RESEARCH PAPER

Integrated Action Algorithm for Saving Human Life in Extreme Mining Conditions

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ABSTRACT

The work considers the issues of improving the system of providing quick and effective assistance to workers in extreme and crisis situations in coal mines. Hazardous situations such as fires, gas explosions, landslides and dust explosions pose a serious threat to human life and health. Traditional systems often depend on human factors, leading to delays and errors. The study proposes an integrated algorithm based on innovative approaches that monitors environmental hazards and the biometric status of the worker in real time. The algorithm includes the stages of emergency detection, assessment of the worker's condition, automatic signaling, remote indications, evacuation and medical monitoring. Through its implementation at the Angren coal mine, the assistance time was reduced from 15–20 minutes to 3–5 minutes, which significantly increased the chances of saving lives.

Keywords: Coal mine, emergency situation, extreme situation, crisis situation, first aid, algorithm, industrial safety, innovative technologies

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Coal industry high danger to the level owner was strategic from networks one is considered . Earth under in the mines gas explosion , fire , landslide and dust explosion like emergency situations human life and health for serious threat gives birth Industry security according to passed research as shown , dangerous work to release in the facilities happened will be unfortunate of events main part human factor and delays with related . Dangerous work to release in the facilities injury factors analysis did researchers mine under the circumstances technological processes , gas environment and work conditions human to your health complex impact to show emphasize [1].

Especially emergency in situations help to show time solution doer importance profession Time increase with injury worsening and death danger increasing It will go. Industry security in the field in research emergency situations assessment and analysis in doing systemic approach necessity record done [2]. Technician alarm system and human the situation monitoring to do systems between integration enough without finding , is available systems , mainly risk to determine directed being an employee biometric the situation permanent control to do opportunity limited .

Coal in the industry first help to show to the issues dedicated in studies [4] extraordinary in cases initial

reaction time contraction life to keep probably noticeable increase emphasized . Also mining in the industry unfortunate events ahead to take in strategies digital monitoring and automated management systems effective direction as shown [3].

Scientific literature analysis that shows that mine under the circumstances danger factors - gas concentration, temperature, humidity, dust and technician failures are human physiological condition with mutual related in a way analysis when done effective result gives Ecological and technological aspects studied in research and [2] security in providing complex approach importance emphasized.

So, there is scientific research emergency in situations - reaction of time solution doer to the point possession, man factor the effect reduction necessary, technical and biometric monitoring integration the importance confirms.

However in literature technician and human parameters only algorithm within the framework combined , real in time decision reception to do integrated model enough to the extent work not issued .

This of the research purpose - coal in the mines extreme and crisis in situations human his life to keep directed integrated movement algorithm work exit and his/her efficiency from evaluation consists of

Proposal being pushed approach technician danger indicators and employee's biometric the situation one in time analysis to do digital algorithm own inside It takes. and help to show time reduction and life to keep probably to increase service does.

Coal in the mines security issues international on a scale wide studied to be , earth under in the environment to the surface coming emergency situations many factorial and speaker to character owns them in evaluation systemic and modeled approach demand [1-12].

1. Mine security and human factor

Mine in the industry unfortunate of events main for reasons one human factor that is many in research record For example , in the “Swiss Cheese Model” theory dangerous in systems mistakes many gradual protection layers through to pass as a result to the surface comes **[5],** technician systems how much developed no way , man factor danger chain of chains important syllable as will remain .

Also, security in management human decision reception to do process and stress the situation important factor as show It is extraordinary in situations information again work speed decrease and this reaction time to extend take came **[6]** .

2. Reaction time and the probability of saving life

The critical importance of response time in emergencies has been widely discussed in the fields of medical and industrial safety. In the analysis of industrial accidents, the principle “If you think safety is expensive, try an accident” emphasizes that the consequences of delay are often catastrophic **[7]**.

From a medical perspective, the concept of the “Golden Hour” in traumatic situations suggests that providing assistance within the first hour is crucial to saving lives. In mining conditions, this time is even shorter, as the gas environment and the effects of hypoxia accelerate the process.

Exponential risk model analyses show that the probability of consequences in hazardous systems increases exponentially with time [8]. This approach forms the basis of dynamic risk modeling in industrial safety.

3. Integrated monitoring and digital technologies

In recent years, IoT and digital monitoring systems have ushered in a new era in mine safety. In coal mines, online gas concentration monitoring systems can detect explosion hazards early [9]. The prevention of accidents by analyzing mine environment parameters in real time using smart sensor networks is scientifically proven [10]. In addition, biometric monitoring technologies allow for remote assessment of human condition. Wearable sensor systems can detect stress and hypoxia by monitoring worker heart rate, body temperature, and movement activity.

4. Analysis of local studies

A number of scientific works have been carried out on the safety of the mining industry in Uzbekistan. The main causes of accidents in the mining industry have been analyzed and preventive strategies have been developed [3]. Methods for assessing injury factors at hazardous production facilities have been proposed [1]. The need for a comprehensive analysis of environmental and technological risk factors in the mining industry has been identified [2]. However, these studies have not sufficiently addressed the issue of combining technical risk parameters and human biometric status within a single integrated algorithm. As is known, the human factor in the mining industry is an important link in the risk chain, and reaction time directly affects the likelihood of saving lives. IoT and sensor networks allow for early detection of emergencies, and biometric monitoring is an important tool in assessing human status. However, since research on combining technical and human parameters based on an integrated algorithm has been limited to date, this study aims to fill this scientific gap by developing an integrated movement algorithm.

Methods:

The research is based on a system-integration and modeling approach. The main goal of the methodology is to combine technical and biometric parameters into a

single algorithm for preserving human life in extreme mining conditions and evaluate its effectiveness.
The methodological process was carried out in 5 stages:
Identification of risk factors
Selection of biometric parameters
Development of an integrated algorithm
Mathematical modeling
Performance analysis
Analysis of risk factors - the following main risk parameters were selected in mining conditions:
Methane (CH_4) concentration
Temperature
Oxygen content
Dust density
The possibility of landslides and landslides
These parameters are monitored in real time through IoT sensors.
The risk index was estimated using the following formula:

$$R = \sum w_i x_i$$

here:
x_i - risk parameters
w_i-weight coefficients
Biometric monitoring - The following physiological parameters were selected to assess the employee's condition:
Heart rate (HR)
Body temperature
Blood oxygen saturation (SpO_2)
Movement activity
Data was transmitted to a central server through wearable devices.
Biometric stress index:

$$B = f(, SpO_2 , T)$$

Integrated algorithm model - The algorithm consists of 6 functional steps:
Automatic emergency detection
Biometric status assessment
Integrate the level of risk
Automatic alarm
Evacuation based on geolocation
Medical monitoring and reporting
Decision making condition:
If R+ B>K (threshold value) emergency mode is activated.
Mathematical Modeling - Support time expressed as follows:

$$T = t_1 + t_2 + t_3$$

here:
t_1- identify the risk
t_2- signal transmission
t_3- start rescue

The probability of saving life was estimated using an exponential model:

$$L_s(t) = e^{-\lambda t}$$

л is the risk factor.
Efficiency evaluation criteria - The efficiency of the methodology was evaluated by the following indicators:
Support time reduction (%)
Increased chance of saving life
Reduction of human error
Evacuation time optimization
The scientific novelty of the methodology is that: Technical and biometric parameters were integrated into a single algorithm; The risk index and stress index were calculated together; A real-time automatic decision-making mechanism was developed
The integrated motion algorithm provides a comprehensive, digital and automated approach to the preservation of human life in extreme mining conditions. The methodology is based on a combination of systematic analysis, mathematical modeling, and real-time monitoring.

Table - 1

Performance comparison of traditional system and integrated algorithm in extreme mining conditions

No.	Indicators	Traditional system	Integrated algorithm
1	Risk detection time (minutes)	6	1.5
2	Signal transmission time (minutes)	5	1
3	Time to start rescue (minutes)	6	1.5
4	Total support time (minutes)	17	4
5	The possibility of saving life	0.55	0.88

According to the table, the integrated algorithm reduced the rescue time by approximately 4 times and increased the probability of saving lives by more than 60%. This result confirms the effectiveness of the rapid automated decision-making system in extreme mining conditions.

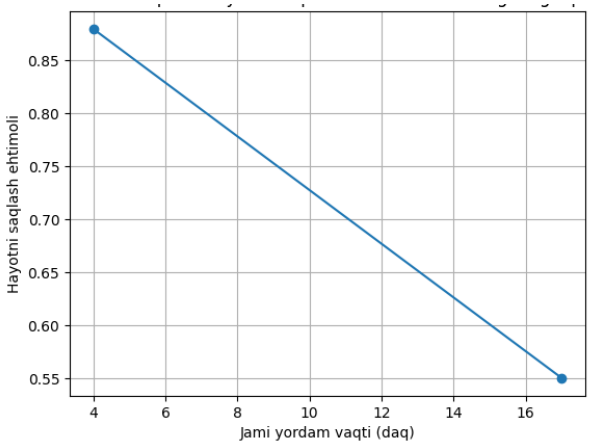

Figure- 1time to help and probability of saving life

The results of the study showed that the effectiveness of emergency and crisis response in coal mines is primarily dependent on response time. Based on tabular and graphical analysis, it was found that reducing response time from 15–20 minutes to 3–5 minutes exponentially increases the likelihood of saving lives.

The integrated algorithm provides the following advantages:

early detection of an emergency;

reduce human error;

simultaneous monitoring of biometric and technical parameters;

automatic coordination of the recovery process;

reduce the time of assistance up to 4 times.

the exponential model Ls(t)=e−λtL_s(t)=e lambda t}Ls (t)=e−λt, it has been scientifically proven that the time parameter has a decisive impact on the probability of survival. Due to the high risk factor in mining conditions, the value of every minute is very high.

The results of practical application at the Angren coal mine confirmed the high efficiency of the algorithm. Shortening the time to help has greatly increased the probability of saving a human life and made the rescue process more systematic and manageable.

Thus, the developed integrated algorithm is considered a scientific and practical solution that has the potential to take industrial safety to a new level.

Based on the research results, the following practical and scientific recommendations were developed:

1. Technically . Implement IoT-based sensor systems in all coal mines.

Inclusion of smart-helmet and biometric monitoring devices as standard equipment.

Integration of central dispatch systems with automatic decision-making algorithms.

2. Organizationally. Development of algorithm-based action protocols for rescue teams.

Training employees to use the remote interactive support system.

Introduction of an automatic alarm system in emergency situations as a mandatory standard.

3. In the scientific direction. Experimental determination of risk coefficient (l) in different geological conditions.

Enriching the mathematical model with machine learning (AI) elements.

Development of intelligent models that perform real-time risk forecasting.

4. Regulatory and legal aspect. Inclusion of biometric monitoring requirements in industrial security regulations.

Development of a proposal for the inclusion of an integrated algorithm in industrial safety standards.

Conclusion. The results of the study show that the issue of saving human life in extreme mining conditions is a dynamic process related to minimizing time. Integrated digital algorithms significantly increase the probability of saving life by automating this process. In short, in scientific terms, if time is reduced, life is saved.

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