**ISSN 2518-170X (Online)**
**ISSN 2224-5278 (Print)**

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

# Х А Б А Р Л А Р Ы

# ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
Satbayev University

# N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

**SERIES**

**OF GEOLOGY AND TECHNICAL SCIENCES**

# 3 (459)

**MAY – JUNE 2023**

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

*NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.*

*Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.*

*НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.*

**«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/



Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

---

**«Известия НАН РК. Серия геологии и технических наук».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/



---

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

---

**News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.**

**ISSN 2518-170X (Online),**

**ISSN 2224-5278 (Print)**

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/



---

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 3, Number 459 (2023), 206–221
https://doi.org/10.32014/2023.2518-170X.310

UDC 665.6.7: 665.733.3

**© B. Orazbayev[1], M. Urazgaliyeva[2], A. Gabdulova[3], Zh. Moldasheva[1*], Zh. Amanbayeva[4], 2023**

[1] L.N. Gumilyov Eurasian National University, Astana, Kazakhstan;
[2] Caspian University of Technology and Engineering named after Sh. Yessenov, Aktau, Kazakhstan;
[3]Dosmukhamedov Atyrau University, Atyrau, Kazakhstan;
[3]Atyrau Oil and Gas University, Atyrau, Kazakhstan.
E-mail: zhadira1985@mail.ru

# METHODS OF MULTI-CRITERIA SELECTION IN PETROLEUM GEOLOGY UNDER CONDITIONS OF FUZZY INITIAL DATA

**Orazbayev B.B.** — Professor of the Department of System Analysis and Control, Gumilyov Eurasian National University, Doctor of Technical Sciences, Professor, Republic of Kazakhstan. Astana.
E-mail: batyr_o@mail.ru. ORCID: https://orcid.org/0000–0003–2109–6999;
**Urazgaliyeva M.K.** — Doctoral student of the Caspian University of Technology and Engineering named after. Sh. Yessenov
E-mail: mira_090578@mail.ru. ORCID: https://orcid.org/0000-0002-3622-2356;
**Gabdulova A.E.** — Kh.Dosmukhamedov Atyrau University, Atyrau, Kazakhstan
E-mail: kabae@list.ru. ORCID: https://orcid.org/0000-0001-8753-2007;
**Moldasheva Zh.Zh.** — Doctoral student of the Department of Information Systems of the Gumilyov Eurasian National University, Republic of Kazakhstan, Astana
E-mail: zhadira1985@mail.ru. ORCID https://orcid.org/0000–0002–0559–3410;
**Amanbayeva Zh.Sh.** — Senior lecturer of the Faculty of "Information Technologies" of Atyrau University of Oil and Gas named after S. Utebayev, Republic of Kazakhstan, Atyrau city
E-mail: zhak-7777@mail.ru. ORCID https://orcid.org/0009-0005-2200-4453.

**Abstract.** The article is devoted to the study and to the solution of one of the urgent problems of petroleum geology, related to the choice of optimal parameters for the development and production of oil in conditions of uncertainty due to the lack and fuzziness of the initial information. The problems of solving problems of multi-criteria choice for optimizing the operating modes of oil wells in a fuzzy environment are investigated and approaches to their solution are proposed. Mathematical formulations of the problems of choosing the optimal parameters of the object of study in a fuzzy environment are formalized and obtained based on the modification of the ideal point principle and a given number of priorities of local criteria. Algorithms for solving the set problems based on the involvement of DM in the process of choosing a solution using the level set α, the principles of an ideal point and the lexicographic ordering of criteria are developed and described. The proposed algorithms for solving problems of multi-criteria choice in fuzzy are heuristic and allow you to iteratively improve solutions in the dialogue between "DM — decision support system". At the same time, the decision support system is a software and hardware complex consisting of software-implemented object models and proposed algorithms for solving the tasks. In the proposed algorithm of the formulated multicriteria choice problem based on the use of the modified ideal point (desired solution) principle, the improvement of the criteria values for some fixed values of the ideal points is realized only by reducing the level α, i.e., the reliability of the solution. By adjusting the desired values of local criteria, it is possible to take into account the DM's preferences for different local criteria, which allows changing their weight coefficients. This allows the DM to choose the best solution depending on the current production situation and the market demand for the manufactured products. The proposed method based on the lexicographic principle is applicable when it is impossible to predetermine the desired values of the criteria and, given a number of priorities of local criteria, allows you to consistently improve their values. The obtained results of the study make it possible to more effectively solve the problems of multi-criteria choice when optimizing objects of petroleum geology in a fuzzy environment.

**Key words:** Multicriteria choice, decision maker (DM), fuzzy information, ideal point principle, lexicographic ordering of criteria

**© Б.Б. Оразбаев[1], М.К. Уразгалиева[2], А.Е. Габдулова[3], Ж.Ж. Молдашева[1*], Ж.Ш. Аманбаева[4], 2023**

[1]Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан;
[2]Ш.Есенов атындағы Каспий технологиялар және инжиниринг университеті, Ақтау, Казақстан;
[3]Х. Досмұхамедов атындағы Атырау университеті, Атырау, Казақстан;
[3]С. Өтебаев атындағы Атырау мұнай және газ университеті, Атырау, Казақстан.
E-mail: zhadira1985@mail.ru

## АЙҚЫНСЫЗ БАСТАПҚЫ ДЕРЕКТЕР ЖАҒДАЙЫНДА МҰНАЙ ГЕОЛОГИЯСЫНДА КӨПКРИТЕРИЙЛІ ТАҢДАУ ТӘСІЛДЕРІ

**Оразбаев Б. Б.** — Л.Н. Гумилев атындағы Еуразиялық ұлттық университеті, «Жүйелік талдау және басқару» кафедрасының профессоры
E-mail: batyr_o@mail.ru. ORCID: https://orcid.org/0000–0003–2109–6999;
**Уразгалиева М.К.** — Ш. Есенов атындағы Каспий технология және инжиниринг университеті
E-mail: mira_090578@mail.ru. ORCID: https://orcid.org/0000-0002-3622-2356;
**Габдулова А.Е.** — Х.Досмұхамедов атындағы Атырау университеті, «Бағдарламалық инженерия» кафедрасының магистр, аға оқытушысы Атырау, Қазақстан
E-mail: kabae@list.ru. ORCID: https://orcid.org/0000-0001-8753-2007;
**Молдашева Ж.Ж.** — Л.Н. Гумилев атындағы Еуразиялық ұлттық университеті, «Ақпараттық жүйелер» кафедрасының докторанты
E-mail: zhadira1985@mail.ru. ORCID https://orcid.org/0000–0002–0559–3410;
**Аманбаева Ж.Ш.** — С. Өтебаев атындағы Атырау Мұнай және газ университетінің «Ақпараттық технологиялар» факультетінің аға оқытушысы, Атырау қ.
E-mail: zhak-7777@mail.ru. ORCID https://orcid.org/0009-0005-2200-4453.

**Аннотация.** Мақала мұнай геологиясының өзекті мәселелерінің бірі, бастапқы ақпараттың жетіспеушілігі мен айқын еместігіне байланысты анықсыздық жағдайында мұнай кенорындарын игеру мен мұнай өндіру процесстерінің оптималды параметрлерін таңдау мәселелерін зерттеуге және шешуге арналған**.** Айқын емес ортада мұнай ұңғымаларының жұмыс режимдерін оптимизациялау үшін көпкритерийлі таңдау есептерін шешу мәселелері зерттеліп, оларды шешу тәсілдемелері ұсынылды. Айқынсыздықта зерттеу нысанының оптималды параметрлерін таңдау есептерінің математикалық қойылымдары идеалды нүкте принципін модификациялау және локалды критерийлердің басымқылырының берілген саны негізінде рәсімделген және алынған. α деңгейлі жиынын пайдалана отырып, шешімді таңдау процесіне ШТҚ-ны қатыстыру негізінде қойылған есептерді шешу алгоритмдері, идеалды нүкте және критерийлерді лексикографиялық реттеу принциптеріне негізделген. Айқынсыздықта көпкритенрийлі таңдау есептерін шешу үшін ұсынылған алгоритмдер эвристикалық болып табылады және «ШҚТ — шешімдерді қолдау жүйесі» арасындағы диалог арқылы шешімдерді итеративті түрде жақсартуға мүмкіндік береді. Мұнда шешімдерді қолдау жүйесі бағдарламалық қамтамасыз ету арқылы жүзеге асырылған нысан модельдері мен  қойылған есептерді шешуд үшін ұсынылатын алгоритмдерінен тұратын бағдарламалық-аппараттық кешен болып табылады. Модификацияланған идеалды нүкте (қажетті шешім) принципін пайдалануға негізделген тұжырымдалған көпкритерийлі таңдау есебін шешуге ұсынылған алгоритмінде идеалды нүктелердің кейбір бекітілген мәндері үшін критерий мәндерін жақсарту $\alpha$ деңгейін, яғни шешімнің сенімділігін  төмендету арқылы ғана жүзеге асырылады. Локалды критерийлердің қажетті мәндерін өзгерте отырып, олардың салмақ коэффициенттерін өзгертуге, яғни ШҚТ басымқылырын ескеруге болады. Бұл ШҚТ-ға ағымдағы өндірістік жағдайға және өндірілген өнімге нарық сұранысына байланысты ең жақсы шешімді таңдауға мүмкіндік береді. Лексикографиялық принципке негізделген ұсынылған тәсіл критерийлердің қажетті мәндерін алдын ала анықтау мүмкін болмаған кезде қолданылады және локалды критерийлердің басымдықтарын басымдықтары берілгенде, олардың мәндерін тізбектей  жақсартуға мүмкіндік береді. Зерттеуде алынған нәтижелер айқын емес ортада мұнай геологиясы нысандарын оптимизациялау кезінде көпкритерийлі таңдау есептерін тиімдірек шешуге мүмкіндік береді.

**Түйін сөздер:** Көпкритерийлә таңдау, шешім қабылдаушы тұлға (ШҚТ), айқын емес ақпарат, идеалды нүкте принципі, критерийлердің лексикографиялық реті

**© Б.Б. Оразбаев[1], М.К. Уразгалиева[1], А.Е. Габдулова[3], Ж.Ж. Молдашева[1*], Ж.Ш. Аманбаева[4], 2023**

[1]Евразийский национальный университет имени Л.Н. Гумилев, Астана, Казахстан;
[2]Каспийский университет технологии и инжиниринга им. Ш.Есенова, Актау, Казахстан;
[3]Атырауский университет им. Х. Досмухамедова, Атырау, Казахстан;
[4]Атырауский университет нефти и газа им. С.Утебаева, Атырау, Казахстан.
E-mail: zhadira1985@mail.ru

# МЕТОДЫ МНОГОКРИТЕРИАЛЬНОГО ВЫБОРА В НЕФТЯНОЙ ГЕОЛОГИИ В УСЛОВИЯХ НЕЧЕТКОСТИ ИСХОДНЫХ ДАННЫХ

**Оразбаев Б.Б. —** Профессор кафедры «Системного анализа и управления» Евразийского национального университета имени Л.Н. Гумилева, доктор технических наук, профессор. г. Астана
E-mail: batyr_o@mail.ru. ORCID: https://orcid.org/0000–0003–2109–6999;
**Уразгалиева М.К. —** докторант Каспийского университета технологий и инжиниринга им. Ш. Есенов
E-mail: mira_090578@mail.ru. ORCID: https://orcid.org/0000-0002-3622-2356;
**Габдулова А.Е. —** Атырауский университет им. Х. Досмухамедова, Атырау, Казахстан
E-mail: kabae@list.ru. ORCID: https://orcid.org/0000-0001-8753-2007;
**Молдашева Ж.Ж. —** докторант кафедры «Информационных систем» Евразийского национального университета имени Л.Н. Гумилева, Республика Казахстан, г. Астана
E-mail: zhadira1985@mail.ru. ORCID https://orcid.org/0000–0002–0559–3410;
**Аманбаева Ж.Ш. —** старший преподаватель факультета "Информационные технологии" Атырауского университета нефти и газа имени С. Утебаева, г. Атырау
E-mail: zhak-7777@mail.ru. ORCID https://orcid.org/0009-0005-2200-4453.

**Аннотация**. Статья посвящена исследованию и решению одной из актуальных задач нефтяной геологии, связанной выбором оптимальных параметров процессов разработки и добычи нефти в условиях неопределенности из-за дефицита и нечеткости исходной информации. Исследованы проблемы решения задач многокритериального выбора для оптимизации режимов работы нефтяных скважин в нечеткой среде и предложены подходы к их решению. Формализованы и получены математические постановки задач выбора оптимальных параметров объекта исследования в нечеткой среде на основе модификации принципа идеальной точки и заданном ряде приоритетов локальных критериев. Разработаны и описаны алгоритмы решения поставленных задач, основанные на привлечение DM в процессе выбора решения с использованием множества уровня $\alpha$, принципов идеальной точки и лексикографического упорядочения критериев. Предложенные алгоритмы решения задач многокритериального выбора в нечеткой являются эвристическими и позволяют итеративно улучшить решения в диалоге между «DM — система поддержки принятия решений». При этом система поддержки принятия решений представляет собой программно-аппаратный комплекс, состоящий из программно реализованных моделей объекта и предложенных алгоритмов решения поставленных задач. В предлагаемом алгоритме сформулированной

задачи многокритериального выбора на основе использование модифицированного принципа идеальной точки (желаемого решения) улучшения значений критериев при некоторых фиксированных значениях идеальных точек реализуется только за счет снижения уровня $\alpha$, т.е. надежности решения. Корректируя желаемых значений локальных критериев, можно учитывать предпочтения DM к разным локальным критериям, что позволяет менять их весовые коэффициенты. Это позволяет выбрать DM наилучшего решения в зависимости от сложившейся производственной ситуации и рыночного спроса на производимую продукцию. Предложенный метод на основе лексикографического принципа применим, когда невозможно заранее определить желаемых значений критериев и при заданном ряде приоритетов локальных критериев позволяет последовательно улучшить их значения. Полученные результаты исследования позволяют более эффективно решать задач многокритериального выбора при оптимизации объектов нефтяной геологии в нечеткой среде.

**Ключевые слова**: многокритериальный выбор, лицо, принимающее решение (DM), нечеткая информация, принцип идеальной точки, лексикографическое упорядочение критериев

**Introduction**

With the expansion of the range of production tasks, including in geology, in which the best solution is selected from a variety of alternatives in which a special role in making decisions belongs to a person, there is a need to take into account human characteristics when describing the system. When solving such problems, uncertainty and complexity are generated, associated with a large number of alternatives, a vague description of the selection criteria, possible limitations and parameters of the geological system under study (Urazgaliyeva et al., 2023; Orazbayev et al., 2020). At the same time, the main part of the initial information needed to solve the problem is formalized knowledge and experience in the form of the judgment of the decision-maker (LPR), experts in the subject area, for example, experienced geologists. The judgment of the LPR, experts is usually expressed in natural language and is characterized by vagueness, ambiguity, which is due to the peculiarities of human psychology and language (the diversity of concepts and categories of thinking) (Ryzhov, 2017). As a rule, in the process of setting a problem and choosing a solution, the LPR finds it difficult to formulate optimization goals clearly enough, i.e. its ideas about the "best" alternative are fuzzy.

The judgment, the statement of the LPR evaluating the system, the selection criteria, as a rule, have a verbal form of the form "the more, the better" or contain an approximate indication of the numerical values of the restrictions of the type "this parameter should be approximately in such a range". In addition, expert information in the form of point or verbal gradations is used to evaluate the systems under study according to criteria measured in a scale of intervals or order (Lukianova et al., 2019). Thus, the vague nature of the descriptions in the formulation of multicriteria selection problems and in the preferences of experts when choosing a solution lead to the need to formalize and solve fuzzy problems based on the methods of fuzzy set theories (Zimmermann, 2018; Rakhmetov et al., 2022).

Multicriteria selection problems in practice are often formulated and solved in the form of mathematical programming problems, which are investigated in the works (Pishvaee et al., 2020; Liang et al., 2018, Shvedov, 2017). When setting and solving problems of fuzzy mathematical programming, the main difficulties arise due to the multi-criteria nature of the problem being solved, uncertainty and lack of initial information necessary for constructing a model of the problem and choosing a solution (Orazbayev et al., 2021). At the same time, the problem of uncertainty in the formalization and solution of multicriteria selection problems may be associated with randomness or vagueness of the initial information.

If uncertainty arises due to the random nature of the initial information, then such uncertainty can be eliminated or reduced using methods of probability theory and mathematical statistics, for example, those studied in the works (Botev et al., 2020; Gmurman, 2020; Mary, 2019). It should be noted here that in order to apply probabilistic methods to solve uncertainty problems, it is necessary to fulfill the conditions of the basic axioms of probability theory. The main axioms of probability theory include: repeated execution of experiments to collect data under the same conditions; the presence of an array of statistical data; statistical stability of the object of study, etc. But in reality, these conditions are often not met, for example, some important parameters, production indicators that affect the quality of the object are poorly measured or not measured at all, the necessary amount of statistical data is missing. Such tasks include multi-criteria selection tasks in a fuzzy environment, where it is necessary to use and take into account subjective information or DM preferences when choosing the optimal solution. Under these conditions, the use of probabilistic methods to solve uncertainty problems in selection problems is not justified.

Often, even the use of probabilistic, statistical methods is possible, the complexity of collecting and processing statistical data can lead to inefficiency in the use of these methods. Thus, the conditions for the applicability of probabilistic methods, a large error in calculations or the economic inexpediency of using these methods require other, for example, non-statistical approaches to describing and solving real problems of multi-criteria selection in conditions of uncertainty. As the most effective approach to solving multicriteria selection problems in the conditions of uncertainty, it is possible to identify fuzzy schemes for solving such problems based on expert evaluation methods and fuzzy set theories set forth in the works (Lukianova et al., 2019, Gutsykova, 2017, Sabzi et al., 2018; Ryzhov, 2017; Zimmermann, 2018; Pishvaee et al., 2022).

In the work of Leonova N.L., a study of the sensitivity of solving linear programming problems used to solve optimization problems of production, i.e. complex objects and processes under conditions of uncertainty (Leonova, 2020). But in this work, the issues of solving the problems under study in the conditions of initial information fuzziness are not investigated. In works on stochastic programming (Can Li et al., 2021; Goel et al., 2019) an approach to solving the problems of uncertainty arising from the presence of stochastic variables is proposed. In these studies, an approach to the development of optimization algorithms that can effectively solve initial problems in noisy information conditions is proposed. In these analyzed research papers, the usual, i.e. clear information is used to analyze the state of the optimized objects and in the optimization process, and the lack of information is not explicitly taken into account in the models. But in practice, many real objects and tasks are described by fuzzy information, which is the experience, knowledge, intuition, judgments of experts in the subject area, LPR about the functioning of the object and reflects their ideas in the process of choosing the best solution. Moreover, it is often very difficult or impossible to transform such fuzzy, semantic information into clear information. In the process of such conversion, many important information can be lost. Therefore, the need to take into account such fuzzy information stimulates the development of new, fuzzy approaches to solving multicriteria selection problems in a fuzzy environment (Orazbayev et al., 2019: 1–6).

The purpose of this study is to formalize and obtain a correct formulation of the multi-criteria selection problem for solving problems of geology in uncertainty and to develop algorithms for their solution.

**Research materials and methods**

In practice, optimization problems are often characterized not only by multi-criteria, but also by the inconsistency of these criteria in the field of effective solutions and fuzziness (for example, criteria, constraints, priorities, weights, etc.). To solve such multi-criteria optimization problems in this paper, they are formalized and posed as multi-criteria selection problems in a fuzzy environment. To solve the obtained problem, heuristic algorithms for their solution are proposed, based on the use of a set of level α from the mathematical apparatus of fuzzy set theories and on involving in the process of choosing a solution of the LPR.

To formalize the task of multi-criteria selection for solving problems of petroleum geology in a fuzzy environment, the following designations are introduced: $f_1(\mathbf{x}),\ldots,f_m(\mathbf{x})$ criteria that evaluate the effectiveness of the chosen solution. These criteria constitute a vector of criteria $\mathbf{f}(\mathbf{x})=(f_1(\mathbf{x}),\ldots,f_m(\mathbf{x}))$, где $\mathbf{x}=(x_1,\ldots,x_n)$ vector of input parameters (independent variables); $\boldsymbol{\gamma}=(\gamma_1,\ldots,\gamma_m)$ vector of weight coefficients $\gamma_1,\ldots,\gamma_m$, evaluating the importance of criteria $f_1(\mathbf{x}),\ldots,f_m(\mathbf{x})$.

Each solution is characterized by the value of criteria in points $x_1,\ldots,x_n$ : $f_1(x_1,\ldots,x_n),\ldots,$ $f_m(x_1,\ldots,x_n)$. Первым этапом решения задачи многокритериального выбора, а иногда ее окончательным решением, является определение таких значений вектора $\mathbf{x}=(x_1,\ldots,x_n)$, highlighting the set of effective solutions (the Pareto set) in which the values of one particular criterion $f_i(\mathbf{x})\in f(\mathbf{x}),\ i\in I$ м it can be improved only by worsening the value of other criteria $f_j(\mathbf{x}),\ j\in I,\ i\neq j$, где $I=\{1,\ldots,m\}$ multiple criteria indexes.

Then the solution of the multi-criteria choice problem in a fuzzy environment consists in choosing the LPR of such a solution (alternative) that provides the best values of the criteria $f_1(\mathbf{x}),\ldots,f_m(\mathbf{x})$ in an acceptable set, taking into account the imposed restrictions. In this case, one or more criteria or restrictions are characterized by fuzziness. In this regard, when setting and solving such problems, it is necessary in one way or another to use the methods of expert assessments (Lukianova et al., 2019; Gutsykova, 2017; Sabzi et al., 2018) and the theory of fuzzy sets (Ryzhov, 2017; Zimmermann, 2018; Pishvaee et al., 2022).

In depending on the source of fuzziness, multi -criteria selection tasks in a fuzzy environment can be divided into the following main types:

1. Multi-criteria selection tasks with fuzzy criteria $\tilde{f}_i(\mathbf{x}), i=\overline{1,m}$;

2. Multi-criteria selection problems with fuzzy maximization operators

$\widetilde{\max} f_i(\mathbf{x})$, instructions of the form: «It is desirable that $f_i(x), i=\overline{1,m}$, there was more»;

3. Multi-criteria selection problems with fuzzy constraints. Such fuzzy constraints can be formalized as: «It is desirable that the values of the constraint function be at least $\varphi_q(\mathbf{x}) \tilde{<} b_q, q=\overline{1,L}$ (no more $\tilde{>}$, approximately equal $\tilde{\cong}$);

4. Multi-criteria selection tasks with a fuzzy weight vector, a number of priority criteria and/or constraints;

5. Multi-criteria selection problems with fuzzy constraints on independent variables $\mathbf{x}=(x_1,\dots,x_n)$ like: $\mathbf{x}\in\tilde{C}$, where $\tilde{C}$ fuzzy set;

In this paper, multi-criteria selection problems for solving geological problems with fuzzy criteria and constraints will be formulated and their solutions based on expert evaluation methods and fuzzy set theories will be proposed. The tasks of multi-criteria selection are set and solved on the basis of the maximin principle and subject to a known number of priority criteria. The proposed methods for solving the multi-criteria selection problem are based on minimizing the mismatch of the criterion values from their desired values. The procedure for optimizing the parameters of a geological object is carried out on the basis of models that are fuzzy in such conditions. To solve the proposed multicriteria selection problems, sets of level α are used, with the help of which the original fuzzy problem is replaced by a set of clear tasks.

**Results**

The mathematical formulation of the multi-criteria choice problem for solving a geological problem in the initial environment based on the ideal point and minimax methods is obtained in the following form.

Find the vector of input parameters $\mathbf{x}^*=(x_1^*,\dots,x_n^*)$ geological system, which is a solution to the problem of multi-criteria selection, which provide the best approximation of the vector of selection criteria $\mathbf{f}(\mathbf{x})=(f_1(\mathbf{x}),\dots,f_m(\mathbf{x}))$ to their desired values $\mathbf{f}^*(\mathbf{x}^*)=(f_1^*(\mathbf{x}^*),\dots,f_m^*(\mathbf{x}^*))$:

$$\min_{\mathbf{x}\in X}\left|\tilde{f}_i(\mathbf{x},\alpha_i)-f_i^*(\mathbf{x})\right|, i=\overline{1,m}, \tag{1}$$

$$X=\left\{\mathbf{x}:\mathbf{x}\in\wedge\arg(\varphi_q(\mathbf{x},\mathbf{y})\tilde{\geq} b_q)\wedge\alpha\in L_\alpha(\tilde{\alpha}), q=\overline{1,L}\right\}, \tag{2}$$

где $\tilde{f}_i(\mathbf{x},\alpha_i)$ fuzzy local criteria (all or part of them), the values of which are calculated by models; $f_i^*(\mathbf{x}), i=\overline{1,m}$ desirable (ideal) values of local criteria set by the LPR;

$\varphi_q(\mathbf{x},\mathbf{y}) \tilde{\geq} b_q, q=\overline{1,L}$ — fuzzy constraints; $b_q, q=\overline{1,L}$ — set numbers; $L_\alpha(\tilde{\alpha}_i)=\{\alpha_i : \mu_A(\alpha_{is}) \geq \alpha, \alpha \in [0{,}5 \div 1.0], s=\overline{1,\rho_i}\}$ the set of level α of fuzzy parameters introduced to account for the fuzziness of parameters $\alpha_i$ on the s — th term.

In the resulting formulation of the multi-criteria selection problem in a fuzzy environment, the values of the selection criteria $f_1(\mathbf{x}),...,f_m(\mathbf{x})$ The parameters are determined on the basis of mathematical models of the optimized geological system: $\mathbf{y}=(y_1,...,y_m)=f_1(\mathbf{x}),...,f_m(\mathbf{x})$ depending on the value of the input parameter vector $\mathbf{x}=(x_1,...,x_n)$ (Kuanbayeva, et al, 2022). At the same time, mathematical models of the optimized system should also be developed taking into account the fuzziness of the initial information, i.e. fuzzy models are synthesized.

Values of fuzzy constraints $\varphi_q(\mathbf{x},\mathbf{y})=\varphi_q(\mathbf{x}, f_1(\mathbf{x}),...,f_m(\mathbf{x})) \tilde{\geq} b_q, q=\overline{1,L}$ as can be seen from (2), it also depends on the vector of input parameters that affect the operation of the system and the chosen solution, and are determined using models of the geological system

Local criteria $f_i(\mathbf{x}), i=\overline{1,m}$ combined into a vector function $\mathbf{f}(\mathbf{x})=(f_1(\mathbf{x}),...,f_m(\mathbf{x}))$ , which expresses the interest of the LPR in a particular state or mode of operation of the system. In practice, depending on the current situation, the importance of local criteria changes. Each of the m criteria depends on the vector of input parameters $\mathbf{x}=(x_1,...,x_n)$ and it may differ in its coefficients of relative importance $\gamma_1,...,\gamma_m$, the values of which vary depending on the current situation.

Given the values of the input parameter vector $\mathbf{x}=(x_1,...,x_n)$ criteria $f_i(\mathbf{x}), i=\overline{1,m}$ they take certain values. One of the tasks of multi-criteria is the selection of such vectors $\mathbf{x}=(x_1,...,x_n)$, which highlights the Pareto set.

Expediency of minimax formulation of the multicriteria choice problem (1)-(2) it can be explained by the fact that most production systems are expensive, and the task of optimizing them has to be solved under conditions of uncertainty. Under these conditions, it is reasonable to evaluate the quality of the system according to the minimax principle, which ensures a guaranteed result. To effectively solve the problem of multi-criteria choice (1)-(2), an approach based on the idea of identifying and taking into account the preferences of LPR simultaneously with the study of an acceptable set of solutions for finding effective solutions implemented on human-machine systems can be used.

The human-machine decision-making procedure is a cyclical process of interaction between a person, i.e. a computer and a computer. The cycle consists of a phase of analysis and decision-making (setting tasks for a computer) performed by the LPR, and an optimization phase (finding a solution and calculating its characteristics) implemented by a computer. In the process of interaction, the LPR clarifies the characteristic features of the task, reveals additional information, thanks to which the computer determines more and more perfect solutions.

Thus, as a result of solving the problem of multi-criteria selection for the optimization of geological systems in conditions of scarcity and vagueness of initial information, rational modes of operation of the system are determined and selected according to the selected criteria. The flowchart of the developed heuristic algorithm for solving the problem of multi-criteria selection in a fuzzy environment (1)–(2) based on the minimax principle using a set of level α is shown in Figure 1.

Fig. 1 – Block diagram of the algorithm for solving the multi-criteria selection problem in a fuzzy environment

We describe the main blocks of the proposed heuristic algorithm for solving the problem of multi-criteria selection in a fuzzy environment.

In block 2, the initial data, the values of the intervals of the set of level α, for example, from 0.5 to 1.0, and the corresponding reliability levels (RL) are entered. For example, the following can be highlighted RL: RL=1, by $0.9 \leq \alpha$ 1.0 highly reliable solution; RL=2, by $0.7 \leq \alpha$ 9.0 reliable; RL=3, by $0.5 \leq \alpha$ 0.7 medium reliable; RL=4, by $0.0 \leq \alpha$ 0.5 low reliable.

In block 3, the DM enters the ideal, desired values of the criteria $\mathbf{f}^*(\mathbf{x}^*) = \left(f_1^*(\mathbf{x}^*),\dots,f_m^*(\mathbf{x}^*)\right)$.

The solution of the minimization problem (1) on the set of acceptable solutions X, determined by the expression (2), is performed in block 4, i.e. the difference between the values of the optimization criteria is minimized $\tilde{f}_i(\mathbf{x}, \alpha_i), i = \overline{1,m},$ and their ideal, desired values

$f_i^*, i = \overline{1,m}.$ The current results obtained for various levels of reliability

$\min_x; \tilde{f}_i(\mathbf{x},\alpha_i)$ output in block 5.

In block 6, the received current values of the criterion are checked $\tilde{f}_i(\mathbf{x},\alpha_i)$ and RL satisfy DM or not. If yes, i.e. $\tilde{f}_i(\mathbf{x},\alpha_i)$ and the RL satisfy the DM, then to output the final solutions selected by the DM go to block 10. Otherwise, i.e. if and RL do not satisfy DM, then in block 7 DM enters a new value of α and/or makes the transition to the next level of reliability according to the formula DM=DM+1.

In block 8, the condition of not exceeding the reliability levels RL of the specified

REG value is checked. If it does not exceed, i.e. RL≤$RL^G$, then the search for new solutions continues starting from block 4. If it exceeds, i.e.. RL>$RL^G$, then the DM adjusts the desired values of the criteria

$f_i^*, i = \overline{1,m}$ in block 9, the search for new solutions is carried out starting from block 4.

Block 10 displays the final best solutions selected DM: $\mathbf{x}^* = (x_1^*, \dots, x_n^*)$ the optimal value of the vector of input parameters of the geological system, providing the best values of the criteria

$f_i^*(\mathbf{x}^*, \alpha_i)$ with the required set of level α and the required level of reliability RL.

This proposed and described algorithm is based on a combination of the idea of the ideal point methods and allows the DM to choose a compromise solution between the values of the optimized function and the reliability of the recommended control, depending on the state of the object, the production situation. Such an algorithm is effectively used when the values of local criteria are characterized by fuzziness, for example, due to the fuzziness of the model, the management goal, etc. and the DM code, it is necessary to obtain a solution result that is close to the desired results.

Let's consider other approaches to solving the problem of multi-criteria selection, which also rely on mathematical models of the optimized system. These approaches are based on modification of the well-known principles of multi-criteria optimization (Orazbayev et al., 2019: 182194; Chen et al., 2018).

*Methods for solving the problem of multi-criteria selection using the principle of lexicographic ordering of criteria. In these methods, the criteria are ordered by importance, after which the best alternative is considered to have a higher score on a more important criterion, regardless of the scores on the other criteria.*

Let's say as above $\mathbf{x} = (x_1, \dots, x_n)$ the vector of the input parameters of the oil production system, and the criteria depending on them are ordered by importance, and the criteria may be fuzzy

$$\tilde{f}_1(\mathbf{x}) \succ \tilde{f}_2(\mathbf{x}) \succ, \dots, \succ \tilde{f}_m(\mathbf{x}).$$

where $\succ$ a sign that the criteria $\tilde{f}_i(\mathbf{x})$ preferable to the criterion $\tilde{f}_{i+1}(\mathbf{x}), i = \overline{1, m-1}$.

Then it is possible to make a consistent optimization, i.e. the choice of a solution according to the scheme, lexicographic principle:

$$1.\ X_1 = \{\mathbf{x} : \arg \tilde{f}_1^*(\mathbf{x}, \alpha_1) = \arg \underset{\mathbf{x} \in \Omega}{opt}\, \tilde{f}_1(\mathbf{x}^*, \alpha_1)\}$$

$$2.\ X_2 = \{\mathbf{x} : \arg \tilde{f}_2^*(\mathbf{x}, \alpha_2) = \arg \underset{\mathbf{x} \in X_1}{opt}\, \tilde{f}_2(\mathbf{x}^*, \alpha_2)\}$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$L.\ X = \{\mathbf{x} : \arg \tilde{f}_L^*(x, \alpha_L) = \arg \underset{\mathbf{x} \in X_{L-1}}{opt}\, \tilde{f}_L(\mathbf{x}^*, \alpha_L)\} \quad (3)$$

where $X_1$, $X_2$,…, $X_L$ many alternatives; $\alpha_q \in L_\alpha(\tilde{\alpha}_q)$ parameters that take into account the fuzziness of the original information; opt - optimization operator max or min It is clear that if the optimized criterion, for example, is the productivity of oil wells, the quality indicators of the object, the profit from the products sold, etc., then max is selected as the optimization operator. If the criteria express losses, production costs, material, energy and other costs, then min is selected as the optimization operator.

The disadvantage of this approach is that the mutual importance of local criteria is not taken into account. To solve this problem, you can enter the values $\Delta_q$, $q=\overline{1, L-1}$ , allowing to take into account the importance of particular criteria (the principle of quasi-optimality).

$$
\begin{aligned}
&1.\ X_1 = \{\mathbf{x} : \arg \widetilde{f}_1^*(\mathbf{x},\alpha_1) = \arg \underset{\mathbf{x}\in\Omega}{opt}\, \widetilde{f}_1(\mathbf{x}^*, \alpha_1 - \widetilde{\Delta}_1)\}\\
&2.\ X_2 = \{\mathbf{x} : \arg f_2(\mathbf{x},\alpha_2) = \arg \underset{\mathbf{x}\in X_1}{opt}\, f_2(\mathbf{x}^*, \alpha_2 - \Delta_2)\}\\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\
&L.\ X_L = \{\mathbf{x} : \arg \widetilde{f}_L^*(\mathbf{x},\alpha_L) = \arg \underset{\mathbf{x}\in X_{L-1}}{opt}\, \widetilde{f}_L(\mathbf{x}^*, \alpha_L) - \Delta_L\}
\end{aligned}
\qquad (4)
$$

In this case, if, depending on the current situation, the mutual importance of the criteria changes, then the DM values are adjusted in the dialog mode $\Delta_q, q=\overline{1, L}$ .

Using the principle described above, we can propose the following algorithm for solving the problem of multi-criteria selection in a fuzzy environment with a given set of criteria priorities.

Step 1. Enter the reliability levels of the values of the optimized parameters, which are determined on the basis of fuzzy models of the system.

Step 2. DM set priorities of criteria, arrange local criteria by their importance ($\succ$): $\widetilde{f}_1(\mathbf{x}) \succ \widetilde{f}_2(\mathbf{x}) \succ,\ldots,\succ \widetilde{f}_m(\mathbf{x})$ .

Step 3. Perform sequential optimization of criteria according to scheme (3) or (4):

$$X_q = \{x : \arg \widetilde{f}_q^*(\mathbf{x},\alpha_q) = \arg \underset{\mathbf{x}\in X_{q-1}}{opt}\, \widetilde{f}_q(\mathbf{x}^*,\alpha_q)\} \text{ or}$$

$$X_q = \{x : \arg \widetilde{f}_q^*(\mathbf{x},\alpha_q) = \arg \underset{\mathbf{x}\in X_{q-1}}{opt}\, \widetilde{f}_q(\mathbf{x}^*,\alpha_q) - \Delta_q\}$$

where $q=\overline{1, L};\ X_0 = \Omega$ , при $q$=1 the original set of alternatives. Optimization is performed for different levels of control reliability.

Step 4. DM present the results of the current optimization $\mathbf{x}^* = (x_1^*,\ldots,x_n^*)$ and the corresponding values of the criteria. $\widetilde{f}_q(\mathbf{x}^*,\alpha_q)$. If the DM is not satisfied with the current results, then he corrects the values $\alpha_q$ and/or reliability levels and go back to step 3 to improve the solution. If the current solutions satisfy the DM, then proceed to the next step to output the final solution.

Step 5. DM based on his preference and taking into account the current situation in production and the market, he chooses the final solution: $\mathbf{x}^* = (x_1^*,\ldots,x_n^*)$ the optimal values of the input parameters of oil wells and the corresponding best values of local criteria.

$\tilde{f}_q(\mathbf{x}^*, \alpha_q)$. Thus, the condition for stopping the solution search procedure is to obtain results satisfying the DM.

**Discussion**

Analyzing the proposed methods for solving multicriteria selection problems in a fuzzy environment, it can be noted that heuristic methods for solving these problems based on the DM reading when choosing the final solution are the most effective way to solve selection problems in a fuzzy environment. These methods are iterative methods that allow, based on the knowledge, experience and intuition of the DM, to consistently improve the chosen solution in the «DM-computer» circuit in an interactive mode. At the same time, the computer programmatically implements a decision support system based on optimization object models and decision selection algorithms, such as the heuristic algorithms proposed above. It is difficult to carry out a dialogue in such a system without using languages close to natural, capable of describing fuzzy categories that are close to human concepts and representations. In this regard, it is advisable to use linguistic variables. Linguistic variables can make it possible to adequately determine an approximate verbal description of the process, the operation of the system in the case when there is no exact deterministic description. At the same time, it should be noted that many fuzzy parameters described linguistically are often no less informative than an accurate description.

The features of the proposed heuristic algorithms include:

– improvement of the values of local criteria for some fixed values of reference levels $f_i^*, i = \overline{1,m}$ it is possible only by reducing the level of α, i.e. the level of control reliability;

DM by adjusting the desired (reference) values $f_i^*, i = \overline{1,m}$ may give preference to one or another local criterion $\tilde{f}_i(\mathbf{x}, \alpha_i), i = \overline{1,m}$, that is, to change their weights;

by selecting the most effective procedures (depending on the type of function (model) $\tilde{f}_i(\mathbf{x}, \alpha_i))$ для минимизации отклонения от желаемых значений критериев

$\left|\tilde{f}_i(\mathbf{x}, \alpha_i) - f_i^*\right|$, you can increase the speed of finding a solution;

iterative procedure for sequential minimization of the maximum deviation of the values of local criteria from the reference levels $f_i^*, i = \overline{1,m}$ repeats until the DM is satisfied with the current results.

One of the effective algorithms for solving multicriteria selection problems is an algorithm belonging to the class of deformable configuration methods (Rykov, 2019). This algorithm is a generalization of the methods of deformable configurations for the case of solving the multi-criteria choice problem. It should be noted that in order to apply this algorithm in the case of fuzzy optimization, it is necessary to pre-process odd information, for example, based on sets of level α, which allows us to proceed to a clear statement of the problem being solved.In these algorithms, DM is used to evaluate and compare the values of the quality function. He is required to divide the vertices of the simplex into different groups and evaluate the success of the step by comparing two values of the quality function at the centers of neighboring simplices. At the same time, the construction of the quality function in an explicit form is not required. In this way, using the non-formalized DM representations of the quality function, the uncertainty of the task associated with multi-criteria is overcome.

**Conclusion**

The problems of solving multicriteria selection problems in oil geology in a fuzzy environment and approaches to their solution are investigated. Heuristic methods for solving multicriteria selection problems based on sets of α and various optimality principles or their combination are proposed and described.The problem of multi-criteria selection in petroleum geology is formalized and a mathematical formulation is obtained in the form of a fuzzy mathematical programming problem based on the ideal point principle using multiple levels $\alpha$. A heuristic algorithm for solving the formulated multicriteria selection problem in a fuzzy environment with different levels of reliability of the solutions obtained is developed and described.

The main results of the study are:

– depending on the source of fuzziness, the types of multicriteria selection tasks in a fuzzy environment are systematized and described:

– a mathematical formulation of the multi-criteria choice problem in a fuzzy environment based on the principle of an ideal point and the application of a set of levels is formalized and obtained $\alpha$. The formulated statement of the problem allows us to present the original fuzzy problem as a set of clear tasks depending on the value $\alpha$ and solve by suitable methods;

– the problem of multicriteria selection with ordered local criteria is formulated on the basis of the principle of lexicographic ordering of criteria. To take into account the changing importance of local criteria, a modification of the lexicographic principle of optimality is proposed by introducing concessions $\Delta_q, q = \overline{1, L}$.

– based on the principles of the ideal point and the lexicographic principle of optimality, iterative algorithms for solving formulated multicriteria selection problems based on the use of a set of level α are developed and described. The condition for stopping the procedure of searching and choosing the best solution in the proposed algorithms is to obtain results satisfying the DM.

The presented research results are promising and can be effectively used to solve problems of optimization of petroleum geology and to choose the best solution in a fuzzy environment.

**REFERENCES**

Botev L., Johnson P., 2020 — *Botev .L, Johnson P.* Applications of statistical process control in the management of unaccounted for gas. Journal of Natural Gas Science and Engineering. 76(2), 103194. DOI 10.1016/j.jngse.2020.103194.

Can Li, Ignacio E. Grossmann, 2021 — *Can Li, Ignacio E. Grossmann*. A Review of Stochastic Programming Methods for Optimization of Process Systems Under Uncertainty. Front. Chem. Eng. 2. Pp.1–20. https://doi.org/10.3389/fceng.2020.622241.

Chen Y., He L., Li J., Zhang S., 2018 — *Chen Y., He L., Li J., Zhang S.* Multicriteria design of shale gas water supply chains and production systems towards optimal life cycle economics and greenhouse gas emissions under uncertainty. Computers & chemical engineering, 109. Pp.216–235. DOI: 10.1016/j.compchemeng.2017.11.014.

Kuanbayeva B., Rakhmetov M., Turkmenbayev A., Abdykerimova, Tumysheva A., 2022 — *Kuanbayeva B., Rakhmetov M., Turkmenbayev A., Abdykerimova, Tumysheva A.* The effectiveness of using interactive computer models as methodological tools in science school education. orld Trans. on Engng. and Technol. Educ., 20, 4. Pp. 306–311. URL: http://www.wiete.com.au/journals/WTE&TE/Pages/TOC_V20N4.html.

Leonova N.L., 2020 — *Leonova N.L.* Problems of linear programming and methods for their solution. [Задачи линейного программирования и методы их решения] St. Puterburg. BHV, 178 p. ISBN 975-7-9367-0511-3 (In Rus.).

Liang T.-F, Tien-Shou Huang T.-Sh., Yang M.-F., 2018 — *Liang T.-F, Tien-Shou Huang T.-Sh., Yang M.-F.* Application of fuzzy mathematical programming to imprecise project management decisions. Quality & Quantity/ 46. Pp. 1451–1470. https://link.springer.com/article/10.1007/s11135-011-9460-y https://link.springer.com/article/10.1007/s11135-011-9460-y.

Lukianova V., Shutyak Y., Polozova V., 2019 — *Lukianova V., Shutyak Y., Polozova V.* Expert assessment method in socio-economic research and Scales transformations. Advances in Economics, Business and Management Research, 99(3). Pp. 355–360. DOI: 10.2991/mdsmes-19.2019.67.

Gmurman V.E., 2020 — *Gmurman V.E.* Probability theory and mathematical statistics: [Теория вероятностей и математическая статистика]. -Moscow: Yurayt. 12th ed. 479 p. ISBN 978-5-534-00211 (In Rus.).

Goel V., Grossmann I.E., 2019 — *Goel V., Grossmann I.E.* A stochastic programming approach to planning of offshore gas field developments under uncertainty in reserves. Comput. Chem. Eng. 28. Pp.1409–1429. doi:10.1016/j.compchemeng.2019.10.00.

Gutsykova S., 2017 — *Gutsykova S.* The method of expert assessments. Theory and practice. [Методы экспертных оценок. Теория и практика]. Moscow/ Kogito-Center. 144 p. ISBN: 978-5-9270-0209-2 (In Rus.).

Mary C.M., 2019 — *Mary C.M.* Probability and Mathematical Statistics: Theory, Applications and Practice 278 p. ISBN 978-1611975772.

Orazbayev B., Assanova B., Bakiyev M., Krawczyk J., Orazbayeva K., 2020 — *Orazbayev B., Assanova B., Bakiyev M., Krawczyk J., Orazbayeva K.* Methods of model synthesis and multi-criteria optimization of chemical-engineering systems in the fuzzy environment. Journal of Theoretical and Applied Information Technology 98(06). Pp.1021–1036. https://www.scopus.com/record/display.uri?eid=2-s2.0-85083790104&origin=resultslist&sort=plf-f.

Orazbayev B., Moldasheva Zh., Orazbayeva K., Makhatova V., Kurmangaziyeva L., Gabdulova A., 2021 — *Orazbayev B., Moldasheva Zh., Orazbayeva K., Makhatova V., Kurmangaziyeva L., Gabdulova A.* Development of mathematical models and optimization of operation modes of the oil heating station of main oil pipelines under conditions of fuzzy initial information. Eastern-European Journal of Enterprise Technologies, 6: 2(114)). Pp. 147–162. DOI: https://doi.org/10.15587/1729-4061.2021.244949.

Orazbayev B.B., Ospanov Ye.A., Orazbayeva K.N., Makhatova V.E., Urazgaliyeva M.K. Shagayeva A.B., 2019 — *Orazbayev B.B., Ospanov Ye.A., Orazbayeva K.N., Makhatova V.E., Urazgaliyeva M.K. Shagayeva A.B.* Development of mathematical models of R-1 reactor hydrotreatment unit using available information of various types. Journal of Physics: Conference Series. 1399(45) 156053. Pp. 1–6. DOI: 10.1088/1742-6596/1399/4/044024.

Orazbayev B.B., Ospanov Y.A., Orazbayeva K.N., Serimbetov B.A., 2019 — *Orazbayev B.B., Ospanov Y.A., Orazbayeva K.N., Serimbetov B.A.* Multicriteria Optimization in Control of a Chemical technological System for Production ff Benzene With Fuzzy Information. Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering. 330(7). Pp. 182–194. DOI 10.18799/24131830/2019/7/2194.

Pishvaee M.S., Torabi S.A, Razmi J., 2022 — *Pishvaee M.S., Torabi S.A, Razmi J.* Credibility-based fuzzy mathematical programming model for green logistics design under uncertainty. Computers & Industrial Engineering. 62(2). Pp. 624–632. https://doi.org/10.1016/j.cie.2011.11.028.

Rakhmetov M., Sadvakassova A., Saltanova G., Yessekenova A., 2022 — *Rakhmetov M., Sadvakassova A., Saltanova G., Yessekenova A.* Usage and effectiveness of educational platforms in Kazakhstan during the Covid-19 pandemic., World Transactions on Engineering and Technology Education. 20(3). Pp. 226–231. URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-85136288448&origin=resultslist&sort=plf-f .

Rykov A.S., 2019 — *Rykov A.S.* Search engine optimization. Methods of deformable configurations [Поисковая оптимизация. [Методы деформируемых конфигураций]. -M.: Nauka, 216 p. ISBN · 977-7-9558-0507-7 (In Rus.).

Ryzhov A.P., 2017 — *Ryzhov A.P.* The theory of fuzzy sets and its applications [Теория нечетких множеств и ее приложения]. Publishing House of Moscow State University, M.; p. 115. (http://www.intsys.msu.ru/staff/ryzhov/FuzzySetsTheory&Applications.pdf (In Russ.).

Sabzi H.Z., King J.P., Abudu Sh., 2018 — *Sabzi H.Z., King J.P., Abudu Sh.* Developing an intelligent expert system for streamflow prediction, integrated in a dynamic decision support system for managing multiple reservoirs: a case study. Expert systems with applications. 82(3). Pp.145–163. https://doi.org/10.1016/j.eswa.2017.04.039.

Shvedov A.V., 2017 — *Shvedov A.V.* Fuzzy mathematical programming. [Нечеткое математическое программирование]. Control Sciences. 3(1). Pp. 2–10. https://cyberleninka.ru/article/n/nechetkoe-matematicheskoe-programmirovanie-kratkiy-obzor/viewer (In Rus.).

Urazgaliyeva M.K., Bayamirova R.Y., Bissembayeva K.T., Sabyrbayeva G.S., Bekbauliyeva A.A., 2023 — *Urazgaliyeva M.K., Bayamirova R.Y., Bissembayeva K.T., Sabyrbayeva G.S., Bekbauliyeva A.A.* Methods for assessing the characteristics of oil reserves with fuzzy geological information and development of oil field. NEWS of the National Academy of Sciences of the Republic of Kazakhstan SERIES OF GEOLOGY AND TECHNICAL SCIENCES. 1(457). Pp. 211–225. https://doi.org/10.32014/2023.2518-170X.271.

Zimmermann H.-J., 2018 — *Zimmermann H.-J.* Fuzzy Set Theory – and Its Applications. Springer Science+Business Media, LLC. Fifth Edition 2018; p.525. ISBN: 978-94-010-3870-6. DOI: 10.1007/978-94-010-0646-0.

**CONTENTS**

**Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan**

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:
**www:nauka-nanrk.kz**
**http://www.geolog-technical.kz/index.php/en/**

**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 14.06.2023.
Формат 70x90$^{1}/_{16}$. Бумага офсетная. Печать – ризограф.
20,0 п.л. Тираж 300. Заказ 3.

---

*Национальная академия наук РК*
*050010, Алматы, ул. Шевченко, 28, т. 272-13-19*