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A NEW METHODOLOGY OF COMPLEX SYSTEMS MANAGEMENT

Abstract. The development of research in the area of complex systems management is considered in the given work. Six levels of management are analyzed. They are distinguished based on criteria of management object complexity, management information and objectives. A new approach to the development of complex systems management models is represented. It combines the internal and external information not only for measurement of the current state, but also it provides the tools for management performance evaluation with the help of analysis of the influence of management results on the external environment.

Keywords: management methodology, complex system, monitoring, external environment, performance, web.

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JEL Classification: B41, I23, O20

Introduction. Performance is an essential factor of living standards improvement in industrial countries with a developed market economy. Since Ukraine has set a course for European integration, this becomes a core factor for the movement towards restructuring of the economy and enhancement of its performance and quality.

Any complex system functioning under the conditions of competitive market economy is an open system. It acts in the external environment, interacts with consumers, suppliers, competitors, as well as state and public institutions. This makes it necessary to coordinate the behavior with all stakeholders and to bear social responsibility for the results of activities. Therefore, the problem of performance improvement has become a global economical, social, political and technical problem which requires an effective solution.

Literature review and the problem statement. Modern complex systems use different performance measurement systems for management purposes. This intends the existence of definite measurement criteria. However, usually the implementation of performance measurement systems has a formal or even mistaken character which may lead to wrong decisions and irreversible effects. Such situation grounds the necessity to explore the problem of complex systems management as a collection of such tasks as goals setting, development of performance management system, resources distribution, monitoring and evaluation. This is the basis of a single theoretical and methodological approach and corresponding information technologies and software.

Nowadays we can observe a fast development of markets and intense rivalry, that's why the demand for information of non-financial character becomes more and more critical. The evolution of indicators of enterprise's development strategy has proven that a traditional finances-oriented approach has some important disadvantages. For instance, this includes the absence of non-financial indicators, a subtle connection with strategic planning, orientation on past results, short-term and fragmentary orientation on external and internal aspects of enterprise's activities.

The constant growth of the complexity of structure and processes in modern management systems leads to involvement of big volumes of data and, thus, to sophistication of models and methods of information processing. Despite the level of modern computer technologies development, the information used for management of complex systems is still characterized as incomplete, inaccurate, subjective and semi structured. This causes a low effectiveness of the formal models of data processing. On the other hand, the defined drawbacks of information do not allow to improve management performance based on the existing approaches. All these problems result in the necessity not only to improve existing models and methods of management but to search for the new data sources for management and new ways of solving the problems of performance and quality management.

So, **the purpose** of this work is the improvement of the processes of performance and quality management in complex systems by means of the new approach of management.

Research results. *The main stages of development of approaches to complex systems management.* Many authors devoted their works to the problems of management of complex systems. Among them are I. Ansoff [Ansoff, Bosnian, Storm 1982], V. N. Burkov [Burkov, Irikov 2014], D. O. Novikov [Novikov, Ashimov, Sultanov 2013], V. L. Volkovich [Volkovich, Godlevsky 1991], V. S. Mihalevich [Mihalevich, Volkovich 1982], T. Saaty [Saaty, Vargas 2006], A. D. Tsvirkun [Tsvirkun 2003], and many others. The theoretical background for solving the problems of management of complex systems development is formed by the general theory of systems, system analysis, and optimization methods. Often the problems of complex systems management are solved on the basis of ideology of management by objectives [Irikov, Trenev 1999].

According to the formulated goal of this paper, let's consider the development of scientific ideas in the domain of complex systems management as a regular process involving a complex management object and taking into the account high requirements to information quality used for management.

It is widely known that modern management theory starts from the classical control theory, namely from Watt's governor [Glad, Ljung 2000]. This

device, which provides the constant angular velocity of revolution of vehicle's axle, for the first time realized the principle of management based on negative feedback. This principle is now one of the key management principles in any complex systems. Consequently, it can be claimed that the first stage of management is the challenge to provide a stable functioning of management object. Let's classify as the approaches of the first level of management those ones which consider relatively simple object that can be explored by means of classical methods and for which management we use only the information about the change of its parameters under the conditions of the known analytical function of definition of the output parameters.

The research in the area of stability of control inputs in technical systems leads to the creation of the classical automatic control theory [Glad, Ljung 2000]. The problem of control in its classical statement supposes that the feedback must be built to provide the transition of the dynamical system from the neighborhood of one state of equilibrium to another. It is important that information, based on which the feedback and control inputs are formed, is gathered from the "outputs" of the management object which can be complex enough in modern systems of automatic control. Current research of the control with a feedback are directed on the development of approaches to management in the real time mode and definition of a big number of controlled parameters. Modern research in this area is focused on the transient processes of dynamical systems. So the second level management is represented and considers complex dynamical objects as a closed system.

Usually a statement about the complexity and open character of the modern management systems does not require any proof. Interaction of the management object with the external environment is a significant aspect for the management of the third level. The main peculiarity of the methods and approaches of this level is a stochastic statement of the classical control problem [Glad, Ljung 2000], i.e. accounting of the random influences of the external environment on the definition of the values of controlled parameters of management object. The important fact here is that on this stage of evolution of methods of complex systems management we add the information about external environment to the general information that must be considered during the feedback definition. Such problem statement caused the appearance of various methods of accounting uncertainty and randomness of the external environment and internal processes of complex system [Glad, Ljung 2000].

Management of the fourth level is definitely a cybernetic approach [Glushkov 1974]. Cybernetics as a science about the general laws of obtaining, storage, transmission and processing of information in complex management systems formulated the basic principles of the development of management systems and automation systems. An essential contribution to the development of cybernetics was done by such Ukrainian scientists as M. M. Amosov, P. I. Andon, A. V. Anisimov, V. M. Glushkov, V. F. Gubarev, V. S. Deineka, M. Z. Zgurovsky, O. G. Ivakhnenko, I. M. Kovalenko, V. M. Kuntsevich, O. V. Palagin, I. V. Sergienko. The objects of cybernetics are any controlled systems considered to be abstract and independent of their material nature. For a long time the cybernetic principles have been predominating among the advanced approaches to complex systems management.

The complexity of the management object caused the development of the cybernetic approach in different directions of applied research. Today this approach is not irrelevant. However, it can be noted that methods of

management of the fourth level are focused on the management objects and on the completely new view (comparing with the previous levels) on the problem of complex systems management. Still methods of the fourth level are predominantly based on the information about management object or external environment, but only from the point of view of the controlled object.

The growing complexity of systems and its processes, namely in economical and social systems, caused the search for the new approaches and the development of cybernetic principles for the new circumstances. Therefore, we suggest to consider adaptive methodology of management [Armitage, Berkes, Doubleday 2008] as the fifth level. It is focused on the dynamics not only of the management object, but also on the constant change of the external environment. Modern management approaches based on objectives are the typical examples of the management of the fifth level.

Starting from the late 1980s we can observe the rethinking and development of existing concept management towards multifeature orientation. New models based on the new concept of Performance Measurement became quite popular. The representatives of the new management models are Data Envelopment Analysis, Performance Measurement in Service Business, Balanced Scorecard, Tableau de Bord, Productivity Measurement and Enhancement System [Okes, Westcott 2002].

These contemporary management concepts based on performance measurement, as far as the concept of strategic management, determine the necessity to study the external environment of the controlled system. So the objective laws of the environment should be explored and the parameters should be forecast which is a precondition to management decision formulation. Summarizing these approaches we can introduce the notion of the management of the sixth level as the methodology of proactive management [Okes, Westcott 2002]. The distinct feature of these methods is a high degree of accounting of information from the external environment, i.e. the targeted collection of data about the environment of the complex system. However, this information reflects only the environment where the system is functioning. Thereby, management is based on the information which is collected inside the control circuit. A methodology of control inputs forming corresponds to the management of the fifth and the fourth levels, but takes into account the component of the external environment.

So the conducted analysis of the existing approaches to complex systems management allows one to define a set of problems that must be resolved.

Firstly, the complexity of systems and their processes require involvement of big volumes of heterogeneous, non-formalized, fuzzy and conflicting data. This demonstrates the need to make research directed on the improvement of existing systems and the development of new information technologies of data processing for management goals.

Secondly, as the analysis has shown, existing approaches are focused on the information that is collected inside the system. In this case data retrieved from external sources are used only for description of the external environment. This causes the need to explore the possibilities of using the external information for management purposes.

Thirdly, the existing management methods are based on the usage of expert information. This confirms the relevance of the research in the direction of the further development of expert methods, namely the issues of forming, processing and combination of scales used by experts for estimation.

Combining information from internal and external sources for improvement of management performance. Based on the analysis of existing approaches to performance and quality management, we can make a conclusion the tool that currently formalizes the management process is the system of key performance indicators. Such systems are the basis for performance and quality management. They are oriented on measurement and evaluation of a set of indicators which are chosen by taking into account all aspects of system's functioning. They differ in the principles of building the structure of indicators and are oriented on different stakeholders.

As the analysis has shown, the complexity of the management object from one side and the extension of goals and tasks of management from another side caused the appearance of new management concepts relying on the system of measurement and evaluation of management performance and quality. The main issue of these approaches is an unformalized and subjective character of the system of indicators that should be measured.

For management purposes, it is necessary to know the values of performance and quality indicators which can't be obtained directly from the system. This problem is presented as monitoring and evaluation [Kusek, Rist 2004, Cherednichenko, Yanholenko 2013].

Monitoring is a continuous process of data collection about research object on specified indicators [Kusek, Rist 2004]. It provides all stakeholders with indications of achievement of objectives of the given object's functioning. Monitoring is always complemented by evaluation. Evaluation is the process of obtaining estimates of results of a system's functioning and respective correspondence to the stated goals [Kusek, Rist 2004]. These two processes are considered as a single one, since they are interconnected and are a part of management cycle.

The definition of indicators for monitoring and evaluation presupposes the agreement on short-term and long-term goals and results which are interesting for management. Key indicators which are used for monitoring of the results must be agreed with the top management of an enterprise. The stage of results monitoring includes definition of data sources and methods of data collection. On the first iteration, the baseline values of indicators are determined. Then they are observed in real time. Evaluation of results based on the collected data provides management with explanation of why the stated goals were or were not achieved and in what extent. On the stage of using findings of monitoring and evaluation the analysis of results is conducted which may leads to correcting the plan for further development. Excepting this, some efforts must be realized in order to support the continuous work of monitoring and evaluation system.

There are two approaches to the construction of monitoring system: implementation-focused and results-based [Göergens, Kusek 2009]. Data collected during monitoring must provide the management system with information concerning the achievement of stated goals. These data must meet the following criteria: precision, recall, relevancy and timeliness. The main difference between two approaches is in the target orientation. In the case of implementation-focused monitoring the estimation of goals achievement is based on indicators associated with system outputs. And in the case of results-based monitoring, indicators reflect the outcomes. So, the evaluation is focused either on the obtained products (services) or on the effect of activities' outcomes. The comparison of two approaches is given in table 1.

Table 1 – Comparison of the approaches to monitoring and evaluation

Criterion	Implementation-focused monitoring and evaluation	Results-based monitoring and evaluation
Goal	To provide the information about the aspects of realization of the project (program or strategy)	To provide the information about project success
Logical model	Inputs ↔ Actions ↔ Outputs	Goals ↔ Results
Target orientation	Outputs	Outcomes
The direction of data collection	Data about inputs, actions and outputs	Data about outputs and their contribution to the achievement of the expected results
Realization	Systematic reports on prepared inputs and obtained outputs	Systematic reports on quantitative and qualitative information about results achievement

Source: authors' own development

We can conclude that the main task solved by results-based monitoring and evaluation is to determine the degree of success of project (program) realization towards the expected outcomes [Kusek, Rist 2004]. Such type of monitoring and evaluation is a powerful tool for results measurement and usage of obtained information as a feedback for decision making. The given work considers results-based monitoring and evaluation.

Measurement is the process of getting the information about quantitative characteristics of an object's features by experiment [Cherednichenko, Yanholenko, Iakovleva, Kustov 2014]. Quantitative values of indicators allow managers to take grounded decisions. The current values can be compared with the past values and with the target values which allows to explore the dynamics and to correct the trajectory of the development of complex system.

Monitoring and evaluation is usually performed with respect to all lines of activity. The internal data sources are mainly used in this process which may lead to some degree of subjectivism. We can name such data sources for monitoring as official reports: i.e. documentation of structural divisions and information obtained from employees and consumers. Information from external sources is rarely used. To these types of sources we can refer rankings and reports of public and state organizations. However, data from rankings are not quite useful from the management point of view, since most commonly the methodology of indicators calculation remains confidential.

Except mentioned traditional data sources, we can claim that results of enterprise's activities may have their reflection in the web space, which is an external environment [Cherednichenko, Yanholenko, Iakovleva 2013, Cherednichenko, Yanholenko 2013]. Access to such data is open. Nevertheless, they are almost not used for monitoring of the performance and quality indicators.

Despite of what data are used for monitoring, the estimation of the quality of monitoring results is practically absent for today. The issues of quality of

obtained results remain unsolved which discredits precision and reliability of collected data.

The main idea of the given work is that existing approach to complex systems management must be complemented with new mechanisms of collection, processing and evaluation of data retrieved from the external sources (fig. 1). We will consider the web as an external environment containing information that is a reflection of a real world in some extent. Further we consider complex systems in a management circuit of which we can see a person. Results of work of such systems can be characterized based on the analysis of information stored on the web-sites of some portals, blogs, forums, social networks, etc.

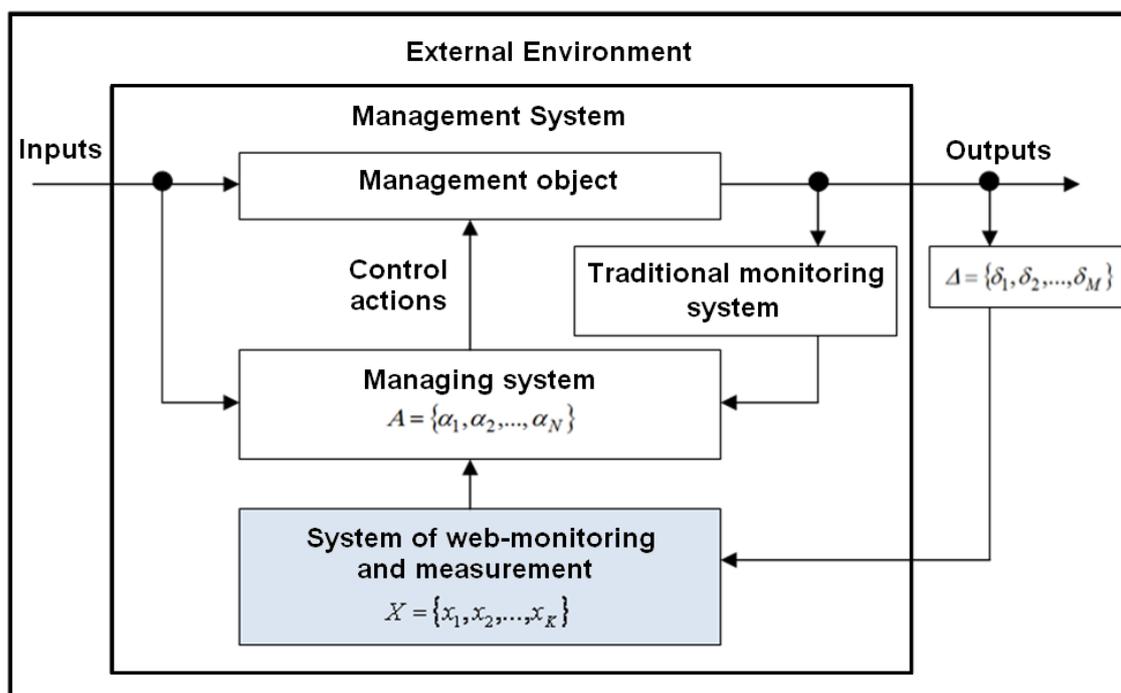


Figure 1 – Management system based on combination of internal and external sources

Source: authors' own development

Conclusions. Nowadays traditional monitoring system gathers and processes data which are in fact located inside management system. The main drawbacks of such approach are limitation of data sources and difficulties in obtaining of estimates of management results. Except this, estimates obtained inside management system are characterized by some degree of subjectivism and incompleteness. In order to improve this situation, in the given work we suggest to complement traditional management system with a new scheme of monitoring of indicators which are available for observation in the external environment, in particular, on the web. The involvement of external data sources may increase data integrity and objectivism, while the usage of the web provides the possibility of automation of monitoring process.

So the suggested approach to complex systems management combines internal and external information not only for measuring the current state of the system but also in order to evaluate management results by means of introduction of new external data sources.

Future research in the area of new methodology of complex systems management determines for us a set of problems to be solved. Firstly, information gathered by monitoring system on the web has an unformalized, semi-structured character. It is stored in different formats and has a definite degree of incompleteness, inaccuracy, etc. this requires to solve the problem of integration of heterogeneous information taking into account its business value for management purposes.

Secondly, the conducted research allows us to claim that data for monitoring must be collected both inside and outside the system. Therefore the problem of the common data sharing occurs. In particular, the degree of confidence, priority and usefulness of data must be defined. Taking into account that indicators' measurement is usually performed in different scales, the problem of common usage of these scales arises. Also the further research will be directed on methods of transformation and interpretation of the obtained estimates of performance and quality indicators.

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