State policy for managing seismic territories in Kazakhstan

Dana Kangalakova[1*], *Zaira* Satpayeva[2], and *Kanat* Kangalakov[1]

[1]Institute of Economics Science, Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, Almaty, Kazakhstan
[2]Caravan Resources Group, Planning Department, Almaty, Kazakhstan

Abstract. Despite the relatively small number of destructive earthquakes in modern times, their numerous faults mean that the danger of earthquakes is still high. The purpose of the study is to study the chronology of the earthquake in the territory of Kazakhstan and its consequences, as well as to identify the features of the state governance system for seismic activity in the territory of the Republic of Kazakhstan. The methods intended to analyze historical facts and describe public policies, as well as visualize maps of tectonic plates in the Almaty city were used in this study. The results showed that the most seismic zone in the Republic of Kazakhstan is the Almaty city, located on 27 tectonic plates. The Almaty city was twice subjected to devastating earthquakes; therefore, the recurrence rate of destructive earthquakes is high. In this regard, an effective earthquake mitigation policy is required to minimize damage. Besides, this study describes the state seismology governance system in Kazakhstan. The study results can be the basis for the development of comprehensive measures intended to reduce the destructive consequences for seismically active zones.

1 Introduction

An earthquake is a cataclysm that occurs due to vibrations of the earth's surface and earthquake shocks caused by the movement of tectonic plates. Measurements of earthquake strength range from 1 to 9 under the Richter scale; when magnitude 1-2 earthquakes are felt as weak earthquake shocks, magnitude 8-9 earthquakes lead to serious damage and faults at a distance of hundreds of kilometers. The causes of an earthquake depend on the type of origin; it can be volcanic, tectonic, explosive, etc. The consequences of strong earthquakes have a colossal negative impact on the country's public governance system. That is, a cataclysm entails the death of the population, destruction of territorial infrastructure, massive damage to buildings and other objects. According to earthquakelist.org [1] (an analytical center that generates seismic data from the United States Geographical Survey (USGS) and the European-Mediterranean Seismological Center (EMSC)), the largest number of earthquakes was recorded in Mexico in 2024 (1227 earthquake shocks, the highest earthquake score is 6.4), followed by Indonesia (1111 earthquakes, the highest score is 6.4), Japan (1105, the highest score is 7.5), etc. Kazakhstan (Almaty) ranks the 12th place, where 238 earthquakes were recorded in 2024 with the highest score being 7.0. The city statistics show that the most significant earthquakes occurred in Taichung (Taiwan, 527 earthquake shocks with magnitude of 7.4) and Taipei (Taiwan, 526 earthquake shocks with magnitude of 7.4). This is followed by Kaohsiung (Taiwan, 511 earthquake shocks with magnitude of 7.4), Davao (Philippines, 511 earthquake shocks with the magnitude of 7.1), Saitama (Japan, 294 earthquake shocks with the magnitude of 7.5), Tokyo (Japan, 246 earthquake shocks with the magnitude of 7.5), Almaty (Kazakhstan, 222 earthquake shocks with the magnitude of 7.0), etc. Thus, this study examines earthquakes in the Almaty city. The Almaty city is the most seismically active territory of Kazakhstan located at the foot of the Zailiysky Alatau mountain that is a part of the Tien Shan. As it is known, mountains arise when two lithospheric plates collide with the continental crust, and the edges of these plates are crushed into folds. Consequently, there is a high level of seismic activity in such areas, and the Almaty city is located in a seismically active zone with a high level. Almaty is the main economic, financial and innovation center in Kazakhstan. Almaty was founded in 1854, and its original name was Verny. It plays a centuries-old economic, cultural and political role. The city has a population of 2.2 million persons and is a city of national importance. The city is of strategic importance in the development of Kazakhstan; the main strategic enterprises, including innovative and scientific ones, are concentrated in Almaty (about 90%). Consequently, Almaty plays a significant role in the development of Kazakhstan. Thus, the purpose of the study is to study the chronology of the earthquakes in Almaty, their consequences, as well as the state governance system aimed at seismic activity in the territory of the Republic of Kazakhstan.

The causes of the earthquake are unclear and cannot be predicted. Consequently, many countries and many scientists have devoted their efforts to study the causes of earthquakes and their prediction, since earthquakes on land deformed the earth's surface, and earthquakes in

* Corresponding author: danakangalakova@gmail.com

water caused huge waves off the coasts of the mainland territories of countries. The earliest studies were performed in the early 19th century. One of the early studies is that of Heim [2], a Swiss geologist who went on an exploration expedition and studied the surface of the earth and the effects of an earthquake in China. Gutenberg [3] studied the causes of waves and earthquakes in water areas. The earliest earthquake forecasting studies can be found in the works of Vere-Jones [4]. The author tried to develop a methodology intended to predict the seismic activity of the territory. Thus, the public governance system requires update under modern requirements. And, a lot of research has been devoted to the seismically active zone of the Almaty city, located at the foot of the Zailiysky Alatau mountain. Kruger F., Kulikova G. and Landgraf A. [5] studied the etiology of earthquakes in Central Asia, where earthquakes occurred in 1885 (Belovodskoye), 1887 (Verny) and 1889 (Chilik). The authors showed with the help of modeling of historical seismograms that the earthquakes had an even greater magnitude than it was officially reported. In 1911, another powerful earthquake occurred again. During it Deyev E.V. and Korzhenkov A.M. [6] conducted field research and identified the source of the earthquake. It was destructive in nature and had had low magnitude for many years. Thus, the Almaty city is located on faults of tectonic plates. It is a source of destructive earthquakes [7]. After the earthquake in Gaziantep (Turkey) [8], government agencies and seismologists in Kazakhstan began to think about measures that would minimize the earthquake consequences. However, the point of active government action was the earthquake recorded in January 2024.

2 Methodology

This research uses methods of visualization, chronological analysis and description of the state governance system of the seismic industry. The research algorithm is presented in Fig 1.

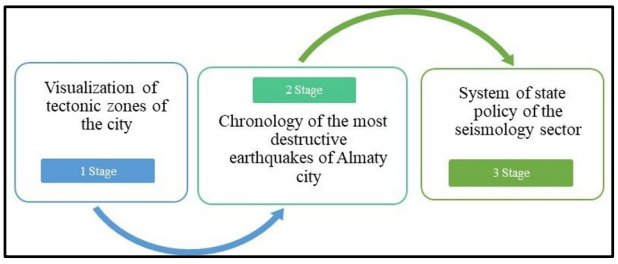

Fig. 1. Research algorithm

In the first stage, the study uses mapping of the tectonic zones of the city, which shows the future risks associated with a destruction monitoring system that can prevent devastating consequences. This map can serve as a guide for urban planning and earthquake response organizations. The second stage of the study examines the devastating earthquakes that have struck the city since its foundation. Based on the data and geographical changes in the city's territory, which were changed due to previous earthquakes, it is possible to assume and predict the scale and level of upcoming earthquakes. The state seismological policy is considered in the third stage of the study. An effective seismological policy is the key to optimal territory management during seismic activity. In this regard, the current policy of Kazakhstan in the field of seismology and the assessment of the readiness of state policy for seismic activity in Kazakhstan will be considered.

3 Results and discussion

Kazakhstan is located in Central Asia and is the ninth country in terms of territory. It borders with Kyrgyzstan, Uzbekistan, Turkmenistan, and Russia. The Tien Shan and Ile Altai Mountains are located in Kazakhstan's southeastern territory. These regions are earthquake-phone, and as they are located close to the tectonic fault of the earth's crust, there are repetitions of seismological activities. Almaty is Kazakhstan's most populous city and a major commercial, financial, and cultural center. It is located in the foothills of the Trans-Ili Alatau at an altitude of 700-900 м (2300-3000 ft).

Almaty was twice destroyed during the Verny (1887) and Kamensky (1911) earthquakes. The country's seismologists identified 27 tectonic faults under the city After the devastating earthquakes. Figure 2 shows tectonic faults that are more common closer to the western part of the Tien Shan Mountain range or the southern part of the Trans-Ili Alatau. The number of faults decreases to the north of the city. Almaty is the only city in Central Asia where a magnitude 10 earthquake can be predicted. In general, building codes do not contain a concept to calculate a magnitude 10 earthquake; this concept exists only in seismology. Besides, the city is located in a deep hole filled with sediment brought by rivers. It means that the soil under the city is fragile, and when the air shakes, the intensity of the earthquake increases by 1-1.5 points. Figure 2 shows a map of Almaty and tectonic faults in the territory of the city.

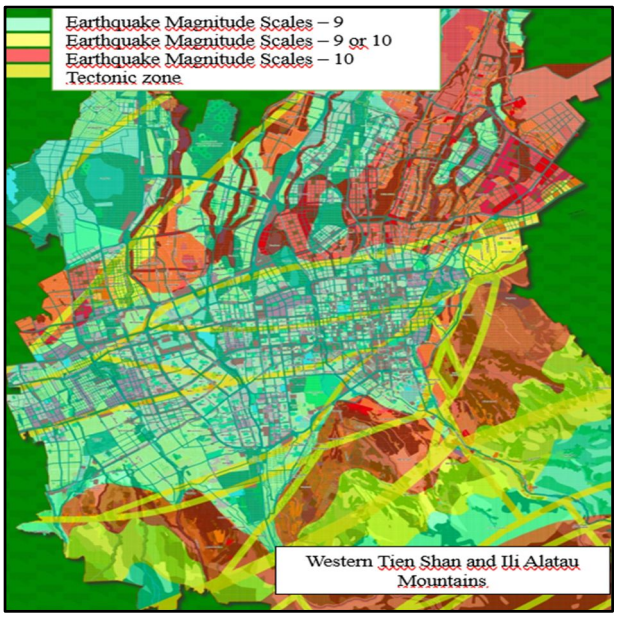

Fig. 2. Tectonic zones in Almaty

Figure 3 shows data on multi-storey residential complexes. As it was mentioned before, there are more tectonic faults to the south of the city, and their number decreases to the north; however, as we can see in the map, residential complexes are concentrated in the city center. Besides, the location of residential complexes coincides with the location of tectonic zones. Thus, the Almaty city is located in the most earthquake-prone zone in Central Asia. Losses and damage will be enormous if the Verny or Kemin earthquakes are repeated.

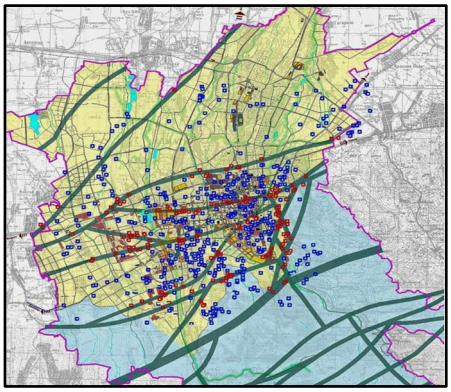

Fig. 3. Layout of multi-storey residential complexes constructed on tectonic faults

And, the most destructive earthquakes occurred more than 100 years ago in Almaty. The Verny earthquake occurred on the northern slope of the Trans-Ili Alatau, 10-12 kilometers south of the city at a depth of about 60 kilometers on May 28 (June 9), 1887, at 04:35 local time. The magnitude of the earthquake estimated under the Richter scale was from 7.3 to 7.8. According to official data, the city's inhabitants were about 22 thousand persons; 161 persons died, 1,798 brick houses were destroyed, only one survived. Mostly brick houses were built in the territory of the city, there were few wooden ones (Fig. 4).

Fig. 4. Verny earthquake, 1887

Figure 5 shows the Akzhar collapse that was the largest consequence after the Verny earthquake in 1887.

Fig. 5. Akzhar collapse

Thus, the very first destructive earthquake not only wiped the city off the face of the earth, but also changed its landscape. Wood was mainly used in the construction of the city after the earthquake. The second devastating earthquake occurred on January 4, 1911. The epicenter was located near the eastern tip of the Trans-Ili Alatau, approximately 40 kilometers from the Almaty city. Its magnitude was 8 under the Richter scale. Seven hundred and seventy-six houses were destroyed, 35 persons died, and 168 persons were injured.

One of the last major earthquakes in the city in 2024 was recorded on January 23 at 00:09 local time. The epicenter was in the area 264 km southeast of the Almaty city, in the territory of Kyrgyzstan, at a depth of 65 km. Energy class was 15.1. Magnitude was 6.7. Forty-four persons with various mild to moderate injuries sought medical care. Besides, first shift classes in schools and colleges were canceled in Almaty. The buildings did not collapse; minor repair deformations were recorded. Thus, the Almaty city was destroyed and rebuilt twice. At the moment, the number of residents in Almaty is officially 2.2 million persons; however, since the city was declared to be of strategic importance, it attracted more labor from the periphery of the country. According to unofficial data, the number of residents is even more significant. In this regard, effective public policy is required to ensure a safe life for the posspulation. The public policy system is shown in the Fig. 6.

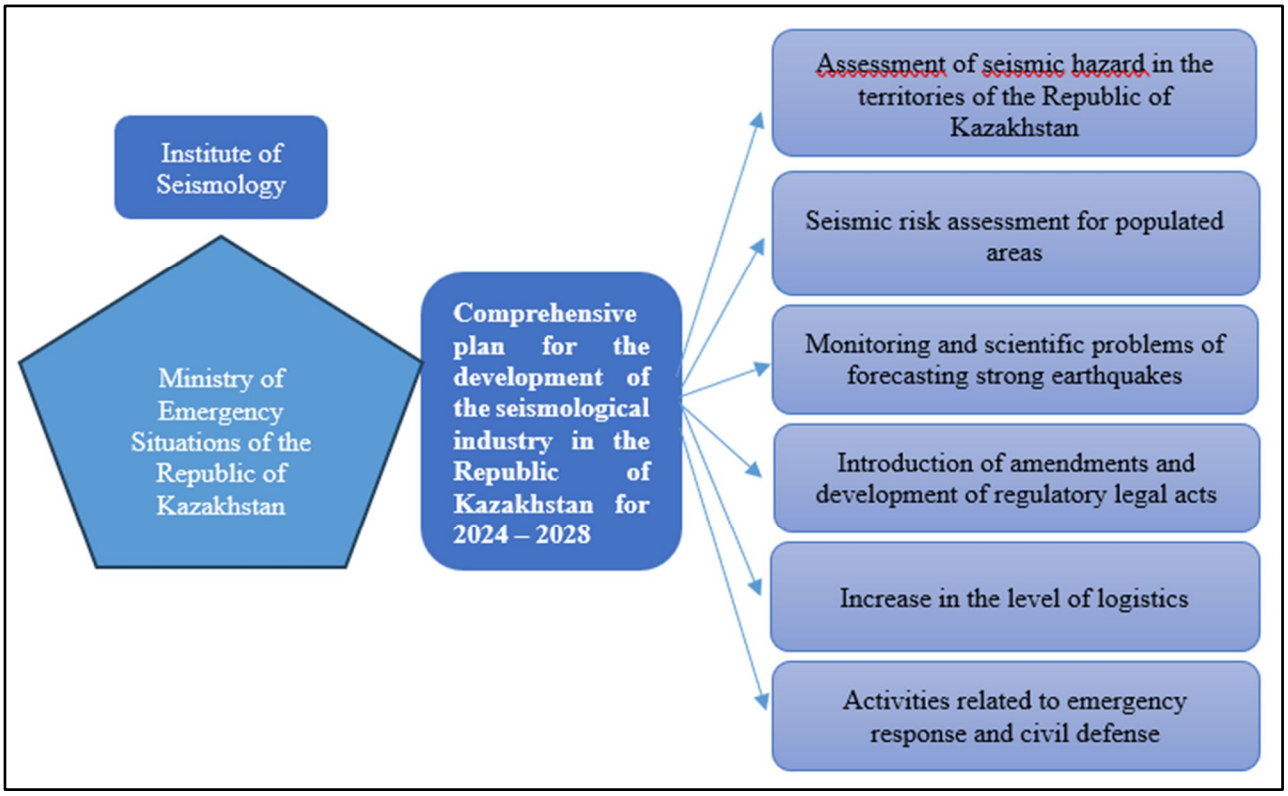

Fig. 6. System of state policy of the seismological industry of the Republic of Kazakhstan

The Ministry of Emergency Situations of the Republic of Kazakhstan is the main body pursuing state policy regarding seismic phenomena. The main seismic activity research center is the Institute of Seismology, an organization subordinate to the Ministry. This institute was created in 1976 and solved the following problems: assessment of the seismic hazard for the territory of the Republic of Kazakhstan (seismic zoning), solvation of scientific problems of predicting strong earthquakes, as well as assessment of the seismic risk of populated areas. However, the current state of the Institute of Seismology is insufficient to conduct advanced seismological research; in connection with the recent earthquakes, the President of the Republic of Kazakhstan instructed to resume research and equip the organization with advanced technologies to reduce seismic risks in Kazakhstan.

The situation in the scientific field of seismology requires special attention. The research conducted by the Institute of Seismology is based on outdated equipment. The Institute of Seismology was renamed in 2024 as the National Center for Seismological Research, but it does not have essential funding. In addition, 17 thousand dollars were planned to improve the infrastructure in seismological science, but more than these funds are needed for the proper level of research. There are 68 seismic stations located in Kazakhstan, which are 80 times smaller than Japan's when the territory of Kazakhstan is enormous compared to Japan. However, even in Japan, seismologists cannot predict powerful tremors and their localization. In Kazakhstan, the method of forecasting with the help of animals is still used. However, money is no longer allocated for their maintenance: food for rabbits, lizards, chickens, snakes, and other wards that serve seismology is bought by the employees themselves. Regarding scientific personnel in the seismological industry, this industry is rare among young people, since the average monthly salary is about 200-450 dollars. In this regard, this industry needs a significant human resource potential of scientific personnel and young people. The primary scientific staff of the National Seismology Center is in the pre-retirement age, which also affects the results of scientific research, which requires a set of unique and complex skills to ensure the quality of scientific work. By gender, the potential of scientific personnel includes more men than women. It should be noted that the scientific composition of Kazakhstan shows that 53% of women scientists are registered in the country, which means that women are more interested in scientific research and choose the investigator profession. Thus, to improve seismological science, Kazakhstan would be better off developing a unique program for young women scientists aimed at increasing human resources in seismological science and diversifying scientific research.

Besides, the “Comprehensive Plan for the Development of the Seismological Industry in the Republic of Kazakhstan” was adopted in 2024 [9]. It should be noted that no special events related to seismology were held in Kazakhstan before it. The comprehensive plan includes six areas.

The first direction includes assessment of the seismic hazard in the territory of the Republic of Kazakhstan. As mentioned earlier, the Almaty city is a central earthquake zone. However, other regions where the mountain range continues should also be classified as areas where earthquakes are possible. In this regard, this direction involves the development of sets of seismic microzoning

maps with a scale of 1:10,000-50,000 for the territory of cities and regions. Micro districting will help determine which areas of the territory are most vulnerable to seismic impacts. In addition, this tool is used to determine the soil characteristics in an earthquake-prone area. This data is used to design buildings and structures, considering the level of seismic hazard. As is known, the southeastern territory of Kazakhstan is located near the Tien Shan Mountains and the Trans-Ili Alatau, which does not exclude seismological activity and require detailed study.

The second direction is assessment of the seismic risk of populated areas, significant objects and forecasts of damage from an earthquake. This area involves certification of seismic resistance and reliability of a structure, as well as calculation of potential damage in the event of an earthquake. An analysis will be carried out not only of buildings but also of other vital elements of urban infrastructure, including water supply, electricity and gas supply systems, transport routes, and healthcare facilities, and attention will also be paid to socially significant facilities - hospitals, schools, and government agencies. Damage forecasting includes not only the calculation of probable financial losses but also an assessment of the consequences for the population, such as loss of life, evacuation, and restoration work. The third direction is monitoring and solvation of scientific problems of forecasting strong earthquakes. In this direction, more attention will be paid to the work of seismologists who will monitor strong earthquakes in the world and calculate patterns and similarities in their recurrence. It also provides for the development of domestic software intended to process seismic monitoring data. In this regard, it is necessary to consider the importance of scientific personnel in seismological science, which will become the driving force of scientific research. The quality of scientific research will depend on the quality of scientific personnel. Therefore, Kazakhstan's scientific and educational system should strengthen scientific personnel's activities in seismological science and diversify research by attracting female scientists. The fourth direction concerns the improvement of the regulatory framework. This direction will include regular updating of building codes and regulations, taking into account new research and technologies; the establishment of mandatory certification of all buildings for earthquake resistance, with mandatory revision of certifications at certain intervals, especially in seismically active zones; the development of stricter standards for critical infrastructure (hospitals, schools, transport hubs, power plants) providing for their resistance to strong earthquakes; providing training and retraining of personnel working in the seismological field, including engineers, builders and urbanists and implementing educational programs and advanced training courses on new technologies and approaches in seismology and construction, etc. The fifth direction is increase in the level of data transmission. Namely, it is planned to create a digital archive system to convert seismic data into a digital version. It is also planned to provide the use of satellite/ultra-short-wave communications at seismic stations. To improve data transmission using digital tools in seismology, it is necessary to implement cloud technologies for real-time data storage and processing, use the Internet of Things sensor networks to automatically collect information, and increase data transfer speeds using modern network solutions such as 5G and fiber optics. Integrating data from various sources and using standards and artificial intelligence for automatic analysis and forecasting will increase the efficiency of data use. Significant financial and human resources will be required to implement this direction. In addition, there will be a need to train interdisciplinary personnel, which will contribute to improving the seismological sector in Kazakhstan.

The sixth direction includes measures for emergency response and civil defense. It includes developing emergency evacuation plans, training the population to act in earthquake conditions, creating early warning systems, and providing infrastructure ready for emergencies. These measures increase disaster preparedness, reduce risks to people's lives, and ensure a quick and effective response to emergencies. Moreover, it includes the development of a draft digital version of the Emergency Response Action Plan on a global and regional scale with mandatory computer modeling of a possible situation in the event of a devastating earthquake, the identification of alternative options for provision of the population with drinking and domestic water, carrying out activities to check the readiness of infrastructure for earthquakes and other emergencies, etc.

Thus, the state governance system of the seismic industry requires huge investments and decisive measures to improve the country's seismological system. The implementation of the measures mentioned above will ensure effective management of the seismological territory of Kazakhstan and ensure the preparedness of the population for emergencies.

4 Conclusion

Public policies regarding seismic activity in an area are vital to reduce damage from the effects of an earthquake. The consequences of the earthquake will be enormous without government intervention. These destructive earthquakes have already occurred in the territory of Kazakhstan. The Almaty city, with a population of 22 thousand persons, experienced two devastating earthquakes in 1887 and 1911 resulted in the formation of 27 tectonic plates that can be activated at any time. Currently, the population of Almaty is 2.2 million persons. The most dangerous areas of the city are located closer to Mount Ile-Alatau, and the most densely populated area of the city is the center, where multi-storey residential complexes are located. Thus, the Almaty city could be completely destroyed in the event of a devastating earthquake, and the consequences would be dire. The state seismic monitoring system was in decline until 2024. The main seismology research center was not an active research organization because it lacked sufficient funding, and seismologists changed directions of research due to low pay. Seismological scientists in Kazakhstan predict repetition of destructive earthquakes, since the two previous earthquakes have the etymology of

repetition, since they are located at the junctions of the earth's crust plates. A new wave in the development of the seismology science was the earthquake happened on January 23, 2024, which led to the approval of a comprehensive plan for the development of the seismology industry. This plan includes six areas: from improvement of the material, technical and regulatory framework to educate the population during an emergency. Thus, the governance system for seismically active areas of Kazakhstan has received a new wave of development.

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