Monitoring the effectiveness of organizational and technological complexes of enterprises for the processing and disposal of solid waste

Igor Kovalev[1,2,3,4*], *Dmitry* Kovalev[2,5], *Evgenia* Tueva[2], *Valerya* Podoplelova[2,6], *Dmitry* Borovinsky[7], and *Svetlana* Efa[4]

[1]Siberian Federal University, Krasnoyarsk, Russia
[2]Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia
[3]China Aviation Industry General Aircraft Zhejiang Institute Co., Ltd, China
[4]Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russia
[5]National Research University "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers", Tashkent, Uzbekistan
[6]Sochi State University, Sochi, Russia
[7]FSBEE HE Siberian Fire and Rescue Academy EMERCOM of Russia, Zheleznogorsk, Russia

Abstract. The features, requirements and architecture of the monitoring subsystem of automated management systems for solid waste processing and disposal enterprises are discussed in the article. The article proposes system architecture for the efficiency monitoring subsystem, which is implemented in the structure of the organizational and technological complex of enterprises for the processing and disposal of solid waste. This subsystem collects data on the operation of production and its management system and analyzes it in order to summarize it into specified aggregate indicators. It should be noted that the performance monitoring subsystem also implies automation of both information collection and issuance of recommendations in the event of a decrease in efficiency. This allows for the issuance of acceptable recommendations to significantly free up the time resources of the decision maker.

1 Introduction

To ensure increased efficiency of solid waste processing and disposal enterprises, it is necessary to create model-algorithmic support for monitoring systems [1-4]. The presence of such systems is important for justifying and making decisions, as well as for adjusting control actions on the structural components of organizational and technological complexes (OTC). For geographically distributed enterprises, there is a need to create a subsystem for monitoring their effectiveness for planning and optimizing the debugging of quality control department activities. This subsystem should effectively support monitoring systems in a single information space of corporately united enterprises, providing general access to databases of operation of control and measurement information of all quality control departments included in the structure of the corporation [5]. Monitoring and control over the

* Corresponding author: kovalev.fsu@mail.ru

https://doi.org/10.1051/e3sconf/202344305010

effective work of the quality control department of enterprises for the processing and disposal of solid waste will allow not only to monitor the environmentally stable operation of each production, but also to effectively manage the quality, finances and personnel of the entire set of related productions. This requires the introduction of appropriate methodological and mathematical support. Thus, the development of new methods and modification of existing decision support methods for automated monitoring of the comparative effectiveness of quality control departments, the creation of their model and algorithmic support as part of the monitoring subsystem is an important scientific, technical and practical task [6, 7].

2 Materials and methods

Let's define monitoring as a process of systematic or continuous collection of information about the parameters of a complex object or activity to determine trends in changes in parameters. One of the most important parts of any modern complex production system is the subsystem for monitoring the states of both its elements (complex technical objects) and the production system itself as a whole [8].

Condition monitoring presupposes obtaining in explicit form generalized assessments of the implementation of the operating program of the object in question, the degree of its performance, the location and type of malfunction that has occurred, assessments of predicted phenomena and processes with a given accuracy and forecast interval, taking into account specific goals and operating conditions at various stages of its operation. The main element of the monitoring system is the functional element of this system, which solves the problem of collecting, processing and analyzing all types of measurement information for an arbitrary type and number of end users of the monitoring system.

Benefits obtained by implementing comprehensive performance monitoring are given below [9]:

- fundamentally increasing the degree of independence, objectivity and efficiency in assessing production and economic processes;
- creating the necessary basis for further improvement of the tools for strategic management of an enterprise, in particular, when carrying out investment operations;
- formation of the necessary information and analytical base for solving practical issues related to restructuring and diversification of activities, primarily at the level of individual industries.

The monitoring system is the basis for a comprehensive restructuring of the activities of the organizational and technological complex, carried out through business process reengineering. Reengineering consists of a fundamental rethinking and radical redesign of business processes in OTC to achieve fundamental improvements in the main indicators of its activities [10].

A functional element in the information technology to support monitoring is a standard automation module, which combines a system for supporting the human-machine interface and software for ACS operator stations.

The basic concepts that are used when studying and constructing monitoring can be considered. These are concepts such as the state of the system, the external environment, the function of the system, and the structure of the system.

The state of a system is a set of properties, features (parameters) of the system that reflect the most essential aspects of the functioning of the system.

The external environment is objects that do not belong to the system under consideration, but influence it.

The function of a system (fuhctio - lat. - execution, improvement) characterizes the manifestation of its properties in a given set of relationships and represents the method of action of the system when interacting with the external environment.

The structure of a system refers to the characteristics of stable connections and methods of interaction between elements of the system, which determine its integrity, structure, and the basis of its organization.

In relation to complex systems, which include enterprises for the processing and disposal of solid waste, first of all, the following main types of structures are distinguished [11]:

- structure of goals, functions and tasks solved by a complex system;
- organizational structure;
- technical structure;
- topological structure;
- structure of software, mathematics and information support;
- structure of technology for managing a complex system.

Let us define concepts related to the state of the enterprise.

The macrostate of an enterprise is a generalized state of the production system, where one or several objects (subsystems) that are part of this system can simultaneously exist.

The structural state of an enterprise is a macrostate of an enterprise, characterizing both the current state of objects included in a given type of structure and the state of relations between them.

The structural dynamics of an enterprise is the process of transition of the structure (structures) of an enterprise from one to another given macrostate under the influence of various kinds of reasons (internal, external, objective, subjective and others).

For high-quality monitoring, as well as the successful functioning of production, it is necessary that these systems be controllable, that is, capable of changing their structure (structures), states, parameters, methods of functioning in various conditions and situations.

Control system is a system consisting of a control subsystem and a control object. At the same time, in the control subsystem itself, there is in turn a subsystem for monitoring the state of the control object and a subsystem for the formation and implementation of control actions.

Managing the structural dynamics of an enterprise is the process of forming and implementing control actions that ensure the transition of production to a given multi-structural macrostate.

As the main management functions that are implemented in the OTC monitoring subsystem, we will highlight:

- the function of determining goals and courses of action;
- planning function (long-term, long-term, operational);
- operational management function, including functions of physical implementation of control actions (plan development), functions of accounting and monitoring the state of the control object and the control subsystem;
- condition analysis function, including the function of diagnosing it;
- coordination function.

There are limiting states where all enterprise facilities are inoperable and the level of losses is maximum. These transitions have different nature: some are controlled, others are uncontrolled. One of the goals of management is to reduce the possibility (probability) of a complex organizational and technological system transitioning into the least desirable macrostates.

The measured parameters of OTC are indicators (characteristics) of the properties of automation objects, represented in the form of values of measured (telemetered) parameters (TMP). Calculated parameters are indicators (characteristics) of the properties of automation objects, calculated using various methods and algorithms based on the values of the measured parameters. The main way to identify (evaluate) quality control is the collection, processing and analysis of this information.

Collection of measurement information during monitoring is the process of obtaining and distributing all values of the measured parameters. And the processing of measurement information is understood as the process of obtaining estimates of the measured parameters of enterprise objects based on the collected data, equipped with an indicator of the degree of confidence in these estimates. Analysis of measurement information is the penultimate stage in the monitoring process, which consists in obtaining the values of parameter estimates that are elements of the monitoring goal, based on the use of the values of the measured parameters.

The purpose of analyzing measurement information as a process is to obtain generalized estimates of the set of parameters of enterprises for the processing and disposal of solid waste, the values of which explicitly indicate either the degree of performance of the monitoring object under consideration, or the location and type of malfunction, or are estimates of predicted phenomena and processes with a given accuracy and forecast interval.

3 Results

One of OTC intended for information support of management, as noted earlier, is the performance monitoring subsystem (PMS). In the context of increasing requirements for automated production management systems, the effectiveness of its operation is largely determined by the effectiveness of the monitoring system as a subsystem of the quality control department. Moreover, within the framework of the monitoring system, large and extremely large flows of information circulate, a significant part of which is measurement and accounts for over 80% of the total volume of information used in the quality control circuit. At the same time, the requirements for the processing and presentation of the results of processing this portion of information are quite stringent, since on its basis the monitoring system is managed in real time.

3.1 Formation of a subsystem for monitoring the effectiveness of OTC

Let’s define the concept of PMS OTC. The OTC efficiency monitoring subsystem is a component of the organizational and technological complex monitoring system, responsible for analyzing and ensuring the comprehensive efficiency of enterprises.

One of the properties that the subsystem for monitoring the effectiveness of OTC should have to a certain extent is adaptability, (adaptatio – lat. - adjustment) the ability of the system to change its behavior in order to maintain, improve or acquire new characteristics in a time-changing environment, a priori information about which is incomplete. This property arises as a result of the system having a certain mechanism for changing parameters, structure or control strategy based on information received during the operation of the system. From the point of view of adaptive systems and the adaptation mechanism, it is advisable to distinguish between the processes of learning, self-learning, adaptive control, adaptive organization and self-organization.

Automation of monitoring processes is a complex task, and its solution faces the following problems:

- measurement and accounting of parameters characterizing the state of the enterprise;
- determination of a suitable set of hierarchical models for solving planning and control problems;
- effective application of mathematical methods.

Implementation and maintenance of PMS OTC requires a number of the following steps:

1. Implementation of a monitoring subsystem:
   - comprehensive analysis of the enterprise;
   - methods of implementing the subsystem;
   - planned results of implementation.
2. Ensuring effective operation of the monitoring subsystem:
   - selection of analysis mode (continuous or periodic polling);
   - depth of influence on the production system (up to which structures, which structures remain subject to self-regulation);
   - adequacy and exclusion of erroneous analysis (verifiability).
3. Application of the functions of OTC monitoring subsystem to improve the efficiency of enterprises:
   - methods of producing recommendations based on analysis;
   - structuring and formalization of recommendations (unification for automated control systems of different enterprises with their own characteristics);
   - application of recommendations (in the form of directives, control actions of automated control systems, instructions for changing the structure, direct and independent reconfiguration of production systems and control objects).

Let us analyze the main tasks that the subsystem must solve to carry out its functions. The tasks of the performance monitoring subsystem in OTC are listed below:

1. Analysis and assessment of the target and information technology capabilities of the enterprise.
2. Analysis of the observability of the production system, and the achievability of efficiency improvement goals.
3. Analysis and forecasting of structural states, situations, and conditions of the enterprise relative to external influences.
4. Determination of the external environment in questions:
   - indifference of the external environment in influencing the automation process and/or performance of production activities;
   - degree of uncertainty of information about parameters (deterministic, stochastic, with a fuzzy description, with uncertainty, with a combined description of uncertain factors).

Apart from that the following additional functions are implemented in the structural control loop:

- technical diagnostic function (TDF), including the following operations: determining the state of the object, searching for the location of the state change, assessing the depth (volume) of the change in the state of the diagnostic object;
- the function of reconfiguring the structure (structures) of enterprises includes the following operations: assessing the state according to TDF data, searching for options for an acceptable structure (multi-structural macrostate) of production, choosing the best option, purposefully changing the connections (structures) and operating modes of the elements (subsystems) of OTC, monitoring the results of the impact on the structure (structures) of the enterprise with the help of TDF;
- the emergency protection function (EPF) includes operations: assessment based on TDF data of the type of failure in an object (simple, emergency), in the event of an emergency failure - localization of the area of its influence on operable elements of the system, transfer of the organizational and technical system using structure reconfiguration to one of operational states or into a failure state corresponding to simple failures.

The monitoring subsystem is also subject to the requirements of OLAP (On-line Analytical Processing) systems. This service is a tool for analyzing large volumes of data in real time [12]. According to the classification given in [13], the developed monitoring subsystem by type of task is a system for monitoring the state of production and the automated control system as a whole. The nature of the information flow is discrete. Data arrives at discrete moments in time (with processing at the rate of arrival). The performance monitoring subsystem can be represented as scientific software.

OTC subsystem can also refer to coordinating systems that involve changing the structure of the production system, breaking (dismembering) interactions, connecting and nesting interacting subsystems. The main shortcomings (and corresponding problems) identified to date during the creation of an automated performance monitoring system include the following.

Many automated systems (primarily control systems) are mainly of the nature of information systems in which the processes associated with decision-making itself are not automated, or the proportion of automation of the latter processes is insignificant compared to the automation of the processes of collecting and processing information. They make little use of the possibilities of using methods and algorithms of complex modeling to justify decisions.

Many automated systems do not have the necessary scientific software to conduct a systematic analysis of the functioning of a production facility and manage the quality of its functioning.

The creation of an automated system is not properly linked to development tasks, endowing this system with a high degree of flexibility and adaptation to changes in the environment.

Thus, the problems of creating and developing automated systems are, first of all, model-algorithmic and information problems that require the development of a fundamental theoretical basis for their solution [14].

Among the main features of the processes of functioning of information support systems related to the stage of analysis of measurement information, the following can be mentioned:

- strict time restrictions on obtaining the results of measurement information, namely in real-time data processing mode (no more than a few seconds should pass from the moment of measuring the parameter value to obtaining the results of the information analysis, that is, information about the state of the object of analysis, and often for dynamic operations within one second and its fractions;
- high requirements for the reliability and accuracy of analysis results;
- large (or even extremely large) flows of processed measurement information;
- a variety of types of measurement information used to make decisions about the state of the control object, both by the physical nature of the measurement information and by a large number of software and hardware that are sources of information.

Methods for presenting data in the monitoring subsystem are considered one of the important issues. By now, methods such as semantic networks, frames, and productive models have been used, which have confirmed their right to life as the basic components of the general apparatus for representing knowledge. In accordance with the principles of constructing promising information systems based on intelligent algorithms, the elementary object that carries the main computational (from the point of view of information processing) load is an active object or agent. The role of the agent is played by a computational model, which plays the main semantic role in the formation of an assessment of the organizational and technological complex [14].

3.2 System architecture of the monitoring subsystem

The main disadvantages of the considered monitoring systems [5-7] are the incomplete use of existing mechanisms and mathematical techniques for monitoring efficiency, cumbersomeness, leading to the absorption of time and computing resources of the enterprise. However, in [15] mathematical models of the structure of object monitoring are given and the technologies used in the construction and implementation of monitoring, such as system analysis, structured programming and others, are well considered. Some works [9-11] note weak formalization and automation of monitoring systems, leading to the impossibility of implementing these systems fully in the enterprise automated control system. It must be taken into account that strategic plans for the development of the enterprise are drawn up on the basis of conclusions and recommendations obtained from the results of performance monitoring in OTC.

The analysis carried out allows taking into account some common features of monitoring subsystems. So, the blocks of the monitoring subsystem responsible for input, processing, and output of information can be found [5]. In this regard, PMS architecture is proposed that reflects the entire set of requirements generated earlier.

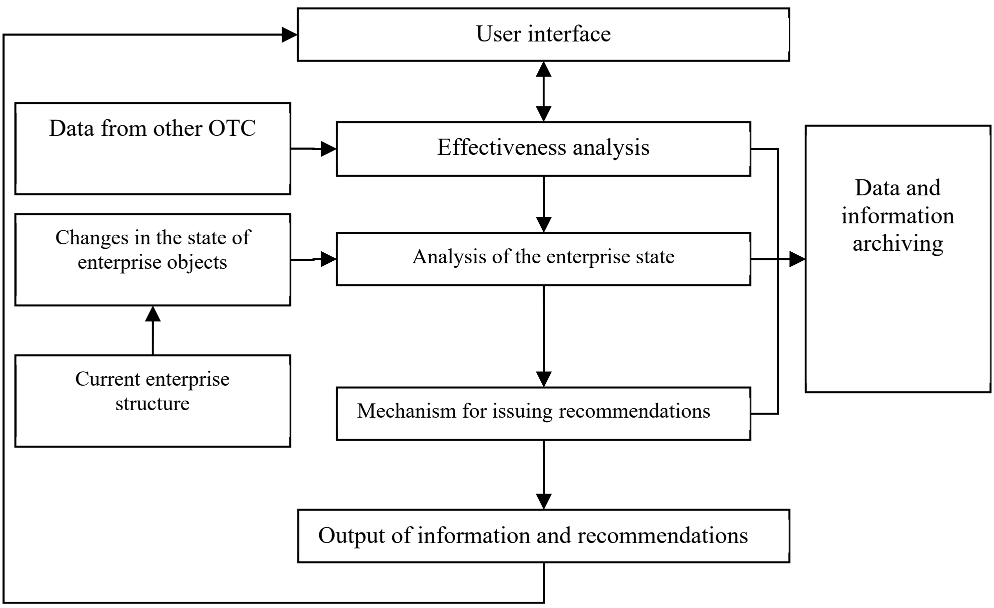

Fig. 1. System architecture of the subsystem for monitoring the OTC effectiveness of solid waste processing and disposal enterprises.

Figure 1 shows the system architecture of the performance monitoring subsystem in OTC of solid waste processing and disposal enterprises. The user interface allows receiving information about the results of the monitoring subsystem and adjusting its operation. There are basic interface requirements:

– reliability and accessibility of the displayed information;
– simplicity and ease of interaction with the subsystem;
– maximum controllability of the processes of analyzing efficiency and issuing recommendations to the enterprise.

At the beginning of the work, an important role is played by the "Current enterprise structure" block, which determines the appearance of the analyzed technological system for

PMS. Its difference is a complete analysis of the operation of each object, the current characteristics of the state, including technological parameters.

The “Change in the state of enterprise objects” block also analyzes the structure of the enterprise, but in the future this block is used to compare the initial and current state of the production system, records rearrangements in the structure, including failure of enterprise objects, backup replacement due to repair or maintenance.

The “Data from other OTC” block provides information on characteristics that are analyzed using the DEAMEXIN method proposed in the second chapter to determine effectiveness. The data is processed in the “Analysis of Enterprise Efficiency” block, and ineffective enterprises are identified. The received information is transferred to the “Analysis of the enterprise state” block, in which it is compared and processed together with data on the current state of objects analyzed in OTC, and data on the structure of the enterprise. The calculated coefficients and parameters are “lowered” into the “Mechanism for issuing recommendations” block, where they are used to obtain recommendations for improving the efficiency of enterprises. The dependences of efficiency fluctuations on changes in the structure and condition of objects analyzed in the quality control department are also highlighted. Recommendations and dependencies are displayed on the user terminals of the performance monitoring subsystem and in the enterprise’s automated control system.

Current calculations, data, and received information are archived in the “Data and Information Archiving” block for subsequent use and comparison, as well as when planning structural transformations of the production system when forecasting the activities of a specific solid waste processing and disposal enterprise.

4 Conclusion

The work analyzes methods and systems for monitoring OTC of enterprises for the processing and disposal of solid waste. The features, goals and objectives of monitoring enterprises are considered, which allow judging the need to implement a subsystem for monitoring the effectiveness of quality control departments. Important aspects of monitoring are the functions of collecting and analyzing measurement information at the stage of determining the state of the enterprise and its management system.

A subsystem for monitoring the effectiveness of OTC is considered, which collects data on the operation of production and its management system and analyzes it in order to generalize it into specified aggregate indicators. PMS also implies automation of both the collection of information and the issuance of recommendations in the event of a decrease in efficiency, which allows, when acceptable recommendations are issued, to free up the time resources of the decision maker.

As part of the study, system architecture for PMS OTC was proposed, which is supplemented with a methodology for assessing efficiency, a mechanism for analyzing the production system based on the vector of the structural state, a mechanism for issuing recommendations, as well as additional blocks for collecting and archiving information and data. It should be noted that the proposed mechanism for issuing recommendations allows automating the process of issuing recommendations due to the accumulated knowledge base about the state of production in different periods of time.

References

1. A. Singh. J. Environ. Manag. **240**, 259-265 (2019)
2. D. Kovalev, et al. Modern Innovations, Systems and Technologies **1(3)**, 1-21 (2021)
3. F.M. Tsai, et al. J. Clean. Prod. **275**, 124-132 (2020)

4. J.P. Doussoulin, et al. Sustainability **14**, 15887 (2022)
5. A. Shabi. Modern Innovations, Systems and Technologies **2(4)**, 0201-0213 (2022)
6. A. Aljarbouh, M.S. Ahmed, M. Vaquera, B.D. Dirting. Modern Innovations, Systems and Technologies **2(1),** 9-17 (2022)
7. M.V. Pokushko, et al. Informatics. Economics. Management **1(1)**, 0101-0109 (2022)
8. E.V. Tuev, M. Kozlova, O. Olshevskaya. Modern Innovations, Systems and Technologies **1(2)**, 34-45 (2021)
9. A.W. Dametew. International Journal of Environmental Monitoring and Analysis **3(2)**, 50-66 (2015)
10. M. İncekara. Journal of Cleaner Production **356(17)**, 131712 (2022)
11. C.G. Cheah, et al. Environmental Research **213**, 113619 (2022)
12. A. Diniz da Silva, et al. Revista GeSec **14(8)**, 14241-14261 (2023)
13. S. Bin, et al. Procedia CIRP **29**, 450-455 (2015)
14. W. Czekała, J. Drozdowski, P. Łabiak. Appl. Sci. **13(15)**, 8847 (2023)
15. I.V. Kovalev, et al. IOP Conf. Ser.: Earth Environ. Sci. **677**, 052115 (2021)