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Sustainable Development of Mining by Utilizing Innovative Global Methods to Reduce Mining Hazards

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ABSTRACT

Historical analysis of mining demonstrates that this profession is highly hazardous and has adverse effects on human health and the environment. The sensitivity of civil institutions and the obligation of governments to monitor and legislate indicate the high level of damage caused by mining activities to the miners' health. From a global perspective, mechanical, chemical, and biological hazards, risks arising from energy sources, physical pressure on workers, risks of falling from heights, and psychological hazards are major threats in mining activities.
Artificial intelligence, Internet of Things (IoT), and drones can play an influential role in risk alerting to workers and implementing preventive measures by collecting and intelligently processing information. Moreover, technologies such as robotics, drones, and autonomous vehicles can replace humans in hazardous areas and reduce human casualties and injuries.

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1 .Introduction

Mining has been a crucial industry for centuries, providing the world with valuable resources that we rely on every day. However, as global demand continues to rise and mines get deeper and more complex, traditional mining methods are becoming increasingly inefficient. Enter smart mining solutions – the latest innovation in this age-old industry. By implementing cutting-edge technology like autonomous vehicles and connected mines, companies can optimize their operations like never before. But with these exciting benefits come significant challenges as well. Smart mining is revolutionizing the traditional mining industry by integrating cutting-edge technologies and data analytics to optimize processes and enhance productivity while minimizing risks. By leveraging automation, robotics, artificial intelligence, and the Internet of Things (IoT), miners can make informed decisions, mitigate hazards, and maximize resource extraction [1-5]. One of the key advantages of smart mining is improved safety, achieved through automation and remote monitoring systems that reduce miners' exposure to hazardous environments [6-8]. Additionally, smart mining enhances operational efficiency by utilizing advanced sensors and monitoring devices to gather precise data on various parameters, enabling proactive maintenance, optimized resource allocation, and improved productivity [9-10]. Moreover, smart mining practices contribute to sustainable development by minimizing environmental impacts, such as managing water usage, reducing energy consumption, and monitoring and mitigating pollution. Overall, smart mining presents a future that is safer, more efficient, and environmentally responsible. In this article, we will explore the ins and outs of smart mining solutions – from their potential advantages to the hurdles that must be overcome to implement them successfully.

2. Workplace Safety

The issue of safety in the workplace (in general) and safety in mines (specifically) has been of interest to technology and innovation stakeholders and entrepreneurs. Particularly, in order to eliminate human casualties and accidents, innovators and technology developers have started collaborating with large mining companies, and in this regard, the role of startups and the development of innovative technologies is noteworthy (Fig. 1).

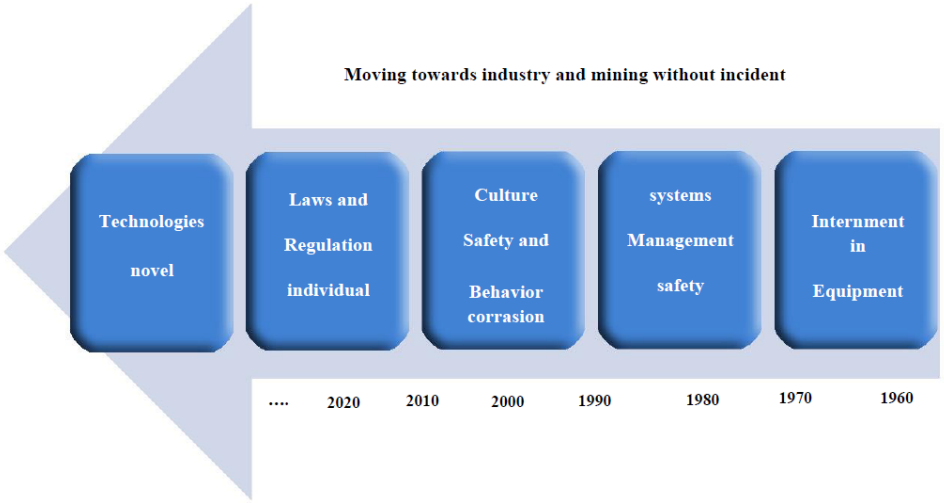

Fig. 1. Different approaches to improve industrial and mineral safety over time.

From a safety perspective, the technologies of the Fourth Industrial Revolution have created numerous opportunities to improve and enhance workplace safety. New technologies can be used to create transparency, monitoring, reporting, and accurate diagnosis of safety challenges in mines (Table 1).

Table 1. Summary of new technologies and their application in mine safety [2].

Achievements in Mines Safety	Application Area	Technology
-Safe Training -Avoiding training in real high-risk environments Reducing safety training costs - Establishing a smart base of educational records -Three-dimensional mining sites and improving the quality of education -Simulation of explosion operations in mines and safety training to employees	Employee Skills Training	
-Creating augmented reality versions of miners' equipment on handheld computers and employee helmet displays to increase accuracy and control	Increased accuracy and control	Augmented and Virtual Reality
-Assessment of work environment and providing safety with data analysis platform -Identification, tracking and monitoring of health, safety and environment affairs	Data Analysis	
-Vehicle drivers equipped with smart helmets to analyze brain waves		Artificial Intelligence
-Automatic rock fall warning in mines, - optimizing the energy distribution from the explosions.	Remote control of the car Machinery and Supervision of Operations	
-Using sensors with automatic warning of fatigue and inattention and carelessness while working in mine - Smart helmets with dangerous gas, sound and temperature detection sensors -Monitor and alert employees if they approach dangerous tools and locations	Wearable equipment and smart sensors	Internet of Things
Improve communication between mine personnel and increase their safety in underground environments	Wireless Communication Development	
-Monitoring equipment with advanced sensors to improve safety and reduce environmental hazards -Monitor tailings dams safely and keep employees away from harsh working conditions	Monitoring the health of equipment and operations	
-Robot development to be present in mines ahead of employees -Reduce the risk of unforeseen risks in mines by entering robots into the most dangerous parts of the mine -Using robots for exploration activities in high-risk areas	Keeping employees away from high-risk areas	Robotics
-Preventing errors, carelessness or damaging equipment to employees -Accurate and safe digging of tunnels in mines and no need for miners to be present in high-risk areas	Automatic equipment	
-Improve safety indicators by eliminating the driver, including preventing accidents and injuries caused by indiscretion -Controlling the underground loaders and preventing the presence of operator in the high-risk environment and increasing the accuracy and movement of the loader and preventing accidents with people	Vehicle Automation and Driver Removal	Self-driving vehicles

Achievements in Mines Safety	Application Area	Technology
-Driving trains and increasing the safety level of miners by keeping them away from the environment of danger and human error.	Replacing employees in high-risk areas	UAVs
-Exploration, mining surveying and calculating the volume of deposits in mines instead of labor in high-risk areas. -Collecting and processing information in mines without the need for operator presence in hazardous areas		
Replacing humans in monitoring and inspection tasks		
-Inspection of containers and equipment of the ship in the transport of cargo (replacing the workforce) -Control of the presence or absence of personnel in explosion zones -Measuring the number of explosive parts, the direction of dust movement after the explosion and preventing the hazard of personnel entering hazardous areas	Inspection and Warning	
-Creating a 3D map of mines to improve the safety of miners		
Identify the origin of the material and prevent unsafe, high-risk and inhumane miners	Finding the origin of the material	Blockchain
Tokenize valuable assets such as gold and diamonds and prevent unsafe and destructive mining for the environment.	Tokenizing assets	

3. Augmented and Virtual Reality Technology

Simply to define two technologies of augmented reality and virtual reality, it can be said that virtual reality does not exist in reality and is produced by computers, and does not correlate with the real world around the user. In contrast, augmented reality refers to the widening of the real world using virtual tools and by adding information to the real world using special analogues, smartphones and tablets.

Virtual environments provide many benefits for safe training of employees, including exposure to hazardous environments, opportunities for experiential learning, and high levels of control over training. Augmented and virtual reality enable the reduction of training costs in a simulated and safe environment, leaving employees safe in acute conditions and improving educational productivity in a safe environment.

From the perspective of extracting valuable and natural underground resources, leading companies in the oil and gas industry have been pioneers in developing new safety awareness methods. These methods are also applicable in other industries, such as R&D, and with a large labor force, such as mines [11, 12].

Virtual and augmented reality seek to transform the mining industry through improving mine efficiency, reducing maintenance costs, safety, and protection for miners, providing virtual visits to mining sites, and training in real environments. In simple terms, training staff in a safe environment and away from the environment of mining, and at the same time, an environment close to reality, is an advantage that this technology brings.

Virtual reality technology has other uses for the safe training of miners. For example, simulation of mining operations with the application of modern technologies can guarantee the health of the employees. Since there is a possibility of high risks and casualties if the miners do not make precise calculations to select the appropriate location of the explosives, this action can cause breaking and throwing rocks into unforeseen paths and creating a dangerous position underground and above it, and endangering the safety of the employees. Simulation allows for accurate calculations [13, 14].

4. Artificial Intelligence Technology

One of the most efficient solutions to improve safety indicators in the workplace is the use of artificial intelligence technology.

In short, artificial intelligence technology is an area that encompasses the ability of devices to learn like humans and also the ability to respond to certain behaviors.

Artificial intelligence technologies have come through the targeted analysis of operational data collected by sensors to help improve safety in mines. Data collection is provided by using intelligent sensors embedded in factories and wearable equipment of employees, and artificial intelligence algorithms by analyzing these data enable intelligent monitoring of activities and warning about hazards. This technology in addition to the advantages that it creates in the safety sector, also improves productivity and reduces costs [15].

Some actions taken in this technology are as follows:

1. Automatic stone fall alarm system in open pit mines, which aims to strengthen the alarm system of the walls of these mines and uses artificial intelligence, big data, and unmanned aerial vehicle (UAV) technologies.
2. Instability alarm system for automatic monitoring of waste dams of mines, for which artificial intelligence, big data, and drone technologies are used.
3. Optimization system of energy distribution resulting from explosions, which creates an appropriate and specified charge for each drilling operation and leads to reducing the failure of hole formation by explosion. Artificial intelligence and big data technologies are employed in this sector.
4. A comprehensive intelligent surveillance system is carried out by artificial intelligence and the Internet of Things to reduce the need for personal surveillance.
5. The all-round remote control of mining machines is carried out by artificial intelligence, robotics, and augmented and virtual reality to increase productivity and safety.
6. Simulation of intelligent discharge of underground mines, which improves discharge protocols.

5. Internet of Things Technology

The Internet of Things (IoT) simply refers to the communication of sensors and devices with a network through which they can interact with each other and with their users. The industrial Internet of Things in factories is aided by receiving data from sensors or through wearable equipment and sensors and alarms embedded in it [16].

One of the achievements and results of the integration of IoT and artificial intelligence technologies is the development of wearable equipment for employees in the workplace, and the use of this equipment allows for communication between employees. In addition, warning equipment in these wearables can make the worker more accurately aware of workplace environmental hazards. Also, analyzing the data taken from this equipment can have a significant effect on the health and safety of employees. Apart from wearable equipment, the application of a wireless communication network with the capability of operating underground can help improve communication among employees in the mines.

6. Robotic Technology

Due to the expansion of the use of robots and computer automation in many occupations, in addition to employment issues, safety issues in the workplace have also been raised. Nowadays, the use of robots in factories has become a common practice and undoubtedly has led to the health of employees and has created numerous opportunities to improve the safety and health of the workplace. This is primarily because robots can take the place of employees in potentially hazardous environments. Secondly, robots can perform human activities with fewer errors [17].

In the field of development of robotic technology, attention to the automation of processes and equipment and their role in industrial safety is very important. Due to the limitations and problems of mining, robots are very desirable options for increasing safety. Importantly, robots and automation, in the

most difficult, costly, and dangerous part of mining activities, will help build safe and stable working conditions for all underground miners.

7. Autonomous Vehicle Technology

Self-driving vehicles in the final state refer to cars that operate without driver assistance and with the help of advanced technologies. The emergence and expansion of the use of these vehicles will bring many benefits and will obviously save countless lives.

Transport, loading, and unloading of materials is one of the riskiest sectors in mines, and the greatest losses occur when humans are responsible for the operation of transport equipment. Given the growing opportunity for driverless vehicles, heavy machinery companies are optimistic about automating this equipment [18].

In general, automation through self-driving equipment can help improve mining processes. Considering that accurate performance of repeatable tasks is of great importance for miners, self-driving equipment and vehicles with continuous and non-stop work, the elimination of human errors, the elimination of weather effects, and the fatigue factor of employees increases safety and productivity in mining sites.

8. UAV Technology

Remotely guided aircraft, which are unmanned and also known as drones, have become an essential tool for businesses in recent years. In the not-too-distant past, the most widely used of this technology was in the military industry, but in recent years, the use cases of drones have been tested in almost all industries, and now many industries have been able to integrate this technology with their business model, reduce their labor costs, and improve the efficiency and safety of their services.

The use of drones in various projects has significantly reduced workplace deaths and injuries. UAVs make it easy to access unsafe and dangerous areas and can provide full visual data from these areas. Drones can be used to survey hazardous areas so that fewer employees are at risk. Also, drones equipped with sensors can detect and report hazardous gas leaks [16].

Robots, self-driving and semi-autonomous equipment, help mines greatly by removing employees from hazardous mining and work areas. UAV technology has also come to the aid of miners, and the use of this technology has reduced employees' exposure to potential risks, especially compared to traditional surveillance methods. The use of drones to conduct necessary inspections in various mining operations, in addition to moving employees away from hazardous areas and activities, also helps improve accuracy. Another application of drones is the exploration and mapping of mines (open and underground mines) [19].

UAV technology has a wide range of applications, especially in mining. Exploration, surveying, maintaining safety and increasing security are among the applications of this technology. The popularity of drones in the mining industry has increased dramatically in recent years.

9. Blockchain Technology

In the safety sector, blockchain technology can be used to identify hazards for early detection to prevent accidents, and the opportunity to learn corrective actions by setting up incident reports. To this end, the use of digital forms under blockchain enables companies to monitor and follow up on tasks and actions required before or during an incident using software or mobile phones [20].

In general, blockchain technology has wide applications in the field of supply chain and smart contracts.

This technology contributes to the transparency and indecency of supply chain processes. In mines, blockchain technology has also been used to improve the supply chain, but as mentioned earlier, it has a special application in the field of safety in identifying the origin of materials. Specifically, to prevent illegal mining or the sale of materials produced in high-risk areas without human or environmental issues, traceability is very effective.

A mining company in Congo uses blockchain to track the journey of cobalt, an essential mineral for battery production. This transparency helps battery manufacturers assure their customers of responsible sourcing. One of the most pressing concerns in mining is its environmental impact.

10. Conclusion

The Fourth Industrial Revolution and new technologies have significant effects on all areas of business. In the issue of safety in the workplace, the application of these technologies will lead to a serious reduction of risks and safety promotion. From the perspective of leading countries, the capacity of previous measures to improve safety procedures is saturated, and new waves of transformation must be activated to achieve the goal of zero incidents. In other words, the reports and actions observed globally show that new technologies are capable of achieving challenging goals in the field of industrial safety and especially in mines. Therefore, while guidelines, regulatory oversights, standards, and control measures are still necessary to maintain the safety indicators of mines, new technologies can both act as enablers of old solutions and provide new capabilities to achieve zero incidents in the mining environment. Modern technologies can be used to record, track, monitor, analyze, and prevent information change and conversion.

Ethical Considerations

The authors avoided data fabrication, falsification, and plagiarism, and any form of misconduct.

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Conflict of Interest

The authors declare no conflict of interest.

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