

**ABSTRACT**  
**Of the thesis by**

**OSPA NOV YERBOL AMANGAZOVICH**

**"Development of mathematical model and algorithms for decision-making smart control systems production facilities", submitted for the degree of doctor of philosophy (PhD) on the specialty 6D070200 - "Automation and control"**

**Relevance of the research topic.** Currently, production facilities tend to be complex systems that are characterized by multiparametricities, multi-criteria, and uncertainty, often caused by the fuzziness of the available source information. As one of the promising approaches to solving research problems, optimization and management of such production systems can distinguish valid methods of making decisions by applying the relevant mathematical apparatus, of methodology of system analysis, methods of theory of fuzzy sets and expert assessments that take into account the experience, knowledge, and intuitions of experts, the decision makers (DM), i.e. the creation and application of intellectualized systems.

Today there is a series of works on methods of modeling and optimization of complex industrial facilities, on formalization and solution of decision-making problems in their management, many problems of an applied nature have been solved. However, there is a class of objects, different production situations and management tasks, formalization and solution of which in the framework of traditional approaches can not be obtained or does not give significant results. Such objects and tasks include production facilities of oil refining, metallurgical and other industries, functioning in conditions of uncertainty associated with the fuzziness of the initial information, and the problem of formalization and solving the problems of choosing rational modes of their operation in different production situations. In addition to the fuzziness of the initial information, the solution of these problems complicates the complexity and multicriteria of control objects. In this regard, at the present time, the study and solution of decision-making problems on effective management of production facilities, taking into account the multicriteria and fuzziness of input information and the creation of intellectualized decision-making systems based on the experience and knowledge of DM in decision-making, the use of methods and means of information technology is a very urgent task of science and production.

**Purpose of research.** The aim of the study is to develop methods for multi-criteria selection and construction of models of the selected production facility (object of study) with fuzzy initial information, and on their basis to create functional blocks of intellectualized systems that allow choosing a rational mode of operation of the object in different production situations.

**Research objectives.** In accordance with the aim, the following research objectives are set and solved:

- selection and research of a specific production facility, chemical and technological system (CTS) functioning under conditions of uncertainty and fuzzy initial information;
- formalization of various statements of problems of multicriteria choice in the management of production facilities in a fuzzy environment and development of methods for their solution;
- development of a methodology for the study of complex CTS and the construction of a system of their mathematical models in the conditions of information scarcity and fuzzy initial information;
- creation of architecture and basic functional blocks of intellectual (intellectualized) decision-making system (IDMS) for management of production facilities with the use of fuzzy set theory methods, expert assessments, i.e. development of a package of models of the object of study; heuristic algorithms for search and selection of effective modes of operation of the object; knowledge base and data; user-friendly interface;
- research of properties of the offered algorithms, approbation and use of results of scientific researches in industrial practice.

**Object of research.** The object of the dissertation research is a complex for the production of benzol, which is a complex chemical and technological system of the oil refining industry.

**Subject of research.** The subject of research is modern mathematical including informal methods of solving production problems in conditions of shortage of initial information (expert assessments, modeling, optimization and management) of research objects.

**Methods of research.** Methods of mathematical modeling, methods of multicriteria optimization and mathematical apparatus of fuzzy sets, as well as methods of organizing and conducting expert assessments, industrial and experimental verification of research results and technical and economic analysis were used to solve the objectives of the research.

**Scientific provisions and results to be defended:**

a) *new formulations of multicriteria selection and control problems* in a fuzzy environment and a developed *set of heuristic methods* for their solution, brought to the *dialog algorithms FMM; FMCC -Δ; FPS-PS*, which on the basis of modification of compromise schemes and principles of optimality in the case of fuzzy initial information, pose and solve problems using high-quality information, which will provide adequate solutions to complex production problems under uncertainty;

b) *the technique of creation of system of models* consisting in construction of various types of models of aggregates on the basis of available information of various character (theoretical, statistical and fuzzy) and uniting them in uniform system (package);

e) *the structure and main functional blocks of the intelligent decision-making system* for the selection of effective modes of operation of the complex for the

production of benzol in various production situations and in conditions of uncertainty;

C) *heuristic algorithms of multicriteria selection* in a fuzzy environment, and the results of their software implementation.

**The scientific novelty of the results** is as follows:

a) on the basis of modification and combination of compromise schemes: *Maximin, the main criterion and the Pareto optimality principle*, new statements of multicriteria choice in the management of production facilities (on the example of a benzol production complex) in a fuzzy environment are formalized for the first time and new heuristic algorithms for their solution are developed, which differ from the known ones in that the problems are posed and solved under uncertainty, using the available fuzzy information as much as possible. This approach allows taking into account the internal relationship between the parameters and obtain effective solutions to complex production problems in a fuzzy environment;

b) the novelty of the proposed methodology for constructing a system of models of CTS is that due to the introduced criteria for comparison and selection, as well as through the use of available information of various nature (including fuzzy), effective types of models are built, which are combined into a single system. The proposed method allows building effective models under uncertainty, systemically simulate CTS and determine the "bottleneck" of the system;

c) the proposed architecture and the main functional blocks of the intellectualized decision-making system for controlling benzol production processes differ from similar ones in that the system includes heuristic algorithms for searching and selecting effective modes of operation of the object in a fuzzy environment; knowledge and data base; user-friendly intellectualized interface;

d) the investigated properties and results of approbation of the proposed heuristic algorithms of multicriteria choice in a fuzzy environment, approbation and use of the results of scientific research in industrial practice shows the effectiveness of the proposed approach to solving the problem under study.

**Connection of work with other research works.** The dissertation work was carried out in accordance with the plans of research works of the Department of System analysis and management of L. N. Gumilyov Eurasian National University. In the process of research "Development of models and methods of decision-making in a fuzzy environment", (2017-2018. initiative research) state registration number 0118RKI0220 was carried out.

**Practical significance of the work.** The proposed approach and the developed methodology for constructing models of CTS and heuristic methods of multicriteria selection in a fuzzy environment allow building effective models and select effective modes of technological units of real CTS of oil refining, petrochemistry and other industries.

The obtained statements of multicriteria choice problems for control in a fuzzy environment and the developed algorithms for their solution allow finding rational modes and effectively manage complex CTS of various industries under conditions of uncertainty.

The developed methods of modeling, decision-making and management are used in the construction of mathematical models of technological units of the complex for the production of benzol of Atyrau refinery and solving problems of effective management of the process of production of benzol on the basis of the obtained models.

The results of the dissertation work are used in training courses taught by the Department of Automation and information technologies of the Shakarim State University of Semey, for specialties 5B070200-Automation and control, 5B070400-Computer engineering and software.

**Information about the implementation of scientific research.** The results of the dissertation work are implemented in educational processes and accepted for implementation in production:

1) pilot tests of the system of models and multi-criteria selection of effective modes of operation of the main units of the complex for the production of benzol of Atyrau refinery were carried out and adopted for implementation (there is a corresponding act );

2) were implemented in the educational process of the faculty of information and communication technologies of the Shakarim State University of Semey for students majoring 5B070200 "Automation and control", 5B070400 "Computer technology and software" and 6M070200 " Automation and control»;

3) were implemented in the educational process of L. N. Gumilyov Eurasian National University (acts of implementation in the educational process are attached).

**Personal contribution of the applicant.** The personal contribution of the author is :

- development of a new methodology for constructing a system of CTS models based on the use of available information of various nature (including fuzzy), which allows building effective models under uncertainty;

- development of a system of mathematical models of the main units of the complex for the production of benzol at Atyrau refinery;

- formulation of new problems of multicriteria selection and decision-making in fuzzy environment and development of effective algorithms for their solution;

- testing of research results in experimental and industrial conditions and in the application of their scientific and educational system.

**Approbation of the results of the thesis.** The main provisions and results of the work were reported and approved at the following international and scientific conferences:

1. XXI scientific and practical international conference "Scientific review of physical and mathematical and technical sciences in the XXI century" - Moscow, 2015.

2. International scientific and practical conference: "Innovative approaches and technologies to improve the efficiency of production in the conditions of global competition"-Semey, 2016.

3. World Congress on intelligent control and automation. Guilin, China, 2016
4. III Scientific and practical international conference "Intelligent information and communication technologies as a means of implementing the third industrial revolution in the light of the strategy "Kazakhstan-2050", Astana, 2016.
5. 16th International conference on management, automation and systems. – Korea, 2016
6. XI International scientific conference of students and young scientists "Science and education-2016" - Astana, 2016.
7. III International scientific-Practical conference "Information technologies in science management, Social sphere and medicine" Tomsk, 2016.
8. 9<sup>th</sup> Int. Conference on Theory and Application of Soft Computing, Computing with Words and Perception,- Budapest, 2017.

#### Publications.

The results obtained in the dissertation are published in 20 papers, including 5 articles recommended by the Committee for control in the field of education and science of the MES of Kazakhstan and 1 author's certificate No. 93 08.10.2018

1. Prinjatija reshenij pri upravlenii rezhimami raboty tehnologicheskikh ob'ektov v nechetkoj srede [Decision-making in the management of operating modes of technological objects in a fuzzy environment]. Bulletin of the L. N. Gumilyov Eurasian National University.- Astana, 2015.- №6(109). - Part 1. – P. 42-52.

2. Мұнай өңдеу технологиялық кешендерінің математикалық модельдерін айқынсыздық жағдайда құру тәсілі. [Method of development of mathematical models of technological complexes of oil refining production in conditions]. Bulletin of the L. N. Gumilyov Eurasian National University. - Astana, 2016. - P. 289-298.

3. Бензол өндіру технологиялық кешенінің құрымдалған моделін құру. [Development of a structured model of the technological complex of benzol production]. Bulletin of Satbayev Kazakh National Technical University. - Almaty, 2017. - No. 62 (120). – Pp. 352-358.

4. Razrabotka matematicheskikh modelej tehnologicheskikh kompleksov v nechetkoj srede na osnove sistemnogo podhoda [Development of mathematical models of technological complexes in fuzzy environment on the basis of system approach]. Bulletin of the state University. Shakarim State University of Semey. – Semey 2017. - No. 3 (79). - Pp. 26-32.

5. Gibridnyj metod razrabotki matematicheskikh modelej himiko-tehnologicheskoy sistemy v uslovijah neopredelennosti.[Hybrid method of development of mathematical models of chemical-technological system under uncertainty]. Journal of Mathematical modeling. - Moscow, 2017. - Volume 29, No. 4, - pp. 30-44.

6. The computer program "Sistema modelirovaniya i prinjatija reshenij po upravleniju rezhimami raboty kompleksa po proizvodstvu benzola"["System of

modeling and decision-making on management of modes of work of a complex on production of benzol"] (the author's certificate No. 93 08.10.2018 )

Two papers from the list are in the **SCOPUS** database:

1. Mathematical modeling for a reforming unit of chemical technological system in refinery production under uncertainty. International Journal of Applied Engineering Research. ISSN 0973-4562. Delhi.2016. -Volume 11, Number 11 P. 7278-7283

2. Hybrid method of development of mathematical models of chemical-technological systems under uncertainty. Mathematical Models and Computer Simulations ISSN: 2070-0482. Vol. 10, No. 6, 2018. P. 748.

3. Decision-making in the fuzzy environment on the basis of various compromise schemes. 9th International Conference on Theory and Application of Soft Computing, Computing with Words and Perception, Procedia Computer Science 120, 2017. – C945-952. Budapest, Hungary.

The main results of the dissertation were reported and discussed at international and foreign scientific conferences:

1. Mnogokriterial'naja optimizacijarezhimovrabotyagregatovnefteprovoda v nechetkojsrede i jevristical'skij algoritmeeresheniya [Multiobjective optimization of operating modes of the units of the pipeline in a fuzzy environment and a heuristic algorithm for its solution]. XXI Scientific and practical international conference "Scientific review of physical and mathematical and technical sciences in the XXI century" - Moscow, 2015.

2. Ақпараттың жетіспеушілігі және айқынсыздығымен сипатталатын өндірістік нысандардың модельдерін жасақтау. [Development of models of production facilities characterized by lack and uncertainty of information] Materials of the International scientific and practical conference: "Innovative approaches and technologies to improve the efficiency of production in the conditions of global competition" - Semey, 2016. – Volume 1. – P. 438-441

3. Mathematical modeling and decision-making on controlling modes of technological objects in the fuzzy environment. World Congress on Intelligent Control and Automation. Guilin, China 2016. P. 103-109.

4. Podhody k upravleniju tehnologicheskimi sistemami v uslovijah neopredelennosti [Approaches to the management of technological systems in conditions of uncertainty]. Materials of the III Scientific and practical international conference "Intelligent information and communication technologies as a means of implementing the third industrial revolution in the light of the strategy "Kazakhstan-2050". – Astana, 2016. – P. 344-346.

5. Razrabotka matematicheskikh modelej reaktorov UZK [Development of mathematical models of ultrasonic inspection of reactors]. Materials of the III Scientific and practical international conference "Intelligent information and communication technologies as a means of implementing the third industrial revolution in the light of the strategy "Kazakhstan-2050". – Astana, 2016. – P. 346-349.

6. Бензол өндіру кешенінің негізгі агрегаттарының математикалық модельдерінің жүйесін құру. [Creation of a system of mathematical models of the main units of the benzol production complex]. Materials of the III Scientific and practical international conference "Intelligent information and communication technologies as a means of implementing the third industrial revolution in the light of the strategy "Kazakhstan-2050". – Astana, 2016. – P. 299-302.

7. Control of Fuzzy Technological Objects Based on Mathematical Model. 2016 16-th International Conference on Control, Automation and Systems (ICCAS 2016) Oct 18-19 2016 in HICO, Gyengju, Korea. –P. 1487-1493.

8. Мұнай өңдеу технологиялық кешендерін модельдеу және оптимизациялау үшін интеллектуалды шешім қабылдау жүйесі. [Intelligent decision-making system for optimization and modeling of oil refining technological complexes]."Science and education-2016" Collection of materials of the international scientific conference of students and young scientists. - Astana, 2016. – P. 514-519.

9. Sistemnyj podhod k razrabotke matematicheskikh modelej slozhnyh tehnologicheskikh ob'ektov v uslovijah neopredelennosti [System approach to the development of mathematical models of complex technological objects under uncertainty]. III International scientific-Practical conference "Information technologies in science management, Social sphere and medicine" Tomsk, 2016. – Volume 1. – P. 63-65.

10. Decision-making in the fuzzy environment on the basis of various compromise schemes. 9th International Conference on Theory and Application of Soft Computing, Computing with Words and Perception, Procedia Computer Science 120, 2017. – C945-952. Budapest, Hungary.

**Volume and structure of the dissertation.** The dissertation work consists of an introduction, 4 chapters, conclusion and a list of used sources consisting from 98 titles, an appendix and contains 130 pages, 116 pages of which are the main text.

*The introduction* substantiates the relevance of the research topic, purpose, object, objectives and methods of research, scientific novelty, scientific provisions, practical value and implementation of the results of the work, provides information about publications and approbations of the work.

*In the first chapter* research and analysis of problems of development of mathematical models of production facilities and decision-making on their management are carried out; features of production facilities in the conditions of uncertainty are studied, production situations for which tasks of management of modes of work of CTS are put and solved.

*The second chapter* is devoted to the development of effective mathematical models of the main units of the complex for production of benzol (object of study) under uncertainty on the basis of information of different nature and heuristic methods of decision-making on management of modes of the object of study in fuzzy environment based on the developed models.

*In the third chapter* the structure is constructed and the main functional blocks of the intellectualized control system are created with the use of the developed models and heuristic methods of decision-making. Approaches to improving the intelligence of decision support systems are considered.

*In the fourth chapter* there investigated the properties of the developed algorithms for solving problems of decision-making on management of the CTS, examined and shown correctness, the performance and stability of the proposed algorithms to solve decision-making problems, the efficiency of the developed models and methods. In this chapter, the software implementation of the block of simulation of the semi-virtualized control system of the benzol production complex is also carried out.

*In conclusion*, the results of the work done in the framework of the thesis are summed up.

The content of the dissertation is completed with a list of used sources and appendices.