Technology for developing expert modules and DSS comprehensive platform for reliability and risks monitoring in the Oil and Gas Engineering

M Yu Zemenkova, Yu D Zemenkov, V V Golik and S Belsky

Tyumen Industrial University, 38, Volodarskogo str., Tyumen, 625000, Russia

E-mail: muzemenkova@mail.ru

Abstract. The paper describes the proposed technology for the development of expert modules and DSS for integrated reliability and risk control systems for oil and gas industry, as part of a complex of intelligent technological management of reliability and efficiency of oil and gas systems developed at TIU. All stages of the development of system modules for controlling technical risks, the features of the structure of the decision-making model for DSS, and the components of a static and dynamic expert system for transport and storage of hydrocarbons are considered. The features of creating decision support systems are described, their main functions and decision criteria and their main provisions. As an example, one of the modules of intelligent neural network engineering control for predicting halos of thawing soil in the vicinity of the pipeline and passing communications, and buildings is shown, a model for visualizing processing results is proposed.

1. Introduction
In order to comply with modern environmental safety requirements, for high-quality monitoring of accident risk indicators at a hazardous production facility in the oil and gas complex and for reliable assessment of accident and incident risk values, modern information processing systems based on the processing of online information and databases should be used[1-4].

The complexity of the processes at large-scale objects of transport and storage of hydrocarbons requires the use of modular technologies.

A collaborative intellectual technological reliability and efficiency management of oil and gas systems (CI-TREMS) is developed at the Department of Hydrocarbon Resources Transport, a fundamentally new technology of intelligent neural network engineering control, forecasting and prevention of emergency situations, incidents, accidents, optimization and ensuring the effectiveness of technical solutions in the process control of industrial enterprises.

Consider some aspects related to the proposed technology for the development of the system and its modules. In the development, methods of system analysis dealing with decision-making problems in the analysis of a large amount of information of various nature were used.

2. Materials and methods
The development of an expert system module or a decision-making support system as part of a complex of intelligent technological management of the reliability and efficiency of oil and gas systems includes the following steps:
1. Development of a source database: a list of initial parameters, requirements for data accuracy, a minimum quantity, areas of definition of arguments and functions are determined;

2. Development of tools for collecting the database: modern technologies, instruments, tools, etc. are used, manufacturers and technologies for collecting source data are defined;

3. A system analysis of the object is carried out in the context of the goal of the ES (DSS): there can be various morphological, factorial, structural analysis, analysis of connections, the image of connections in graphic, logical and mathematical forms, neural;

4. Mathematical models, methods of data processing and analysis are substantiated: formulas, dependencies and mathematical methods by which assessment and forecasting are performed;

5. Methods of data analysis, classification, graphs, neural networks, interpretation rules, etc.;

6. The substantiation and calculation of the target criterion (minimum 1) is carried out (based on which a decision is made). Description of possible options and decision-making criteria and methods for their adjustment, decision-making criteria and decision-making technology, description of the method used;

7. Selection and justification of the optimization model and optimization method*; methods: programming, deterministic, random (stochastic), combined, one-dimensional or multidimensional, etc.; optimization model calculation example;

8. Development of the main algorithm of the expert system in the form of block diagrams: 1) algorithm for mathematical calculation; 2) decision making algorithm;

9. Development of software for ES (DSS): screen design; development of a software product that implements a computer model of the system or automates the applied algorithms (calculations, analysis); Python, Excel, Matlab, Matcad, Sharp, Windows forms, and other programs which products can be compatible with operational dispatch control systems; listings, screenshots, description of the program in stages, user manual

Decision making in a complex system is carried out by a technical tool or by a person and is based on a comparison and assessment of options for action. The setting of both the main and particular goals in the system is also usually subject to analysis and research. And again, the main procedure in this case is the decision.

As known, the study of decision-making procedures and the system organization associated with this is an urgent problem of creating and operating complex systems. We emphasize that all this can be carried out on the basis of specially developed methods, techniques, standard models for organizing the system and making decisions.

Under management, in its most general form, we understand the process of forming the targeted behavior of the system through the information impact produced by a person or device when implemented at a hazardous production facility—an algorithm of action in an emergency or in the face of an incident threat.

The decision-making model is most often depicted in the form of a circuit with cells, connections between cells and logical transitions. Cells contain specific actions, procedures, which can be very diverse. A joint study of the procedures and their organization follows from the fact that without taking into account the content and features of the cells, creating schemes is impossible. These schemes determine the decision-making strategy in a complex system. It is the study of a coherent set of basic procedures which one should begin solving a specific applied problem with.

The use of a separate software tool is an elementary system analysis procedure. As a result, it is the person—the "decision maker" (DM)—using computer technology who gives an indication of the use of the research results in practice. The functions of the decision maker, the scope of his actions, the separation or not separation from the researchers of the system are problems that in general also apply to the field of system analysis. A variety of counting, controlling, storing, transforming, advising, depicting and other computing techniques is both an integral part of the complex systems themselves, and research.

The specifics of applications of expert systems in comparison with other artificial intelligence systems is as follows. Expert systems are used to solve only difficult practical problems. The expert
systems are not inferior to the decisions of a human expert in the quality and effectiveness of solutions. Expert systems solutions have "transparency", i.e. can be explained to the user at a qualitative level. This quality of expert systems is ensured by their ability to reason about their knowledge and conclusions. Expert systems are able to replenish their knowledge in the course of interaction with an expert. It should be noted that at present, the technology of expert systems is used to solve various types of problems (interpretation, prediction, diagnostics, planning, design, control, debugging, instruction, management) in a wide variety of problem areas, such as finance, the oil and gas industry, energy, transport, space, metallurgy, mining, telecommunications, etc.

An expert system is a software tool that uses expert knowledge to provide highly efficient solutions to informal tasks in a narrow subject area. The basis of ES is a knowledge base (KB) about the subject area, which accumulates in the process of construction and operation of ES. The accumulation and organization of knowledge is the most important property of all ES.

A typical static ES consists of the following main components:
- solver (interpreter);
- working memory (WM), also called a database (DB);
- knowledge base (KB);
- knowledge acquisition components;
- explanatory component;
- dialog component.

The distinguished data that the program works with about technical features and operating conditions, any operational and design information is called a knowledge base, while general knowledge about finding solutions to problems is called an output mechanism.

The knowledge base (KB) in ES is designed to store long-term data describing the area in question (and not current data), and rules describing the appropriate data transformation of this area. Operational, diagnostic information can be used. The database (working memory) is intended for storing the source and intermediate data of the problem currently being solved. This term coincides in
name but not in meaning with the term used in information retrieval systems (IRS) and database management systems (DBMS) to refer to all data (primarily long-term) stored in the system.

The solver, using the source data from the working memory and knowledge from the knowledge base, forms a sequence of rules that, when applied to the source data, lead to the solution of the problem. The knowledge acquisition component automates the process of ES filling with knowledge, carried out by an expert user. The explanatory component explains how the system received the solution to the problem (or why it did not receive the solution) and what knowledge it used to make it easier for the expert to test the system and increase the user's confidence in the result. The knowledge base contains facts (data) and rules (or other representations of knowledge) that use these facts as the basis for decision-making.

**The output mechanism contains:**

- an interpreter defining how to apply the rules for deriving new knowledge based on information stored in the knowledge base;
- a dispatcher setting the procedure for applying these rules.

Such ESs are called static ESs and have a structure depicted in Figure 2; they are used in those applications where you may not take into account changes in the environment when solving the problem.

The dialog component is focused on organizing friendly communication with the user both in the course of solving problems and in the process of acquiring knowledge and explaining the results of work.

Representatives of the following specialties participate in the development of ES:

- expert in a problem area, the tasks of which will be solved by the ES;
- knowledge engineer is a specialist in ES development (the technology used by them and methods are called knowledge engineering technology (methods));
- programmer for the development of tools designed to accelerate the development of ES.

It should be noted that the absence of knowledge engineers among the participants in the development (i.e., their replacement by programmers) either leads to failure in the process of creating an ES, or significantly lengthens it.

The expert determines the knowledge (data and rules) that characterize the problem area, ensures the completeness and accuracy of the knowledge entered into ES.

The knowledge engineer helps the expert identify and structure the knowledge necessary for the operation of ES; makes the choice of the toolkit that is most suitable for this problem area, and determines the way of representing knowledge in this toolkit; isolates and programs (by traditional means) standard functions (typical for this problem area) that will be used in the rules introduced by the expert.

The programmer develops the toolkit (if the toolkit is developed anew), containing in the limit all the main components of the ES, and carries out its interfacing with the environment in which it will be used.

The expert system operates in two modes: the mode of acquiring knowledge and the mode of solving the problem (also called the consultation mode or the ES usage mode).

In the mode of knowledge acquisition, communication with ES is carried out (through the knowledge engineer) by an expert. In this mode, the expert, using the knowledge acquisition component, fills the system with knowledge that allows the ES in the solution mode to independently (without an expert) solve problems from the problem area. The expert describes the problem area as a combination of data and rules.

A higher class of applications where it is required to take into account the dynamics of changes in the surrounding world during the execution of applications is called dynamic ES and their generalized structure will look like in Figure 3.

Compared with a static ES, two more components are introduced into a dynamic ES:

- subsystem of modeling the external world (external operating conditions of objects);
subsystem of interfacing with the outside world (operating features related to the working conditions of objects).

Dynamic ES communicates with the outside world through a system of controllers and sensors. In addition, the components of the knowledge base and the output mechanism are substantially changed to reflect the temporal logic of events taking place in the real world.

There are platforms that are an object-oriented environment for building and maintaining expert real-time systems designed to monitor, diagnose, optimize, plan and manage a dynamic process.

![Dynamic ES](image)

**Figure 3.** Dynamic ES

Dynamic ESs communicate with the outside world through a system of controllers and sensors. In addition, the components of the knowledge base and the output mechanism are substantially changed to reflect the temporal logic of events taking place in the real world.

Expert systems are designed for high-quality solution of problems in a field defined by developers, in rare cases, in several fields.

Decision Support System (DSS) is a computer-based automated system that, through the collection and analysis of a large amount of information, can influence the decision-making process of an organizational plan, the purpose of which is to help decision-makers in difficult conditions for a complete and objective analysis of subject activity.

Interactive systems allow managers to obtain useful information from primary sources, analyze it, and identify existing business models for solving specific problems.

According to user interaction, three types of DSSs are distinguished:

- **passive** ones help in the decision-making process, but may not put forward a specific proposal;
- **active** ones are directly involved in developing the right solution;
- **cooperative** ones involve interaction of the DSS with the user.

The proposal put forward by the system, can be modified, improved, and then send back to the system for verification by the user.

![DSS structure](image)

**Figure 4.** Typical DSS structure
After that, the proposal is again presented to the user, and so on until he approves the decision. By the method of support, they distinguish:

- **model-oriented DSSs** that use access to statistical or other models in their work;
- **DSSs based on communications** that support the work of two or more users engaged in a common task;
- **Data-driven DSSs** that have access to the organization’s time series.

They use in their work not only internal, but also external data; **document-oriented DSS** manipulate unstructured information contained in various electronic formats; knowledge-oriented DSSs provide specialized factual solutions to problems.

**The decision-making criterion** is a function that expresses the preferences of the decision-maker (DM) and determines the rule by which an acceptable or optimal solution is chosen.

Based on the results of data analysis, decisions are made. The following acceptance criteria are most often chosen: Sevage, Hurwitz criterion, Hodge-Limon criterion, Germeyer criterion; criteria of accordance to the decision: minimax criterion, Bayes-Laplace criterion, criterion with any evaluative information, the choice of which should be performed, the criterion of products, the minimax composite Bayes-Laplace criterion.

These criteria can be used in turn, and after calculating their values, one has to arbitrarily select some final solution among several options. This allows, firstly, obtaining better insight into all the internal connections of decision-making problems and, secondly, weakening the influence of the subjective factor.

Depending on the degree of unknownness of the upcoming behavior of the initial decision-making parameters, risk conditions are distinguished, in which the probability of occurrence of individual events that affect the final result can be established with some accuracy, and uncertainty conditions, in which, due to the lack of necessary information, such probability cannot be established.

The theory of decision-making under conditions of risk and uncertainty is based on the following starting points:

- the decision-making object is clearly determined and the main possible risk factors are known from it.
- the indicator that best describes the effectiveness of this decision is selected for the decision-making object.
- the indicator characterizing the level of its risk was selected for the decision-making object.
- there are a finite number of decision alternatives
- there are a finite number of situations in which an event develops under the influence of changes in risk factors. The number of such situations in the decision-making process should be determined in the range from extremely favorable (the most optimistic situation) to extremely unfavorable (the most pessimistic situation).
- for each combination of decision-making alternatives and events, a final indicator of the effectiveness of the decision can be determined (the specific value of the amount of net profit, net present value, etc., corresponding to this combination).
- for each of the situations under consideration, it is possible or impossible to assess the probability of its implementation. The possibility of making a probability assessment divides the entire system of risk decisions into the previously considered conditions for their justification (“risk conditions” or “uncertainty conditions”).
- the decision is made according to the best of the considered alternatives.
The CI-TREMS complex includes a different number of individual modules responsible for various aspects of production.

For example, one of such modules is the TPS program for monitoring the thermal engineering parameters of the soil along the route of the pipeline. This software module can work both autonomously and use the power of modern CAD software for more accurate and in-depth analysis (Figure 5).

The module allows accurately predicting soil temperature fluctuations, simulating the behavior of soil and structures located on it during thawing of the permafrost throughout the entire period of operation of the pipeline, or other structures and facilities under construction and operated in the Arctic region of Russia.

3. Conclusion
In the age of digital technology and the widespread automation of production, such intelligent systems as CI-TREMS [5-14] can reduce the number of emergencies at enterprises in the oil and gas sector, optimize the operation of existing facilities and help with the design of new stations and structures. Work requires a lot of labor to implement in real individual enterprises.

The modules can have simple visualization based on complex models and trends, allowing the operator to make safety decisions to reduce the risks and likelihood of accidents.

Throughout the entire life cycle of an enterprise, equipment or a specific unit, both integrated and individual modules will predict and warn about emergency situations, incidents, accidents. For most experts, it will be indispensable in optimizing and ensuring the effectiveness of technical solutions and managing processes of industrial enterprises in the oil and gas sector.
References

[1] Russian enterprises will switch to environmentally friendly technologies 2019 Available at: https://news.ecoindustry.ru/2018/03/s-2019-goda/

[2] Decree of the President of the Russian Federation 2017 Environmental Security Strategy of the Russian Federation until 2025 No. 176

[3] Federal Service for Ecological, Technological and Nuclear Supervision, available at: http://www.gosnadzor.ru/industrial/oil/lessons/

[4] Boards of the Federal Service for Ecological, Technological and Nuclear Supervision 2011 The concept of improving state policy in the field of industrial safety until 2020, available at: http://docs.cntd.ru/document/902354089.

[5] Zemenkova M Yu 2019 Methods to reduce technological and environmental risks in the transport and storage of hydrocarbons (Tyumen: TIU)

[6] Federal Service for Ecological, Technological and Nuclear Supervision 2018 Safety Guide "Guidelines for the classification of industrial events in the field of industrial safety at hazardous production facilities of the oil and gas complex" No. 29 available at: http://sudact.ru/law/prikaz-rostekhnadzora-ot-24012018-n-29-ob/rukovodstvo-po-bezopasnosti-metodicheskie-rekomendatsii/

[7] Zemenkova M Yu, Kurushina V A, Golik V V and Zemenkov Yu D 2019 System analysis and monitoring of energy technology complexes. Guidelines for the course project for students of the direction 21.04.01 Oil and gas business of the program "Reliability and Safety of Hydrocarbon Resource Transport Facilities" of all forms of training (Tyumen: Publishing Center BIK, TIU)

[8] Zemenkova M, Zemenkov Yu, Gladenko A and Podorozhnikov S 2016 Estimation of Emissions During Monitoring of Pipelines in the Dynamic Mode of Operation MATEC Web Conf. DOI: 10.1051/matecconf/20168604053

[9] Dudin S, Bahmat G, Zemenkov Yu, Voronin K and Shipovalov A 2017 Strategy for monitoring and ensuring safe operation of Russian gas transportation systems MATEC Web Conf. DOI: 10.1051/matecconf/201710606004

[10] Dudin S M, Zemenkov Yu D, Maier A V and Shabarov A B 2016 Research and Design of Thermophysical Gas-Liquid Mixture Parameters in Product Pipelines IOP Conference Series: Materials Science and Engineering DOI: 10.1088 / 1757-899X / 154/1/012021

[11] Pimnev A L, Zemenkova M Y, Zemenkov Y D and Iljyashchenko D P 2016 Mechanical Properties of the Assembly Welded Joint of the Oil Transportation Tank after a Long-Term Service IOP Conference Series: Materials Science and Engineering 127 (1) DOI: 10.1088 / 1757-899X / 127/1/012049

[12] Zemenkova M Y, Shipovalov A N and Zemenkov Y D 2016 Mathematical Modeling of Complex Hydraulic Machinery Systems When Evaluating Reliability Using Graph Theory IOP Conference Series: Materials Science and Engineering 127 (1) DOI: 10.1088 / 1757-899X / 127/1/012056

[13] Pump Station 2019, available at: https://3dwarehouse.sketchup.com/model/f44232ef-4732-409a-b34b-fa4eca4e37503/Pump-Station

[14] Chizhevskaya E L, Zemenkova M Y and Mayss N A 2020 Directions to Improve Effectiveness of Management of the Industry Company Personnel IOP Conf. Series: Earth and Environmental Science 459 052093 DOI: 10.1088 / 1755-1315 / 459/5/052093