Data Analytics Applied to the Mining Industry

Ali Soofastaei

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By

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Preface

One of the Initial landmarks in human civilization is mineral resources production. From the Stone Age to the Bronze Age and the Iron age, our ability to innovate in our extraction processes for the most useful elements has been developed. It is becoming increasingly difficult to access and extract minerals. Mining costs increase due to rising labour costs and energy prices. To have a sustainable and affordable industry, there is no other way but to use new technologies. In order to reduce time and energy consumption and manual efforts to finalize mining projects effectively, computers and machines have been developed. Although the use of computer software in increasing the quality and reducing production costs in mines is widespread today, achieving better results requires the use of Artificial Intelligence (AI) and Machine Learning (ML) in this industry. Although today, all managers in the mining industry believe that they should use AI and ML, most of them do not know the correct way to use this science. Other than mere AI scientists at universities do not have full access to industry problems as well as related data. This book potentially can make a bridge between developed knowledge by scientists at universities and research centres and industrial researchers at mining companies. The ultimate objective of making the relationship between scientific knowledge and industrial experience is to learn the machines intelligently to think and evaluate the same thing as humans in different situations in mining operations. In the past, computers were doing as expected, but the systems now can think and behave like human beings with AI. High-

Structure of the Book

Ten chapters have been designed for this book aimed to transfer the main part of practical advanced analytics knowledge to the researches who are studying and working in the mining industry. All presented information is supported by practical examples and scientific details. The chapters contain enough information for beginners to get familiar with the high technology and science application to solve mining business problems and more detailed technical information for advanced readers.

In Chapter 1, an initial review briefly gives a background of the digital transformation of mining. Modern technology is growing very fast, and businesses must adjust to new changes. In helping companies to this industrial revolution, digital transformation plays an essential role. The development of digital technology such as automation, sensors, advanced analytics, smart systems, etc. has compelled companies to consider new technologies more productive and efficient. As one of the lead industries in many countries, the mining industry faces a significant challenge when the sophistication of human, technical, and management systems is inadequate to open the doors to the old industry of the modern world. Digital transformation is a significant challenge. In order to address this challenge, the mining companies should work hard to meet this goal, as well as the universities, to develop the learning and research programs for potential mine engineers in the mining department. This chapter considers the mining industry's need for digital transformation and presenting a three-part review of the principal elements of digital transformation, including data, connectivity, and making decisions. At the end of this chapter, there is a summary of both the mining industry and academic research perspectives on digital transformation to benefit mining firms.

Chapter 2 is about using advanced data analytics in the mining industry. The mining industry faces massive amounts of data that have hidden layers of information and knowledge. In addition, it is difficult for the industries to effectively and efficiently implement the data generated by their format, size, variety, and speed. Complexity in data processing and interpretation allows enterprises to use advanced technologies to solve raw data management problems. Big data analytics is a groundbreaking approach to data management. It uses machine learning (ML) and artificial intelligence (AI) methods to take advantage of the data that is collected. Chapter 2 consists of technical discussions regarding some mostly used ML and AI technics in the mining industry. The presented discussions in chapter 2 cover big data analytics, deep learning, and also machine learning application in the internet of things (IoT).

The realistic data collection, storage, and recovery technique in mining companies will be discussed in Chapter 3.To explore all of Big Data's potential and relevant technologies; basic data principles need to be thoroughly understood. The multiple available data sources and interdependencies between them need to be understood before any process of data analysis begins. In the composition of the business context and, therefore, the aims of the analysis program, different types, formats, and magnitudes of data are essential factors. This chapter opens a door in front of mining researchers to think deeply about the type of data, source of data, critical performance parameters, data quality (assessment, strategies, and improvement), data acquisition, data storage, and data retrieval in the mining industry. This chapter covers geological, operational, geotechnical, and mineral processing data.

The objective of chapter 4 (Making sense of data) is to create a data preparation framework to be used as a guide and best practices supporter for the adoption of data mining in the mining industry. Part I reviews essential aspects of data collection transition to data preparation and provides a summary of sources of data in the mining industry; Part II outlines steps, techniques, and issues to prepare data before analysis and modeling; finally, Part III provides extended data preparation considerations and applications for specific cases. Data analysis might seem a very technical activity at first glance, but with little guidance, every analyst and decision-maker can become a "data literate" and start mining datasets. Precisely, this chapter intends to play this role of guidance. However, it is essential to say that the chapter does not explore all the possibilities of data preparation, instead, the main goal is to generate initial interest in exploring data; for those readers who are interested in excavating their information and knowledge a universe of material, articles and references are yet to be explored in this (data) mining journey.

Chapter 5 presents the most used analytics tools in the mining industry. Presently, advanced analytics is a critical component of successful businesses in various industries. Mining plays a leading role in the development of the other industries and is rapidly developing in this industry with the help of the analytical tool. Many kinds of analytics have been discussed in theory. Nonetheless, choosing a practical instrument requires industrial experience and adequate competence in the knowledge involved. This chapter attempts to explain some practical analytical tools that address the problems of the mining industry. An introduction discusses the concept of each method, and the appropriate usage is discussed separately. The toolkits included in this chapter cover statistical and predictive approaches. The investigated predictive models in this chapter were included the regression, time series, and machine learning methods. This chapter attempts to provide clear insights into the selection of the best analytical instruments for researchers to have better thoughts.

Process analytics is an essential practice for companies in order to deliver high standard services or products to their customers. These technical analytics play the primary role in the mining industry, and the quality of data analytics is directly related to the accuracy of mining processes analytics. Chapter 6 explains more details about mining operational analytics and the importance of analytics to improve prediction, optimization, and making decisions. Traditional analytics approaches that are fundamentally developed around process data, such as Lean Six Sigma and business process analytics, are facing several limitations when confronted with the challenges of the big data era, characterized by real-time, high speed, dynamic changing, and multivariate requirements. Those methodologies can reach the next level by incorporating modern big data analytics techniques and technologies to boost their analytical power. Both literature and industry are full of real case applications that support the introduction of big data analytics as game-changing technology in the process analytics – and improvement cycle. Studying this chapter recommend to the mining researchers who are interested in applying advanced data analytics method to solve the practical mining business problems.

The authors technically discuss the predictive maintenance of mining machines by using advanced data analytics in Chapter 7. The way mining machines operate is dependent on the production of mines. It is, therefore, essential to maintain them. For an extensive mining transport system, the maintenance process is extremely demanding because it consists of many components. Maintenance techniques in mine sites exist in different forms. Prevention, failure, and predictive groups may identify mining maintenance strategies. Since the machines' reliability depends on several variables, it is not possible to fix the repair time for each component beforehand. Therefore, predictive maintenance is the most appropriate method. This approach provides continuous information on the state of the analyzed unit, thus monitoring the deterioration process and allowing the most appropriate duration of repairs to be scheduled. In the mining industry, development in online and standard acquisition systems is currently popular. Predictive maintenance today relies on the use of data fusion to continuously analyze data obtained from various machines in real-time. It is necessary to suggest a set of time series indicators for management and maintenance purposes that allow for a full and objective evaluation of the artifacts in terms of technology, economics, and organization, as well as an estimation of the remaining life of the artifacts. This type of analysis is a big data solution on an industrial scale. Consequently, the appropriate techniques for data analysis must be applied.

Fuel consumption and greenhouse gas emissions are two primary critical challenges in front of mining companies. The application of advanced data analytics to increase energy efficiency, reduce fossil fuel consumption, and consequence decrease the gas emissions in mines are the main subjects that will be discussed in Chapter 8. In many different activities like drilling, manufacturing, transport, research and processing, and coal mining, use much energy and release greenhouse gases. Better control of processes can substantially reduce these fuel consumption and emissions of gas. The mining technique and the equipment used to determine the kind of source of energy in any mining activity. Mines and machinery for deciding the type of power source in any mining operation. These machines, according to the production capacity and site layout, are haul truck excavators, diggers and loaders and use considerable amounts of fuel to operate in surface mining; therefore, mining is encouraged to conduct specific research projects on the energy efficiency of mobile equipment. Classical approaches used widely for energy efficiency and gas emission reduction are inadequate. The application of deep learning models and artificial intelligence is expanding in different industries and is a new revolution in the mining industry. This chapter gives an overview of the use of artificial intelligence technologies to predict and reduce the use of energy and greenhouse gas emissions in mines.

Decision making is the last level of maturity in data analysis, and it will be discussed in detail in Chapter 9. This phase completes the analytics process that starts by gathering the data. Improving the quality of decisions affects the efficiency in the mining industry. Making the decision is one of the critical skills that mine managers need to lead the operation and maintenance teams effectively. Data analytics can also potentially help the managers to make better decisions related to safety, energy efficiency, final product cost, etc. This chapter explains in detail the effect of advanced analytics to improve the quality of managers' decisions in different situations. After a short introduction, the organization design and KPIs are explained, and then the advanced analytics role in making practical solutions is clarified. At the end of this chapter, the expert systems components, types, and methodologies, especially in mining, are explained.

Chapter 10 presents a useful discussion regarding the future skills that the mining industry needs. The science and technology are growing very fast, and industry leaders must make comprehensive plans to transfer new knowledge and updated technology into their companies. This approach not only can help the industry to increase the efficiency in different areas but also potentially can help societies to have a sustainable environment. The application of advanced analytics and using innovative methods such as machine learning, artificial intelligence, and deep learning algorithms are pioneer technologies to the current industrial revolution. If we are interested in having a successful digital transformation plan in the mining industry, it is essential to make sure we not only can update the employees but also we have an acceptable training system to prepare the new workers, managers, and making decision people for future. This dream will be made real when there is a functional relationship between universities and companies. The mining industry, as a critical industry, plays a critical role in training the new miners for future mining projects globally. The chapter presents some new requirements, skills, and related training programs in the mining industry.

This book tries to help readers to have a better vision of advanced analytics in the mining industry, and the authors hope that this volume will be a valuable resource for industry professionals and researchers. The presented chapters in this volume signify state of the art regarding critical topics in advanced analytics, machine learning, and artificial intelligence. The breadth of coverage and the depth in each of the sections make it a useful resource for all mine managers and engineers interested in the new generation of a data analytics application. Above all, the author hopes that this volume will spur on further discussions on all aspects of advanced data analytics applications in the mining industry.

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Chapter 1: Digital Transformation of Mining

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Abstract

Modern technology is growing very fast, and companies need to adapt themselves to the new changes. Digital transformation plays a critical role in helping entities for this industrial revolution. Improving digital technology such as automation, sensors, advanced analytics, intelligent systems, etc. has forced the companies to think about more productivity and efficiency by using new technologies. The mining industry, as one of the leading industries in many countries, is facing a significant challenge to use the digital transformation when the maturity of people, technology, data, and management systems is not good enough to open the doors of the digital world in front of this old industry. To tackle this challenge, not only the mining companies should work hard to pass this bottleneck, but also the universities need to change their curriculums in the mining departments to have better learning and research programs for future mine engineers. This chapter considers the mining industry's need for digital transformation and presenting a three-part review of the principal elements of digital transformation, including data, connectivity, and making decisions. At the end of this chapter, there is a conversation on the outlook of digital transformation in both the mining industry and research direction in academia to deliver support for mining businesses.

Introduction

Adapting the mining industry with technology changes is an exciting research subject [1, 2]. Studied research about sociotechnical theory in an Australian mine site shows one of the first experiences to transition from hand-got mining to longwall methods. As a practical experience, this study illustrates a successful transition from a traditional mining method to an advanced process when sociopsychological and production influences grew over this technology transition [1].

The fourth industrial revolution was happening when the world is facing with the digital decade [3]. In mining, a massive amount of data is collected from many equipment and machines working in the sites that is much more than ever before [4]. These data can potentially make excellent opportunities for mining innovation to find new solutions for business problems through Digital Transformation (DT) in this industry [5]. The main goal of DT programs in mining has come to describe how companies become accustomed to digital modifications [6-13]. Moreover, there is not the same definition of digital mining transformation [13]. Figure 1 demonstrates a technology-driven process consists of three main components of DT; Data, Connectivity, and Decision Making [9].

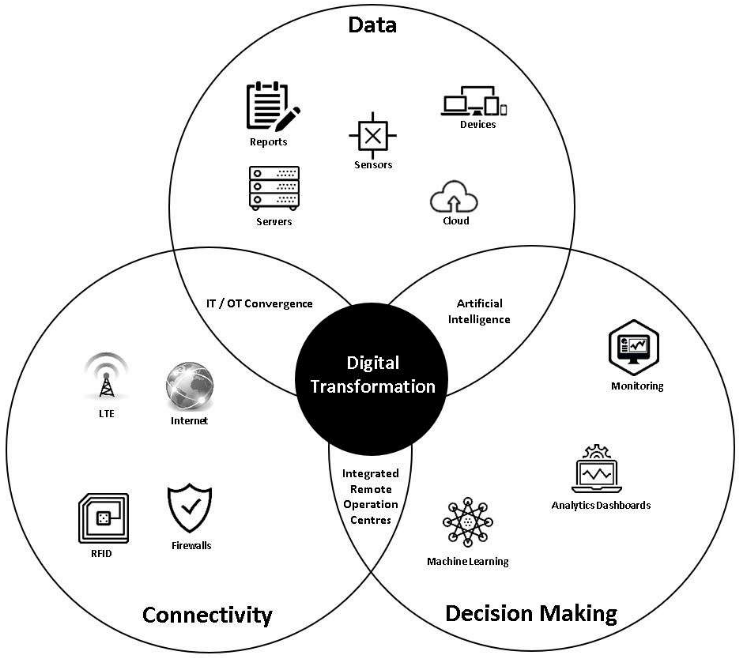

Figure 1: Digital transformation components

A successful DT plan can increase the digital capabilities and develop the sociotechnical capacity in a mining company [2, 14]. DT can also change all aspects of the business to improve the mining operation and maintenance [15]. However, mining companies are struggling to start the DT plans based on their technical and management challenges they are facing with them practically.

The pressure on mining companies to adopt themselves with digital technologies is on both sides: supply and demand. In general, the trouble starts on the side of the consumers. Some examples of this pressure are explained as follows.

Influential factors on-demand:

- Consumers more connected and more significant decision power.

  The digital economy produced a cultural transformation that has set a higher level of expectation and user experiences from consumers. This change redirected the decision forces from the mining companies to the final consumers.

- Consumers are more focused on user experience than with the possession of the property itself.

  New business models developed by the digital economy lead a transformation in the consumers' preferences mainly among the young generation, migrating more and more the focus from owning to using.

- Liquid expectations.

  The more developed a digital economy is, the more consumers extrapolate the consuming experience of a determined category of mining product to other markets, thus significantly amplifying what the market traditionally defines as "competitor." Currently, competitors are not necessarily inside the mining industry.

- Faster adoption cycles of new ideas and technologies have made markets quickly disappear.

  The classic curve of mining innovation diffusion is facing a significant change. The process of transmission that once slowly flowed between the social system participants nowadays quickly converges between the winner solutions.

Influential factors on supply:

- They are unbundling phenomena by the startups.

  The entire process of a productive chain, which before was executed for a big mining company, currently can be achieved by hundreds of small companies that perform each one of the small steps of the whole process in a more efficient way.

- Exponential cost reduction of the technological process

  This pattern, which has been observed since the end of the 50 decades, has become economically feasible in a series of projects that previously did not leave the drawing board.

- New competitors being created every day.

  It is essential to plan a digital transformation plan to predict the effect of market conditions on the mine value chain. The companies that do not review their operational models and especially their business models will not have space in this dynamic competitive environment. This digital transformation plan can be reached through three strategical drivers:

  - **Digital Business Transformation**

    Attending the new demands of business models. The primary investment area to implement this strategical approach is a junction of the technological parks with the relevant set of new and existing data to foster the use of Machine Learning and Artificial Intelligence (AI). This approach can help to identify new trends and market demands.

  - **Digital Clients Transformation**

    Revision of the client experience B2C or B2B. The integration of different platforms to guarantee clients information unification, jointly with the digital transformation of the marketing function are the necessary condition to implement this strategical driver. The application of AI unitedly with mobile technologies and social media are essential to customizing the offerings to guarantee higher client engagement.

  - **Digital Company Transformation**

    Operational excellence of production process and technological park. Each productive process automation is required to implement this part of the strategy, which ranges from the operation itself to the system for decision-making. The use of IoT, robotics, and AI are some of the elements that allow automation and identification of opportunities for improved efficiency.

To maximize the return of investment in digital is required to focus on some leveraged strategies; on the contrary, the train of digital transformation takes the risk of stopping at prof of concepts and first results never turning out to be sustainable.

- **Agile leadership**

  Strategic view and fast-paced in the decision-making process.

- **Workforce focused on innovation**

  Digital mindset infused in the workforce

- **Network**

  Keeping the mindset of ecosystem collaborating inside the value chain (e.g., suppliers, logistics, clients) and outside (e.g., startups, universities).

- **Access, management, and usage of data**

  The capacity for creating knowledge to improve the decision-making process.

- **Appropriate technological infrastructure**
  Guaranteeing processing capacities, data and business security, and interoperability among systems.

In the past, the mining companies could choose to be later/early adopters regarding the new technologies. However, this is no longer the reality nowadays, consider what is highlighted above, and the journey on DT becomes an essential plan for all companies working in the mining industry.

In overall, there are four highlighted summaries for DT in the mining industry as follows:

1- Mining companies should start digital transformation program as an essential revolution in this industry;

2- There are three foundational components of the digital mining transformation process. These components are information, intranet and internet connectivity, and decision support;

3- Digital transformation delivers a conversation on how it will be an essential part of the achievements of mining businesses into the future era; and

4- Digital transformation recognizes strategic fields in which organizations of higher learning can supply the required resources to support the mining industry.

There are some suggestions to have successful progress in the DT journey in the mining industry. Firstly, it is essential to define a clear responsibility for digital investments. Secondly, companies should invest in use cases, not just in technologies. Thirdly, it is necessary to use the result-based actions according to the theoretical designed approach. Fourthly, take full advantage of the low hanging fruits, i.e., low cost and fast, successful opportunities which will help the company to create a digital culture. Fifthly, take risks in assessments that identify common problems of several company sectors. Therefore, it will be easier to scale and reuse the lessons learned. Sixthly and finally, the suggestion to have a successful digital transformation plan in mining is thinking about a multidisciplinary concept, and this approach needs innovative discoveries in all company sectors.

Digital Transformation in the Mining Industry

A short industry review shows the need for DT and challenges. The mining industry needs critically to use DT to increase safety, productivity, and efficiency. However, this industry is behind most other industries, as shown in Figure 2.

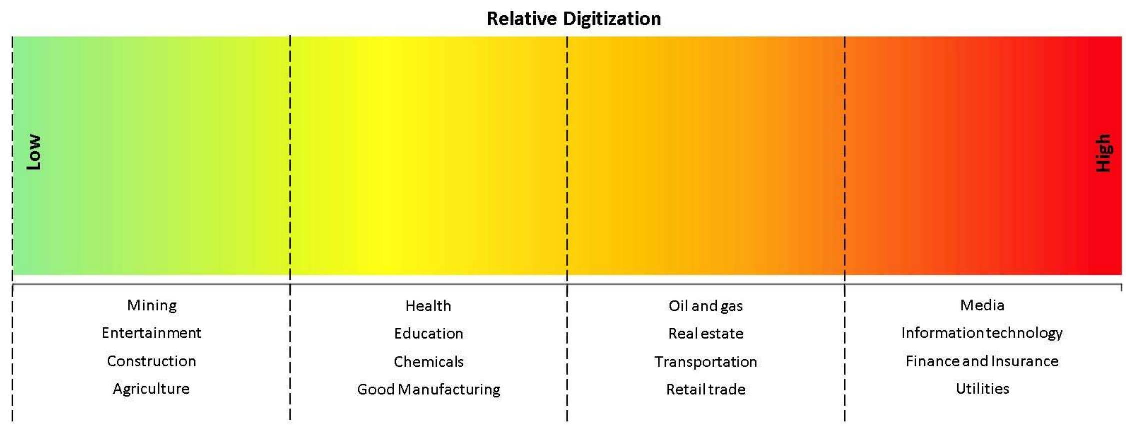

Figure 2: Relative digitalization by industries [16]

A completed review of yearly published documents from the industries' top ten mining Companies shows that 6 out of 10 stated that digital transformation is a part of its policy, 3 out of 10 corporations list qualitative consequences from digitalization programs and only 1 out of 10 might provide quantitative value for the benefits of digital transformation [17]. However, this story has been changed, and currently, there are many other completed successful DT plans in big mining companies globally.

Just As in cases where mining businesses are running to have achievements from digital transformation programs, there stays a substantial need for employees with the non-conventional skills essential to execute it [18]. Technically it is difficult to assess what precisely every mining business is performing for DT. However, the developments for the industry overall may be created by exploring the regularity of related terms as they publish in annual businesses' statements. Yearly reports for forty-one of the biggest global mining companies were investigated for some general conditions concerning information, analytics, people, and technology (see Figure 3).

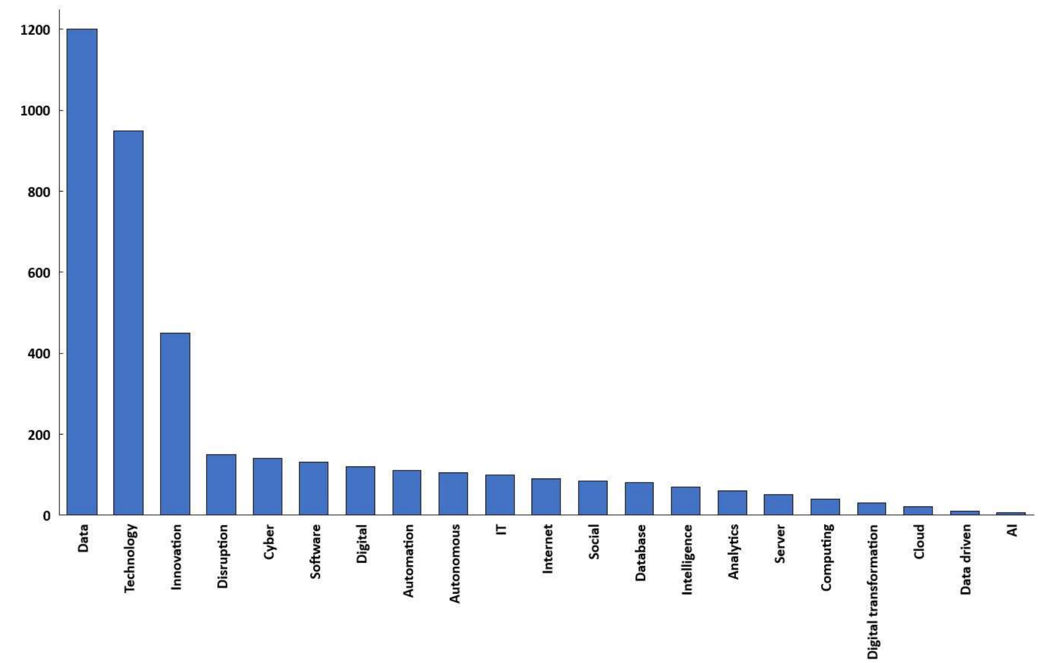

Figure 3: Regularity of DT-associated terms in mining companies annually published reports [18-24]

Figure 3 demonstrates the number of cited terms related to the DT in some published annual reports by top mining global companies. The terms technology and data exist for the most part in the reviewed documents.

Nevertheless, these phrases were frequently cited out of the perspective of DT. Creativity Innovation was cited very regularly and ordinarily close related to the term technology, which indicates that technology and innovation are the foremost popular concern through top mining businesses. In this investigation, the term cyber has been mentioned one hundred thirty-two times and generally from the perspective of cybersecurity, becoming its importance for approximately half of the businesses. Autonomous and automation and merged were cited about as much as cyber. More than half of the mining companies mentioned information technology. Still, operations technology has been stated just once by one business. After All, DT has been cited by three businesses for a full amount of eleven times. The small number of companies quoted from DT may mean that companies do not know what DT is, choose to use different stages in order to convey a similar concept, or do not regard DT as something worthy of its shareholders.

A completed assessment across all business sections in mining operations shows that over 80% of them have essential digital transformation initiatives in their minimum and long term plans [25]. Besides, 40% more companies with practical digitization approaches are expected to find new, unexpected ways to improve the effectiveness of their businesses. The new digital funds for mining are eight times larger than in the industry five years ago, and projects are completed in 50% of the time, for these companies in contrast to their peers [11]. In several other mining fields, DT derives profits from the production of consumer-focused goods, and that increases customer understanding [13, 26]. However, other mining companies have many customers, and the products of mining provide many additional benefits before reaching the end-user. This is a financial opportunity to improve customer engagement for mining companies. For the sake of a broader section of the mining community, diversity, geo technology and digital awareness are directly related to the mining company's ability to implement the DT programs [27-30]. Around 32% of the working population in mining were suppliers [31], digital governance (DGs) only confuses as mining companies have less influence than their staff over providers. This means a few years ' retirements, workforce reduction, lack of skills, and also has a significant impact on the ability of the industry to respond to the changing technological transformations.[32].

Diverse mining companies rely on the techniques of ERP as an alternative to the implementation of DT strategies [33-35]. ERPs are essential to set procedural standards, but they do not establish organizational comprehension or competitive advantages[35-38].

In addition, ERPs allow multiple companies to acquire DT solutions off-the-shelf. These systems and software products, however, will necessarily not adhere to DT design, including introducing innovation models and a new culture of management of information management [6, 8, 13, 18, 25, 39].

Data Sources

The difference between Information Technology (IT) and Operations Technology (OT) needs to be clarified in the mining industry. Data is considered an asset, and today, having access to the massive data quickly makes a new challenge named big data [40-47]. Big data is a challenge, but it can be a great opportunity to develop new know-how to deal with business problems. High-quality electronic circuits with integrated self-observation and intelligent methods are economically low and result in an extensive exchange of information in mining [48]. Big data are shown that suit variety, speed, volume, and accuracy [45]. Variety means multiple ways of producing data. Speed means that the information is evolving in a dynamic environment. A large volume implies a large amount of data. Veracity reveals significant numerical and noise errors. Most knowledge on my web is obtained from OT and often set as logged data. The RDBMs periodically handled structured information and the application query language (SQL) Similar Database management systems [49-52]. In addition, organized information can be time-series data, often from signal-based data, and managed by data historians [53, 54]. Similarly, standardized information for one-time encounters in preliminary information is also different; for example, the specifics of the Fleet Management System (FMS)[55, 56] May want to have outliers eliminated during cycle times as a result of FMS errors.Unstructured information is available in various ways, and without alternative or multilateral channels is very difficult to operate [57]. Useful information in any system depends on robust data structures to guarantee its speed, accuracy, and testability [40].

IT is generally all about computer technology, including networking, hardware, software, and the Internet. OT usually refers to software and hardware that regulates and controls physical objects, procedures, and measures within a business[18, 58]. In addition, the OT methods used by an institute in its workflow movements are characterized[59]. There are strong ties between an association's implementation of new information and subsequent structural adjustment [8]. Also, OT frequently includes the department or team within the company responsible for OT study, maintenance, development, performance, and management [60].

DTs have merged the OT core with the enhancement of software and introduced operational prototypes both for the operator and for the business. Strictly regulated and significant worldwide operations pose many risks [61], and risk minimization includes the acquisition of skills between OT and IT expertise [8, 62].

The IT framework is not intended to include proven expertise that creates information primarily for mining companies [18]. OT and IT typically played individual roles in mining companies. A wide range of emerging technologies such as engine to the machine, networked sensors, neural networks, cloud machines, machine learning, predictive analysis, optimization technologies, policy maps, edge computing, wireless networking and the development of Internet-capable applications, including monitoring systems, has been integrated into the connected architecture of OT and IT [62, 63].

Figure 4 displays the results of finished inquiries into the performance of OT and IT cooperation [62]. The research included 151 people who worked for energy companies using industrial management techniques.

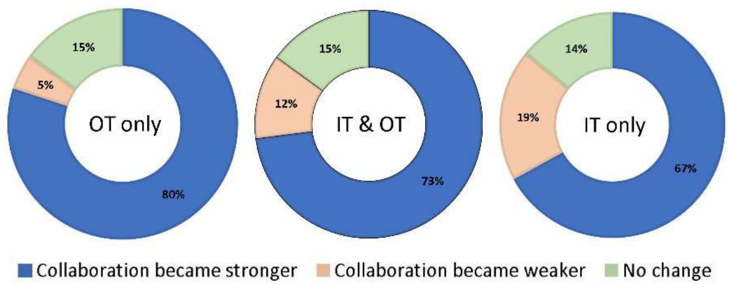

Figure 4: IT and OT teams work [62]

The results shown in Figure 4 indicate that the OT-IT relationship is both in quantity and improving efficiency. The survey found that 73% of the respondents now accepted a more reliable and more effective relation; 19% of the IT sectors surveyed believe it is currently weaker than in the previous survey [62]. The survey also found that it was challenging to discover new talent in both the OT and IT industries.

DT also has increased access to human-generated information in mining, such as pre-shift risk assessment records, ear charts, explosive management reports, pit plans, block models, and maintenance task orders. Workers may also receive information at mines to verify, for example, whether their eyes are opened by the facial features of mobile equipment drivers [64]. Already, heat stress data for miners in dry underground environments [65]. New technologies have many opportunities in this field to enhance information collection [65].

Currently, there are new data sources in the mining industry. Uncrewed aerial vehicles (UAVs), Self-directed processes, smart equipment, robots, metadata (information generated as a consequence of information analysis and exchange), wearables are including the new information resources which will need mining processes to adopt better DT approaches [66-68]. OT's advance in mining companies raises information quality and quantity. Having access to the latest datasets, including photogrammetric information from UAV surveys, wearable in-house staff in real-time, on-belt sensor ore feed quality, or equipment performance information with an incomparable granularity [47, 52, 69]. Modern mining also has real-time mining environment monitoring sensors such as moisture, temperature, and gasses for underground or sloping mines, weather patterns, seismic, and boiling controls for surface mining, remote machine safety, repair, and substantive operation of equipment [70].

Connectivity

Connectivity is one of the essential components of the DT. Connectivity is broken down into six subjects, involving data knowledge exchange, the IoT, cybersecurity, integrated platforms, wireless communications, remote operation centers, and 5G technology.

Information of Things (IoT)

The enormous network of connected physical devices is generally mentioned as the IoT. Figure 5 displays the IoT mining landscape.

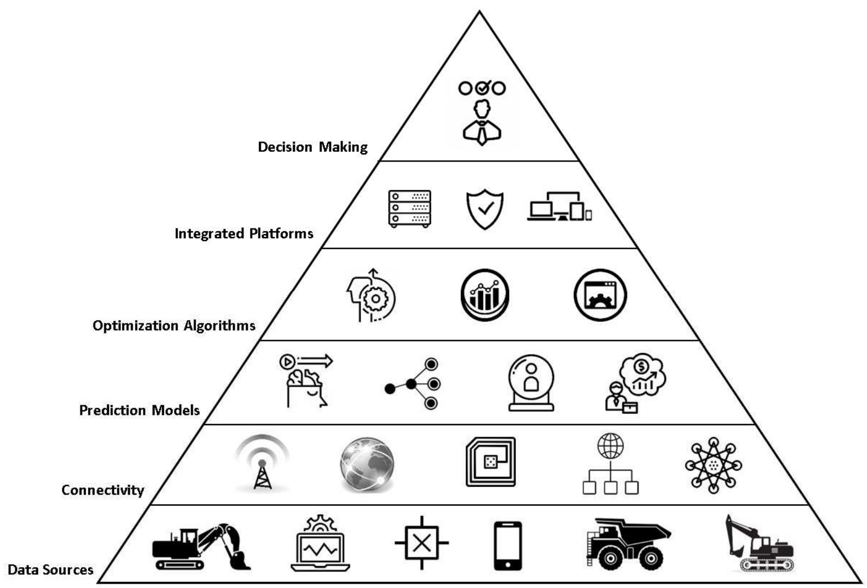

Figure5: The IoT in mining IoT landscape [38]

Commercial IoT reflects IoT (IIoT) in the commercial domain. However, the IoT and IIoT words are utilized exchangeable regularly [71]. IoT is generated by a managed information flow process from built-in machines and OTs to data storage facilities and analytical platforms, where data flows to users. [48]. As shown in Figure 5, mining companies can attach processing machinery, heavy equipment, staff, and sensors to connected platforms by using IoT. Such integrated frameworks contribute to better decision-making through data/information analyses.

Data Exchange

Collecting the enormous information is not helpful [51]. A database can be developed, organized, grouped, and defined to support business analysis and decision-making processes, including information from multiple sources [7, 37, 50, 72-75]. Data storage systems act as organizational repositories of information that can be commonly used by an entity to test and analyze a variety of parameters of interest, such as the performance of motor components shortly before failure. Data for the engine components could be generated from an unconnected and remote part of the company. However, they could be transmitted into a database where a valuable analytical tool could be created, used anywhere within the company, possibly far beyond where the engine is connected [76]. Instead of lying on a file, information gathered can be of interest by supplying the consumer with real-time data about the demands of the sellable commodity before it reaches its destination. The ETL procedure represents up to 80% of the work required for the generation of a data store [50]. ETL includes the following subjects.

- Detecting data from its primary resource,
- Generating applications to obtain, fill, and adapt the information to a general structure, and
- Inserting it into the data store.

Different companies use martial data as a reduced method for data storage, depending on the nature of data in data stores. Data marts are small data warehouses that provide DSS for a limited number of operators.[77].

Safety of the cybers

Approximately 18 billion IoT machines are expected to be available in various industries in 2022[139]. IoT devices are being populated and used so rapidly that the issue of how they affect cybersecurity is becoming more and more apparent [61]. In general, given potential cybersecurity risks, these devices are supplemented because it can minimize mining companies' operational and maintenance costs. This is true, especially with small embedded devices, which are only newly built to be smart. For these machines, safety is frequently different from traditional ones, which follow more predefined protocols of communication. Cloud services complicate the security problem of those industries that have previously been restricted to a company's network and have internet connections[78].

Remote Operations Centres (ROCs)

The remote operating centers (ROCs) promptly develop essential mining tools for synthesizing, managing resources and relying on vast numbers of inputs. Conventional techniques such as simple reports and tablets are not enough for implementing and analyzing information.

ROCs use long-term technology, such as data visualization and cloud computing, by companies outside the mining industry to ensure a realistic and practical approach to fast and impactful critical decisions [79].

Also, ROCs reduce the risk and boost the work experience of workers. Staff will be removed from risk by using semi-autonomous equipment, thus eliminating the need for cost-effective and less reliable security systems, such as PPE, engineering controls, etc. The NIOSH hierarchy of controls offers the most effective and acceptable approach to the eradication of risk by employees who are exposed to hazards [80]. In ROCs, employees generally operate in secure, climate-controlled rooms and can monitor other equipment at the same time, thus significantly improving productivity, protection, and energy efficiency.

Platforms incorporated

By integrating various OT and IT technologies, mining companies are turning their operations into information systems (IS). Experiences with mining projects show that scalability is essential in every integrated platform.

Programmable Application Interfaces (APIs) provide a suitable and scalable solution for incorporating a variety of functional groups and information sources with a unique system in mining companies [81]. An API provides a protocol to ask for resources from an application for a developer or an external system [77]. An alternative can be linked, and data can be shared using the APIs as a multiplatform program. The field of information systems management (MIS), which generally had nothing to do with computers [82], experiments on the implementation and acceptance of IS by operators are currently underway.[83]. The complicated environment of Mining requires building recognition, labor problems, plant operations, data quality, the complexity of the workplace, inclusive knowledge components, and ongoing technical training for IS mining specialists to be successfully integrated.

By using the Internet Protocol (IP), IoT turns the physical world into a kind of IS. By linking goods to information, this revolution removes the gap between data and materials. What is left is a complete restructuring of machinery and process management. Figure 6 demonstrates such a scenario as an interconnected network.

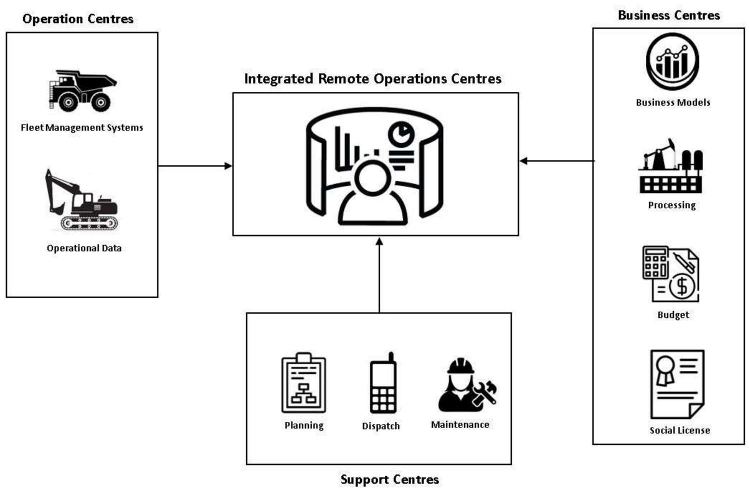

Figure 6: Integrated platform for mining

Since many mining companies still have an integrated platform, the term indicates and implies that integrated systems, equipment, machinery, and workflows merge into one unit.

Wireless Communications

Generally, mine sites are in remote areas, and their environment is extremely harsh. Furthermore, the mine operations are continually changing [61, 84]. There are significant obstacles to large mobile devices' wireless interconnections at mine sites. These mobile tools have been used extensively for decades, but only for many years are network hardware companies supporting their devices until they become obsolete [61]. Miners need cable systems that can meet the different and versatile needs of their company over time. Besides, the risks to cybersecurity increase when data transmission volume [61, 85] and networking specifications [86].