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

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

№1
2026

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

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

1 (475)

JANUARY – FEBRUARY 2026

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, 2026

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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

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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: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan Nº KZ50VPY00121155, issued on 05.06.2025
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
http://www.geolog-technical.kz/index.php/en/

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)

Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).

Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ50VPY00121155 мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*

Мерзімділігі: жылына 6 рет.

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

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)
Собственник: ТОО «Центрально-Азиатский академический научный центр» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан № KZ50VPY00121155, выданное 05.06.2025 г.
Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*
Периодичность: 6 раз в год.
http://www.geolog-technical.kz/index.php/en/

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NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 1.
Number 475 (2026), 135–154

https://doi.org/10.32014/2026.2518-170X.595

UDC 550.343.2
IRSTI 37.31.19

©Ismailov V.A.*, Aktamov B.U., Yodgorov Sh.I., Yadigarov E.M., Avazov Sh.B., 2026.
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ASSESSMENT OF THE POSSIBLE SEISMIC RISK OF RESIDENTIAL BUILDINGS IN THE SAMARKAND REGION BASED ON A SCENARIO EARTHQUAKE

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Abstract. The Samarkand region is situated in a seismically active zone and is characterized by the vulnerability of its housing stock, with various structural designs, to strong earthquakes. The acceleration of urbanization processes, the increasing proportion of outdated buildings with low seismic resistance, as well as the uneven quality of construction across regions, further emphasize the need for a scientifically based assessment of seismic hazard in the region. This study aims to determine the level of seismic load on residential buildings and the extent of potential structural damage by developing an earthquake scenario model for the Samarkand region. As part of the study, an inventory of residential buildings in the Samarkand region was conducted, classifying them according to their structural type, construction materials, and structural systems. Based on the selected earthquake scenario, seismic impact parameters were calculated, and the expected damage levels for buildings of various structural types were estimated. The results obtained were used to identify areas with high seismic risk, and the vulnerabilities of buildings were systematically analyzed. The analysis revealed that seismic risk varies significantly across the districts of the region, with buildings lacking sufficient lateral stiffness, outdated structures, and low-rise buildings being particularly vulnerable. Some areas were classified as having a high probability of serious structural damage in earthquake scenarios. Furthermore, the study's findings enable a regional differential assessment of seismic risk and serve to identify building types requiring priority reinforcement and high-risk areas within the Samarkand region. This approach establishes an important scientific and practical foundation for integrating seismic safety into urban and territorial planning processes, gradually strengthening the existing seismically unstable housing stock, and improving the emergency preparedness system.

Key words: seismic hazard, seismic impact, seismic vulnerability, seismic risk, scenario earthquake, economic loss, residential buildings, database

Funding. *This research was supported by the Academy of Sciences of the Republic of Uzbekistan under the applied funding "Development of a scientific basis for assessing various levels of seismic risk in seismically active areas and reducing losses from earthquakes" and the Agency for Innovation Development, #AL8924073457 "Development of a macroseismic database platform for damage to buildings and structures in epicentral zones during strong earthquakes".*

For citations: *Ismailov V.A., Aktamov B.U., Yodgorov Sh.I., Yadigarov E.M., Avazov Sh.B. Assessment of the Possible Seismic Risk of Residential Buildings in the Samarkand Region Based on a Scenario Earthquake. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2026. No.1. Pp. 135–154. DOI: https://doi.org/10.32014/2026.2518-170X.595*

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САМАРҚАНД ОБЛЫСЫНДАҒЫ ТҰРҒЫН ҮЙЛЕРДІҢ СЕНАРИЙЛІК СІЛКІНІС НЕГІЗІНДЕ ЫҚТИМАЛ СЕЙСМИКАЛЫҚ ҚАУІПТІЛІГІН БАҒАЛАУ

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Аннотация. Самарқанд облысының аумағы сейсмикалық белсенді аймақта орналасқан, ал әртүрлі құрылымдық шешімдері бар тұрғын үй қоры күшті жер сілкіністеріне осал болып келеді. Урбандалу үдерістерінің жеделдеуі, сейсмикалық төзімділігі төмен ескі ғимараттар үлесінің артуы, сондай-ақ өңірлер бойынша құрылыс сапасының біркелкі болмауы аймақтағы сейсмикалық қауіпті ғылыми негізде бағалау қажеттілігін одан әрі арттырады. Аталған зерттеу Самарқанд облысы аумағы үшін жер сілкінісінің сценарийлік моделін әзірлеу арқылы тұрғын ғимараттарға түсетін сейсмикалық жүктеме деңгейін және ықтимал құрылымдық зақым көлемін анықтауға бағытталған. Зерттеу аясында Самарқанд облысындағы тұрғын үйлерге түгендеу жүргізіліп, олар құрылымдық типтері, құрылыс материалдары және конструктивтік жүйелері бойынша жіктелді. Таңдап алынған жер сілкінісі сценарийі негізінде сейсмикалық әсер ету параметрлері есептеліп, әртүрлі құрылымдық типтегі ғимараттар үшін күтілетін зақымдану деңгейлері бағаланды. Алынған нәтижелер негізінде сейсмикалық қауіптілігі жоғары аудандар анықталып, ғимараттардың осал тұстары жүйелі түрде талданды. Талдау нәтижелері облыс аудандары бойынша сейсмикалық тәуекел деңгейінің айтарлықтай ерекшеленетінін көрсетті. Сонымен қатар бүйірлік беріктігі жеткіліксіз, ескірген және аз қабатты ғимараттардың әсіресе осал екендігі анықталды. Кейбір аудандар сценарийлік жер сілкінісі жағдайында елеулі құрылымдық зақымдану ықтималдығы жоғары аумақтар ретінде жіктелді. Зерттеу барысында алынған нәтижелер сейсмикалық қауіпті аймақтарды дифференциалды түрде бағалауға мүмкіндік береді және Самарқанд облысы жағдайында бірінші кезекте нығайтуды қажет ететін ғимарат түрлері мен қауіптілік деңгейі жоғары аудандарды анықтауға негіз болады. Бұл тәсіл сейсмикалық қауіпсіздікті қала құрылысы мен аумақтық жоспарлау үдерістеріне кіріктіру, қолданыстағы сейсмикалық тұрғыдан әлсіз тұрғын үй қорын кезең-кезеңімен нығайту және төтенше жағдайларға дайындық жүйесін жетілдіру үшін маңызды ғылыми-практикалық негіз қалыптастырады.

Түйін сөздер: сейсмикалық қауіп, сейсмикалық әсер, сейсмикалық әлсіздік, сейсмикалық тәуекел, сценарийлік жер сілкінісі, экономикалық шығын, тұрғын үйлер, мәліметтер базасы

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ОЦЕНКА ВОЗМОЖНОГО СЕЙСМИЧЕСКОГО РИСКА ЖИЛЫХ ЗДАНИЙ В САМАРКАНДСКОЙ ОБЛАСТИ НА ОСНОВЕ СЕНАРНОГО ЗЕМЛЕТРЯСЕНИЯ

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Аннотация. Территория Самаркандской области расположена в сейсмически активной зоне и характеризуется уязвимостью жилищного фонда с различными конструктивными решениями к сильным землетрясениям. Ускорение процессов урбанизации, увеличение доли устаревших зданий с низкой сейсмостойкостью, а также неравномерность качества строительства по районам области дополнительно усиливают необходимость научно обоснованной оценки сейсмической опасности в регионе. Данное исследование направлено на определение уровня сейсмической нагрузки на жилые здания и величины возможного конструктивного ущерба путем разработки сценарной модели землетрясения для территории Самаркандской области. В рамках исследования была проведена инвентаризация жилых зданий Самаркандской области, которые были классифицированы по конструктивному типу, строительным материалам и конструктивным системам. На основе выбранного сценария землетрясения были выполнены расчеты параметров сейсмического воздействия и оценены ожидаемые уровни повреждений зданий различных конструктивных типов. По результатам анализа были выявлены районы с высоким сейсмическим риском и систематически проанализированы уязвимые стороны зданий. Результаты исследования показали, что сейсмический риск существенно различается по районам области, а также выявили, что здания с недостаточной боковой жесткостью, устаревшие и малоэтажные здания являются наиболее уязвимыми. Некоторые районы были классифицированы как территории с высокой вероятностью значительного конструктивного ущерба в условиях сценарных землетрясений. Кроме того, полученные результаты позволяют проводить региональную дифференцированную оценку сейсмического риска и служат основой для определения типов зданий, требующих приоритетного усиления, а также районов с повышенным уровнем риска в пределах Самаркандской области. Представленный подход формирует важную научно-практическую основу для интеграции требований сейсмической безопасности в процессы градостроительства и территориального планирования, поэтапного укрепления существующего сейсмически неустойчивого жилищного фонда и совершенствования системы подготовки к чрезвычайным ситуациям.

Ключевые слова: сейсмическая опасность, сейсмическое воздействие, сейсмическая уязвимость, сейсмический риск, сценарное землетрясение, экономический ущерб, жилые здания, база данных

Introduction. According to official statistical data, as of October 1, 2024, the permanent population of the Samarkand region reached 4,275.3 thousand people, showing a growth of 66.8 thousand people (1.6%) compared to the start of the year. The urban population constituted 36.6%, whereas 63.4% resided in rural settlements (Samarkand Regional Statistics Department, accessed October 28, 2024).

To develop a seismic risk map in the Samarkand region, Geographic Information System (GIS)–based software tools were used to organize, systematize, and evaluate the relevant data regional distribution of information on seismic risk, the number of buildings and structures, the geographical location of residential buildings, the seismic vulnerability coefficient of buildings and territories, the cadastral value of buildings, etc (Artikov et al., 2022).

Strong seismic events in the region result from the interaction and deformation of heterogeneous crustal blocks. Such earthquakes are typically concentrated within elongated and relatively narrow zones associated with active fault systems, which are particularly susceptible to intense tectonic movements. The spatial distribution of these seismogenic structures, together with the regional seismic regime and the characteristics of ground motion they generate, forms the fundamental basis for seismic hazard assessment. Contemporary seismic zoning maps delineate areas of expected seismic intensity, indicating levels that are likely not to be exceeded within a probabilistic timeframe of 50–100 years (Artikov et al., 2021).

Reliable identification of seismic hazard zones expected to exhibit activity in the coming years requires an analysis based on the temporal, spatial, and magnitude-related regularities governing seismic processes at the sources of the strongest earthquakes. In this context, the interrelationship between the seismic dynamic behavior of different active tectonic structures should be examined, with due consideration given to their characteristic scales and geometrical dimensions (Ibragimova et al., 2021; Zavyalov, 2006)

A comprehensive and integrated evaluation of all these parameters plays a key role in regional socio-economic development, particularly in the context of comparing the effectiveness of seismic risk mitigation measures across different administrative territories (Riznichenko, 1992). The aim of this study is to evaluate the potential economic losses by examining the seismic risk of individual residential buildings in the event of strong earthquakes with a high likelihood of occurrence at the regional scale.

Relevance. Globally, forecasting potential losses from strong earthquakes in seismically active regions and mitigating their impacts are considered highly important. Consequently, efforts are focused on assessing seismic risk through comprehensive research, predicting it over specific timeframes, and implementing measures to reduce earthquake-related consequences. Evaluating expected economic losses from seismic events contributes to the socio-economic resilience and sustainable development of countries exposed to high seismic hazards.

Currently, forecasting potential losses and mitigating the impacts of strong earthquakes at the regional level remain highly significant issues for the republic. Seismic events, which substantially affect the development of districts and cities in seismically active areas, are closely linked to the scale of economic losses within these regions. Efforts are actively underway to assess seismic risk through comprehensive studies and to provide timely forecasts, enabling the implementation of effective measures to reduce earthquake-related consequences.

Materials and methods. Certain statistical patterns emerge in the spatial and temporal distribution of successive strong earthquakes within seismically active zones. An analysis was conducted on over 200 significant seismic events with magnitudes of $M \geq 4.8$ recorded since 1900 (Artikov et al., 2021), it was found that in 65% of cases, the time interval between two successive earthquakes within the same seismically active zone does not exceed five years (Bisch et al., 2021). Furthermore, time intervals of 6–10 years, 11–15 years, and 16–20 years each represent roughly 10% of consecutive seismic events. The predominance of short intervals (0–5 years) among successive earthquakes suggests that seismic occurrences in active zones are temporally clustered rather than evenly distributed, reflecting distinct periods of heightened seismic activity (Ibragimova et al., 2021; Riznichenko, 1992; Zavyalov, 2006)

Subsequent investigations of the present seismological conditions in seismically active zones were carried out through a comprehensive analysis of forecasted seismic regime parameters. This approach allowed for characterizing the dynamics of fault-source areas by approximating the timing of major fault-generating processes. Particular focus was placed on 29 seismically active zones with a documented history of strong earthquakes (Ibragimova et al., 2021; V.A. Ismailov et al., 2024; Riznichenko, 1992)

As depicted on the map, from historical times to the present, the region has experienced several earthquakes with magnitudes of $M \geq 5.0$, including events of $M \geq 6.0$, predominantly in the eastern part of the study area. The majority of these seismic events occurred during historical periods. One of the earliest documented earthquakes took place near Samarkand in 1799, with a magnitude of $M = 6.0$. Later significant earthquakes include the Oratepa events of 1897 in the South Fergana seismogenic zone, with magnitudes of $M = 6.6$ and $M = 6.7$. A map has been compiled to illustrate the epicenters of major and strong earthquakes recorded over the past 150 years (Figure 1).

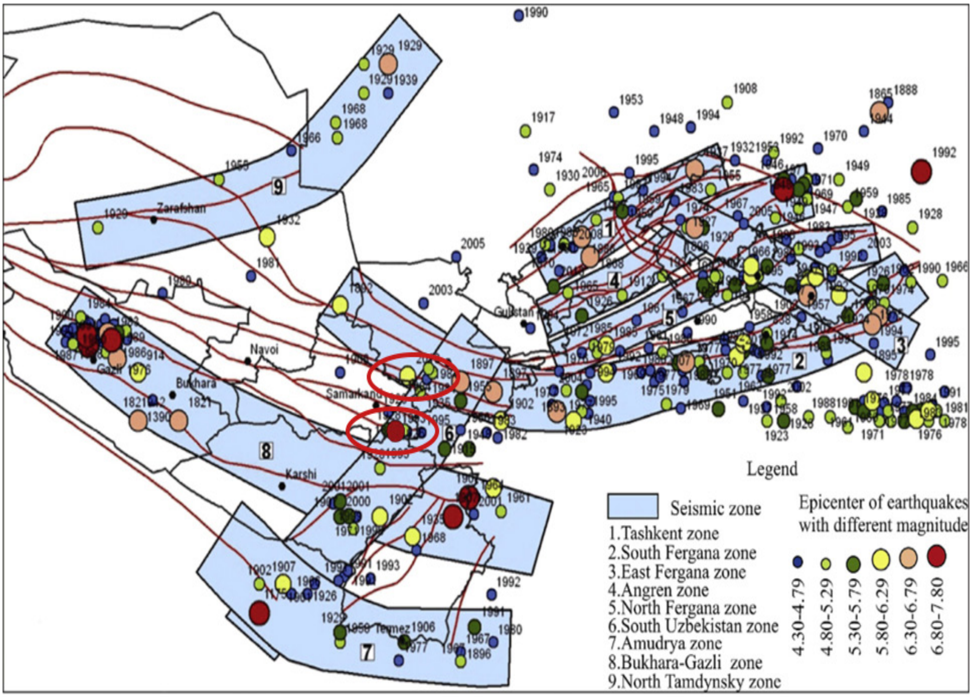


Figure 1 - Map of Epicenters of Historically Recorded Strong Earthquakes (T.U. Artikov, R.S. Ibragimov et al.)

Structurally, the region lies within the transitional zone between the Tien Shan orogen and the Turanian platform. Strong earthquakes in this area are linked to the ongoing geodynamic activity of the Zarafshan seismogenic zone, whose seismic potential, based on seismotectonic data, is estimated to reach a maximum magnitude of M_{max} = 6.5 (Ibragimova et al., 2021)

In the southern part of the Samarkand region, two deep latitudinal fault systems—the Southern Tien Shan and Hisor-Kokshal—exhibit very high seismic potential, with a maximum estimated magnitude of M_{max} = 7.5. Earthquakes of M ≥ 7.0 have occurred repeatedly within these seismogenic zones. In the northern part of the region, the North-Kulguktau-Turkiston, Kurshab, Zarafshan, South-Auminzatav-Aktav, and Kyzylkum frontage seismogenic zones are located, each with a considerable seismic potential estimated at M_{max} = 6.5 (Ibragimova et al., 2021)

Prior to the era of instrumental observations, the most significant seismic events in the region were the 1490 earthquake with a magnitude of M = 5.8 and the 1799 earthquake with a magnitude of M = 6.0, both of which occurred within the Zarafshan seismogenic zone (Artikov et al., 2021).

In 1897, the South Fergana seismically active zone experienced two historical earthquakes in Ura-Tub, with magnitudes of M = 6.6 and M = 6.7. The most powerful Karatau earthquakes, with a magnitude of M = 7.3, occurred in 1907 along the Hisar-Kukshaul fault system. During the early period of instrumental observations, one of the notable events was the 1915 earthquake in the Zarafshan seismically active zone, which registered a magnitude of M = 5.7. Between 1926 and 1928, moderate earthquakes occurred in the region, with the largest reaching M = 5.4 (Artikov et al., 2021).

Recent seismic activity has been primarily linked to the North-Kuljuktov-Turkestan seismogenic zone. Within this zone, the Marjonbulak earthquake of 2013 registered a magnitude of M = 6.1, followed by the Kitab earthquake of 2016 with M = 5.0. Additionally, in 2017, an earthquake with a magnitude of M = 5.1 occurred near the village of Bakhmal (Ibragimova et al., 2021)

Results and discussions. Based on an analysis of comprehensive forecasting parameters, a map depicting the areas expected to experience seismic activity in the coming years has been prepared (Figure 2). To assess the current level of seismic hazard from source zones, four gradations have been defined, determined by the number of identified anomalous indicators. These gradations are referred to as conditional areas:

-Low probability of earthquakes in the coming years: 0–3 forecast indicators detected (yellow areas);

-Moderate probability of earthquakes: 4–5 forecast indicators detected (brown areas);

-High probability of earthquakes: 6–7 forecast indicators detected (orange areas);

-Very high probability of earthquakes: 8–11 forecast indicators detected (red areas).

A synoptic forecasting methodology has been developed to identify areas likely to experience seismic activity in the coming years. This approach considers both the influence of local internal tectonic stresses within each seismically active zone and the impact of external stresses generated by destructive earthquakes occurring in the region.

Regions that have historically experienced strong earthquakes are considered potentially hazardous within seismically active zones. Given their relatively low variability over decades and centuries, the progression of seismotectonic processes—including the current stress levels in these zones—was analyzed, indicating that these areas are likely to experience significant seismic activity in the coming decades.

Areas exhibiting current anomalies in various seismic regime parameters have been identified. These seismically active zones were classified according to the number of detected anomalous indicators, enabling an estimation of the likelihood of strong earthquake occurrence.

Regions in Uzbekistan expected to experience seismic activity have been identified in the context of potential strong earthquakes in the Central Asian region.

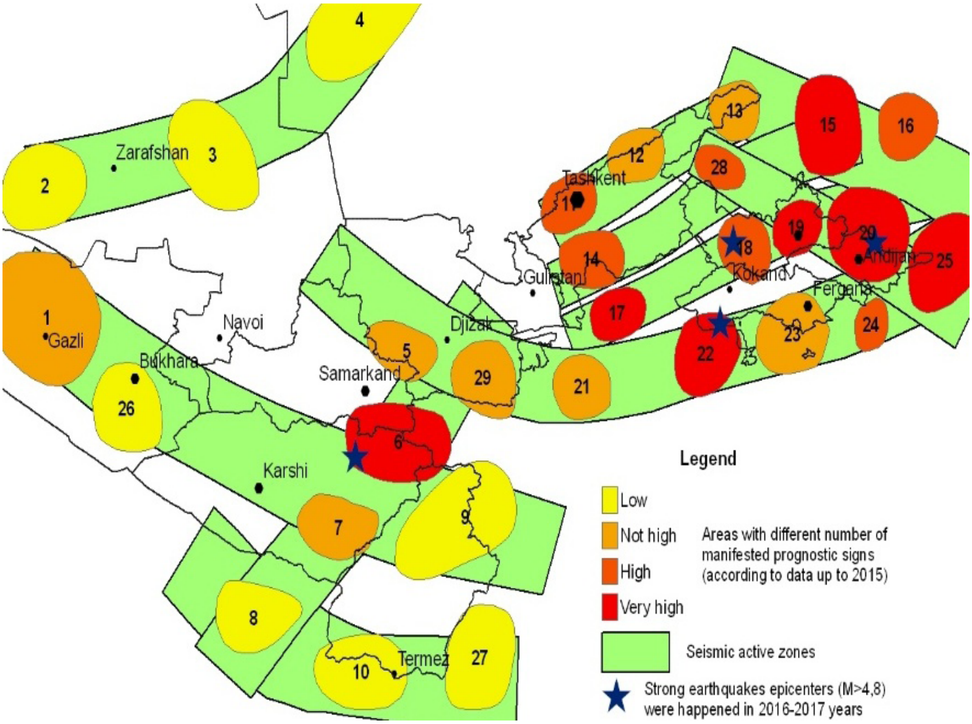


Figure 2 - Map of areas expected to experience seismic activity in the coming years based on comprehensive seismic regime forecast parameters (T.U. Artikov, R.S. Ibragimov et al.)

At present, Uzbekistan has seven regions classified as having a very high probability of experiencing a strong earthquake, and six regions with a high probability. Of these, twelve are situated in Eastern Uzbekistan, while one is located in Central Uzbekistan (Ibragimova et al., 2021)

The high-probability seismic hazard zone in Central Uzbekistan is subdivided into two areas of seismic activity within the Samarkand region. Seismic events in this zone are expected to reach a minimum magnitude of M = 5 (Artikov et al., 2022).

The scenario earthquake was selected using the «INTensity MAP v3.0» software. This program, version «INTensity MAP v3.02», was developed by specialists at the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan for seismic hazard assessment (DGU 09237). Its primary purpose is to evaluate the seismic impact based on specified earthquake parameters under average ground conditions.

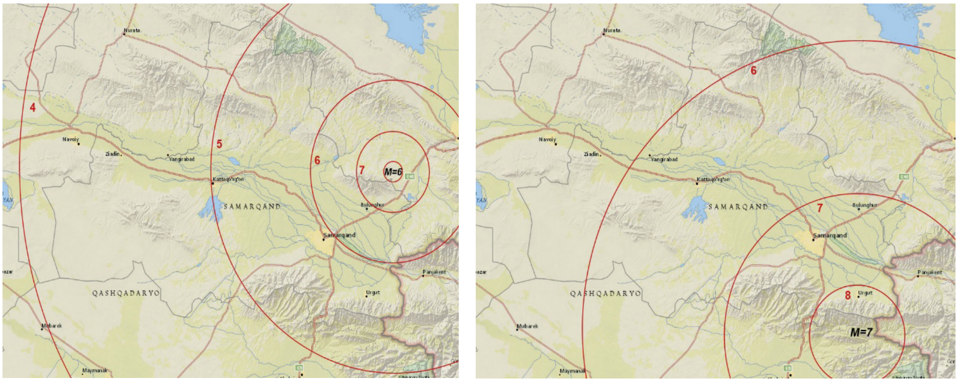
Methodological Approaches to Seismic Risk Assessment. Seismic risk is typically evaluated using two primary approaches: deterministic and probabilistic.

Seismic impact. The proposed research methodology focuses on evaluating and analyzing seismic risk using probabilistic approaches. The probabilistic method estimates the likelihood of seismic effects at a site arising from various seismic sources. In probabilistic assessments of seismic impacts on structures and buildings, three main factors are considered: the intensity of the impact, the spectral characteristics of ground vibrations, and the probability that the calculated values will be exceeded within a specified time period (Ismailov et al., 2024; RADIUS, 2000)When evaluating the impact force, parameters such as ground vibration intensity (expressed in terms of acceleration, velocity, or displacement) and the attenuation characteristics of seismic waves for the specific area are taken into account.

Three main seismic zones affecting residential buildings in the territory of the Samarkand region are distinguished. They are divided into the South Fergana, South Uzbekistan, and Bukhara-Gazli seismogenic zones. The seismic activity of these zones is M=5.5; Magnitude M=6.5 and M=7.5. When assessing the activity of these seismogenic zones, the following main criteria are used: assessment of active faults and the occurrence of historical earthquakes in these faults.

Taking these aspects into account, in the 1st scenario, the seismogenic zone of South Fergana and South Uzbekistan, in the 2nd scenario, the seismic activity of the junction of the seismogenic zones of South Uzbekistan and Bukhara-Gazli, the presence of earth fissures, and the frequent occurrence of earthquakes in this area are considered to be the most active. Therefore, the structure of fault placement at the junctions of seismogenic zones is considered very complex; at such a time, the probability of causing a strong earthquake increases, which leads to an increase in the activity of the adjacent seismogenic zone.

Based on the probabilistic approach, two earthquake scenarios are illustrated in the map shown in Figure 3. The main seismic hazard is divided into two zones: the North-Eastern part of the study area is considered to have no seismic hazard, while the South-Eastern part is identified as a seismic hazard zone (Yodgorov et al., 2025). Using the «INTensity MAP v3.0» program, two earthquake scenarios were selected and evaluated based on the parameters shown in Figure 3.



1-scenario (x=67.18, y=39.96, M=6, h=5km) *2-scenario (x=66.45, y=39.40, M=7, h=15km)*

Figure 3 - Schematic map of earthquakes with scenario estimation of earthquake intensity

The main task of the program is to calculate the intensity of seismic impact in accordance with the average ground conditions based on the parameters of the given seismic source - magnitude, location of the epicenter, focal depth, and propagation characteristics. At the same time, the program allows, during the modeling process, to generate intensity maps, taking into account local seismotectonic conditions, energy dissipation, and the factors of formation intensification.

As a result, the use of the «INTensity MAP» program serves to form a reliable initial database for scientifically based selection of a scenario earthquake, assessment of the strength of the predicted seismic impact in the spatial distribution of the territory and subsequent analysis - risk modeling, damage forecasting, and planning of sustainability measures (Yodgorov et al., 2025).

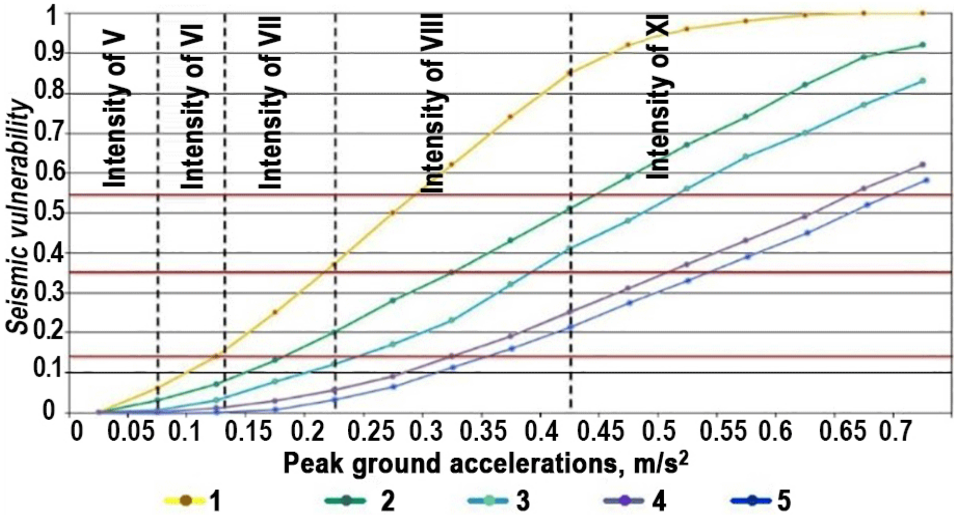
Seismic Vulnerability. Seismic vulnerability refers to the ratio of the expected cost to restore structures that can withstand a destructive seismic event of a given intensity, compared to their initial value. Vulnerability ranges from 0 (no damage) to 1.0 (irreparable damage). By knowing the current value of a structure, the potential damage can be estimated. The relationship between vulnerability and seismic impact (e.g., in intensity points) is known as the vulnerability function. Vulnerability functions form a critical functional basis for assessing regional seismic losses.

A vulnerability function represents a relationship used to predict the statistics (such as the mean or standard deviation) of the distribution of seismic losses. It predicts how much damage a structure (e.g., a residential building or a bridge) will suffer under the probability of a seismic event (Vakhitkhan Alikhanovich Ismailov et al., 2024b, 2024a)

Vulnerability functions (Figure 4) for structural building types identified within the territory of the Republic of Uzbekistan were developed using the GESI_Program software. This computer program assesses structural damage during specified seismic events. The software was developed between 1999 and 2001 as part of the United Nations Global Earthquake Safety Initiative pilot project (RADIUS, 2000; Tyagunov et al., 2012).

The primary data used to develop the program were collected in 1998-1999 as part of the international project «Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters», implemented by the UN-IDNDR. The vulnerability function used for seismic risk assessment was created through research studies conducted in cities such as Addis Ababa (Ethiopia), Antofagasta (Chile), Bandung (Indonesia), Guayaquil (Ecuador), Zigong (China), Izmir (Turkey), Skopje (Macedonia), Tashkent (Uzbekistan), and Tijuana (Mexico). The results of this scientific study were used in an experiment in which the same building materials were utilized in each city. The findings revealed that the vulnerability index for the city of Tashkent did not exceed 10% of the total indicator (RADIUS, 2000).

In addition to vulnerability functions, boundary conditions for damage—characterized by the total direct costs of restoring buildings to their original state—were also presented. Furthermore, the relationship between the maximum ground acceleration (PGA) and intensity (on the MSK-64 macroseismic scale) was calculated using the equation: Imax=0.41/−0.755±0.08 (Aktamov et al., 2025; Khusomiddinov et al., 2025).



1 – raw brick (pakhsa), 2 – fired brick, 3 - Wooden, 4 – concrete, 5– metal.

Figure 4 - Vulnerability function for buildings using different types of construction materials

Buildings built using local materials ("guvalak", "pakhsa" and "raw brick"); buildings built of fired bricks; wooden (shallow, fine) residential buildings; reinforced concrete (panel, large-panel, monolithic and reinforced concrete) buildings; buildings with a metal frame or diaphragm (joint) frame are included in various types of buildings (Alkaz et al., 2012; Paikun et al., 2022).

It should be noted that the average vulnerability of buildings and structures is calculated based on the determined seismic vulnerability values for buildings subjected to seismic impacts. The seismic vulnerability of buildings and structures is assessed according to the following methodology (Tyagunov et al., 2012).

$$MVR = \frac{\sum_{i=1}^{n} N_i \cdot MVR_i}{\sum_{i=1}^{n} N_i}$$

In this context, MVR represents the vulnerability index of buildings and structures, with its value corresponding to the average for buildings of the selected type. N denotes the number of buildings of the same type subjected to seismic impacts. The (MVR) indicator allows for a quantitative comparison of the seismic vulnerability of buildings and structures across districts and cities, and it plays an important functional role in relative assessments (Lingeshwaran et al., 2021; Luo et al., 2020; Wang and Pan, 2020; Yamakawa et al., 2019)

Classification by type of building materials. One of the most important stages of seismic risk assessment is the classification of buildings according to the degree of their reaction to a given seismic impact. According to cadastral data, residential buildings erected in the Samarkand region are divided into the following types of building materials:

- buildings built using local materials (type A guvalak, pakhsa and raw brick) without anti-seismic measures;
- buildings built of fired brick (type B);
- wooden (panel, thin, double-thin) residential buildings (type V);
- concrete (panel, large-panel, monolithic and reinforced concrete) residential buildings (type C);
- metal-framed (iron beams, heavy-duty connections) residential buildings (type D).

According to cadastral data, 3 types of building materials were used in the construction of residential buildings in the Samarkand region (Table 1).

In the Samarkand region, residential buildings constructed using local building materials represent a higher proportion compared to multi-storey buildings. These locally constructed buildings are most widespread, particularly in rural areas, including settlements, towns, and districts.

Table 1. Distribution of the regional housing stock by type

Area	Reinforced concrete	Fired brick	Local clay materials
Samarkand region	499	24475	594173

According to the Cadastral agency, there are 594,173 buildings built using local building materials in the Samarkand region; 24,475 buildings made of fired bricks; 499 concrete (panel, large-panel, monolithic and reinforced concrete) buildings.

Residential buildings located in the region were divided by type and systematically analyzed. This data was used as an important primary source in assessing seismic risk. Information is provided on the distribution of residential buildings with different seismic effects by type of building materials depending on their territorial location (areas with different seismic effects) (Table 2).

Table 2. Distribution of residential buildings and building materials by type in areas with different seismic effects in a scenario earthquake.

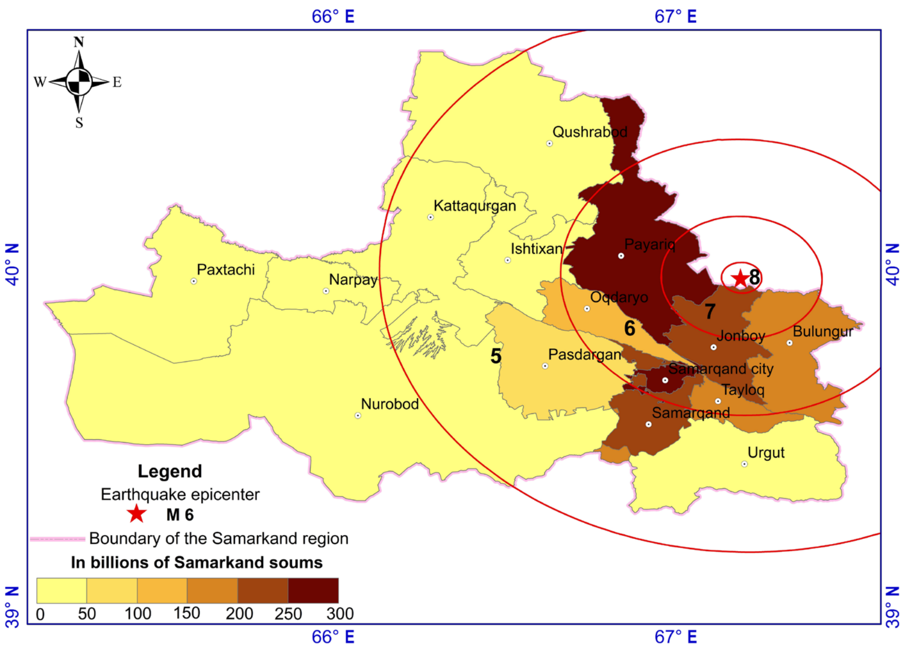
Structural types of buildings			Total	Seismic impact in points (MSK-64)
Reinforced concrete	Fired brick	Local clay materials		
36	7828	245201	253065	6
454	13949	267926	282329	7
9	2698	81046	83753	8

In this research work, we focused on one, but the most important element of risk - the average damage to buildings under a given seismic impact. It is this element of seismic risk that directly affects economic damage and threatens human health or life (Table 3). Due to the location of various seismogenic zones in the territory of Samarkand region and adjacent areas and the high probability of occurrence of strong earthquakes with an intensity of 6, 7, 8 and 9 points, we assessed the seismic risk under the influence of earthquakes with an intensity of 6, 7 and 8 points.

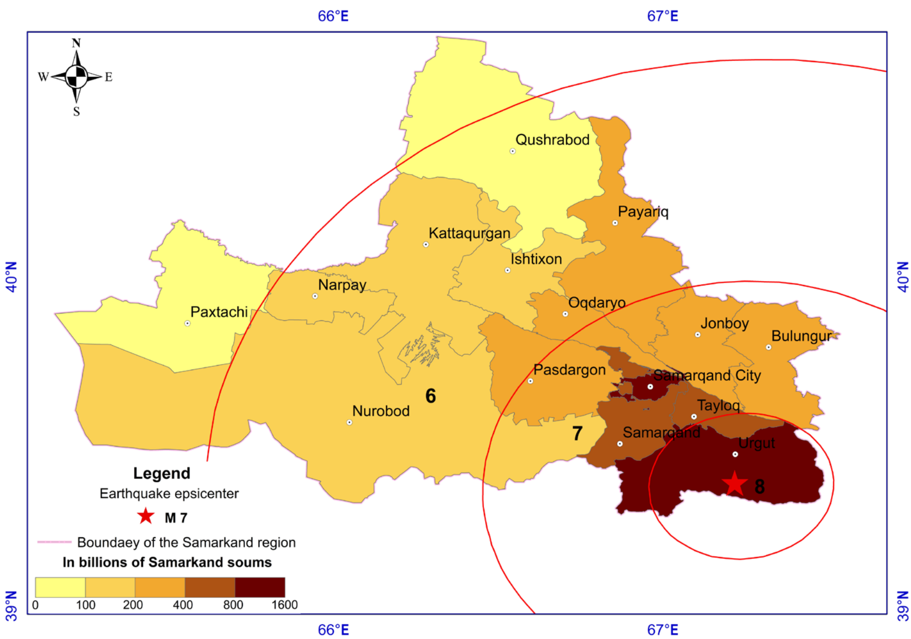
Table 3. Economic damage caused by various seismic impacts in the districts of the Samarkand region

Districts	**Number of buildings**	**Fired brick**			**Local clay materials**			**Reinforced concrete**			**New risk**
		6	**7**	**8**	**6**	**7**	**8**	**6**	**7**	**8**	
Akdarya	**34718**	459	1023		19041	11503		1			**217,843**
Bulungurian	**38480**		419			35554	11		1		**313,831**
Jomboy	**37966**		1008			35631					**362,698**
Ishtikhan	**50680**	321			43018			4			**182,132**
Kattakurgan city	**14036**	3979			9903			9			**48,910**
Kattakurgan	**60747**	1632			53072			4			**197,455**
Koshrabad	**21208**	119			20886			2			**65,561**
Narpay	**38031**	82			36464			9			**103,254**
Nurabad	**25053**	308	33		19037	5486		3			**124,976**
Payaryk	**57856**	837	410		34001	13317		3			**263,960**
Pastdargom	**69283**	90	869		9690	51165		1	9		**327,779**
Pakhtachi	**90**	1			89						**0,276**
Samarkand city	**53180**		5496			47492			89		**647,953**
Samarkand	**52900**		2935			46009			353		**556,027**
Taylak	**41644**		1745	1661		20333	12888		2		**535,200**
Urgut	**73955**		11	1037		1436	68147			9	**1865,041**

Using the collected database, the cadastral value of residential buildings in the study area is an important practical aspect for the development of seismic risk maps of residential buildings in the regions, as well as for the implementation of policies to increase the seismic resistance of residential buildings at the regional level, increase seismic safety, and prepare for catastrophic earthquakes. Economic seismic risk map of the Samarkand region assessed for a scenario earthquake (Figure 5).



1-scenario (x=67.18, y=39.96, M=6, h=5km)



2-scenario (x=66.45, y=39.40, M=7, h=15km)

Figure 5 - Map of economic seismic risk assessed for the Samarkand region based on a scenario earthquake

To assess seismic risk at the administrative-territorial level, it is necessary to account for the distribution of the housing stock across all administrative districts, considering zones of varying seismic intensity.

Using cadastral data, a total of 658,300 residential buildings in the region were examined.

The analysis showed that a significant proportion of buildings in the region are constructed from local clay-based materials. For instance, under Scenario 1, structures made from locally produced raw brick (pakhsa) comprise 96% of all residential buildings. Consequently, the majority of primary damage indicators are associated with buildings that are seismically vulnerable due to their clay construction.

To evaluate the potential damage to these vulnerable structures within the study area, economic losses were estimated at the district level.

In this assessment, the estimated seismic risk translates into economic losses of 2.326 trillion sums in Payariq district and Samarkand city; 1.208 trillion sums in Jomboy and Samarkand districts; 6.883 trillion sums in Bulungur and Taylok districts; and 4.693 trillion sums in the districts of Aqdaryo, Bulungur, Qoshrobod, Pasdarg'om, Pakhtachi, Nurobod, Narpay, Ishtikhon, and Kattakurgan.

Based on the Scenario 2 map, the seismic risk assessment results indicate the following potential economic losses: 3.068 trillion sums in Urgut district and Samarkand city; 1.091 trillion sums in Taylok and Samarkand districts; 1.486 trillion sums in Bulungur, Jomboy, Poyariq, Aqdaryo, and Pasdarg'om districts; 65.837 billion sums in Pakhtachi and Qoshrobod districts; and 607.817 billion sums in Nurobod, Narpay, Ishtikhon, and Kattakurgan districts.

This map was created to quantify direct economic losses from strong earthquakes, taking into account the construction materials of all buildings and structures in the Samarkand region.

Conclusion. As of October 1, 2024, the Samarkand region had 658,300 residential buildings, all of which were systematically analyzed using the electronic database. Economic losses were estimated based on building construction materials, geographic coordinates, and actual cadastral values from the State Cadastre Chamber, and corresponding maps were created according to seismic risk levels. Under Scenario 1, for an earthquake at x = 67.18, y = 39.96, M = 6, h = 5 km, the potential economic losses across the districts of the Samarkand region were estimated at 4,691 billion sums. For Scenario 2, an earthquake at x = 66.45, y = 39.40, M = 7, h = 15 km, potential losses were projected at 6,319.4 billion sums.

The results of this study, which assessed the probable social and quantitative impacts of direct losses from seismic events on different structural types of residential buildings across all settlements in the Samarkand region, will serve as a foundation for planning potential socio-economic loss mitigation and for developing scientific and practical programs aimed at reducing seismic risk.

Acknowledgement. We express our gratitude to the scientists and researchers of Institute of Seismology of the Academy of Sciences of Republic of Uzbekistan R.S. Ibragimov, T.L. Ibragimov and M.A. Mirzayev for sharing the valuable geological and seismological data, which was crucial for this research.

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

Ответственный редактор *А. Ботанқызы*
Редакторы: *Д.С. Аленов, Т. Апендиев*
Верстка на компьютере: *Г.Д. Жадырановой*

Подписано в печать 06.02.2026.
Формат 70x90$^{1}/_{16}$. 20,5 п.л.
Заказ 1.

«Central Asian Academic Research Center» LLP
Алматы, Шевченко к-сі, 28