METROLOGY, STANDARDIZATION AND CERTIFICATION

МЕТРОЛОГІЯ, СТАНДАРТИЗАЦІЯ І СЕРТИФІКАЦІЯ

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MEASUREMENT PROBLEMS IN INTEGRATED TECHNOLOGIES OF FUNCTIONAL MANAGEMENT OF COMPLEX SYSTEMS

Г.О. Оборський, О.Л. Становський, І.В. Прокопович, Е.М. Забарна, П.С. Швець. **Проблеми вимірювання в інтегрованих технологіях функціонального управління складними системами.** Управління – це цілеспрямований вплив на систему з метою стабілізації або зміни відповідно до поставлених цілей. З цього випливає той факт, що будь-яке управління має постійно супроводжуватися вимірюванням: як при розрахунку та здійсненні впливу, так і при реєстрації та оцінці змін, що відбуваються. Таким чином, всі параметри системи, як ті, що керовано змінюються (керовані), так і ті, що змінюють (керують), повинні відповідати деяким усталеним правилам і законам теорії вимірювання, перш за все, методам вимірювання фізичних величин, методам обліку похибок вимірювань. і існуючим вимірювальним приладам. У теорії автоматичного керування, яка базується на складних математичних моделях і методах, найчастіше мова йде про управління лише за однією змінною, поява навіть другої викликає такі логічні та обчислювальні труднощі, що вимагають підходів на рівні творчого. мислення і винаходів. У той же час існують складні техніко-організаційні системи, які вимагають управління шляхом зміни не тільки великої кількості параметрів, а й, іноді, і їх комбінацій, або деяких функціональних можливостей. Найскладніший варіант виникає тоді, коли хоча б один керуючий параметр є нечітким . Тоді поєднання чітких та нечітких змінних в єдиний функціонал стає ще більшою проблемою. У інформатиці функціонал є синонімом функції вищого порядку, тобто функції, аргументами якої є кілька інших функцій, або функції, яка в результаті повертає іншу функцію. Функціональний контроль, окрім усіх математичних та апаратних проблем керування в цілому, створює додаткові проблеми, пов'язані з пошуком найбільш адекватних функціональних можливостей та забезпеченням точності та надійності їх вимірювання. Для цього пропонуються нові методи пошуку впливу окремих параметрів керування та функціональних можливостей на об'єкт керування. Зокрема, до таких методів належать методи техніко-економічного титрування, оперативного перетворення результатів вимірювань тощо.
Ключові слова: функціональний контроль, рівні вимірювання, інтегровані технології, організаційно-технічні комплексні системи

G. Oborskyi, O. Stanovskyi, I. Prokopovych, E. Zabarna, P. Shvets. **Measurement problems in integrated technologies of functional management of complex systems.** Management is a purposeful influence on the system in order to stabilize or change in accordance with the objectives. From this follows the fact that any management must be constantly accompanied by measurement: both in the calculation and implementation of the impact, and in the registration and evaluation of changes that occur. Thus, all parameters of the system, both those that change (managed) and those that change (manage), must comply with some established rules and laws of measurement theory, first of all, methods of measuring physical quantities, methods of accounting for measurement errors and existing measuring instruments. In the theory of automatic control, which is based on complex mathematical models and methods, most often, we are talking about control with only one variable, the emergence of even the second causes such logical and computational difficulties that require approaches at the level of creative thinking and invention. At the same time, there are complex technical and organizational systems that require management by changing not only a large number of parameters, but also, sometimes, and their combinations, or some functionalities. In computer science, a functional is synonymous with a higher-order function, that is, a function whose arguments are several other functions or one that returns another function as a result. Functional control in addition to all the mathematical and hardware control problems in general, creates additional problems related to finding the most adequate functionalities and ensuring the accuracy and reliability of their measurement. To do this, new methods are proposed to find the effect of individual control parameters and functionalities on the control object. In particular, such methods include methods of technical and economic titration, operational conversion of measurement results, etc.
Keywords: functional control, measurement levels, integrated technologies, organizational and technical complex systems

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1. Introduction

Under complex systems understand the set of elements united by the unity of goals and forming a certain integrity; it is a purposeful set of interconnected elements of any nature; it is an object that is determined by a set of elements, transformations, rules of formation of sequences of elements; it is an object consisting of elements whose properties are not reduced to the properties of the object itself [1]. It is clear that this definition of complex systems (as well as any other) is not exhaustive and unambiguous [2].

Management is a purposeful influence on the complex system in order to stabilize or change in accordance with the objectives [3]. From this follows the fact that any management constantly must be accompanied by measurement: both in the calculation and implementation of the impact, and in the registration and evaluation of changes that occur. Thus, all parameters of the system, both those that change and those that manage, must comply with some established rules and laws of measurement theory, first of all, methods of measuring physical quantities, methods of accounting for measurement errors and existing measuring instruments [4].

The measurement process is complicated in the case of automatic control. There are many types of control, depending on the degree of automation: manual, automated, automatic [5 – 7].

Thus, the main problems of measurement in integrated technologies of functional management of complex systems are as follows:

– the relationship between the control parameters and the controlled parameters at each current stage of existence of the control object is not always obvious and requires the development of appropriate reliable and accurate models;

– the theory of automatic control, which is based on complex mathematical models and methods, often involves the control of only one variable, even the emergence of the second causes such logical and computational difficulties that require more than one approach to creative thinking and invention. It makes the result of the calculation ambiguous and requires additional mathematical and hardware measures;

– there are complex technical and organizational systems that require management by changing not only a large number of parameters, but also, sometimes, their combinations, or some functionality;

– the most difficult option arises when at least one control parameter is fuzzy [8, 9], then the combination of clear and fuzzy variables into a single functional becomes an even bigger problem.

Finally, the most important factor in managing complex systems is time. Lack of time may not allow accurately and reliably estimating the parameters of the system and building models of relationships between them [10].

2. Literature review and problem formulation

In accordance with the above, the review of publications was performed in the following areas.

Methods and tools for managing complex systems. According to the nature of the change of the control action of the ACS, the following types are distinguished:

– automatic stabilization of technological parameters, in which the control action is constant; these systems are designed to maintain the stability of a physical parameter (temperature, pressure, speed, etc.);

– software control, the control action of which changes according to some pre-known law (for example, a certain program can change the speed of rotation of the electric drive, change the temperature of the product during heat treatment, etc.);

– investigators, control action in which changes according to an arbitrary, previously unknown law (used to control the parameters of control objects when changing external conditions) [11 – 15].

Stabilization in automatic control and regulation is the maintenance of a set constant in time value of the adjustable value $x(t)$ regardless of external (relative to the object of stabilization) and internal perturbing (destabilizing) effects f, seeking to deviate from the set value $x_0(t) = x_0 = \text{const}$. It is possible to stabilize not only any measurable variable, such as the effective value of the electrical voltage, but also any given function (and even the function of several primary measurands).

All problems are exacerbated if the control parameters are complex functions of the primary measured variables or the so-called functionals [16 – 18], are considered as some function of the variables that are included in this functional:

$$F = F(f_1, f_2, \ldots, f_n). \quad (1)$$

The combination of primary variables in a separate functional allows taking into account even the operand behavior of members of the management team of the object of measurement [19] dynamic characteristics of the automatic process control system in nonlinear higher order objects [20].

3. The purpose and objectives of research

The purpose of research is improving the efficiency of functional management of complex systems by creating new methods of planning, development and implementation of measurements in integrated technologies management.

To achieve this purpose, the following tasks were solved.

1. To perform classification of complex management methods and parameters.
2. To present the theoretical basis for the creation of integrated technologies for management functionality.
3. An example of non-traditional measurement in integrated technologies of functional control of complex systems is given.
4. The COMAN system has been created; the principles of development and practical use of this system in the management of organizational reconstruction projects of the educational institution are described.

4. Materials and methods of research

4.1. Classification of complex management methods and parameters

Let's look at the process of managing a complex object, as moving the model of this object, which is performed at some time t (Fig. 1). During the movement, the model can change systematically or unexpectedly under the influence of internal and external influences and direct control. As can be seen from Fig. 1, the overall composition of the considered parameters of the management object during the period of the latter may change significantly. Some parameters for various reasons lose the status of "important for the object as a whole" and removed from the model of management process (parameter 1), some parameters are forced to merge (parameters 2 and 3), some reappear (parameter 4), etc.

Such structural changes in the facility management system as a whole force managers to constantly take care of the current composition of individual management parameters, as well as their importance, up to finding new "combined" parameters and implementing the latter in an automated management system while removing obsolete ones.

Consider classical control, when the calculation of the control action is performed based on the difference between the actual current value of a parameter (measured) and the value of the same parameter, which is currently planned.

We see that with this approach, measurement plays the most important role in the management process. Unfortunately, according to the literature, the class boundaries for the parameters and methods of measuring the state of complex objects do not always coincide with the needs of managing such objects. Therefore we will allocate separate classes of the last, proceeding from such purpose of measurement for management (MFM). Classification of complex methods and parameters MFC is presented in the form of a table (Table 1).

There are four groups of measurement methods, which differ in the number of control parameters (one or more), as well as the clarity of representation of these parameters.

The table shows:

u – clear value of the object parameter;

ξ – fuzzy value of the object parameter;

M – measurement result;

f – the transient function.

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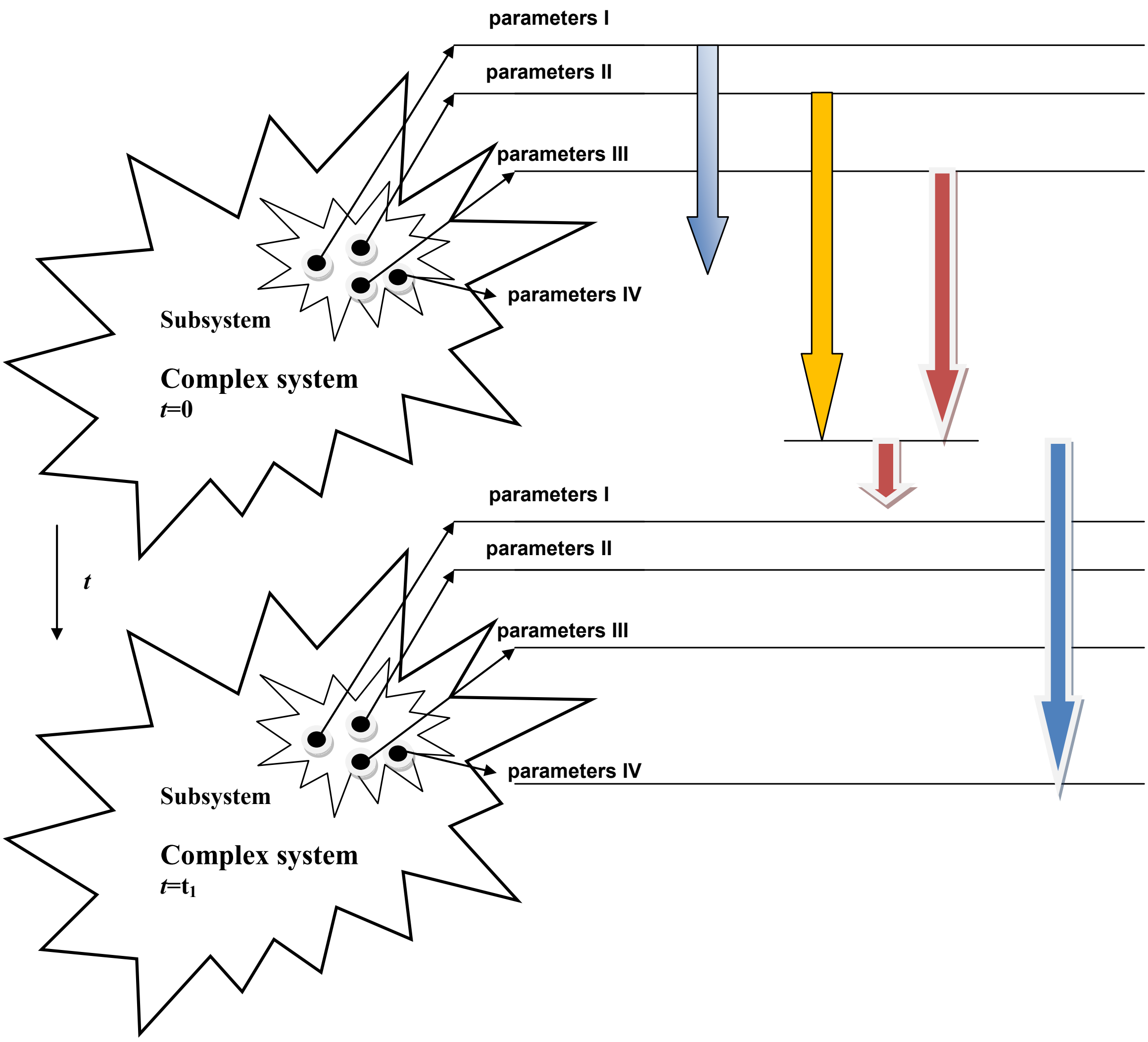

Fig. 1. Scheme of development over time of the complex system parameters that is under control

The figure introduces the concept of “time *t*”, because all such processes take a long time (months, years) and it is in time that the main structural are significantly changes in the management system.

4.2. The theoretical bases of integrated technologies creation on management functionalities

Measurement is the determination of the size of a quantity experimentally. In many applications of human activity there is a need to experimentally evaluate (and therefore – in one way or another to measure) some quantities that can be attributed to the physical in the conventional sense or pseudo-physical.

As you know, physical quantities are characteristics of the properties of a physical object (physical system, phenomenon or process) inherent in the qualitative relationship of many physical objects, and in quantitative terms individual for each object [21].

The most important problem with this approach is the method of combining individual parameters, which are no longer profitable to use as separate independent, and is the search for some functionality that reflects the basic properties of all primary components.

The titration method was used for this association, which is applicable not only in chemistry, where he was born, but also in many control facilities.

Table 1

Classification of complex management methods and parameters for control

1	2	3	4	5
Group of methods and parameters	Number and characteristics of control variables	Measurement method	Transient function	Application example
I	One clear control variable	Comparison with a standard	$M = u$	The diameter of the part
II	Two or more clear control variables	Comparison with a standard	$M(u_1, u_2, ..., u_n) = f(u_1, u_2, ..., u_n)$	Length and diameter of the part
	A large but finite number of clear control variables	Comparison with a standard	$M(u_1, u_2, ..., u_n) = f(u_1, u_2, ..., u_n)$	Geometric characteristics of a complex shape
III	A large but finite number of fuzzy control variables	General condition and efficiency of the system as a whole	$M(\xi_1, \xi_2, ..., \xi_n) = f(\xi_1, \xi_2, ..., \xi_n)$	Tiny and organizational parameters of the folding system
IV	Unknown number of fuzzy control variables	General condition and efficiency of the system as a whole	$M(\xi_1, \xi_2, ...) = f(\xi_1, \xi_2, ...)$	Project, program and portfolio management
I – IV	Unknown number of fuzzy and clear control variables	–	$M(u_1, u_2, ..., u_n) = f(u_1, u_2, ..., u_n)$	–

"Classical" measurement of physical quantities is a set of operations on the use of special technical means in order to obtain the value of the measured quantity in a form convenient for further use. To do this, a unit of physical quantity is stored in the technical means and the process of comparing it with this unit takes place. In the process of measurement is the perception and reflection of a physical quantity, as well as assigning it a certain numerical value. To implement the process of measuring physical quantities, a number of conditions must be met.

1. The measuring physical quantity must be unambiguously determined. Ambiguous quantities such as attitudes towards something, human intelligence, which do not have a common definition, cannot be measured.

2. The physical quantity to be measured shall have a unit of measurement established by common agreement.

3. The technical means must preserve and easily reproduce a unit of physical quantity. According to the general methods of obtaining measurement results, there are direct, indirect, compatible, and cumulative [21].

The last three methods allow you to "do not touch" the object directly when measuring, and get the result by processing all intermediate results. It is in such ways that it is possible to quantify such parameters that are not subject to classical measurement at all. This approach allows us to move from indirect measurement of physical quantities to indirect evaluation of other essentially other quantities. The approach allows including in the list of input parameters that are included in the objects under consideration – devices, processes, substances, etc., heterogeneous characteristics of the latter – actually physical, economic, organizational, environmental, etc. Such involvement requires new approaches that allow indirect measurement to be performed at the subconscious level and at high speed.

4.3. An example of non-traditional measurement in integrated technologies of complex systems functional control

Application of similar to titration measuring technologies in mechanics. An example of such a measurement is the use of techniques inherent in titration processes known from analytical and pharmaceutical chemistry [22].

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As is known, titrometric analysis is a set of methods of quantitative analysis, based on measuring the volume of a reagent solution of known concentration, spent on the reaction with a solution of the substance whose concentration is determined (analyte). The essence of the method is to consistently add to the mixture small doses of a reagent of known concentration (titrant) with known properties and fix the amount of added reagent, which leads to a quantitative change in the mixture after adding another small dose. Knowing the characteristics of the reagent (in chemistry – it is the composition, concentrations, temperature, etc.) can under certain conditions accurately calculate (and therefore measure) the characteristics of the initial mixture, which is the main task of titration. The concentration of the analyte can be calculated by the formula:

$$C_a = C_t V_t M / V_a , \tag{2}$$

where C_a is the concentration of the analyte; C_t – concentration of titrant; V_t is the amount of titrant; M is the molar ratio between analyte and reagent; V_a is the amount of analyte.

Application of similar to titration measuring technologies in mechanic. Let's transfer this approach to the problem of measuring the mechanical characteristics of a system. For example, by fixing one end of a rod rigidly, small doses of load can be added to the other end of the latter according to some known pattern until a quantitative change in its state occurs in the rod (for example, it breaks). By recording the fact of failure and the final load that led to it, we obtain the necessary data to calculate the strength characteristics of the rod material.

Another example is the process of complex technical object managing, such as an aircraft, or an organizational and technical object, such as a project or program.

Application of similar to titration measuring technologies in construction economics and project management. Further transfer this approach to the problem of measuring the economics characteristics of a system. Economic characteristics and parameters of any systems and their subsystems of arbitrary functional purpose are convenient in that they are usually measured using one unit of measurement – the hryvnia (for example). Therefore, these units are relatively easy to compare and combine into a single functional, as mentioned above. The critical change of the system (project) iz, for example, attributing it to the threshold when the concentration is reached.

Application of similar to titration measuring technologies in medicine. The peculiarity of this approach in medicine is that one of the extreme states of a complex system (human) – is a sharp deterioration in health or even death of the latter. Therefore, the assessment of such conditions by experimental actions is unlikely. Exits can include actions such as passive observations of the system, experiments on volunteers, construction of statistical models, comparisons with control groups in natural development, and so on.

As a result, examples of titro analogies in different areas of human activity are presented in Table 2.

Table 2

Examples of titro analogies in different areas of human activity

Area	Discrete "reagent"	Qualitative manifestation of a quantitative variable saturation	Object of measurement
Chemistry	Solution (mixture), mg/l (mg/kg)	Color change	Solution (mixture), mg/l (mg/kg)
Mechanics	Material resistance, Pa	Continuity, destruction	Complex technical system
Economy	Load, funds	Stop the process	Enterprise
Computer Science	Kb	Information collapse	Complex object in general
Medicine	Funds,	Death	The healing process

4.4. The system "COMAN": development and practical using in the project management of the educational institution organizational reconstruction

To test the proposed approaches in practice, a complex object management ("COMAN") system with many fuzzy parameters was developed.

Tests of the COMAN system were carried out during the project of reorganization of the educational process by joining the Odessa Polytechnic State University structural unit of the Odessa Regional Institute of Public Administration of the National Academy of Public Administration under the President of Ukraine.

As a result, a new educational institution was created –Odessa Polytechnic National University.

In particular, the SOMAN system was used to unite household structures, namely the campuses of the mentioned educational institutions.

It was a question of uniting the campuses of both institutions of higher education (hereinafter – ZVO). The purpose of this association: all students had to get appropriate places in the dormitory with the highest possible level of comfort (living space, availability of common and individual living spaces, elevator, hot water, cost of living). The assessment of comfort was based on the average comfort of living in free dormitories before their association. In addition, the living conditions in the dormitory should not be worse than the conditions that existed in the usual living rooms of these dormitories before their association.

Initial data: the number of places in the dormitories of the Odessa Polytechnic State University.

Prior to joining the student dormitory of the Odessa Regional Institute of Public Administration of the National Academy of Public Administration under the President of Ukraine, the following dormitories were part of the campus of the Odessa Polytechnic State University:

– ***dormitory № 1*** (9-storey building was put into operation in 1987, which according to sanitary norms is designed for 608 beds for compact accommodation of higher education, block type (1 block = 2 living rooms, designed to accommodate 5 people), equipped according to the project with 3 elevators with a capacity of 320 kg, with bathrooms (toilet, washbasin) and places for cooking (1 piece per unit) in residential units equipped with hot, cold water supply, sewerage and drainage.

– ***dormitory № 3*** (5-storey building was commissioned in 1963, which according to sanitary norms is designed for 436 beds for compact accommodation of higher education (3 people per room), corridor type, with general sanitary facilities, toilet, washbasin) and cooking facilities for 2 on each floor, equipped with hot, cold water supply, sewerage and drainage systems. Also on the 1st floor of the dormitory building there are public showers.

– ***dormitory № 4*** the 6-storey building was put into operation in 1968, which according to sanitary norms is designed for 1,090 beds for compact accommodation of higher education, block type (1 block = 2 living rooms for 5 people), with bathrooms, washbasin , shower) in residential blocks and places for cooking (2 pcs. on each floor), equipped with hot, cold water supply, sewerage and drainage systems.

– ***dormitory № 5*** (9-storey building was put into operation in 1973, which according to sanitary norms is designed for 604 beds for compact accommodation of higher education (2 people per room), corridor type, with bathrooms, toilet, washbasin, shower) in living rooms and places for cooking (3 pcs. on each floor), equipped with hot, cold water supply, sewerage and drainage systems.

– ***dormitory № 6*** (9-storey building was put into operation in 1975, which according to sanitary norms is designed for 642 beds for compact accommodation of higher education (2 people per room), corridor type, with bathrooms, toilet, washbasin, shower) in living rooms and places for cooking (3 pcs. on each floor), equipped with hot, cold water supply, sewerage and drainage systems.

– ***dormitory № 7*** (13-storey building was put into operation in 1982, which according to sanitary norms is designed for 915 beds for compact accommodation of higher education, block type (1 block = 2 living rooms for 5 people), with sanitary units (toilet, washbasin, shower) in residential blocks and places for cooking (2 pcs. on each floor), equipped with hot, cold water supply, sewerage and drainage systems.

The cost of one bed in all student dormitories of the Odessa Polytechnic State University per month for one graduate is as of 01.12.2021 – 520 UAH/month.

Initial data on the number of places in the dormitory of the Odessa Regional Institute of Public Administration of the National Academy of Public Administration under the President of Ukraine.

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The campus of the Odessa Regional Institute of Public Administration of the National Academy of Public Administration under the President of Ukraine included only one dormitory with such characteristics:

– ***dormitory Genoese, 22-a*** (9-storey building was commissioned in 1978, which according to sanitary norms is designed for 500 beds for compact accommodation of higher education, block type, with bathrooms (toilet, washbasin, shower) in residential units and places for cooking, equipped with hot, cold water supply, gas supply, sewerage and drainage systems.

Associations were held without interruption in the educational process. The purpose of managing the merging process is to minimize the time of the latter. The dormitories were merged during the summer holidays, and the next autumn settlement – taking into account the structure of the new university and the maximum convenience for students to acquire new knowledge and skills with minimal logistics, especially in quarantine restrictions.

5. Conclusions

1. The classification of complex methods and parameters of control is carried out in terms of current plans for the development of the system, first of all, the values of individual parameters of the system components. A classification of complex measurement methods according to groups or methods of parameters, the number and properties of controlled variables, according to measurement methods according to the type of transition functions is proposed. Examples are given.

2. Theoretical bases of creation of integrated technologies concerning functional possibilities of management are presented, namely those concerning difficult methods of representation of parameters of the managed object.

3. An example of non-traditional measurement in integrated technologies of functional control of complex systems, namely measurement using methods and techniques inherent in titration processes known from analytical and pharmaceutical chemistry.

4. The SOMAN system was created; the principles of development and practical use of this system in the management of organizational reconstruction projects of the educational institution, in particular the reconstruction project of Odessa National Polytechnic University and Odessa Regional Institute of Public Administration under the President of Ukraine. An example is given of the educational institutions subdivision reconstruction in order to unite their dormitories without interrupting the educational process.

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