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Underground Mining Radio Communication System's Risk And Reliability

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ABSTRACT
There is a lot of risk of harm and damage caused by disaster in underground mine communication system. Among the disaster risks that can be occurred in underground mine earth quake has high probability. Therefore we have evaluated in assessing risk and reliability of radio communications interdependent systems in this article. By recognizing possible risk in advance we can reduce and can take reserve measures on the disaster harm and damage.

Keywords - disaster, risk, earth quake, reserve measures, reliability

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I. Introduction

Nowadays communication system (call, data, and internet) plays a critical role in the main operation among the systems of technics in the underground mining besides being a part of the national infrastructure sector. The mining sector has a crucial role in the national economic development of Mongolia. A reliable communication system has an important role to ensure employees' safety, productivity, and efficiency of the mining operation [4]. Furthermore, it is impossible to safely operate in the underground mining without reliable communication system. Due to the fact of ensuring the safety of the employees' who work in the danger at the underground mining, regular and reliable systems of communication and information technology is the key. Thus, a scientific estimation to back up the reliability of the communication system is significant [5]. This research work aims to estimate the susceptibility of the seismicity risk to the main communication system of the underground mining.

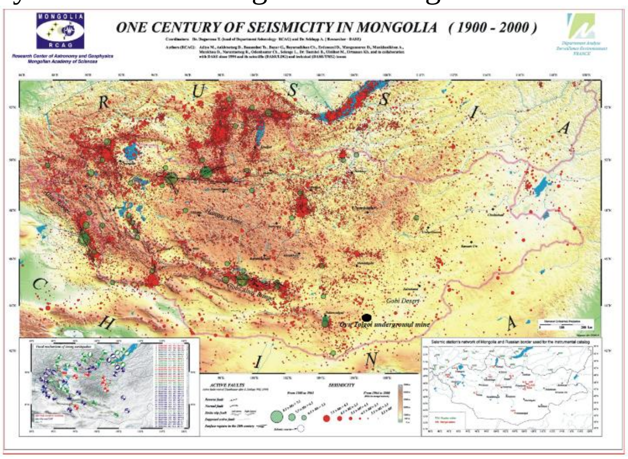


Figure1. Seismicity in Mongolia (1900 - 2000)

Oyutolgoi, underground mining locates in the southern part of Mongolia where less prone to the seismicity. Figure 1 illustrates there had been seismicity ranging from 2,5 to 6,5 magnitudes occurred in the Gobi region where Oyutolgoi operates. (between 1964 and 2000).

Authors identified the following risks that could affect the safe and reliable operation of the communication system in the underground mining. Seismicity risk had chosen for the further estimation of the susceptibility. Figure 2 shows the scheme of the infrastructure system in the underground mining.

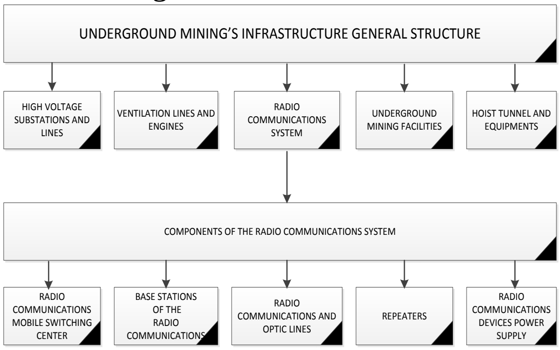


Fig. 1. Underground mining infrastrucure and radio communications system's general structure

Radio communication system of the underground mining operates independently and consists of head-end, base station, a leaky feeder cable with a headend, amplifiersm and radios. Additional LAN network equipment such as switches, fiber optic cables, access points, computer, and PABX telephone operates along with the radio system equipment.

Potential hazards and its effect on the underground mining radio communication system has demonstrated in the table below.

Table 1. Potential hazards and its effect to the underground mining radio communication system

Underground mining communications	
Natural risks	flood
	fire
	earthquake
	big blasting
	pollution (big dust)
	spoil bank (landfall)
Technical risks	Cut fiber optic
	Cut electricity
	Damage the base station, amplifier
	Cut the radiation cable
UG mining catastrophic	Electricity damage
	Hoist cage damage
	Broke tunnel of hoist cage
	Ventilation damage
	Chemical catastrophic

For instance, [6] scholars estimated the geotechnical risk of the underground mining in Australia and explained its effect on the safety management. In other words, they study the correlation between the technology development and safety management.

Based on the [7] response management regarding the mining incident, potential incidents had classified into 3 main levels considering the lack of information, short time and difficulty of the situation. Moreover, the study identified the levels of hazards in the mining and categorize the impact of the damage.

The research work [8] solely based on the theory and expand the database of the statistics on hazardous incidents including natural hazards, weather change, market inflation and so on which is the introduction of new real-indicator of probability axiom. In other research [9] the risk estimation method applied to calculate the communication flow and flexibility in the infrastructure system. They had simulated the equation of soil erosion probability and distribution of the spatial correlation. Some scholars in Mongolia have done this sort of estimation only from the economic perspectives [10] taking mining operation in Mongolia as an example involving project management components such as integration, framework, timeline, finance, quality, human resource, communication, and procurement. Some research chose to focus on the estimation of susceptibility on the certain equipment and its operation. [11] Matrix analysis of the risk on the operation of natural stone factory. Potential risk has estimated by L-matrix analysis method and they identified 3 potential risks namely malfunction of the elevator cable and cutter, electronic damage as well. [12] emphasized the importance of the risk management of seismicity in the vital infrastructure sectors such as water supply, electricity, transportation, and communication. The aforementioned study focused on 2 subjects. Firstly, reliability analysis on seismicity and correlation of sectors in the infrastructure system. Secondly, the cost-effectiveness analysis was conducted on the operations of the infrastructure systems using quantitative methods tackling quality measurement issues. There are similarities between this study and the author's work. Regarding the safety operation, [13] mentioned the major improvements made in the Australian mining sector in last 15 years and one of their major component was the enhancement of risk analysis methods. As a result, the mountain management system has significantly improved. This risk analysis method based on the equipment design and operational system. Quantitative analysis method had applied to identify the correlation among main infrastructure sectors involving electronic supply, communication channels, transportation, and water supply [14], which shows that dynamic methods of the system are one of the main methods to assess the risk. Communication is the most crucial part of this infrastructure and central operation system allows to enhance emergency management and flexibility within the infrastructure sector. [15] Highlighted hazard of fire in the underground mining, mentioning the research regarding the fire risk assessment in the underground mining, smartphone application includes information on fire safety, and fire alarm notice. Recommended systems are sensors, detectors, smartphones, Internet of Things (IoT), cloud computing, application gateways, and an application program. [16] summarized the current methods to assess the risks in the communication and describe the communication flow and coordination among infrastructure systems during the emergency. In the research conducted in the theoretical framework, [17] decision making analysis were based on the theory of аксиом by Wan Newman in the realm of the disaster risk. This study presents the economic analysis of the disaster risks such as climate change and extinct of certain species to the green economy. [18] assessed the disaster risks by non-standard probability approaches. The random variables were considered as negative probability such as disastrous consequences such as human mortality. Potential risks in the communication system have examined on the cases in the US, [19] the impacts of the natural hazards such as a tornado, heavy rainfall, and flooding to the electrical supply, other crucial lifelines including communication system. Quantitative data had illustrated the preparedness level of the wired and wireless networks during the malfunction. Among these disaster risk researches [20] demonstrated the interesting study on the change in people's attitude during natural and technological hazards. This research covered various fields including mathematics, computer science and geography subjects which makes it refreshing. Furthermore, the psychological reaction of the affected community during the emergency had studied by susceptible-infected-recovered (SIR based) mathematical model. Preparedness of the infrastructure system operation is a vital concept during any types of natural and technological hazard incident. [21] focused on the issues regarding the correlation between infrastructure system and networks, ensuring flexible communication throughout the system. A new method has identified that infrastructure performance is based on its response and recovery capacity. Similar research [22] applied the Bayesian method to define the correlation using the probability approach. Understanding the influence of the correlation within the whole systems will ensure the flexible infrastructure system has been proved. Another comparative study [23] illustrated the comparison of the simulation models of the wired and wireless networks in the city area. The first simulation is a separate model and the second one is the dynamic model on the high level, time-based system. The main goal was to examine the preparedness of the 2 models during the communication malfunction. The dynamic model proved to be more reliable and effective as a result. Another study similar to our work was [24] the study that suggested the new mathematical method on the project risk response showing the results in the quantitative norm.

[25] stated that a network malfunction in the region puts various glass fiber cable connections into a danger and could bring a massive loss as well. A preparedness scheme has introduced to prevent such massive damage and reduce the potential risk. This includes risk probability method to analyze the potential disaster loss, also mathematical models to reduce the risk and potential loss as an engineering solution to prevent the glass fiber cable malfunction.

II. EARTHQUAKE INFORMATION IS A RANDOM QUANTITY, ITS MAIN CHARACTER

In principle, unpredictable quantities are called "random measurements" on the basis of the conditions with the results of the experiment. The random quantity is a collection of numbers included in a particular test result [24]. In the spectrum of our continuous research, the interval between earthquakes is itself a random measurement. The interval between earthquakes is calculated based on the data shown in [23]. Based on these results, the probability of an earthquake is calculated. First of all, we will find the average of the sample $\bar{X}$ to determine whether the amplitude of the amplifiers has a speaker. Then the theoretical distribution frequency is m_i^0:

$$m_i^0 = n * \left[e^{-\lambda x_i} - e^{-\lambda x_{i+1}}\right] \quad (1)$$

found by this formula. This is the sample size, λ = 1 / X. α is approved rate. Theoretically, the value of L = k-2 is calculated from the

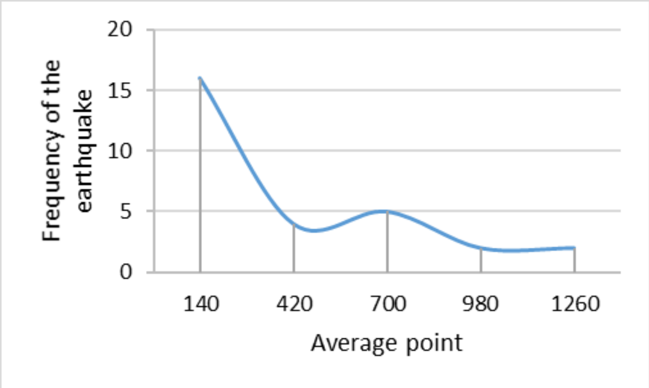
$$\chi^2_{\text{ажил}} = \sum_{i=1}^{k} \frac{(m_i - m_i^0)}{m_i^0} \quad (2)$$

Find $\chi^2_{L,\alpha}$, α from the $\chi 2$ tablet. If the assumptions are fulfilled, the basic hypothesis of the distribution law is permitted if $\chi 2$work < $\chi 2$ L,α is fulfilled. In other words, the random quantity can be trusted with p = 1-α [25].

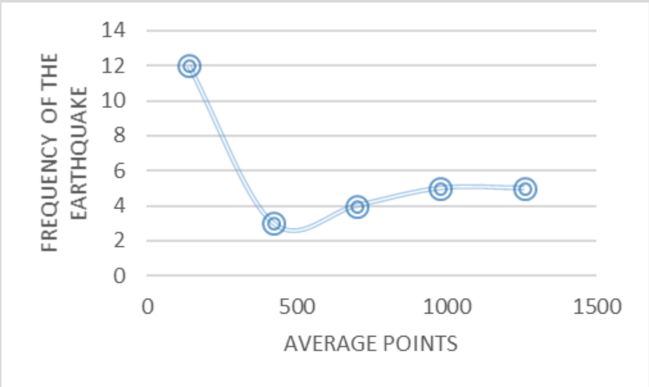
$$F(t)=1-R(t)=1-e^{-\lambda t} \text{ function} \quad (3)$$

The seismic data of the earthquake, the year, and the date of the earthquake were sorted from the lowest to the highest, and calculated the period between the last two consecutive ones. We used Excel calculation for above formulas and below exponential distribution charts. Interval between consecutive two earthquakes (in days) and the results of the exponential distribution chart can be seen from the chart below figure 2 and 3.

We used an earthquake data on US geological survey data [26] to analyze the spread spectrum using the earthquake data and estimate the probability of an earthquake in the underground mine. To do this, we set up a spreading spectrum using the interim periods over the two periods based on information on earthquakes in Umnugovi Aimag. Figure 3 and 4 shows the distribution charts in Umnugovi Aimag.



Exponential Recent and historical earthquake data in Umnugobi aimag



Larges earthquake data in Umnugobi aimag

III. Results of probability

According to the results of the distribution chart and probable estimates, the risk of earthquake and mine infrastructure in the Oyu Tolgoi underground mine and the infrastructure infrastructure is estimated to be 59% for the recent earthquake (3.1-5.4 magnitude earthquake), in the next two years, while large earthquakes (4.2 to 8.8 magnitude earthquake) are 46%. The above results are assumed to be probable of probing to a 95% probability of probability of Poison's test: 17.7 or [3]. According to the [27] web site of the University of Michigan's University of Earthquake study, 3.1-5.4 magnitude earthquakes are classified into medium-middle earthquakes, but heavy but small-scale vibrations are detected, while the 4.2-6.8 magnitude earthquake is strongly classified and may be classified as likely to cause significant damage.

IV. Estimate the reliability of the underground mine radio communications system and the probability of earthquake risk

The unimodal limit formula developed by An and Tang (1984):

$$P_{fij} = \Phi_2(-\beta_i - \beta_j, \rho_{ij}) = \int_{-\infty}^{-\beta_i} \dots \int_{-\infty}^{-\beta_j} \phi_2(-x_i, x_j, \rho_{ij})\, dx_i, dx_j \quad (3)$$

Where,

$$\Phi_2(-x_i, x_j, \rho_{ij}) = \frac{1}{2\pi\sqrt{1-\rho_{ij}^2}} \exp(-\frac{1}{2} * \frac{x_i^2 - x_j^2 - 2\rho_{ij}x_i x_j}{1-\rho_{ij}^2} \quad (4)$$

The reliability indices β_i and β_j correspond to the i th and j th failure modes, respectively; ρ_{ij} is the correlation coefficient between the i th and j th failure modes; and $\Phi_2(.)$ and $\phi_2(.)$ are the probability density function and cumulative distribution function, respectively, of 2D standard normal distribution.

Eq. (3) is an accurate expression for ρ_{ij}. The underground mine radio system is a series of connected circuits and each of the booster devices is connected by a radiator and optical cable.

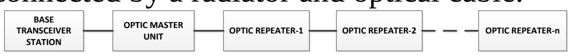


Fig.3. Exponential Recent and historical earthquake data in Umnugobi aimag

Pf = Earthquake probability * Radio users * Impact days (5)

The Oyu Tolgoi underground mine located in Khanbogd soum of Omnogovi aimag, especially the Oyu Tolgoi underground mine details and research work is rarely used, so we use the data sources of US geological survey data [26]. The average probability of underground mine closure is estimated.

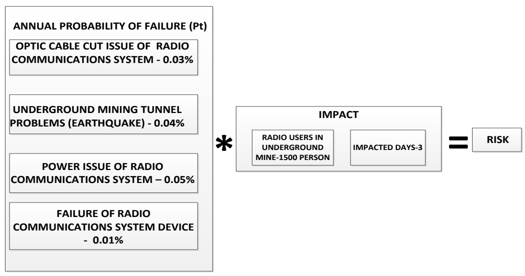


Fig. 4. Estimate the risks to the underground mine communication system

Three of the four risk factors of the underground mine radio communication system shown in Figure 5 are based on data from Oyu Tolgoi's underground mining system, technical faults.

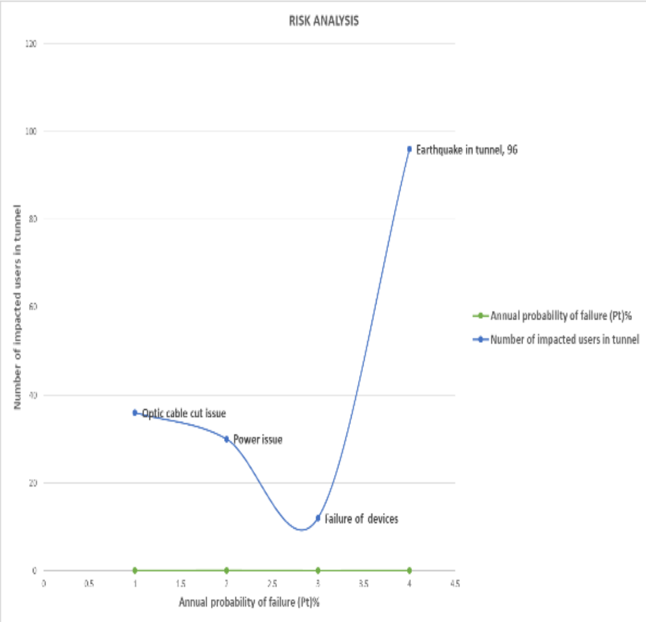


Fig. 5. Exponential Recent and historical earthquake data in Umnugobi aimag

Conclussion

This study emphasizes the importance of seismic susceptibility estimation that provides an opportunity to prevent potential disaster risk (Table 1).

A seismicity is considered as the most disastrous incident with higher susceptibility in this case and the susceptibility of the seismicity in the underground mining has estimated by the analysis on the database provided by geological research materials in the USA [26]. Furthermore, the potential risk on the communication system of the underground mining due to the seismicity has calculated. We will extend our research to the factors to the underground mining communication system reliability in the further, specifically focusing on the analysis of power loss, reliability analysis of radio communication networks-mathematical models and algorithms.

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