ARTIFICIAL INTELLIGENCE AND SUSTAINABLE DEVELOPMENT IN THE MINING INDUSTRY

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ABSTRACT:

The mining industry has changed significantly in recent decades with using advanced technologies such as artificial intelligence (AI) methods and technologies. Expert systems are helping in optimizing processes, increasing the safety. They used to improve productivity and also reduce operating costs. Since the industry's operations have the potential to impact a wide range of environmental and socioeconomic entities. These are achieving by committing to improve environmental performance and addressing the needs of stakeholders and community groups from the outset. Mines can put the concept of sustainable development into practice. Multiple recommendations were made to improve planning, environmental management, cleaner technology implementation, increased stakeholder involvement, formation of partnerships. Finally, case studies of Sukari Gold Mine and CEMEX a multinational cement company (in Egypt is named Suez Cement Company), was presented to illustrate further how mining companies can operationalize sustainable development. This present paper has attempted to bridge a major gap in the artificial intelligence, sustainable development and mining literature by clarifying exactly how sustainable development can be applied in the corporate mining context.

Keywords: Mining industry, artificial intelligence, sustainable development, environmental and socioeconomic entities, Sukari Gold Mine and CEMEX as a cement company.

الملخص:

شهدت صناعة التعدين تحولا جذريا في العقود الأخيرة بفضل إستخدام التقنيات المتقدمة مثل طرق الذكاء الإصطناعي وتعليم الآلة والتكنولوجيات الحديثة. وتساهم أنظمة الخبراء في تحسين العمليات التعدينية وزيادة السلامة والصحة المهنية، فضلا عن رفع الانتاجية وخفض تكاليف التشغيل. ونظرا لتأثير عمليات هذه الصناعة المحتملة على نطاق واسع من الجوانب البيئة والاجتماعية والاقتصادية، فإن الالتزام بتحسين الأداء البيئي وتلبية إحتياجات الشركاء والمجموعات العاملة في هذا المجال. وبداية قد تمكنت المناجم من تطبيق مفهوم التنمية المستدامة حيث قدمت توصيات عديدة لتحسين عمليات التخطيط والادارة

البيئية، وتطبيق التقنيات الحديثة وزيادة مشاركة المستثمرين في مجال التعدين. كما عرضت دراسة الحالة لمنجم السكري للذهب وشركة سيمكس (شركة السويس للأسمنت) متعددة الجنسيات لتوضيح كيفية تفعيل شركات التعدين للتنمية المستدامة. وتهدف هذه الورقة البحثية إلى سد فجوة كبيرة في تطبيقات الذكاء الاصطناعي والتنمية المستدامة والتعدين من خلال توضيح كيفية تطبيق التنمية المستدامة في مجال التعدين.

الكلمات المفتاحية: صناعة التعدين، الذكاء الاصطناعي، التنمية المستدامة، الجوانب البيئية والاجتماعية والاقتصادية، منجم السكري للذهب، شركة سيمكس في صناعة الأسمنت.

1. Introduction:

The purpose of this paper, it to examine both artificial intelligence and sustainable development in the corporate mining context, and provides some guidelines for mining companies seeking to operate more sustainably. There is now a burgeoning literature that examines artificial intelligence and sustainable development in the context of minerals and mining. What is often challenging to ascertain, however, from these numerous perspectives on sustainable mineral extraction, minerals and metals recycling, environmental management, and social performance, is how sustainable development applies to mining companies themselves, and what steps a mine must take in order to improve the sustainability of operations. Since mining processes have the potential to impact a diverse group of environmental entities, and are of interest to a wide range of stakeholder groups, there is ample opportunity for the industry to operate more sustainably. Specifically, with improved planning, implementation of sound environmental management tools and cleaner technologies. In this case can improve performance in both the environmental and socioeconomic arenas, and thus contribute enormously to sustainable development at the mine level.

2. Methodology:

- Artificial intelligence (AI) is pivotal technologies transforming numerous sectors, mining included. AI encompasses the realm of computer science focused on developing systems that can perform tasks traditionally requiring human intelligence, like speech recognition, decision making, and problem-solving.
- The AI can analyze data from sensors and surveillance cameras to identify potentially dangerous situations and warn workers about possible accidents and mention some examples in Egypt as like Sukari Gold Mine and CEMEX (Cement Company).
- Although a number of variations exist, sustainable development is most commonly defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

- In this paper the principles of sustainable development involve integrating economic activity with environmental integrity, social concerns, and effective government system; with mention some examples in Egypt.

3. WHAT is the artificial intelligence when comes to the mining industry?

3.1. Previous Works:

The AI is pivotal technologies transforming numerous sectors. The AI encompasses the realm of computer science focused on developing systems that can perform tasks traditionally requiring human intelligence, like speech recognition, decision making, and problem-solving [1], [2]. Machine learning (ML) also, a subset of AI, specifically concentrates on devising algorithms that enable computers to learn from data and enhance their performance over time. The mining industry, as one of the oldest and most resource-intensive sectors, has always been in pursuit of new technologies capable of enhancing the efficiency and safety of mineral extraction. Machine learning has the potential to prevent or anticipate various incidents at industrial facilities [3]. The application of AI opens up new possibilities for addressing many challenges faced by mining companies' intelligence [4], [5], [6]. The use of AI enables enhanced productivity, lower operational costs, improved workplace safety, and reduced environmental impact. The use of ML algorithms makes it possible to optimize the processes of mining and processing of minerals .For instance, ML-based systems can analyze mining data in real time, suggest optimal routes for mining equipment, and predict the most efficient mining methods [7], [8]. Predictive analytics based on ML improves the prediction of equipment breakdowns and plans its maintenance, which reduces the cost of repair and replacement of equipment. Such approach is especially important for large and expensive mining equipment [9]. For example, monitoring systems can monitor the condition of mines and predict collapses or methane emissions, which allow workers to be evacuated in a timely manner and precautions taken [10]. The ML can also be used to monitor and manage environmental aspects of mining operations, such as air and water pollution control, waste management and land reclamation. It also reduces negative environmental impacts and complies with environmental regulations and standards. Leading mining companies are deploying autonomous vehicles and the AI is driven drilling rigs, reducing the risk to human life and increasing mining efficiency. The ML algorithms are used to analyze large volumes of data collected from sensors and equipment to predict potential equipment failures and plan preventive maintenance [11], [12]. The AI systems help monitor the quality of extracted raw materials in real time, analyzing samples and predicting possible deviations from the standard. ML allows optimization of supply chains and inventory management, which reduces costs and increases operational efficiency [13], [14], [15]. The application of AI in the mining industry represents a significant step forward in the development of the mining industry as shown in Figure 1 which

shows the advantages and opportunities of using AI and ML in the mining industry to increased productivity, reduced operating costs and improved workplace safety.

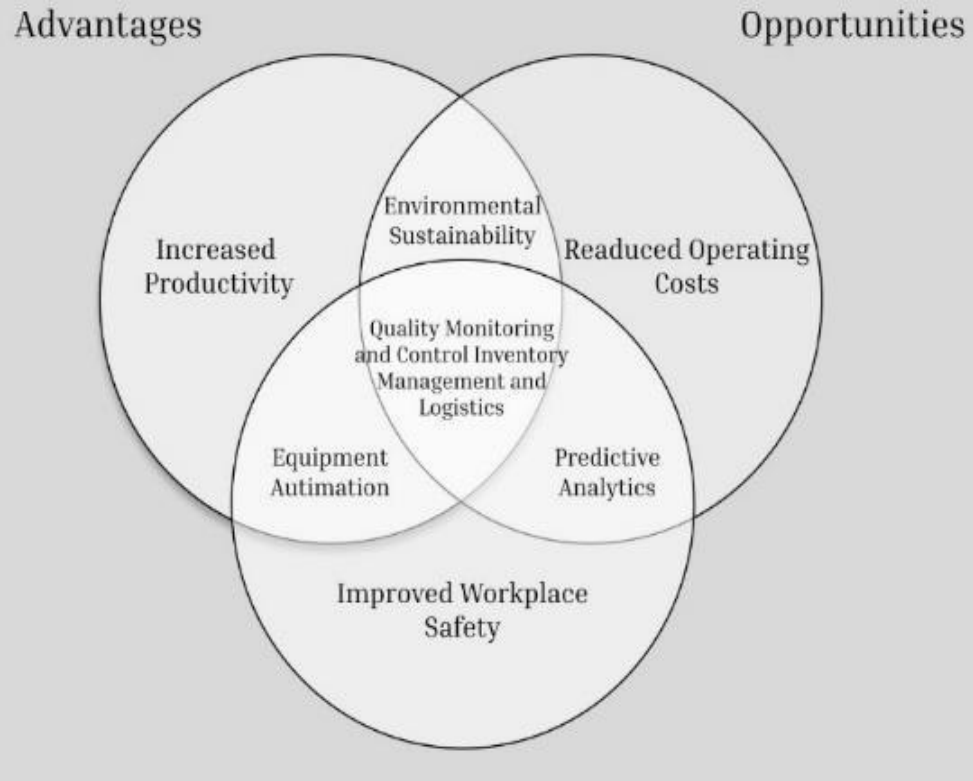

Figure 1: Advantages and opportunities of using AI and ML in the mining industry to increased productivity reduced operating costs and improved workplace safety.

3.2. Applications of artificial intelligence in mining industry:

*** Exploration Plan Optimization:** The AI can provide recommendations to optimize exploration plans, including planning exploration routes and selecting the most suitable exploration methods. This helps improve exploration efficiency and the quality of results. These achieve through the analyzing exploration data and geological information.

*** Subsurface Structure Prediction:** The AI takes advantage of historical geological and geophysical data to create predictive models. This enables accurate prediction of the subsurface internal structure and stratigraphic features. This aspect is very important, especially in the exploration of subsurface resources and the assessment of geological hazards.

*** Resource Distribution Prediction:** By using ML and deep learning algorithms, AI can analyze geological data and environmental factors to predict the distribution and abundance of subsurface

resources. This capability contributes to guiding resource exploration and development, as well as enhancing the accuracy and efficiency of exploration activities.

*** Recognition of Geological Features:** The AI can learn and recognize geological features such as rock types and structural geology. This capability facilitates the accurate identification of potential mineral resource areas and provides enhanced exploration targets.

*** Data Analysis and Interpretation:** The AI can extract essential information from geological data, and then provide accurate data analysis and interpretation, with the aid of ML. Also, the AI can identify geological features, evaluate resource distribution, and provide more accurate guidance for geological exploration.

*** Cost Monitoring and Risk Management:** The AI provides effective strategies for resource management and risk management using cost control models and risk assessment models. The AI enables the formulation of appropriate control and management measures, leading to reduced costs and risk mitigation, while improving the efficiency of resource management.

*** Environmental Risk Assessment:** The AI uses data analysis and modeling techniques to assess environmental risks associated with geological exploration activities. The AI enables precise assessment of environmental risks and their potential impacts. Also, these are through comprehensive and accurate analysis of geological characteristics, environmental sensitivity, and monitoring data.

*** Prediction and Simulation:** The AI uses predictive models and simulation techniques to forecast outcomes and risks associated with resource development operations. The analyzing historical data and relevant parameters, combined with AI's learning capabilities, quality, and potential environmental impacts. This information serves as valuable guidance for resource development decision-making and strategic planning .The AI on mines and geology industry**,** which composed of five categories which are intelligent decision-making support, automation of data analysis, improved safety measures, enhanced resource management and advanced imaging and mapping techniques as shown in Figure 2.

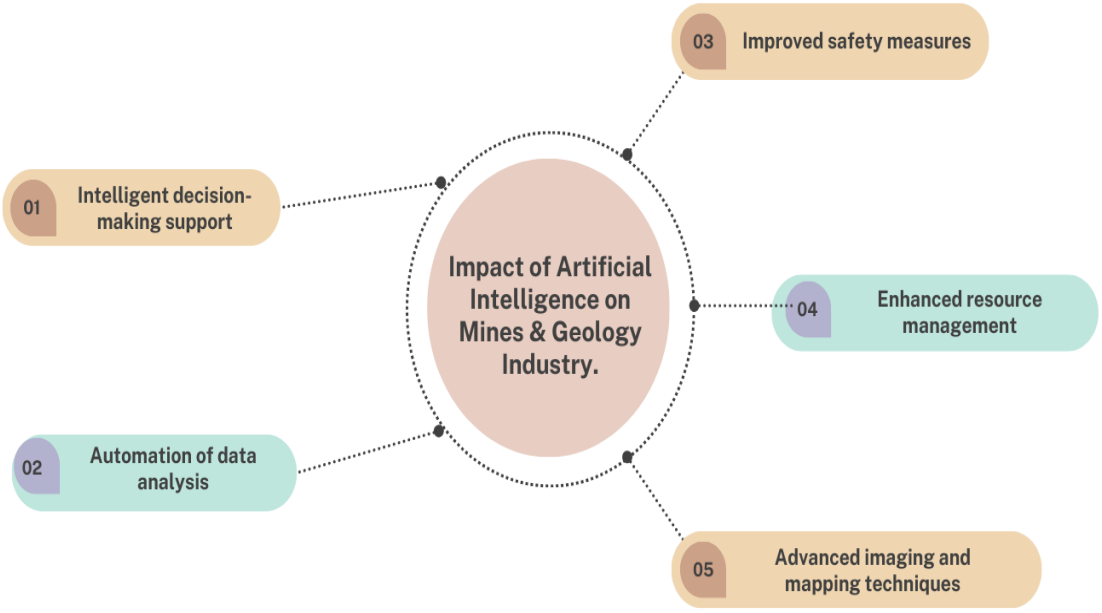

Figure 2: Mind map of the impact of the artificial intelligence on mines and geology industry**,** which composed of five categories are intelligent decision-making support, automation of data analysis, improved safety measures, enhanced resource management and advanced imaging and mapping techniques.

3.3. HOW is artificial intelligence integrated into mining for mineral exploration?

The AI and data analytics are transforming the mining industry by enabling faster and more accurate mineral exploration and processing. AI and data analytics can help identify areas with high mineralization potential quickly and safely, reducing exploration costs and time.

*** Digital Transformation (DT)** The mining industry can benefit from digital transformation, which involves the use of technology and initiatives to reduce production time and cost, increase productivity and meet regulatory requirements.

*** Robotic Process Automation (RPA)** can help extract, upload, validate, format, and calculate data, increasing speed and accuracy compared to human operators. RPA can also assist in estimating and validating ore reserves, production and reconciliation reports.

3.4. Discover more with remote sensing for mineral exploration:

Remote sensing is a method that collects and analyzes data from a distance, using sensors on various platforms such as satellites, airplanes, drones, or ground-based platforms. This method provides a comprehensive view of regional geology, structure, alteration, mineralization,

vegetation, and the environmental and social impacts of mining activities. The team of experts in remote sensing, geology, mineral exploration and geophysics, can assist in selecting the best remote sensing data sources and methods for different projects. They can also process and interpret remote sensing data using advanced techniques, create illustrative maps, models, and reports, as well as identify the locations, types, and grades of potential mineral deposits, along with associated risks and opportunities.

4. WHAT is sustainable development when it comes to the mining industry?

The alternative view is that mining can actually contribute positively to sustainable development by transforming physical resources into new forms of economic and human capital, and by leaving a positive legacy in the areas where mining has taken place. **These are:** 1- Divergent perspectives, Multidisciplinary and mining Sustainability.

2 - Reflect two different approaches to operationalizing sustainable development: the ‘narrow 'model which focuses on protecting the stock of natural capital (that is, the physical and biological environment) and the ‘broader’ model. within these parameters, sustainable development in Mining.

3 - Although significant headway has been made, major challenges and obstacles remain, particularly, at the operational levels of the industry.

4.1. Gold mining and sustainable development:

Dirty gold mining has caused a lot environmental problems over the past few centuries. This type of mining has released multiple toxic substances into the environment and the ecosystems surrounding it, according to [16].

Gold mining destroys causes damage to lands, as it produces a lot of toxic waste. Many people have suggested that protecting the environment and aiming for sustainable development can be achieved by constructing some dams to place the toxic waste in it and make sure that no spills will occur. In Egypt, the best example for using the AI is Sukari Gold Mine, Egypt, in many steps such as exploration of the geological rock units of Sukari area, exploitation the gold mineral, reduced operating costs, increasing productivity, equipment automation and workplace safety (the geological succession of the Sukari Gold Mine in the Southern Eastern Desert, Egypt, where this area consists of essential rock units like basement complexes, pan African nappe complex, pan African molasses sedimentary rocks and Phanerozoic overstep sequences (Figure 3).But, Figure 4 shows general view of Sukari Gold Mine in the Southern Eastern Desert, Egypt. And also, Figure 5 explains the production line (Manufacture) in Sukari Gold Mine which is annually producing 550000 ounces per year.

Another problem that may rise up from gold mining is Acid Mine Drainage (AMD). Sulphuric acid is produced from the reaction of water, bacteria and other rocks from the mine. If this acid goes over rocks that contain lead, cadmium and iron, those metals will be produced and may get

into waterways. Those metals are well known to cause cancer, tumours and can be extremely poisonous [16]. According to the Environmental Protection Agency and American Geosciences Institute, there are multiple ways that can prevent and clean up AMD. **Some of these methods are:**

a - Reclamation of the contaminated land, this can be done by adding lime or any alkaline material that will neutralize the acidity in soil.

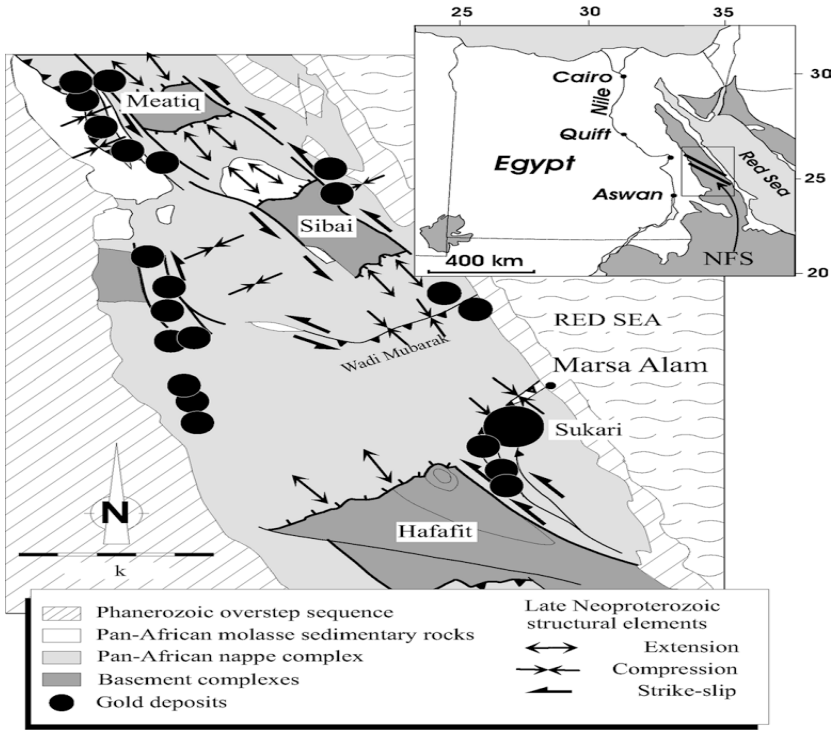

Figure 3: Geological and Structural map of Sukari Gold Mine, in the Southern Eastern Desert, Egypt where this area consists of essential rock units like basement complexes, pan African nappe complex, pan African molasses sedimentary rocks and Phanerozoic overstep sequences.

b- Removing the contaminated soil and moving it to a new site, so it can be treated and monitored.

c - Adding lime or any alkaline material to neutralize the acid can treat water.

d - Having artificial wetlands placed can keep the contaminated material in their location, where microbial action is active.

e - Filling the abandoned mines with materials that can stop the formation of AMD. Flooding the mines with water to remove oxygen that is needed to form AMD can do this.

f - Isolating and relocating the waste from the mine that can form AMD from the reaction with water.

Figure 4: General view of Sukari Gold Mine in the Southern Eastern Desert, Egypt

4.2. About sustainable mining industry (smi):

The Sustainable Mining Industry (SMI)'s function is to coordinate, and provide strategic direction to, the research and education activities of member centres and divisions, around the broad theme of sustainable development. The SMI framework is unique in that it accommodates a wide range of disciplines, including mining and minerals processing engineers, geologists, metallurgists, risk analysis specialists, and social scientists [17].

For example, the Centre for Social Responsibility in Mining is currently involved in collaborative initiatives with the school of social sciences, the school of geographical sciences and planning, the business school, the school of economics, and the school of social work and social policy. The SMI is also involved in **four** cooperative research centres (CRCs):

a - The new CRC for Sustainable Resource Processing.

b- The CRC for Coal and Sustainable Development.

c - The CRC for Mining. d- The AJ Parker CRC for Hydrometallurgy [18].

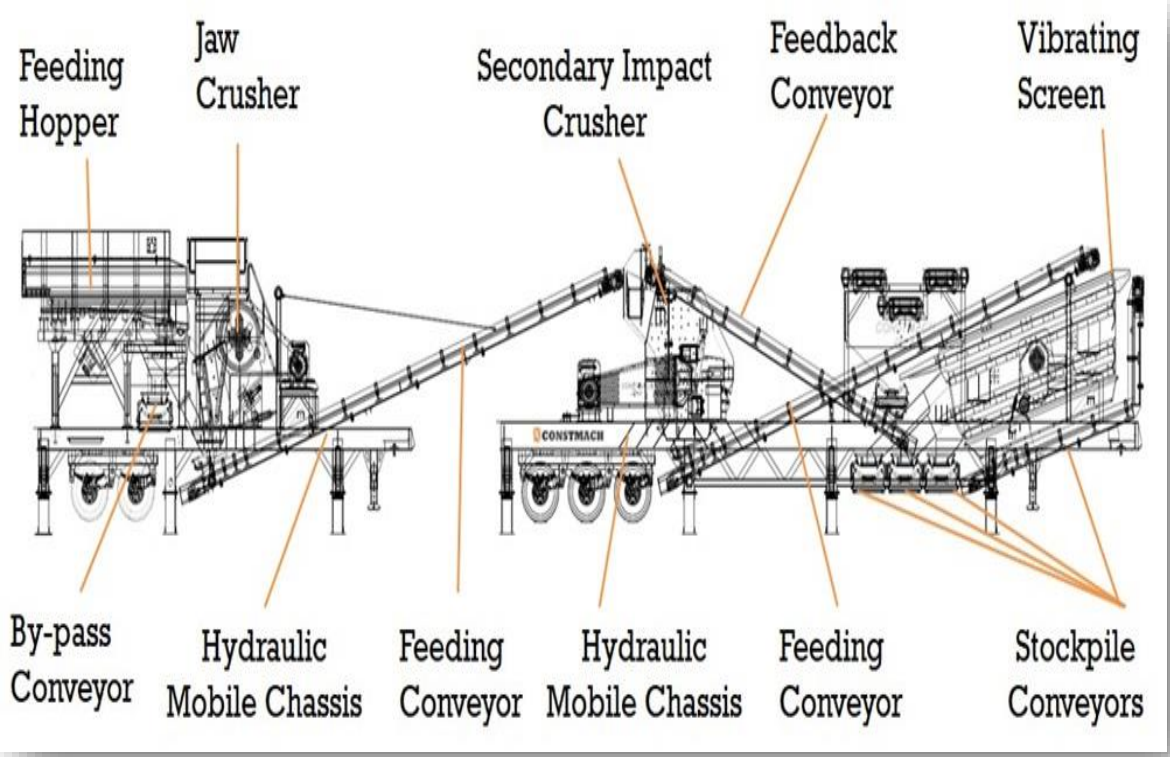

Figure 5: It shows the production line (Manufacture) in Sukari Gold Mine in the Southern Eastern Desert, Egypt, which composed of feeding hopper, by – pass conveyor, jaw crusher, hydraulic mobile chassis, feeding conveyors, secondary impact crusher, vibrating screen and stockpile conveyors.

4.3. Achieving environmental sustainability in mining:

Multidisciplinary studied Mining Sustainability. First, substantial changes will have to be made in how organisations are designed and managed. It needs to be made clear to companies, and the people working in them. This will require the creation of stronger external and internal drivers of change. A 'tolerance for dissonance and ambiguity'. Industry personnel and professionals in particular have to recognise that problems and tasks cannot always be clearly defined in advance and that not everything that is important can be measured (or vice versa). They must be willing to contemplate and explore alternative scenarios, rather than following fixed pathways [19].

4.4. Applying environmental sustainability in mining industry in Egypt:

Egypt is well known for its vast growing mining activities, which makes it crucial to consider the environment in all mining activities. The continued discoveries of new mineral reserves, improved recycling of materials, and advances in technology in recent years have largely lessened the fears of running out of non-renewable resources. For instance, the development of technologies including froth floatation for processing certain metal sulphide ores, the Solvent Extraction-Electro winning process for obtaining copper, and the use of cyanide in gold extraction have all made previously uneconomic grades of ore suitable for mining, thus increasing economically viable mineral reserves [18].

4.4.1. Reducing inputs in the mining process:

The mining process can be causing huge influences on the surrounding ecosystem. Many of the inputs that are used in mining come with negative effects that can damage the environment as well as the availability of resources for future generations. The following section discuses different inputs used in the mining process and the possibility of reducing them [19].

*** Energy:** Mining and metal processing can be very energy-intensive processes. For instance, diesel fuel is used by trucks and excavators during mining, electricity is used to grind ore and refine copper and aluminium, and coal is required in order to smelt iron ore and make steel.

*** Water:** Water is used in a number of applications at mine sites. By diverting surface water and pumping groundwater, mining operations can reduce both the quantity and quality of water available downstream for aquatic ecosystems and other industrial and municipal water users, especially in areas with arid climates.

*** Land Disruption:** Mine sites currently disturb a small fraction of the Earth's total land surface. For instance, less than 0.01% of Canada's land area has been used for the production of minerals and metals since mining began over 100 years ago. However, mining activities use land at every stage of the mine cycle, including exploration, construction, operation, closure, and post-closure [19].

4.4.2. REDUCING OUTPUTS:

*** Waste:** Mine waste includes solid waste, mine water, and air particles, which can vary significantly in their composition and potential for environmental contamination. In addition to preventing soil, water, and air pollution, waste management plans are required in order to select and design appropriate storage facilities for the large volumes of waste produced at most mine sites [20].It is generally recognized that preventing pollution is more economic and effective at reducing environmental impacts than cleaning it up later on (i.e., leaving a legacy of environmental degradation for future generations). Methods for minimizing and eliminating wastes in the production of minerals and metal commodities which include using cleaner production techniques, environmental control technologies, using waste as raw material, and reducing the amount of waste produced through process re-engineering.

*** Acid Rock Drainage:** Acid rock drainage (ARD) forms when sulphide minerals in waste rock and ore at a mine site are exposed to air and water. ARD can pollute surface and groundwater with acidity and dissolved metals, which can adversely affect aquatic organisms and water users downstream.

*** Restoring Environmental Function at Mine Sites:** Mining is a relatively temporary activity, and mine sites have finite operating lives which are determined by the size and quality of the ore deposit being mined. Mine site reclamation and closure activities aim to restore land disturbed by mining activities to an acceptable state for re-use by people or ecosystems.

*** The issue of random ungoverned mining in Egypt:** An example of increased waste outputs in Egypt is extremely clear when it comes to ungoverned mining activated that take place in many locations in the eastern desert of Egypt as well as the southern part of Egypt.

Random miners set up their own grinding mills in locations that might have gold in them, and then use extremely toxic materials such as mercury and cyanide in the process for extracting the gold from the rocks in the area. Such mining activates should be stopped immediately by the government, and harsh sanctions should be placed on those who are caught breaking any of the laws, because they are not only harming the environment, but also they are harming the entire wellbeing of Egypt [20].

4.5. A success story of sustainable development in the field of cement manufacturing:

The manufacture of cement places a heavy burden on the environment, in large part because cement production is an energy-intensive process. Extreme heat is necessary to turn calcium carbonate into lime (a process known as "calcination"), a key step in producing cement. In order to generate this heat, a variety of fossil fuels are used, depending on the kiln. Burning these fuels can release nitrous oxide, sulfur dioxide, and carbon dioxide (CO_2) into the atmosphere.

Still more carbon dioxide is released through the calcination process itself, this is through a natural by-product of the chemical reaction [20].

*** Company Background:** Founded in 1906, CEMEX now ranks as the third largest company in global cement production, with operations spanning across 33 countries, primarily developing nations. The company employs more than 25,000 people and maintains commercial relations with more than 60 countries. After moving into the global market in 1992, the acquisition of two companies in Spain rocketed its sales to $2.2 billion. In 2001, its global sales were $6.9 billon, with a production capacity of 80 million metric tons per year. Figure 6 is showing the general view of the Suez Cement Company in Egypt as a successful example of cement companies and using AI through reduced operating costs, increasing productivity, equipment automation and workplace safety, therefore, the company is always progress.

*** Sustainability at CEMEX:** During its global expansion, CEMEX has maintained a proactive commitment to complying with all environmental regulations in the countries where it operates. The linchpin of this proactive commitment is the concept of sustainable development. CEMEX has taken many steps toward fulfilling its goal of sustainability. This belief is exemplified in the company's signature contribution; a philosophy and operational goal that it calls En Armonia con la Naturaleza (In Harmony with Nature).

Some of the achievements that are helping CEMEX reach its goal include: • ISO 14001 certification of CEMEX facilities throughout the world • reducing electrical consumption in its plants by 160,000 megawatts in 2000 • cutting CO_2 emissions by 263,000 tons in 2000 • recycling 23,294 liters of liquid waste, and 10,433 metric tons of solid waste, as alternative fuels at CEMEX Mexico [21].

Figure 6: It is showing the general view of the Suez Cement Company in Egypt; it uses new methods to become the pollution very low.

*** CEMEX's Sustainable Development Principles:** CEMEX has developed a robust approach to operationalizing sustainable development. In 1994, the company formalized its sustainable development strategy by adopting three principles.

- First, CEMEX committed to employing cutting-edge technology in its operational processes in order to ensure energy efficiency and the optimal use of raw materials.
- Second, CEMEX promoted a culture of environmental, health, and safety awareness within the company and the community.
- Third, CEMEX has sought to use the most effective equipment and systems to protect its employees, its neighbors, its facilities, and the environment.

*** Striving for Eco-Efficiency at CEMEX:** In 1994, CEMEX is formally launched an eco-efficiency program in order to optimize its consumption of raw materials and energy. CEMEX also incorporated innovative practices into production processes and the design of its new plants in order to reduce energy use and depreciation of its assets. Resource conservation is used of natural cementing materials, and utilization of alternative fuel sources. The results of the company's eco-efficiency program have been substantial.

5. Conclusions:

The mining industry has changed significantly in recent decades with the introduction of advanced technologies such as AI and ML methods and technologies used in the mining industry, expert systems that help in optimizing processes, increasing the safety, used to improve productivity and also reduce operating costs.

Since the industry’s operations have the potential to impact a wide range of environmental and socioeconomic entities, by committing to improve environmental performance and addressing the needs of stakeholders and community groups from the outset, mines can put the concept of sustainable development into practice. This study has also offered guidance for mining companies interested in improving the sustainability of their operations. Multiple recommendations were made improved planning, improved environmental management, cleaner technology implementation and increased stakeholder involvement, formation of partnerships [22]. There are case study of CEMEX a multinational cement company, was presented to illustrate further how mining companies can operationalize the AI and the sustainable development. As the 21st century begins, it is becoming increasingly important that mines, for the benefit of ecology, surrounding communities, governments, and its employees, continue to tackle pressing socioeconomic and

environmental issues with improved strategy, and help put sustainable development into practice in the industry.

Challenges in Mineral Exploration in Mining: With the depletion of near-surface mineral reserves worldwide, mining companies must invest more to access lower-grade deposits. Mining and processing these deposits have become more complex and costly, as they require more advanced techniques and equipment. There is also a growing demand for green mining that reduces the environmental and physical impact of the entire process chain.Another challenge facing the mining industry is the increasing volume of data that needs to be well managed for use. Only 10% of the data can be used to deal with variability and optimize processes because the data is not linked to the value chain. The use of AI in mining industries is also limited by the time it takes for implementation [23]. The mining industry is undergoing rapid digital transformation, and advancements in the AI have led to improvements in process automation and the use of robotic devices at mining sites. AI offers the opportunity to optimize operations and increase efficiency, but it is not a universal solution. It depends on the specific needs and conditions of each company and mine. The AI is now widely recognized as a tool for efficient and cost-effective mineral resource extraction. By 2035, the mining industry is expected to enter a new Era of smart mining. Furthermore, The AI can automate and streamline the data processing that is still done manually in many mining operations. The AI can provide fast results by collecting and analyzing data on-site, reducing errors and improving efficiency. According to some estimates, companies can save up to 50% of their expenses by using AI and big data to identify new mines, compared to traditional methods. Moreover, the data obtained can be used in subsequent rehabilitation efforts that restore the natural environment of the area. Finally, the advantages offered by AI where the Mining companies face significant challenges in locating and extracting economically viable minerals from deep or low-grade deposits. AI can help them build more accurate models for predicting the type and location of minerals, saving time and money. The AI can also enhance the safety of frontline miners by enabling rapid decision-making during mineral exploration. By using real-time data and analytics, AI can detect operational problems and prevent accidents and injuries.

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