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SOME ASPECTS OF DECISION MAKING IN A SYSTEM OF ENVIRONMENTAL MONITORING

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Abstract. *The process of environmental management quality, which is based on the information obtained from the system for monitoring environmental parameters has been significantly eased in the past few years, mainly due to the opportunities offered by the networking devices of various types and purposes. Also, the integration of systems for monitoring various environmental parameters with the information systems used in other areas of life, contributes to improving not only the quality of the environment, but also the health and safety of social justice which results in higher quality of life, and provide support to the model of sustainable development. On the other hand, the consequence of rapid technological development is the fact that in the very first decade of this century it became known as the century of risk. For this reason the concept react - correct, based on which the environmental problems were approached in the '80s, has now been replaced by the concept of predict - prevent. However, this concept requires a constant increase in the number of environmental parameters that need to be monitored, which has as a result an increasing number of criteria that should be taken into account during evaluation of the environmental quality. The quality of a decision made on the basis of information obtained by the environmental monitoring system is influenced by the mutual relationship between the amount of information and the number of monitored environmental parameters. In the monitoring system, particularly in practice, the fact that the amount of available information that we get from the system is inversely proportional to the number of monitored parameters and their outcome is decision-making under uncertainty. The phenomena that are monitored in the environment are mostly slow changing over time and they are slowly influenced upon. Decision-making process is largely influenced upon by economic indicators, and by the degree of awareness about the necessity to solve the problems at the monitored territory. Therefore, decision-making problem in most cases ultimately comes down to taking responsibility of decision maker who decides to allow investments in technology that brings a profit, but on the other hand threatens the environment to a certain extent.*

Key words: *monitoring system, system design, decision-making*

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1. INTRODUCTION

The current century is by many contemporaries called the civilization of risks. Risks in technosphere, sociosphere and the ecosphere endanger not only the quality of life, but also bring into question the possibilities of further development of mankind in general. To take into consideration that the risks in the ecosphere in the last decades are in the focus of world public, quality management of the environment is becoming a priority.

The process of quality management of the environment is based on information obtained from the system for monitoring environmental parameters in the territory which is being monitored. Making this process in line with sustainable development requires continuous development and introduction of new and more convenient approach for the application of information technologies for collecting, processing and presentation of information in order to increase the effectiveness of the environmental quality management Comprehensive application of modern information technology in quality management of the environment that includes integration with information systems that are used in other areas of life, should improve the quality of the environment that we have as the end result of a higher level of overall quality of life, and facilitate the realization of sustainable development model.

The process of collecting data on the state of the environment and the implementation of appropriate information systems is based on the same principles that are applied in the implementation of data collection systems in other areas. Data collection is a process with the ultimate goal to manage, and this process is inextricably linked to the man. Collecting data exists in various forms, from making a note on paper to data collection systems that are now exclusively based on the use of computers. Data can be collected anywhere and by anyone with the aim to identify tendencies, warning and alarm, decision-making and management. Moreover, data collection can be organized to be autonomous when it is realized by computers. However, any system of data collection is meaningful if the final decision is not made by an authoritative man. Data describe the particular situation when some condition is satisfied, and on this way data assign some meaning or significance, and thus become information. This condition is usually determined by the time base, an event, and a threshold of some physical size or by comparison with previously acquired knowledge.

This paper analyzes the problem of decision making in a system for monitoring the environment. Bearing in mind that this hierarchically speaking highest characteristics of the system depend on all other characteristics of the system, the paper presents the basic principles of designing a system that defines the minimum set of organizational and technical requirements that are needed for reliable operation of the system and, therefore, for quality decision-making .

2. DECISION-MAKING IN THE SYSTEM OF ENVIRONMENTAL MONITORING

Regardless of the rapid development of technology and improvement of technological processes, there is still no technological process that can be said to be absolutely "clean" in relation to the environment. Due to a smaller or greater degree of imperfection of the applied technology and the still excessive exploitation of natural resources, it is necessary to constantly adapt and change its approach in addressing human security and the environment. Concept *react - correct*, on which problem solving of environment protection in the 80-ies of the last century was based problem, now has been replaced by the concept of *predict - prevent*. However, this concept requires a constant increase in the number of environmental parameters that need to be monitored for system monitoring, which has resulted in an increasing number of criteria to be taken into account when evaluating the quality of the environment. Moreover, during the design process, it is necessary to predict the structure of the system that provides not only the registration of value or level of environmental parameters to be monitored, but, more importantly, the forecast development of the monitored parameters.

2.1. The requirements in the design process that influence decision making

Before the start of the design process it is necessary to answer a few basic questions that represent the starting point for the designing of the system, and on the other hand have direct impact on decision-making during the operation of system. To simplify, there are two groups of questions. The first group consists of the following questions:

- Who requires a system, for what purpose and to whom such system may be needed?
- What are the technical requirements that must be satisfied in order to implement the system?
- Is it able to define the relationship between cost effectiveness /efficiency?
- The second group consists of the following questions:
- Where are measurements / data collection carried out?
- What data is measured / collected?
- How long should the time interval for sampling data be?
- Which of the obtained data and to which degree are important for analysis?
- What should be the accuracy / precision of the collected data?

By answering these questions it is possible to define to whom the data are intended, and therefore to explain the purpose of the system, how the data will be interpreted and indirectly, provide options for further use of the data. Even though the answers have impact primarily on the process of designing the system, they affect the decision-making process which may perform exclusively within the framework provided by the system. Therefore, it is very important during environmental monitoring system design to anticipate the system with "open architecture" in the sense that the structure of the system can be modified according to the feedback we are getting on the base of its performance during the exploitation period. The reasons for modifying the characteristics and structure of the monitoring system unless drastic changes of environmental parameters, may be the changes in legislation and the results of research in specific areas. Figure 1 presents the framework in which they are expected to move in the process of designing a system for monitoring the environment.

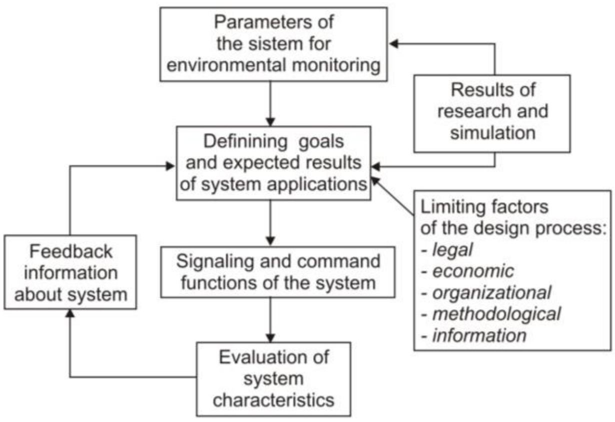

Fig. 1 Frames for system design process

The response of each data collection system depends on its speed and required accuracy, while neither was a critical factor in the system for monitoring the environment; however, some parameters can be monitored several times or just once a day. Control functions of this type of a system are generally reduced on generation different types of output signals that provide information about the level of parameters under surveillance (warning, alarm) depending on the input data. Response speed of the system for monitoring the environment, due to the nature of parameters to be monitored, is not critical for the efficiency of the system. More important is that the information which is obtained in certain time intervals is presented to expert services that are responsible for monitoring the quality of the environment and to the people living in the territory, which is covered by the system.

The system which monitors the phenomenon of the environment must be flexible in terms of easy accepting the changes in environmental parameters that are being monitored.. Because of a variety of impacts based on changes that occur in the environment over time, some of the parameters that were initially dominant can weaken and be replaced by others that have a negative impact on the environment. The reasons for this are numerous: the influence of natural factors (meteorological parameters, time of year, etc.), the introduction of new or changes in existing technologies and production processes, changes in legislation and similar.

Therefore, during the design of environmental monitoring system, several aspects should be taken into account, the most important being the following: legal, economic, organizational, methodological, technological and information aspect.

2.2. Reasons for system integration

There are a number of reasons for the integration of systems for environment monitoring. First of all, our environment can be viewed as a set of three interrelated but independent "worlds": material, energy and information. The current treatment of these worlds independently has a consequence the unilateral conceptual approach in consideration of the constituent elements of the environment. The consequence of this approach is an independent environmental phenomenon treatment without their mutual influences. On the other hand, it is obvious that the degree of loss in technological sphere is increased regardless of technological development. For example, every fire has certain impact on the environment by emission of harmful products or by other means which is reflected on the working environment. Therefore, it is necessary to treat all aspects of protection integrally. In practice, the main reason for the integration of a large variety of protection systems is *adequate distribution of material resources according to vulnerability of some phenomena*. Thus, this is a fastest way to get knowledge about legal, organizational and technological measures needed to efficient prevention in some areas. Besides mentioned reasons, the other reasons for development of integration systems are as follows:

- the need for the pooling of information on adverse impacts on all aspects of human environment;
- the need to take all the data collected in real time, and on this way to enable faster implementation of preventive measures;
- the need for optimizing the management actions of all integrated systems;
- central control of reliability and efficiency of individual systems and their parts, etc.

This is a generally accepted approach used in the theory and practice of the Western and Eastern countries[1], because the level of development of information systems has relation performance / price which become more favorable every day.

There are two aspects of the application of modern information technology which facilitate the implementation of the basic principles of integrated systems: *possibility of early detection and early signal processing* (detection of phenomena at the earliest stage near the origin) and hence faster decision-making, and *implementation of large territorial systems* using existing communication infrastructure.

The **basic principles** that must be followed in the implementation of integrated systems of protection are the following:

1. The principle of integration of different security systems

By integrating various security systems the following outcome may be achieved: materials and staff savings multilevel and multi-functional monitoring and control of a large number of phenomena that can have a detrimental effect. This principle should aspire to a higher level of integration of different systems: not only systems for fire protection, the environment and information systems, but all other systems whose failures could have negative consequences, such as connection systems, energy supply systems, water supply systems, etc..

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[1] К преимуществам создания АИСБЖО (*автоматизированных интегрированных систем безопасности и жизнеобеспечения*) можно отнести:

1. Интеграция систем безопасности в АИСБЖО внутренняя (между системами безопасности) и внешняя (с системами жизнеобеспечения и иными системами).

2. Обеспечение многоуровневой (многорубежной, эшелонированной) безопасности (предотвращение угрозы опасных факторов, их раннее обнаружение и подавление, защита от них и ликвидация оследствий проявления и т. д.) на этапах зарождения, появления, развития, существования и подавления (исчезновения) угроз и опасных факторов.

3. Обеспечение безопасности на всех этапах проектирования и жизненного цикла объекта защиты (концептуальное, функциональное, техническое и рабочее проектирование, строительство, опытная и промышленная эксплуатация, реконструкция, модернизация, вывод из эксплуатации).

4. Моделирование и прогнозирование процессов в АИСБЖО (возникновение и взаимодействие угроз и опасных факторов, их воздействие на персонал, оборудование и окружающую среду, выработка управляющих воздействий на объект и процессы…).

5. Оптимизация при проектировании и эксплуатации АИСБЖО (критерии - минимизация риска появления, проявления и воздействия угроз, времени и стоимости проектирования и эксплуатации АИСБЖО и т. д.…).

6. Использование новых информационных, коммуникационных, организационных и иных высоких технологий, эффективных физических, технических, технологических принципов и средств прогнозирования, обнаружения, локализации, подавления, устранения и ликвидации последствий проявления угроз и опасных факторов...

7. Автоматизация проектирования АИСБЖО (использование САПР).

8. Открытость, распределенность, модульность и иерархичность структуры АИСБЖО, возможность ее адаптации, наращиваемости, и развития.

9. Взаимодействие с едиными дежурными диспетчерскими службами (ЕДДС), на которые возложена координация деятельности десятков специализированных диспетчерских и оперативных служб безопасности и жизнеобеспечения потенциально опасных объектов, зданий, сооружений, муниципальных образований, районов, городов и территорий.

(See details: Н.Г. Топольский: *Интеллектуальные интегрированные (комплексные) системы безопасности и жизнеобеспечения - от объектов до территорий*, Конференция СБ-2004, Москва, 2004.)

System integration can be done in two directions: *in width* - integration according to functions and types of hazards, and integration *into the depths* - according to the degree of supervision of individual technological processes and hazardous factors that they carry out with them. Integration can be carried out according to other criteria, for example according to the territory covered, by time and the similar.

2. Optimal exploitation of the system

During the process of different systems integration, it should be provide solutions that are optimal for implementation, as well as the solutions that offer optimal exploitation of the system. Optimization criteria may include: time and price for design and realization, time and price of exploitation of individual functions, the degree of risk or probability of occurrence of phenomena, etc. Therefore, the design process is an iterative process with particular stages of implementation and realization. Economic criteria for the design by means of information systems today are less decisive factor.

3. Realization of multi-level integrated systems

Integrated protection systems should be multilevel, not only in terms of technical implementation, but also in terms of the existence of several levels of protection. Protection levels can be organized by territory that is monitored and according to the time response of the system. Multilevel treatment of monitored occurrences is made possible by using modern sensors and detectors which provides "filtering" of the relevant data from the system.

In this way, the central control is unloaded with “redundant” data stored in databases in separate systems which retains autonomy in decision-making. Central control unit remains responsible for the decisions which have a global character.

4. Realization of an adequate system for all phases of occurrence development.

Besides early detection of the monitored occurrence, it is necessary to effectively implement the protection of people and property (passive and active), to realize the control functions (passive and active) and to predict the possibility of system reconstruction. The resulting information should be in the required timeframes for presentation to professional services using special lines and connections to households via a global computer network.

5. Modeling and prediction processes

The system should enable the analysis of data within an integrated system of phenomena during the operation of a system. Based on the data of previous events, system should provide not only statistical data and detect trends of the development process, but also enable modeling and prediction for the longer period of time. It is possible to achieve by modern programming means for data processing, and this principle can be implemented quickly and efficiently.

2.3. Basic principles of decision making in the system

It is obvious that monitoring of environmental parameters, and consequently, multiple criteria decision making on the basis of these criteria, requires the existence of an information system that at any time (in "real time") may provide an indication of whether the investment in technology is justified or not in terms of environmental protection. Due to the fact that information systems today are solely based on the use of computer technology, the time required from data collection to decision-making is getting shorter, which significantly facilitates the correction in investment and timely decision making. On the other hand, the information system of environmental monitoring is not a separate entity, and it is inextricably linked with other information systems in one society and it is subject to all the rules of organization of every other information system in terms of information structures, information flows and information workers.

The quality of a decision on the basis of information obtained by the system for environmental monitoring is governed by the mutual relationship between the amount of information and number of environmental parameters to be monitored. In environment monitoring system, a particularly pronounced fact is that usually *the amount of available information that we get from the system is inversely proportional to the number of parameters to be monitored*, which implies that, very often, decisions have to be made under conditions of uncertainty.

Decisions under conditions of certainty are typical for monitoring systems in smaller territorial or organizational units. These decisions are based on sufficient amount of information and on a small number of parameters (for example, water or air pollution by some technological process), and in practice they refer to the situations with simple problems at the operational level of decision-making.

Decisions under risk are characterized by necessary but not a sufficient amount of information in order to decide with full certainty. When using a monitoring system in practice, these decisions are most often related to complex problems, such as for example, small-scale emergencies that arise by discharge or spill of hazardous materials during their transport, charging, or storage, in which the outcome can be determined with a certain degree of belonging to a specific event.

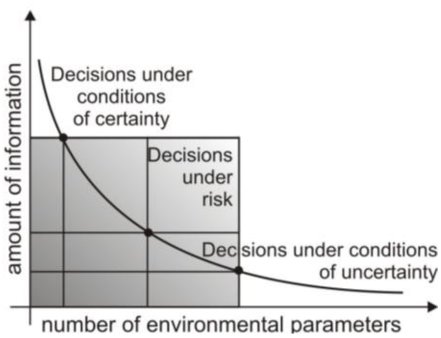

Fig. 2 Decision quality interdependence from parameters information amount

Decisions under conditions of uncertainty relate to very complex problems, in case of large-scale events accompanied by other types of accidents or natural disasters, where the available data are not sufficient to evaluate belonging to a given outcome in solving the problem. In these cases, decision should not be made immediately regardless of the urgency of response, but it is necessary to continue with the analysis of the problem and to gather additional information in order to precisely define the level of risk. It is important to notice that in our conditions, besides economic factors, awareness of the need to solve the problems that exist in the territory have an effect on the decision-making problem.

Therefore, the problem of decision making in most cases results in taking responsibility of decision maker *whether on the basis of the available information should keep or even allow investments in technology that brings a profit, but on the other hand threatens the environment*. One of the solutions that can improve the quality of decision making is the principle of distributed decision making which applied technology allows itself, but not the existing legal regulations.

2.4. The decision-making distribution in the system

The use of modern means of information technology significantly facilitates decision making on the basis of the information obtained from the environment. This refers primarily to increasing density packaging of electronic components, steadily reducing energy consumption required for the operation of equipment and information on permanently reducing prices, which provides higher "level of intelligence" of systems that previously had only function measurements (detection) but decision ones.

This fact creates enables distributed data processing (so-called. *distributed intelligence* of systems), and the ability of decision-making become accessible to those parts of the system that are closest to location of phenomena, and therefore, the closest to organizational units of protection.

With the help of distributed intelligence of the system, it is possible to distribute the responsibility on the basis of the phenomenon that is monitored and make decision on the level of risk and danger. The decision that was made at a lower level may be forwarded to higher technical and organizational levels in the system. A greater degree of autonomy of the lower parts of the system means better "filtering" of information which increases the degree of reliability in concluding that perform higher levels in the system.

In addition, bearing in mind the fact that the system of environmental monitoring is not subject to strict requirements with respect to rate of data collection and does not possess control functions, it is possible to easily take advantage of new information, communication and organizational technology for distributing data over the Internet. Making certain information available to all users of the network significantly increases its value

This kind of reasoning is supported by the fact that a particular phenomenon or parameters to be monitored by system does not have to be treated on the same way in the system. It is possible, if the system allows, to detect a parameter that is not dominant in their ambience, or even do not exist over a longer period. For example, the constant presence of a parameter and its size in the industrial and urban area can have entirely different meanings. Because of the need to be the same, the phenomenon is treated differently in different environments, and it is preferable that the system is organized into multiple levels, from local centers for tracking and informing and with a certain degree of autonomy in decision-making. Also, regardless of the hierarchical structure of the system it is necessary to provide the ability to integrate systems into larger information system with lower or higher levels of filtering data.

3. MISTAKES RELATED TO PROCESS OF DECISION MAKING

Regardless of the capabilities of distributed decision making and distributed responsibility as a consequence of this approach, there are still some “mistakes” which are present on all levels in hierarchical integrated system. The most common mistakes during the decision making process are as follows:

- **The wrong approach in problems solving** - the decisions are made primarily for the problems that are easy to solve, problems that at first glance seem unsolvable usually remain "unsolvable".
- **One-sided approach in problems solving** - providing solutions for one problem at a time, without analyzing the connections with other problems.
- **Making decisions without going into the core of the problem** - information that some parameters are out of range does not mean anything if you do not know the essence of the problem.
- **Making decisions based on the suitable facts** - the facts that do not belong to our knowledge or are less familiar through practice, always have less "weight" than those that are well known to us.
- **Interpretation of data/information so that they meet the criteria that are slightly connected with the problem** - mainly comes down to satisfying personal or narrow interests: to maintain acquired positions, to satisfy the interests of investors, etc.
- **The formation of a team whose members have acquired formal education in the field covering a problem does not automatically mean that the problem is solved** - usually the opposite, a little "unintelligent" sometimes works wonders in the management team.

4. CONDITIONS FOR RATIONAL DECISION MAKING

There are several conditions which are necessary to fulfill for rational decision making. These conditions are realized through the following steps:

Step - Specification of the problem for which a decision is made.

Activities.

Defining the problem and its limitations. Determination of decision makers and stakeholders.

Requirements.

Defining a framework for decision-making (geographical, temporal, financial, ..).

Step – Formulating objectives decision making

Activities.

Defining the objectives and consequences. Defining criteria and indirect results of decision-making.

Requirements.

Defining the hierarchy of desired goals and alternatives for obtaining the final result expressed in real unit: kg, km^2, etc.

Step - Defining knowledge, analysis, and procedures for deciding

Activities.

Defining the knowledge, expertise and skills of decision makers.

Requirements.

Defining the necessary licenses, diplomas, certificates of the decision makers.

Step - Defining the importance of certain criteria

Activities.

Defining the "weight" of each criterion to decide through discussion with decision makers

Requirements.

Defining the list of "weights" for each criterion from 0.1 to 1.0.

Step - Analysis of the consequences of decisions

Activities.

Defining all possible consequences of decisions.

Requirements.

Ranking of possible consequences in terms of significance

5. CONCLUSION

The quality of a decision on the basis of information obtained by the system for environmental monitoring is caused by the mutual relationship between the amount of information and number of environmental parameters which are under surveillance. Modern information technology and usage of state-of-the-art information systems allow distributed data processing, and consequently, distributed decision making. In this way, the ability of decision-making becomes accessible to those parts of the system that are closest to location of phenomena, and therefore, the closest to organizational units of protection.

REFERENCES

1. Burden R.F., Donnert D., McKelvie I., (2004): *Environmental Monitoring Handbook*, McGraw-Hill.
2. Hewitt C. N., (1992): *Methods of Environmental Data Analysis.* Elsevier Applied Science, London.
3. Качанов С.А., Топольский Н.Г. и др., (2003): *Концепция создания структурированной системы мониторинга и управления системами безопасности и жизнеобеспечения потенциально опасных объектов, зданий и сооружений* (утверждена руководством МЧС России). -М.: ВНИИ ГОЧС.
4. Keith L. H., (1991): Environmental Sampling and Analysis: A Practical Guide. Lewis Publishers, Chelsea, Michigan.
5. Petković D., Blagojević M., (1998): *Principi prikupljanja podataka u sistemu za kontrolu životne sredine*, Naučni skup “Kvalitet životne sredine i ekonomski razvoj”, Fakultet zaštite na radu, Niš.
6. Roberts P., (1997): Environmental Assesment auditing and Information Systems, The Drzden Press, London.

NEKI ASPEKTI ODLUČIVANJA U SISTEMU MONITORINGA ŽIVOTNE SREDINE

Proces upravljanja kvalitetom životne sredine koji je zasnovan na informacijama dobijenim od sistema za monitoring parametara životne sredine poslednjih godina je značajno olakšan, zahvaljujući pre svega mogućnostima koje pruža umrežavanje uređaja različitog tipa i namene. Takođe, integracija sistema za monitoring različitih parametara životne sredine sa informacionim sistemima koji se koriste u drugim oblastima života, doprinosi poboljšanju ne samo kvaliteta životne sredine, već i zdravstvene bezbednosti i socijalne pravde što ima kao krajnji rezultat viši nivo ukupnog kvaliteta života i potpomaže ostvarivanje modela održivog razvoja.

Sa druge strane, ubrzani tehnološki razvoj ima za posledicu da je već u prvoj deceniji ovog veka on počeo da se naziva vekom rizika tako da je koncepcija reagovati - ispraviti, na kojoj se do 80-tih godina prošlog veka baziralo rešavanje problema zaštite životne sredine, danas zamenjena koncepcijom predvideti - sprečiti. Međutim, takva koncepcija zahteva stalno povećavanje broja parametara životne sredine koji treba da se prate sistemom za monitoring, što ima za posledicu sve veći broj kriterijuma koje treba uzeti u obzir prilikom ocenjivanja kvaliteta životne sredine. Kvalitet odluke koja se donosi na osnovu informacija dobijenih sistemom za monitoring životne sredine, kao i kod svih sistema za prikupljanje podataka, uslovljen je uzajamnim odnosom količine informacija i brojem parametara životne sredine koji se prate. Kod sistema za monitoring životne sredine je naročito u praksi izražena činjenica da je najčešće količina raspoloživih informacija koje se dobijaju od sistema obrnuto proporcionalna broju parametara koji se prate, što ima za posledicu da odluke vrlo često moraju da se donose u uslovima neizvesnosti.

Pojave koje se prate u životnoj sredini su većinom sporo promenljive u vremenu i na njih se još sporije utiče, na donošenje odluka utiču i ekonomski pokazatelji, kao i činjenica u kojoj meri je razvijena svest o potrebi rešavanja problema koji postoje na teritoriji koja se nadgleda sistemom. Zbog toga, problem odlučivanja se u najvećem broju slučajeva u krajnjoj instanci svodi na preuzimanje odgovornosti donosioca odluke da li treba na osnovu raspoloživih informacija dozvoliti ulaganja u tehnologiju koja donosi dobit, ali sa druge strane u određenoj meri ugrožava životnu sredinu.

U radu su prikazani principi u okviru kojih treba projektovati sistem za monitoring životne sredine tako da može da se određenoj meri modifikuje u skladu sa povratnim informacijama koje se dobijaju na osnovu procene njegovih performansi tokom perioda eksploatacije, i samim tim da se olakša proces odlučivanja u sistemu.

Ključne reči: *sistem monitoringa životne sredine, projektovanje. odlučivanje*