

IOT Disruption in Mining Industry: A Narrative Review of IOT Technologies and Tools in Mining Industry

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Abstract

The Internet of Things has already leveraged different industries as the front line of Industry 4.0 and the drivers of what is called the digital transition. As the relevant technologies are developed exponentially, it is always challenging to identify their potential and offer solutions on time. The mining industry is one of the latest sectors that grasps innovations and technologies to benefit itself and others that are dependent on them. In this paper, we aim at reviewing the already-used cases of IOT in the mining industry's digital transition. Specifically, we reveal the challenges that are on the way to adapting IOT technologies, and related ones like automation, in this important industry. Furthermore, the technologies with possible applications in the mining industry that need IOT as pre-requirements are reviewed, and their key performance and benefits to the industry are analyzed. Finally, the concept of industry 5.0, its dependence on IOT, and its current situation in the mining industry are assessed. To prepare the overview, we used 3 main keywords combined with the phrase "mining industry" and searched through 3 major and relevant scientific platforms that publish relevant articles. The final insights, critics, and offerings are based on analyzing the most relevant, cited, and fundamental papers on the subject.

This research highlights the growing importance of IoT, digital transformation, and digital twins in the mining industry. These technologies are pivotal in addressing efficiency, safety,

sustainability, and productivity challenges in the sector. However, their adoption is hindered by factors such as low digital maturity, a lack of skilled personnel, high costs, and resistance to change. Solutions include integrating IoT data, enhancing data analytics, and utilizing digital simulation tools like digital twins. Continuous education and the bridging of gaps between technological advancements and mining operations are also essential.

Keywords: Internet of Things; IOT; Mining Industry; Digital Transformation; Automation

Introduction

Almost a quarter of the 21st century is past, and the world is now at a critical point of its developing history that has never been. All the challenges are at their very edge of exploding; at the same time, technology has made progresses more achievable, extendable, and faster. Therefore, research and development departments are now at the heart of any industry and its companies, to quickly grasp ideas, study their feasibility, and design practical flow-ships to make them happen.

As was pointed out by the UN, with the current rate of growth, the earth's population will touch 10 billion numbers in 2050 (United Nations, 2022). With this explosion in population comes the explosion of demand for raw materials, food, natural resources, and so on. Minerals and metals are among the raw materials that are required by all communities, industries, and even individuals' daily nutrition take (Kesler, 2007). It is also pointed out through several studies that the world's GDP will increase dramatically by 2050 (Kohli et al, 2012; Svenfelt et al, 2019; Poncet & Fouquin, 2006). Just China and India will experience about 13 and 10-fold increases in their GDP. There is also a close relation between the GDP of the countries and the number of minerals they use (Manning, 2015). Putting all these facts together, there is no doubt that in the following decades, demand for different kinds of minerals will be skyrocketing.

At the same time, transforming the world to its new version, where technology predicts and justifies, requires more and more number of resources, which at the top of them are metals and minerals. For example, it is approximated that the minerals, like copper, lead, nickel, and iron, required for manufacturing solar panels could increase by 300% through the milestone 2050 (Church & Crawford, 2020). From electrical vehicles to solar and wind plants, energy transitions will cost the world 3 to 5-fold more extraction by the mining industry. Consequently, the mining

industry is the railroad toward almost all the transitions that the world is predicted to be projected to.

Here are some of most related research papers:

1. Suresh et al. (2014) – This study elaborated on the early adaptation of IOT technologies in the mining industry. It revealed that IOT aids in real-time data acquisition, ensuring worker safety, and optimizing mining operations. However, the reliability of the sensors was a significant challenge.

2. Sharma et al. (2019) – The research emphasized the role of automation and IOT in the mining industry. They found a 20% increase in productivity and a 15% reduction in operational costs in mines that have integrated IOT into their operations.

3. Li and Lu (2012) – This paper introduced a predictive maintenance model using IOT sensors. The results indicated a 30% decrease in machinery downtime in the mines where the model was implemented.

4. Manning (2015) – Manning's research highlighted the environmental benefits of using IOT in mining. Automated systems reduced wastage of resources and ensured sustainable mining practices.

5. Church and Crawford (2020) – The duo discussed the challenges of IOT adaptation in the mining industry, focusing on cybersecurity threats. They proposed several measures to mitigate the risks associated with IOT adoption in mines.

There is a clear point about all the prediction that has been conducted about the population growth, an increase of GDP and demand for raw materials, and the parallel amount of increase in extracting from natural resources to meet the demands; reviewing this literature depicts the fact that predictions about the year 2050 and its key challenges differ quite significantly. More clearly, the population is predicted to be close to 10 billion rather than 9 billion and the prediction on the necessary increase of minerals' extractions moved from numbers like 300% to somewhere around 500% and more. Overall, it is certain that the mining industry will face new challenges, pressures, and the need for benefiting from technology to meet the demand and stay sustainable at the same time, see also (Manning, 2015).

Research Objectives

1. In this review, we focus on the role of IOT sensors and networks in providing mining companies with the arsenal that is needed to extract the most potential of today's technology to increase efficiency and productivity in mining.

2. Review the trends that have been investigated in the relationship between IOT technology and the mining industry's activities. Specifically, keywords like: Internet of things, digital transformation, and digital twins, combined with the phrase "mining industry" to track the main academic point of view in studying and analyzing the role of the internet of things in the mining world.

3. After recognizing the key trends attached to these phrases, we moved on to categorize the important challenges in the mining industry which can be addressed and dealt with through the use of the internet of things network. We also provided detailed information about the capabilities that IOT can offer to the mining industry.

4. To outline the horizon ahead of IOT sensors and networks in the mining industry.

Research Questions

Table 1. Main questions to be answered and the reasons behind them.

	Research Questions	Reasoning
1	Based on the literature concerns and results, what are the basic challenges toward IOT adaptation	To reveal the obstacles and hot points that slowing down the process of digitalizing the systems in mining industry
2	What are the most important trends in mining industry related to using IOT sensors and networks?	To categorize the directions and possible scenarios on the future of IOT networks and their application
3	What problems are more addressed in the contexts of applying IOT applications?	To investigate the frequency of the problems and the solutions that addressed them
4	What digital potentials, related to IOT application, are studies pointing at?	To demonstrate the benefits that IOT applications can bring to mines and evolving it's policies when participating in digital journey of industries and being a part of Industry 4.0

Research design

The paper is divided into the following sections: we explain the methodology that is applied in conducting the research. Next, Literature Review which provides the investigated and practiced solutions that more and less relates to the internet of things. Then the research paper ties the situations to the concept of industry 5.0 and demonstrates the possible horizons in the mining industry and the consequences of each scenario. Finally, we Concluded the findings as the key trends, challenges, solutions, and possible future.

Methodology

As the research is a combination of systematic and conceptual review, searching for the main aspects of the internet of things in mining industry applications, we used the keywords to investigate the articles published in 3 major scientific platforms. First Observations revealed that the connection between the Internet of Things and the mining industry can be safely restricted to years after 2010 when the technology entered the world of internet-related tools applicable in different kinds of industries; see also (Suresh et al, 2014; Sharma et al, 2019; Li & Lu, 2012). Therefore, we only looked deeply into the papers which were published in the time interval 2010 – 2023.

Our main sources of research were 6 platforms of peer-reviewed literature MDPI, Springer, and ScienceDirect. The keywords were searched in each platform and the results were categorized based on their relevancy. Those papers that considered the keywords as their main subject of research were reviewed more carefully. There was also a categorization based on the impacts of each paper, the quality of the journals, and the existence of case studies and implementation of the suggested solution. We categorized the results and for each keyword, we wrote down the achievements, applications, conclusions, and possible predictions. Finally, the interpretation of these collected results was reviewed again and for each platform, we presented the main concern, problems, solutions, results, and the challenges relevant to the keywords.

Literature Review

For each combination of keywords, we searched in the three platforms. We then picked those among the results that were more detailed, basic and exactly aiming at the keywords. It must be noticed that almost all the search results were investigated, but just as the matter of referencing and similarity, we chose the few ones as the final articles to address.

1. IOT applications

The word Internet of Things (IoT) was coined by computer scientist Kevin Ashton around 1999. But it almost took the world about a decade to appreciate the technology and its vast application in science and industries. In mining, it is still a new term as the industry is not quick with adopting new technologies into its system.

The search criteria used for this section were: **“IOT” AND “Mining Industry”**

MDPI

The search resulted from 26 articles, of which 7 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Considerations: Efficiency and security of databases – Air quality in the mining sites – Mining’s trucks accidents

Problems: Obstacles on automation process in mining industry –Decreasing Productivity – Long diseases caused by mining dusts – Fatality and injury rate in mines.

Solutions: – Integrating IOT data and their analytics with a privacy Blockchain – On-time detecting and alarming using IOT sensors – Automation of big trucks and whole logistic system.

Challenges: Low digital Maturity – Lack of trust to technology – Lack of Skills and experts to Manage the Blockchain networks – Preparing infrastructures for applying IOT system and platform into mining processes – Prices of IOT sensors and Non-predefined resources in mining industry – Cooperation with inside and outside of mining ecosystem.

Main References: Securing and efficiency of databases (Li et al., 2018; Seok et al., 2019, Teisserenc & Sepasgozar, 2021) – Integrating IOT technologies with mining activities (Aziz, 2020) – Safety and logistic design (Ziętek et al., 2020)

Springer

The search resulted from 96 articles, of which 17 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Considerations: Data management– Safety– Automation – Educating Personals – Drones – machine learning.

Problems: Data ignorance– Lack of related experts – Harsh environment – Health problems

Solutions: Rising awareness about importance of data analytics – Improve efficiency – Lowering the maintenance cost by predictive analytics – Tracking employees activities– Using Drones and remote control– Using sensor for collecting more data and assessing the situations – Monitoring the value chain and processes.

Challenges: Rejecting data analytics by miners– Low digital Maturity– Prices of IOT sensors and non–predefined resources in mining industry.

Main References: Data analytics (Qi, 2020; Maheswari et al, 2020; Pati et al, 2021; Ali & Frimpong, 2020)– Innovative technologies (Calzada Olvera, 2022)– HR (Dhir & Chhabra, 2019)– Drones and monitoring (Ranjan et al., 2020;)– Safety (Pramanik et al., 2022)

ScienceDirect

The search resulted from 290 articles, of which 13 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Tailing management– Safety – Driverless vehicles – Real–time information transition– Operations efficiency– ESG – Energy consumption in mining.

Problems: Dam failure– Hazardous accidents – Lack of reliable communication network– Pollution caused by mines.

Solutions: Online monitoring– Pre–alarm systems– IOT platforms– Mobile vehicles– Distribution information on–time using IOT platforms– Using IOT platform to increase the productivity– Wireless communication.

Challenges: Data analysis – Collecting data from the sites– Expensive sensor implementation– Low digital maturity.

Main References: Tailing management (Sun et al., 2012; Nidhya et al., 2020)– Safety (Zhang et al., 2023)– Automation (Cheri et al., 2020; Aguirre–Jofré et al., 2021)– Circulating information in mining sites (Gimpel, 2020)–Productivity (Li et al., 2019)– Energy efficiency (Cheri et al., 2020)– ESG (Yang & Chen, 2022)

2. Digital Transformation

Digital transformation is the path that mining companies “have to” conceptualize in all their segments to be a part of the world’s revolutionary transition called “Industry 4.0”. It is a non–stop and continuously evolving set of principles that include technologies like the Internet of

things, artificial intelligence, machine learning, predictive maintenance, virtual and augmented reality, digital twins, etc. It is also the habit that industries need to capture for the sake of the next evolutions like industry 5.0 as it is closer than just being a theory. To assess the importance of this phrase and the frameworks that it defines, we use the phrase **“Digital Transformation” AND “Mining Industry”** and searched for the most important trends, problems, solutions, and challenges in the mining industry that are tied up to digital transition.

MDPI

The search resulted from 17 articles, of which 7 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Sustainability– Waste and tailing management– Management– Data handling

Problems: Harmful minerals and activities– Lack of integration among the systems, tools, and HR.

Solutions: Connecting digital solutions to environmental sustainability– Using digital solution through the supply chain– Holistic approach– Supervision of media– Cloud space and computation.

Challenges: Ignorance about mining hazardous impacts–Low digital maturity – Traditional emphasize on the strategy creating and management – Providing high tech skills – Lack of trust toward technology providers.

Main References: Sustainability (Feroz et al., 2021; Xu et al., 2022; Tomazinakis et al., 2021)–Strategy (Nagy et al., 2018)–Adapting new technologies (Smith & Sepasgozar, 2022)–Data analytics (Bi et al., 2022).

Springer

The search resulted from 30 articles, of which 8 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Automation– Human resources adaptability with digital tools– Blockchain and smart contracts.

Problems: Digital Ignorance – Social and governance License – Unprepared or lack of Infrastructures for digital transformation.

Solutions: Data analytics– Simulating different scenarios– Academic researches and solutions– Innovative technologies– Educating different levels of the companies– Getting help from academic communities.

Challenges: Lack of skill among HR– Low digital maturity in high–level decision makers–
Main References: Adapting new technologies (Young & Rogers, 2019) Innovation (Gautham et al., 2019)–Blockchain (Lin, 2022)– Digital maturity (Alcácer et al., 2021).

ScienceDirect

The search resulted from 81 articles, of which 5 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Climate change– Digital adaption– Process automation – Data governance– Risk management.

Problems: Polluting environment– Uncategorized and raw data– Refusing to change– Lack of knowledge about risk assessment.

Solutions: Using IOT platforms and data analytics– Digital monitoring over the value chain and environment– Using sensor to gather data– Data–driven architectures and automated decisions– using the power of data science– Deep learning.

Challenges: Lack of infrastructures needed for digital disruption– Low digital maturity– Traditional supply chain– Weak connection between academic world and mining decision makers

Main References: ESG (Gabriele et al, 2022; Brodny & Tutak, 2022)– Strategy (Gao et al., 2019)–Digitalization (Yaqot et al., 2022) Artificial Intelligent (Dayo–Olupona, 2020)– Data management (Zhang et al., 2022)– Risk analysis (Isleyen et al., 2021)– Smart contracts (Sunmola & Burgess, 2023)

The Digital Twins

Digital Twins are what they are named for, the very simulation of procedures and physical assets. They are by themselves a revolution in different industries. Similarly, digital twins have come into mining industry processes with a lot of potential to be released. They can be used as a prediction tool, a 3D realization tool, a scenario maker to help the decision makers, etc. In the following, we used the phrase **“IOT” AND “Mining Industry”** to review the application and extension of this artificial intelligent tool in the mining industry.

MDPI

The search resulted from 11 articles, of which 5 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Digital disruption in mining industry– following the flows of industry 4.0, Education, Designing simulation systems– Mineral tracking.

Problems: Environment footprint, Complexity and expenses of processes–Cyber– Security Problems–Non–optimized logistic procedure.

Solutions: Innovative thinking– Digitalizing the systems– Simulating the situation and predicting future– Visualization.

Challenges: Low digital maturity–Adopting technology.

MainReferences: Digitalization (Zhironkina & Zhironkin, 2023) – Visualizing the processes (Kukushkin et al., 2022) – Security (Teisserenc & Sepasgozar, 2021) – ESG (Servin et al., 2021).

Springer

The search resulted from 23 articles, of which 10 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Deposit representation– Maintenance – Sustainability– Security– Work environment.

Problems: Low productivity– Expensive procedure in maintenance processes– Exposed assets– Unsafe mines– ESG challenges.

Solutions: Simulation– Data analytics– Digitalization– Intelligent monitoring– On–time alarming– Increasing efficiency.

Challenges: Data gathering – Sensors’ prices– Low digital maturity – Digital’s skill scarcity.

Main References: Productivity (Nagovitsyn & Stepacheva, 2021)–Maintenance (Savolainen & Urbani, 2021)– Safety (Löow et al., 2019)– ESG (Guo et al., 2022; Gabriele et al., 2022)– Visualization (Wang et al., 2022)– Automation (Davis et al., 2023).

ScienceDirect

The search resulted from 66 articles, of which 12 of them were considered the most relevant, basic, and cited. Following is the extracted analytics considering the main articles:

Consideration: Integration between systems, machines, and human– Operation design – Automation– Pollution.

Problems: Low productivity over the mining procedures– Non–integrated Systems– Designing Digital twins– High maintenance costs.

Solutions: Exact simulation– Data analytics– Educating through virtual reality– Online monitoring– Automating Procedures–Mathematical modeling– Predictive maintenance.

Challenges: Limited resources– Human and machine errors–Complex maintenance– Digital’s skill scarcity– A lot of sensors to be applied and managed – Integrating data analytics, modeling methods and IOT platforms.

Main References: Productivity (Xie et al., 2022) – Simulation (Hazrathosseini & Afrapoli, 2023; Attaran & Celik, 2023) – Asset management (Bondoc et al., 2022) – Automation (Bertoni et al., 2022) – ESG (Gao et al., 2023) – Digitalization (Xie et al., 2022; Nwalia et al., 2022)– Predictive maintenance (Siaterlis et al., 2022).

Table 2 Research paper summery based on keyword category and source.

Category/Data Source	Considerations	Problems	Solutions	Challenges	Top References
IOT Applications					
MDPI	Efficiency, Security, Air Quality	Automation obstacles, Decreasing Productivity	IOT data integration, IOT sensors	Low digital maturity, Lack of trust	Li et al. (2018), Seok et al. (2019)
Springer	Data	Data ignorance,	Data analytics,	Rejecting data	Qi (2020),

	management, Safety, Automation	Harsh environment	Drones	analytics	Maheswari et al. (2020)
ScienceDirect	Safety, Real-time info, Operations efficiency	Dam failure, Hazardous accidents	Online monitoring, IOT platforms	Data analysis, Expensive sensors	Sun et al. (2012), Nidhya et al. (2020)
Digital Transformation					
MDPI	Sustainability, Data handling	Harmful minerals, Lack of integration	Digital solutions, Cloud space	Ignorance, Low digital maturity	Feroz et al. (2021), Xu et al. (2022)
Springer	Automation, Blockchain	Digital Ignorance, Lack of Infrastructures	Data analytics, Innovative technologies	Lack of skill, Low digital maturity	Young & Rogers (2019), Litvinenko (2020)
Science Direct	Climate change, Process automation	Polluting environment, Lack of knowledge	IOT platforms, Deep learning	Lack of infrastructures, Traditional supply chain	Gabriele et al. (2022), Brodny & Tutak (2022)
The Digital Twins					
MDPI	Digital disruption, Designing simulations	Environmental footprint, Cyber- Security	Digitalization, Simulation	Low digital maturity	Zhironkina & Zhironkin (2023)
Springer	Deposit representation, Sustainability	Low productivity, Unsafe mines	Simulation, Data analytics	Data gathering, Sensor prices	Nagovitsyn & Stepacheva (2021)
Science Direct	Integration, Automation	Low productivity, High maintenance costs	Exact simulation, Virtual reality education	Limited resources, Complex maintenance	Xie et al. (2022), Hazrathosseini & Afrapoli (2023)

This table demonstrating outlines, primer primary considerations, problems, solutions, challenges, and key references associated with IoT applications, digital transformation, and digital twins in the mining industry in better view:

Table 3 demonstration of different aspect of the research based on three main keywords.

Aspect	IoT Applications	Digital Transformation	Digital Twins
Considerations	Efficiency, Security, Air Quality, Accidents	Sustainability, Data Handling, Management	Digital Disruption, Education, Simulation Systems
Problems	Automation Obstacles, Decreasing Productivity, Health Issues	Harmful Activities, Lack of Integration	Environmental Footprint, Complexity, Cybersecurity
Solutions	Integrating IoT and Blockchain, Automation, On-time Detection	Connecting Digital Solutions, Data Analytics, Cloud Space	Innovative Thinking, Digitalization, Simulation, Visualization
Challenges	Low Digital Maturity, Skill Shortage, Infrastructure Costs	Digital Maturity, High-Tech Skill Provision, Trust in Tech Providers	Low Digital Maturity, Adoption of Technology, Sensor Costs
Key References	Li et al. (2018), Aziz (2020), Ziętek et al. (2020)	Feroz et al. (2021), Nagy et al. (2018), Lin (2022)	Zhironkina & Zhironkin (2023), Servin et al. (2021), Guo et al. (2022)

By focus on comparing key aspects of IoT applications in the mining industry as reported in different sources (MDPI, Springer, ScienceDirect). We analyze and visualize Number of Articles per Source, this graph illustrates the following comparisons:

Number of Articles per Source: Compare the total number of articles and the number of most relevant, basic, and cited articles across MDPI, Springer, and ScienceDirect.

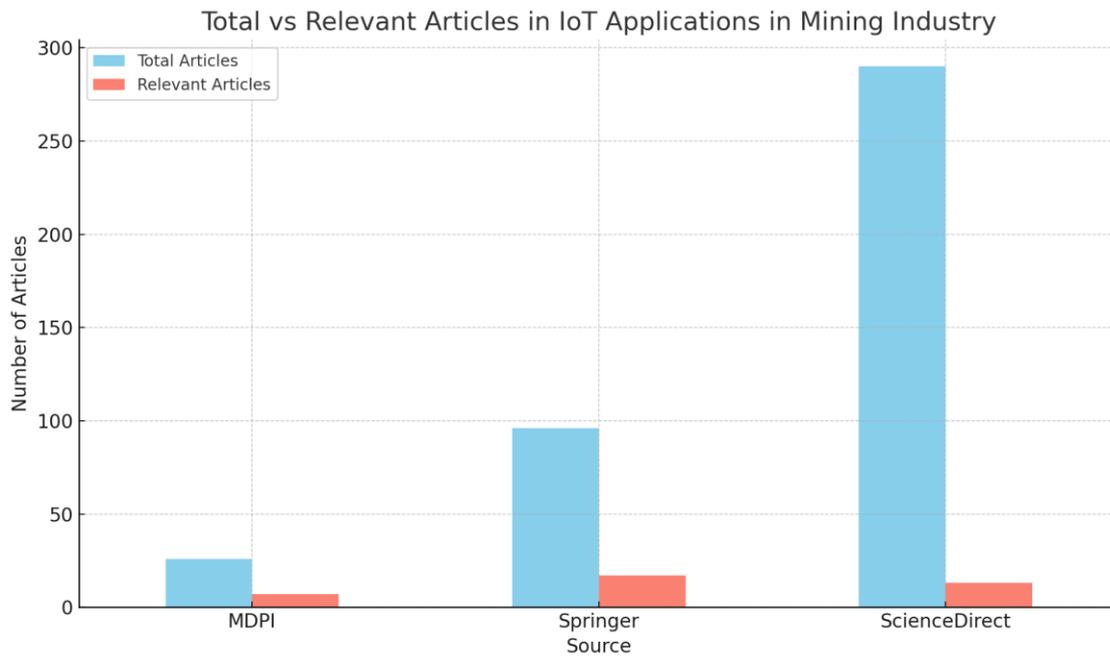


Figure 1. Demonstration of total and relevant article based on this research questions.

Discussion

Based on the literature review, we address the research questions and explain in detail the major concerns, challenges, problems, and solutions that the mining industry experiences related to applying IOT applications to its policies and processes.

Problems and Challenges

Although the mining industry is very slow on adopting new technologies, it is getting faster, where the new challenges that it faces are the reason behind this acceleration. Most important challenge comes from the digital transition and the skyrocketing demand for mining companies' products. Within this transition, the ESG (Environment Social and Governance) challenges are also considered to be addressed as most of solutions like extending the use of renewable energies, completely depend on the progress of digitalizing different industries and their processes. The next challenge is related to the digital maturity among mining managers and employees. In most cases, the capital and planning needed to digitalize a sector is up to the understanding of the C-suits' about the solution. It is also the basic reason behind the lack of trust among mining companies regarding the new technologies that is presented to them. Increasing the digital maturity level among mining communities must start from the top to the bottom. Specifically, solutions that IOT networks and platforms bring into mining sites should be taught before any planning to apply.

As the demands for mining commodities rise, mining companies are under historical pressure to lower and eventually remove their footprint on producing the current bulk of CO₂. Mining companies are among the ones that consume a lot of fossil fuels, especially diesel fuel. Moreover, tailing and waste management are some concerning challenges that the industry has been dealing with and needs to come up with new solutions that address the current volume and the much bigger predicted one soon. There are also the safety problems like fatality and injuries among employees which also darkened the face of this industry. Similarly, mines have problems with managing their dams and there are a lot of reports of disasters taking place just because of mismanagement and the lack of alarming and controlling tools in the sites.

The next challenge is the low level of cooperation that mining companies have in their ecosystem. Mines are very conservative about sharing their data and project information. This also decreases the level of transparency on miners' activities and makes it more complicated to study the industry, and its problems and find solutions for them. Consequently, mines are not good at collecting, analyzing, and making use of data. This is a very concerning challenge as the world is moving toward a future that is governed by big data and data analytic methods and software packages. Finally, migrating mining data to emerging database solutions like clouds and Blockchains is a challenge that only a small portion of the community planned or adapted for it.

As the world is facing a direction where knowledge and the ability to use it is more important than anything else with it comes to hiring an employee, finding skilled and motivated people is a challenge that will be on top of all the challenges by 1 or 2 next decades. Mines are not good at attracting tech-related engineers, because they need to compete with more attractive industries like IT and manufacturing.

Knowledge from Research

Digital transformation is the most promising framework that tries to address all these problems and challenges and offer the industry relevant and applicable solutions. On the frame of all the pathways toward resolving miners' current and near-future problems, there are some digitalization "musts" that have IOT applications in their core. IoT is not just a technology solution; it is the driver of almost all the digital solutions that can be applied in the world of metal and mineral extraction. It was noticed that almost all the papers related to digital transformation have a traceback or forward to IOT sensors, networks, and platforms. Therefore, it's creating, collecting,

analyzing, and making use of data that defines the solution packages to solve current problems in the mining industry.

For example, to get acceptance from managers and bring digital solutions to mines, you should raise their knowledge about data and its importance first. Only in this case, digital maturity can begin to grow, because of all the other solutions related to data and its application in optimizing processes. The very next solution is Digital Twins, which makes more use of data and analytics. Using responsible networks of sensors, digital twins can simulate the present and future environment and procedures of mine, which in turn help managers to create reasonable and possible scenarios that, are also the first step of efficient decision-making.

All these will only be possible if mining companies reach out to academic institutes and get updated and educated with the new and tech-based solutions for their activity. Starting from there, miners need to make lively networks of their ecosystem members and the tech companies that have solutions to offer. Also, other industries like manufacturing and healthcare are already using and enjoying the improvements that IOT solutions brought to their system; benchmarking and cooperating with these pioneers is a good practice to meet the digital transformation and its disruption to processes, before adapting it to the mining systems.

To protect the data and the whole networks connected to IOT devices, the most promising and talk about solution is Blockchain and cryptography that it offers. Blockchains have been used in different industries, mostly through smart contracts, and the positive changes they made are beyond imagination. It is addressed in lots of related articles that Blockchain is the environment that digital transformation and its packages must be protected. Blockchain is also a good alternative for current supply chain management, because of the transparency and security that it brings into contracts and transactions.

Finally, it is the holistic approach that makes all the solutions integrated and brings the best out of all the IoT and digital transformation applications. Most of the milestones pointed at 2050 as a significant time for the world's transformations (like digital and energy transformations). Therefore, there is a sense of connectivity and undeliberate cooperation among industries, especially in the mining industry. With that in mind, it can be noticed that a pinpoint, authorized by the mining society or the international organization can make a pattern that is not recognized clearly but has its merit and benefits. We also observed that digital flows like adapting IOT sensors, networks, and platforms are quite dependent on a social and political concern that makes industries worried about their branding if not pay attention to that concern. Moreover, related

innovative ideas and redesign of the process in the mining industry are completely related to the pressure and manner that social communities have toward the companies. For that reason, we think that the mining industry has changed dramatically over the concerns related to ESG challenges and digitalization has become its tool to act more responsibly and according to social standards. Automation is the final goal of all the IOT networking and related solutions. With no exception, one can find the trace of automatizing, where a part or the whole process becomes automated. IOT is recognized as the main tool that leverages the process and produce enough data that make the automation possible.

Conclusion

The Internet of things is a relatively new subject in the mining industry, but it only needed a decade to fully capture all the aspects of mining processes. The procedures of data creation, collecting, and analytics rely on the sensors of IOT networks. Specifically, digital twins, and similar digital applications, which are used to visualize the mines' environments and procedures, depend heavily on IOT sensors and their on-time data gathering and analysis. On the other hand, digital and energy transitions are the most important drivers when it comes to using sensors in mines; Miners are responsible for the raw materials that are needed for these transitions. Therefore, at the same time as being under pressure of reducing their rate of green gas pollution, mining companies need to increase the number of products significantly. Moreover, mining companies need to deal with the new challenge of attracting and retaining experts with digital-based skills. Overall, it is pointed out by a bulk of the research that low digital maturity among miners, especially the C-suits, is the main obstacle in planning for and applying IOT solutions and other digital applications. For that reason, any attempt with "digital" in its concept should start with teaching different levels of decision-makers in the companies, which also should start with the related data and their meaning, creation, and application. Finally, what is called the knowledge economy has been the new and continuously growing revolution in all the industry starting with Blockchains and smart contracts.

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