reflects the economic side, in terms of optimal timing of the time process. It is known that by placing temporary processes in a certain sequence in time, it is possible to achieve a very significant saving of funds intended for the operation of the system *(Donald: 1981, 71-74)*.

In turn, the system's functioning process is associated with a lot of conflicting tasks, each of which, if solved separately, will not always have the optimal solution as a whole. For example, the methods developed by Donald V. Steward *(Ignateva: 2000, 157)* are quite effective at the stage of planning processes and are not actually acceptable at other stages of the life cycle of complex systems.

The other side of this process is shown in work *(Kokin: 2011, 98)*. For effective integration of time processes, it is important to be able to predict the time of their occurrence. And in this work an efficient method for the prediction of temporal processes is shown.

Another aspect that can occur in the life cycle of complex systems is the social effect. This effect can indirectly affect the time of occurrence of a particular time process. In work *(Kuzmin: 2012, 184)*, this method allows us to quantify the social effect and predict its impact on the time processes of the system.

Also of scientific interest is the method of choosing a technical system developed in work *(Lipaev: 2003, 520)*, since the time prediction of the location of time processes as a complex system depends on it.

In some cases, you need to pay attention to the behavior of a complex system. If the behavior of the system is nonlinear and includes random processes, then we can use, in our opinion, the unique methodology described in work *(Shakhov: 2006, 238)*.

The scientific article *(Urbanovich: 2007, 90)* is devoted to the analysis and design of a special class of complex control systems. As for our case, the article will be useful for fuzzy modeling and identification of complex systems.

The research has shown that the optimal placement of technical object repairs in time remains open until today.

In work *(Rastrigin: 1981, 375)*, a solution of this type of problem using the «magnet method» is proposed. Due to the high degree of theory of this method, it is proposed to improve its practical side.

Let us consider the following problem. Let some complex system consisting of elements, each of which is represented by a group of parameters is given. One of the important characteristics of the system is the need for it to perform a number of functions, which in its turn leads to a change in the functional state of the system as a whole, based on

the results of changing the state of each element separately. In fact, each function of the system is assigned to a system element, so restoring the system element restores the functional state of the system. A functional state is viewed a measure of the system's ability to perform its functions.

For the normal functioning of the system, it is necessary that the functional state of each element was greater than the maximum allowed. When reaching the limit state of the system element, depending on the type of element, appropriate actions must be taken on it, which, on the one hand, entail certain costs, on the other hand, are decisive in the possibility of further operation of the system. Since it is assumed that the functioning of the system is determined by some measure of effect (the relative value of the system's revenue per unit of time), and a change in the limit state of the system element in the larger direction (let's call this process recovery) requires the system to be decommissioned, which entails a change in the indicator in the smaller direction.

Thus, we can assume that there is a variant of placing temporary processes for restoring system functions, in which the cost of recovery will be minimal, and the efficiency of the system operation will be maximum.

Based on this, we shall formulate tasks and perform optimization based on the method of combining temporary processes.

Let there be a system that is represented by the following parameters:

T - analyzed period of operation;

n - is the number of elements of the system;

t_i - the operating time of the i element to the limit state (i = 1,2, ... n);

nr - total number of system stops for the period T;

q_i - cost of the i element (i = 1,2, ... n);

qr_i - the cost of restoring the i element (i = 1,2, ... n);

$\bar{z}$ - the relative costs of stopping the system, as a result of reaching one of the elements of the limit state or for other reasons;

$\bar{d}$ - relative operating income of the system per unit of time.

For greater clarity and accessibility of the main provisions, we shall introduce some restrictions, which, in its turn, will not make significant changes in the subsequent generalizations. Let the number of system elements, the time of operation of an individual element to the limit state, the total number of system stops, the cost of an individual element and the cost of restoring them be constant values throughout the entire period of operation, then a system with three elements will look like this (Fig.1) .

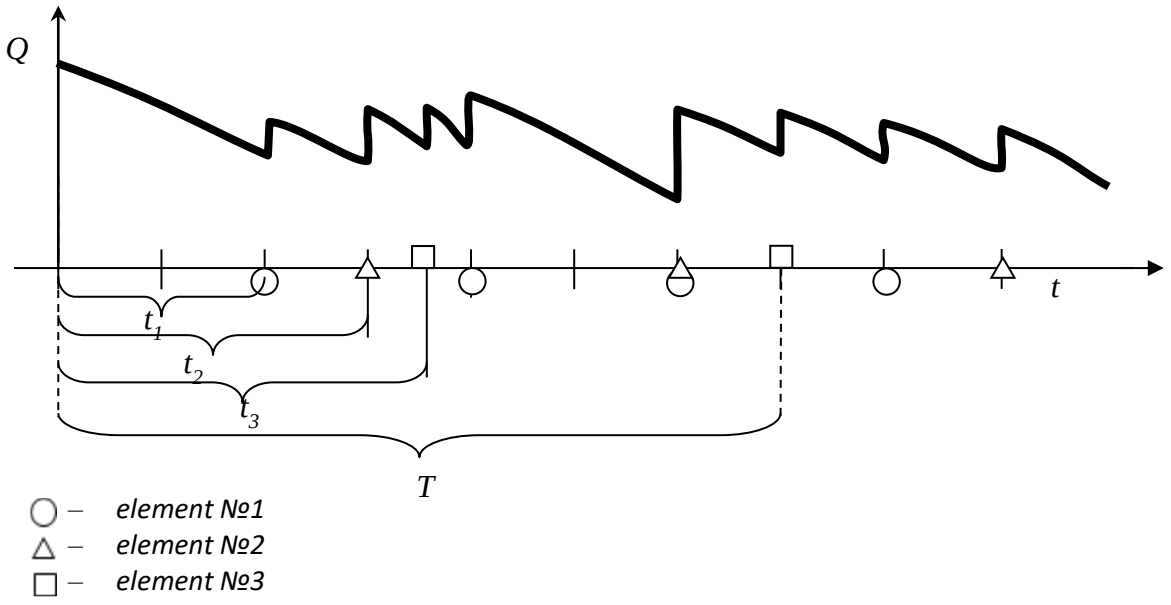


Fig. 1. *The typical life cycle of a system with three elements*

The state of the system in Fig.1 is reflected in the coordinate system: the cost of the system – the time of operation. The curve shows the change in the cost of the system depending on the time processes aimed at restoring the system functions. Each update is accompanied by expenses on the one hand, and an increase in the system cost on the other hand.

Let the operation of the system be determined by the following rules and restrictions:

1) the operation of the main elements begins at point 0;

2) the distance between elements of the same group *i* can be less than or equal to t_i, but greater than 0;

3) the time characteristic is defined by discrete behavior, which indicates that one action is performed per unit of time;

4) the duration of the temporary recovery process of one element is expressed as a unit of time, regardless of the conditions under which it is carried out.

Optimization will consist in minimizing the cost of restoring system functions and increasing the efficiency index by combining temporary processes.

The dependence that determines the need to find a solution is represented by the ratio of the relative cost of stopping the system to the relative effect of the system's operation per unit of time. Let's call it the coefficient of the need to find the optimal solution:

$$k_r = \frac{\bar{z}}{\bar{d}}. \qquad (1)$$

where $\bar{z}$ – the relative costs of the stop system;

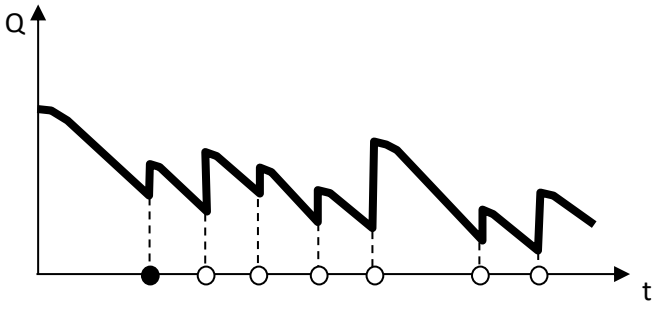
$\bar{d}$ – relative effect of the system.

It is obvious, that if the relative costs of stopping the system tend to zero and the relative effect is constant, then the time processes do not need to be combined, and the solution of the problem of finding the optimal solution does not take place. The opposite judgment also makes sense – the higher the relative costs, the more the need to use the optimization method becomes apparent.

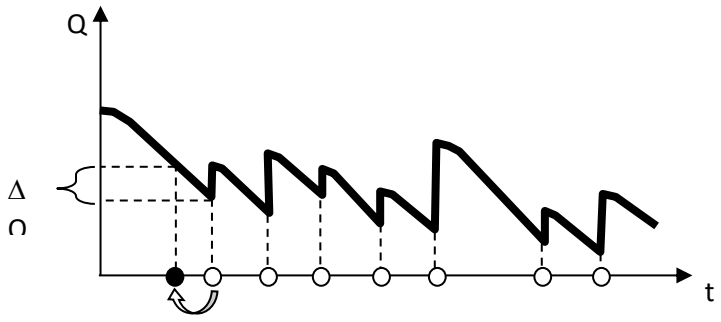
Let's consider two cases that determine the direction of the search for solutions.

1. In the first case, when temporary processes are located in close proximity to each other and their integration does not entail the need for additional funds to restore the system functions in the future. These temporary processes are combined in the direction of processes that are closer in time. The area of such merger is called the zone of unconditional merger.

Fig.2. *The merge point coincides with one of the temporary processes.*



○ - *the point of the time process;*
● - *union point*



○ - *the point of the time process;*
● - *union point.*

2. If temporary processes are located in close proximity to each other, but their integration entails the subsequent need for additional funds, then the integration of temporary processes will depend on a number of factors and conditions that need to be checked. The zone of such an area is called the conditional merger zone.

Determining the conditions when temporary processes are located in the zone of conditional merger to be merged is a key task of the method of combining temporary processes.

Let's define the main provisions of the method of combining temporary processes in complex systems.

1. If there are no additional restrictions, the merge point must match the time of one of the temporary processes.

In the case when the start time of the temporary process is not of fundamental importance and $\bar{d}$ const, the offset of the merge point relative to the temporary process always leads to an increase in the cost of the unused resource of the restored system function (Fig.2,3).

2. Shifting time processes does not entail additional costs if it does not entail the appearance of an additional time process within the predicted time interval (Fig.4).

3. When you increase the cost of stopping the system, merge points tend to be in the area of the forced system stop and noticeably increase their unifying properties.

4. The area of merger is determined by the area in which all unique time processes are located.

5. When merging temporary processes, if this has resulted in a reduction in the number of system stops, there will always be a limit to the costs at which such a combination will be reasoned (Fig.5).

Fig.3. *The merge point is offset relative to one of the temporary processes*

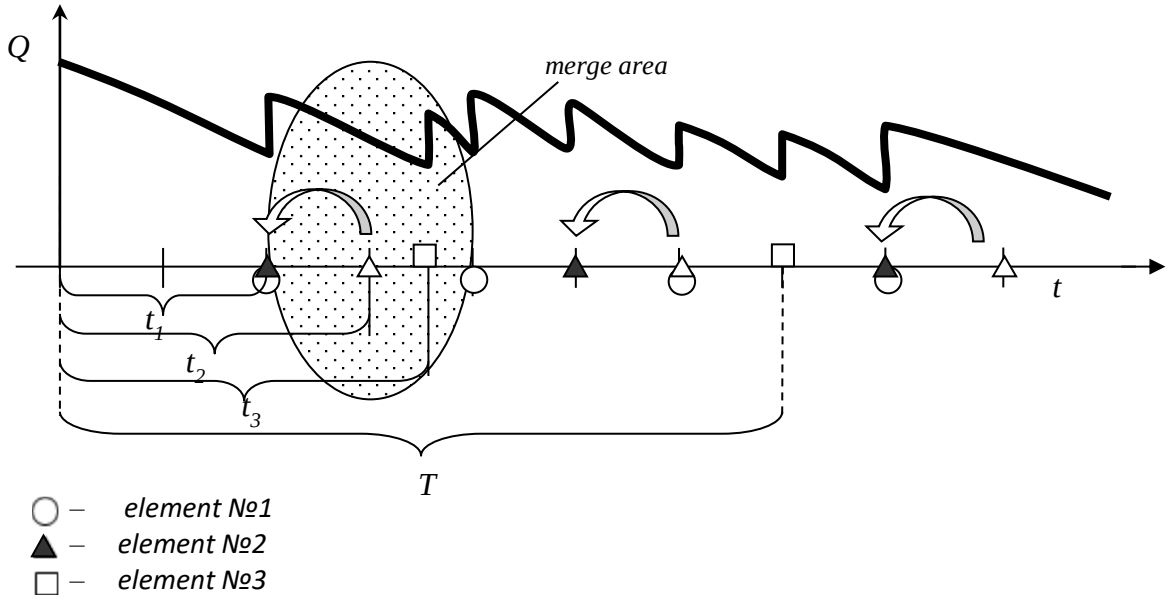


Fig. 4. *Scheme for combining temporary processes associated with the recovery of the second element*

6. Temporary processes that are located in the conditional join area can only be merged if the following conditions are met:

– if the temporary process is not fundamentally located and can be merged;

– if additional costs are required during the merge, but this does not entail an additional temporary process in the future, and the additional costs are less than the cost of stopping the system

$$\overline{z} > \sum \overline{q_t}, \qquad (2)$$

where $\sum \overline{q_t}$, – the cost of temporary processes that appeared as a result of the merger.

– if additional funds are needed to organize temporary processes when merging, and this entails an additional stop of the system, but it combines one or more temporary processes, that is, it is not a local point of merger. A local merge point is a point in the scope of which processes are located, but not one of them can be merged according to restrictions.

– if additional resources are needed during the merger and this entails the organization of additional temporary processes, the merger is performed when the following condition is met (3), Fig.6:

$$\overline{\Delta d} = \overline{d(t_j)} - \overline{d(t_i)} - \overline{d(t_k)},\ \overline{\Delta z} = \overline{z(t_i)} + \overline{z(t_k)} - \overline{z(t_j)},$$

$$\overline{\Delta d} - \overline{\Delta z} > 0, \qquad (3)$$

where $\overline{d(t_i)}$ – system revenue during the t_i period in which the temporary process will be organized;

$\overline{d(t_\kappa)}$ – system revenue during the t_k period – the appearance of a new time process;

$\overline{d(t_j)}$ – system revenue during the t_j, period in which to delete the temporary process is planed;

$\overline{z(t_i)}, \overline{z(t_k)}, \overline{z(t_j)}$ – respectively, the cost of implementing the time process in each of the periods.

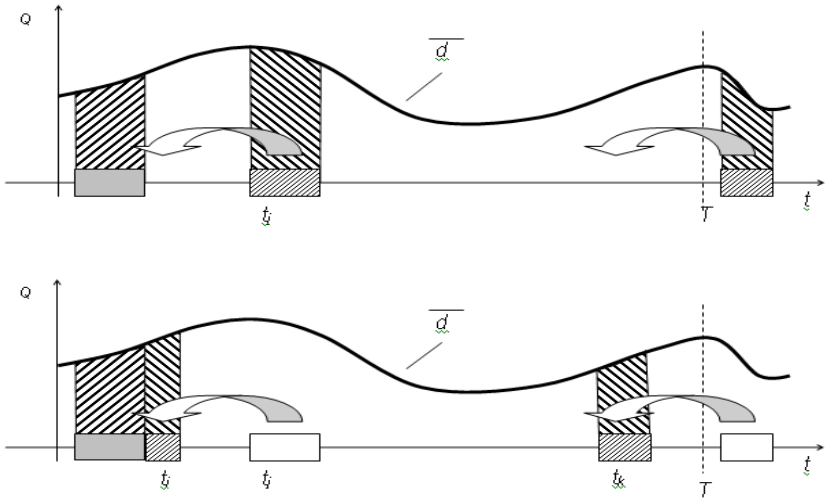


Fig. 6. *Scheme for combining temporary processes*

From the above provisions, it can be seen that the accuracy of the results obtained using this method directly depends on the accuracy of the forecast of such components as: the relative income of the system during the analyzed period; the cost of stopping the system; the cost of implementing temporary processes.

Based on the above, an algorithm for optimizing the process of combining temporary processes according to the criterion of minimum costs for implementing temporary processes can be defined:

1) determine the element composition of the system, the elements of which are responsible for specific functions of the system;

2) note the first time process from the start point of the study period in the direction of the time axis as the point of unification and define the present time as P_1 (in general P_k);

3) define an area of merger bounded by an area in which the time processes of P_κ to $P_{\kappa + t}$ do not repeat;

4) take the following temporary processes that were defined in the step.

1. If no new expenses were incurred when merging temporary processes, they were in the area of unconditional merging and are merged without additional conditions. Repeat step 4, otherwise go to step 5;

5) if the merger requires additional costs or new temporary processes, then we check this merger for its feasibility in accordance with the sixth provision of the proposed method. When a satisfactory solution to inequality (3) is obtained, the temporary processes are moved to the merge point with a transition to step 4, otherwise to step 6;

6) temporary processes that do not satisfy condition (3) become the next point of the P_{k+1} merger;

7) If there are temporary processes after the newly assigned merge point, then go to step 3, otherwise the end of the algorithm.

Let's return to the system whose life cycle is shown in Fig.1. The «Method of combining temporary processes» in this case it gives the following results:

1) element №1 with time t_1 becomes the merge point P_1. Element №2 is located in the region of unconditional merger and is attracted to the merge point P_1. Element №3 is located in the conditional join area and therefore its joins are questionable. If we assume that all elements satisfy the conditions set in the sixth position, then element №3 is also combined with point P_1. The result is the following picture (Fig.7);

2) when selecting the second point of merger, we again select item №1 with a repair time of 2-t_1. Elements №2 and №3 are located in the unconditional Union area and are combined with the point P_2;

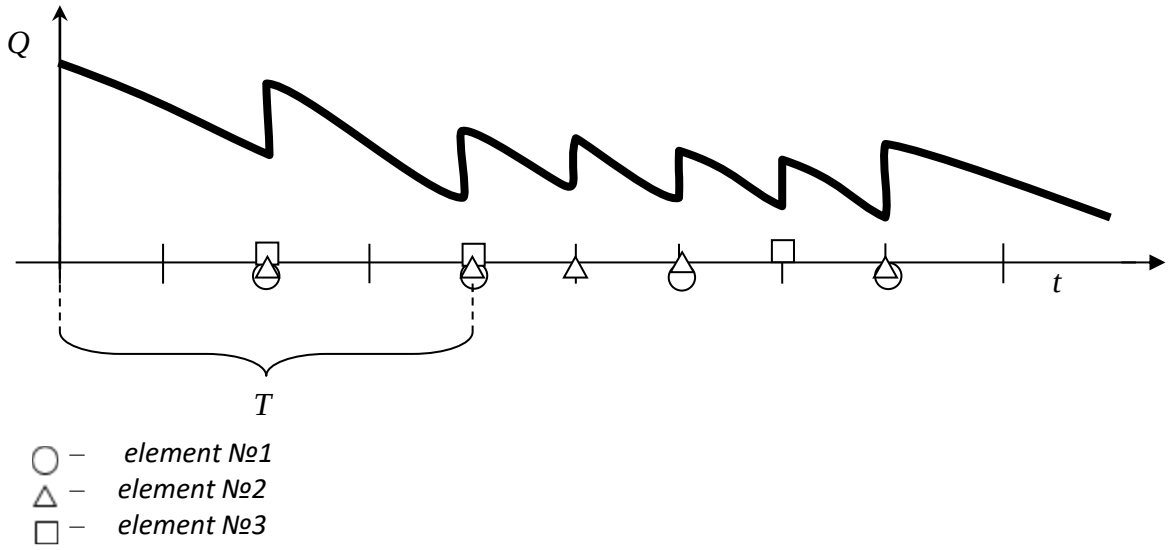


Fig. 7. *Demonstration of a method for combining temporary processes*

3) when you select the third point of merger by a certain chance, the selection falls again on element №1 with a repair time of 3-t_1. There is no merging of elements until this point of unification, because there is no repair work in the interval from P_3 to the end of the study period (Fig.7).

Studies have shown that the task of combining time processes is relevant and has almost no generalized solution. This gives rise to a search in the direction of optimization generalizations of a number of particular tasks.

Thus, the following results were obtained in this study:

1. The classification of temporary processes on the basis of their influence on the functional state of the system is carried out. It is proposed to divide them into three classes: single, repeated and cyclic. They are given a description and the nature of the manifestation is described.

2. Parameters that affect the integration of temporary processes are defined, including: the system's revenue and expenses over time; the cost of implementing a temporary process and the cost of restoring system functions.

3. A method of combining time processes has been developed, which includes six main provisions. On the basis of these provisions, a decision is made on the possibility and expediency of combining temporary processes.

4. An algorithm for combining temporary processes, which allows to determine step by step the need and feasibility of combining temporary processes is developed.

The obtained results allow using information systems to implement the procedure for combining temporary processes, which significantly reduces the probability of errors in decision-making in the management of complex systems.

Further research may be aimed at modifying the method in order to cover more optimization problems that currently need to be solved.

***

Adowan G. A global method for solution of complex systems. *Mathematical modeling*. Vol.5. 1984. Pp.251-263.

Cao S.G., Rees N.W., Feng G. Analysis and design for a class of complex control systems. *Part I: Fuzzy modelling and identification.* Volume 33. Issue 6. June 1997. Pages 1017-1028

Chimshir V., Chimshir A. Method of choice of a technical system for project implementation basing upon situational efficiency criterion. *Electronic Scientific Journal*. 2014. Retrieved from http://www.wspolczesnagospodarka.pl/?p=764

Chimshir V.I. Razrabotka metoda kolichestvennoy otsenki sotsialnogo effekta pri realizatsii sotsiotehnicheskih proektov [Tekst]. *Jurn. Vostochno-Evropeyskiy jurnal peredovyih tehnologiy*. - Harkov: UKJT, 2016. № 2/3 (80). S. 56-62.

Chymshyr V. System's technical condition assessment method and determination of its operation timeframe in uncertainty conditions. *Scientific development and achievements.* Volume 5. London: Science Publishing, 2018. P. 182-195.

Donald V. Steward. Transactions on Engineering Management. Volume: EM-28, Issue: 3. 1981. Pp.71-74.

Ignateva A.V. Issledovanie sistem upravleniya [Tekst]. M.: YUNITI-DANA, 2000. 157c.

Kokin A.G. Imitatsionnoe modelirovanie sistem: Uchebnoe posobie. Kurgan: Izd-vo Kurganskogo gos. un-ta, 2011. 98 s.

Kuzmin E.A. Neopredelennost i opredelennost v upravlenii organizatsionno-ekonomicheskimi sistemami [Tekst]: [Monografiya]. Ekaterinburg : Institut ekonomiki UrO RAN, 2012. 184 s.

Lipaev V.V. Metodyi obespecheniya kachestva krupnomasshtabnyih programmnyih sredstv. M., 2003. 520 s.

Rastrigin L.A. Adaptatsiya slojnyih sistem. Riga: Zinatne, 1981. 375 s.

Shakhov A. V. Proektno-orientirovannoe upravlenie jiznennyim tsiklom remontoprigodnyih tehnicheskih sistem: dis. dokotra tehnicheskih nauk: 05.13.22. Odesa: Feniks, 2006. 238 s.

Urbanovich, P. P. Informatsionnaya bezopasnost i nadejnost sistem [Tekst]. Minsk : BGTU, 2007. 90 s.