"DIGITAL REVOLUTION 4.0" IN THE RAW MATERIALS AND MINING INDUSTRY

MADENCİLİK VE HAMMADDELER SEKTÖRÜNDE DİJİTAL DEVRİM 4.0

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ABSTRACT

The concept of 'Industrial Revolution 4.0', which was first introduced in Germany and has rapidly spread to other developed countries, describes the ongoing automation of traditional production and industrial applications using modern digital technology. In this new era of Industrial Revolution 4.0, the mining industry too has inevitably started to focus on technology and digitalisation. As there are many challenges ahead in this transformation process, DMT's approach to this new era is to offer innovative and holistic Industry 4.0 solutions developed through a fastidious strategy which is expected in assisting to shape the autonomous mining vision of the future. DMT's approach to this digital transformation is to go through initially a "Digital Due Diligence Process" to assess the existing business, identify digital potentials and operating opportunities and define a digitalisation roadmap. DMT's recommendation is that this process is accompanied by independent engineering and technology advice coming from an experienced partner in process design who will establish a "Digital Transformation Office" how these identified points can deliver the expected quality, efficiency, and improvements in health and safety in line with the environmental sustainability. This approach includes three fundamental components:

"**Operations**" which cover the services used to provide companies with comprehensive guidance and support, systematic approaches to continually expand the offering of digital products and services covering the entire lifecycle of raw material extraction such as Reconnaissance, Exploration, Planning and Project Evaluation, Construction, Optimisation of Mining Operations, Environmental Aspects, Mine Closure and Site Remediation;
"**People**" which covers a corresponding digital transformation program for all employees of mining companies;
"**Processes**" which covers process optimisation for its Clients' operations.

This paper describes how a holistic approach can be implemented in this new digital era from the Consultant point of view.

Keywords: Digital revolution 4.0, mining, geology, artificial intelligence, internet of things, sensors

ÖZET

İlk olarak Almanya'da ortaya atılan ve diğer gelişmiş ülkelere de hızla yayılan "Endüstriyel Devrim 4.0" kavramı, geleneksel üretim ve endüstriyel uygulamaların modern dijital teknoloji kullanılarak süregelen otomasyonunu anlatır. Bu yeni Endüstri Devrimi 4.0 çağında, madencilik sektörü de kaçınılmaz olarak teknoloji ve dijitalleşmeye odaklanmaya başlamıştır. Bu dönüşüm sürecinde önümüze çıkacak bir yığın zorluk olduğundan, DMT'nin bu yeni döneme yaklaşımı, geleceğin otonom madencilik vizyonunu şekillendirmeye yardımcı olması amacıyla titiz bir strateji ile geliştirdiği yenilikçi ve bütünsel Endüstri 4.0 çözümleri sunmaktır. DMT'nin dijital dönüşüme

yaklaşımı, var olan işin ayrıntılı olarak değerlendirilmesi, dijital potansiyelleri ve işletme fırsatlarının belirlenmesi ve bir dijitalleşme yol haritası belirlemek için başlangıçta bir "Dijital Durum Durum Saptama Süreci"nden geçilmesidir. DMT'nin tavsiyesi, bu sürece, süreç tasarımında deneyimli bir bağımsız mühendislik ve teknoloji ortağının/danışmanın eşlik etmesi; ve bir "Dijital Dönüşüm Ofisi"nin kurularak kalite, randıman, iş sağlığı ve güvenliği ile ilgili beklentilerin çevresel sürdürülebilirlikle uyumlu tesliminin gerçekleşmesidir. Bu yaklaşım şunları içerir:

”**Operasyonlar**: Madencilik operasyonlarının optimizasyonu gibi hammadde çıkarmanın tüm yaşam döngüsünü kapsayan dijital ürün ve hizmetlerin sunumunu sürekli olarak genişletmek için sistematik yaklaşımlar, şirketlere kapsamlı rehberlik ve destek sağlamak için kullanılan hizmetler, keşif, arama, planlama ve proje değerlendirme, inşaat, çevresel unsurlar, maden kapatma ve saha iyileştirme;
“**İnsanlar**”: Madencilik şirketlerinin tüm çalışanları için ilgili bir dijital dönüşüm programı;
“**İşlemler**”: Müşteriler için süreç optimizasyonu.

Bu makale bu yeni dijital çağda bütünsel bir yaklaşımın nasıl uygulanabileceğini, Danışmanın bakışıyla yansıtmaktadır.

Anahtar Sözcükler: Dijital devrim 4.0, madencilik, jeoloji, yapay zeka, IOT, sensörler

INDUSTRIAL REVOLUTIONS

As we all are witnessing the latest period of societal transformation in human history through a revolution in industrial development currently, the previous industrial revolutions had also been the product of a similar magnitude of changes that resulted in a major structural transformation in the fabric of the societies.

The “First Industrial Revolution” is generally regarded as the transition period between 1760 and 1820 that involved a number of steam/ water-powered machine inventions that enabled and transformed limited quantity of hand production into massive production in textile manufacturing, iron industry, agriculture, and mining. This period was an inevitable culmination of the advancement made in science and technology in the late 18th Century and the beginning of the 19th Century.

The “Second Industrial Revolution”, also commonly known as the “Technological Revolution”, is the period between 1871 and 1914 that resulted in the installation of the extensive network of railways, telegraph, and electricity. A faster transfer of people and produced goods between the distant points was achieved through journeys made in railways whilst the telegrams allowed a rapid exchange of ideas and communication beyond the national boundaries at the time. Increased use of electrification also allowed factories to develop the modern production lines that resulted in a period of great economic growth at the expense of a surge in unemployment as many factory workers were replaced by machines.

The “Third Industrial Revolution”, also known as the “Digital Revolution”, started in the 1960s following the devastation of World War 2 and reached its culmination in the latter part of the 20th century. This was the period, which was catalysed by the development of semiconductors, mainframe computing (the 1960s), personal computing (1970s and 1980s), and the use of the internet (1990s). This was also the era where complex computation has started to emerge by the use of supercomputers that has enabled less human intervention in large computational process.

The concept of the “Fourth Industrial Revolution” (or “Industrial Revolution 4.0”), which was first introduced in Germany (Schwab, 2013) and has spread rapidly to other developed countries (Schwab, 2016), describes the ongoing automation of traditional production and industrial

applications using modern smart technology which was introduced in the later part of the Third Industrial Revolution. In this new system, a new production platform has been prepared by integrating large-scale machine-to-machine communication, internet of objects, rapidly increasing automation, advanced communication network, and self-monitoring and smart machines that can analyse and diagnose problems without the need for human intervention.

The common denominators observed in the previous industrial revolutions are that the fabric of the society and scale of the economics have significantly changed resulting in a new order of business and corresponding legal and administrative adjustments and changes.

The Fourth Industrial Revolution has already identified a number of structural transformation and paradigm shifts in the societies that are expected in the coming years (Schwab, 2016). These particularly include amongst many others:

The Internet of and for Things;
Automated vehicles;
Artificial Intelligence (AI) and Decision-Making;
Robotics and Services;
Cryptocurrencies and the Blockchain;
The Sharing Economy (the use of a physical good/asset, or share service or provide a service by sharing);
3D Printing in Manufacturing, Human health and Consumer Products; and
Designer beings (humans/living things) and
Neurotechnologies (first human with fully artificial memory implanted in the brain).

FOURTH INDUSTRIAL REVOLUTION AND MINING

As more of the “things” start to communicate and interact with each other in a more smart and artificial way in this Fourth Industrial Revolution particularly in the developed countries, it is inevitable that the mining segment will also benefit from this latest transformation in these economies.

Especially in countries with mining industries where wages are high, resource savings and economic extraction of raw materials can only be achieved with more automation and digitalisation.

As Schwab (2016) prophetically concluded, the winners will be those who are able to participate fully in innovation-driven ecosystems by providing new ideas, business models, products and services, rather than those who can offer only low-skilled labour or ordinary capital.

Considering the competitive nature of the business, especially the large international mining companies have already started to adjust themselves by digitising their mining operations across the value chain in line with the future generation of mines. This obviously requires a remodelling of the business for growth and sustainability while using digital technology and innovation as a catalytic enabler within an existing legacy environment that behave like individual isolated units along the route from mine to processing to transport.

The examples of this new approach have already started to populate the mines. The introduction of remotely controllable equipment and autonomous machines such as trains, trucks, drilling machines, as well as sensor driven equipment monitoring have already proven that they can significantly reduce the use of personnel in mining operations and thus the risks to human life.

In addition, the increasingly complex geological conditions encountered in the mines confront companies with the obligation to preserve and, where possible, increase the quality and quantity of raw materials by using efficient methods and equipment as well as prioritising the areas where these challenges can be met by using digital technologies.

Despite many gadgets and devices being a customary part of our daily life for many years, their widespread use in mining has just started. This includes, among other things that are taken for granted in daily life, the establishment of the "internet network" with relevant safety standards in underground mining operations. The implementation of the sensor technology currently standard in automobiles has just been started being implemented after adapting the specific requirements of mining and the associated nuisance effects of dust, mechanical stress, extreme temperatures, water or explosive gases (Clausen and others, 2020). The sensors have particularly become the driving force in efficiency and safety improvements in many mines where the digitalisation is playing a crucial role.

As Virtual Reality (VR) / Augmented Reality (AR) are commonly used in gaming industries, they also make their way into the mining industry to train and upskill the workforce used in high-risk tasks and problem solving the key operational challenges. The competency development can be reinforced better when experiential learning, gamification (adding game mechanics into nongame environments) and just-in-time reinforcement using digitally enhanced environments are used (Pagnini, 2019).

Drones are now commonly used in every aspect of the economy from delivery of goods to remote survey to entertainment. Mine industry has also started to use the drone technology both for inventory management, slope failure management of waste dumps, site surveying, traffic management, and maintenance.

It is also possible that the advancement in 3D printing may enable spare parts to be produced without sacrificing the downtime and production levels in the remote corners of the planet in near future (Pagnini, 2019).

As the satellite technology now allows shipment tracking to be monitored anywhere in the world, opportunity to create better performance in route optimisation and fleet dispatching as well as production level adjustments at the pit level that can result in an optimised integration approach from pit to port (Pagnini, 2019).

Especially in small to medium sized projects/operations in mining, it is difficult to decide where to lay the digital emphasis on and how to prioritise digitalisation and resolve many challenges which can include high capital investments in automated operations and equipment, personnel commitments, IT security, data security and protection, data processing and analysis, information quality and granularity, communication standards, legal hurdles and frameworks, concerns on quality, health, safety and environment (QHSE) and many more. The real challenge is where and how to connect the "silos" and transfer them into a digital hub.

Barnewold and Lottermoser (2021) demonstrated that 107 different digital technologies are currently pursued in mining whilst an analysis from 158 active surface and underground mines showed that the actual implementation of digital technologies is slow in general, and the uptake increases with the run-of-mine production. Large-scale mining operations appear to select and apply digital technologies suitable to their needs, whereas operations with lower production rates do not implement the currently available digital technologies to the same extent. These minor producers

may require other digital transformation solutions tailored to their capabilities and needs and applicable to their scale of operations (Barnewold and Lottermoser, 2021).

Unlike the slow-take of mining companies, the organisations which provide consultancy services to the mining operations have embraced this new digital era with open arms and started providing a number of products and services to their customers.

As an example, for these digitally equipped consultancy companies, DMT's activities, which have a history of more than two centuries in mining consultancy, also focused on technology and digitalisation in this new period of Industrial Revolution 4.0.

As part of prioritising the overall business strategy in this new era, DMT has established a digital technical group which specialised in different aspects of mining by using a range of state-of-art digital techniques to solve a number of issues.

This group can advise its clients on the upcoming challenges of digital transformation based on a broad market study and in-house technical expertise. This process generally starts with a "Digital Due Diligence" of the operations and usually continues with the establishment of a "Digital Transformation Office" (Figure 1).

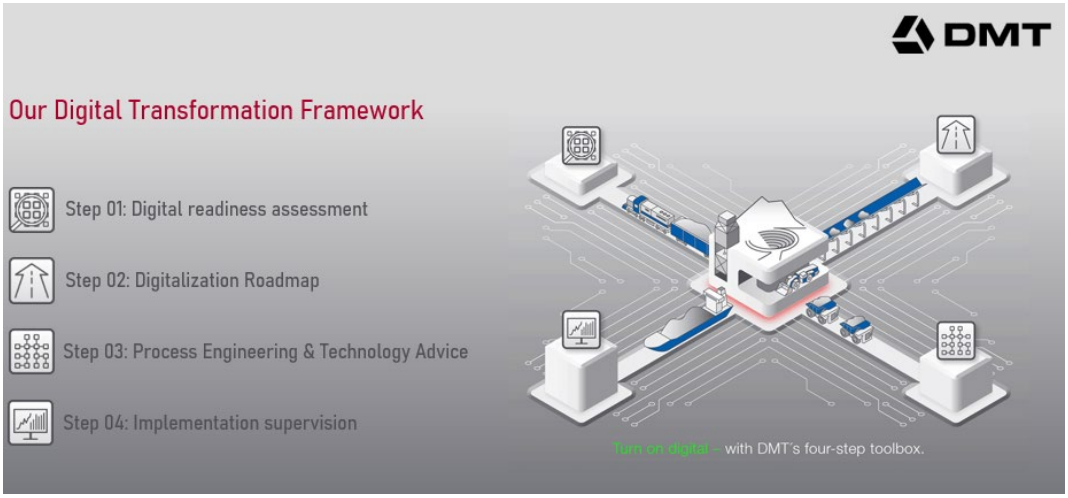

Figure 1. DMT four step toolbox approach in digital transformation for Mining 4.0

The proposed "Digital Due Diligence Process" involves assessing the existing business, identifying digital potentials and operating opportunities and defining a digitalisation roadmap and priorities (Figure 1). DMT's recommendation is that this process is accompanied by independent engineering and technology advice coming from an experienced partner in process design who will establish a "Digital Transformation Office" to deliver these identified priorities in line with the expected quality, efficiency, and improvements in health and safety and environmental sustainability (Figure 1).

As the leader of TÜV NORD GROUP's engineering division, DMT currently offers its customers innovative and holistic Industry 4.0 solutions that cover the following three main pillars (Figure 2) based on the principles of the toolbox approach explained above. These are namely Operations; People and Processes.

Figure 2. Main pillars of DMT's Mining 4.0 portfolio

OPERATIONS

In this context, the word "operations" represents the operational business that exists and DMT presents here both technologies developed in-house, and services used to provide companies with comprehensive guidance and support. Many of the in-house digital technologies in the form of advanced tools and gadgets developed by DMT are already making a significant impact for the mining operations around the world.

In addition to the development of such company-specific operational tailor-made solutions, the impact of digital transformation on the clients' employees in terms of Mining 4.0 should not be ignored. In particular, far-reaching technological changes require wide acceptance among the workforces. In addition, long-term employees, especially in the company, need to be adapted to the challenges of digitalisation. To this end, the structure and culture within the company should be further developed where DMT's corresponding transformation program for the digital world through the Digital Academy of TÜV NORD GROUP may assist all employees of its customers in great extent.

There is also a huge saving potential within mining companies, thanks to an integrated view of the technical and administrative areas. With the implementation of shared and interconnected digital systems, quality, productivity, and throughput times can be optimised from raw material extraction to product distribution. Streamlining administrative processes avoiding isolated solutions in individual areas frees up resources, which can be used to further improve operational processes. DMT has many years of experience in process optimisation, together with an extensive network of collaborators.

Core Operations

DMT is definitely at the forefront of the trend to increase productivity through digitalisation in the raw materials industry. All processes along the entire value chain are affected by this trend, with a wide range of technical solutions already available in the service portfolio. Beyond that, systematic approaches are underway to continually expand the offering of digital products and services covering the entire lifecycle of raw material extraction (Figure 3).

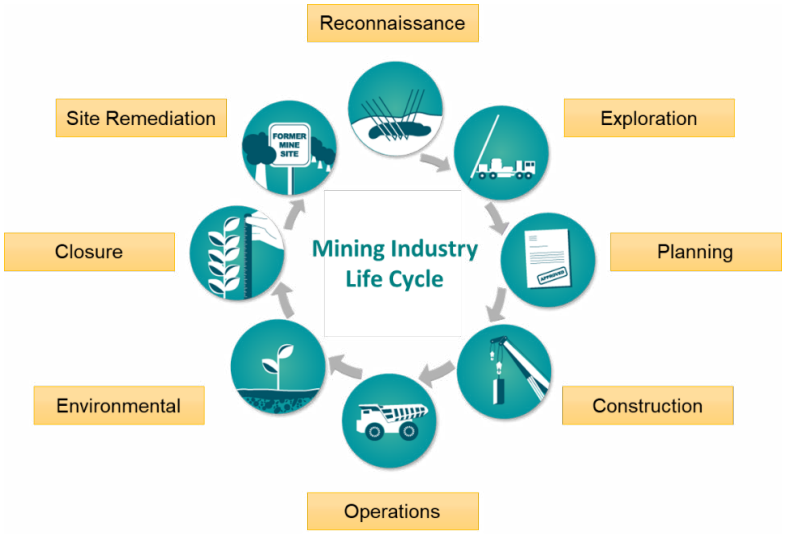

Figure 3. Life cycle of the mining industry

Reconnaissance Studies

Reconnaissance is often the first phase of mining projects, and the high degree of uncertainty at this stage is the main reason for intense efforts to minimise investment risks. The use of state-of-the-art digital technologies enables the acquisition and evaluation of high-quality data through optimum use of people and equipment. To support this work step efficiently, DMT has the power to effectively deploy adequately equipped drones, with the support of technology collaborators. Regarding integrating future developments in this sector, DMT is participating in a research project on the use of sensor-equipped drones within the framework of the European Union-funded "European Institute of Innovation and Technology Raw Materials (EIT Raw Materials)" program. DMT is developing a key technology module in the form of a software solution that, among other things, integrates the acquired data with standard software such as ArcGIS and AutoCAD, thereby greatly accelerating the creation of geological maps.

Exploration Studies

Technical progress under Industrial Revolution 4.0 also has a significant impact on exploration. That is, new advances in automation of data collection, evaluation, analysis, and model building can have a positive impact on the amount of time spent and money invested. An example of this is DMT CoreScan®3 (Figure 4), which enables the digitisation and evaluation of entire drill cores (360°) and their export to a corresponding drill core database. In addition to the analysis of the mine inventory and grain size distribution, a detailed structural evaluation can also be made in this way.

Other DMT solutions in the field of exploration, apart from active involvement in borehole drilling, borehole surveying and logging, include the application of seismic methods such as 2D and 3D seismic reflection, seismic refraction, seismic tomography, as well as their interpretation and modelling, in which large amounts of data are directed and evaluated. The results from these studies can best be used to create a "digital twin" of the mineral deposit, which is constantly updated in real time. At this point, by increasing the degree of automation, the dependence on personal experience in modelling can be reduced, thereby increasing the degree of objectivity. For this purpose, DMT uses modern proprietary software where workflow can be stored and recorded, thus ensuring better reproducibility of results.

Figure 4. DMT CoreScan®3

Planning and Project Evaluation

Within the scope of operational work, complementary short and medium-term plans are made sequentially and at regular intervals. In particular, the short-term plan should be updated daily to get the most out of machinery and other resources. Here, automation and digitisation offer a very high potential for cost savings. For example, the geological models can be updated immediately when excavating seams/ores or driving the developments in underground mines or creating blastholes in open pit mines using appropriate sensor technology. On the other hand, in the case of using transport systems, it can record in real time the motion paths of mining equipment as well as idle and downtime, resulting in significant reductions in cycle times. DMT also supports employers and investor credit institutions in feasibility studies and determination of resources and reserves in accordance with the international standards. In this process, the basis for further planning is laid by creating three- or four-dimensional models (Figure 5.) and creating initial databases. For visualisation purposes, the most advanced Virtual Reality (VR) facilities are used. With VR glasses, planning can literally be made "touchable", even for non-experts. With the use of proprietary software and a broad market study, DMT is able to offer its customers holistic solutions that integrate data from various sources. These solutions include deposit and machine data, as well as data from geotechnical monitoring systems.

In addition to providing advice to mining companies, DMT is also involved in the development of CERA, a standardised analytical and integrated certification system that guarantees the ecological, social and economic sustainability of the extraction, processing, trade and production of all mineral raw materials, including fossil fuels. This system ensures reliable traceability of certified raw materials using various technologies and proof-of-origin methods throughout the value chain. Digital technologies such as the Distributed Ledger or Blockchain play an important role, for example, as transaction databases to track trade and transport routes in a verifiable way.

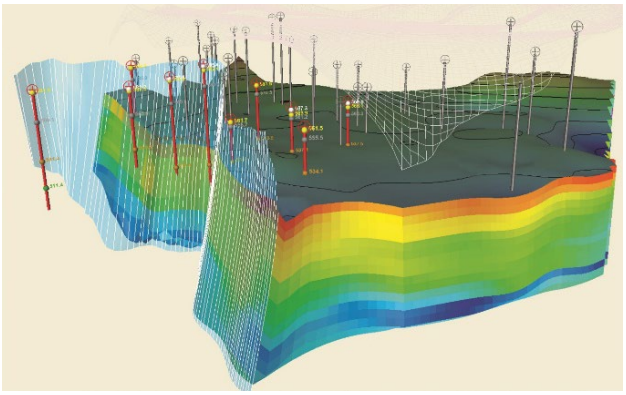

Figure 5. Utilisation of special software for the 3D visualisation of a mine

Construction

DMT's approach on this is to offer "tailor-made" engineering solutions from a single source. For example, the digitalisation used has reduced the construction times of mining-related infrastructure projects and contributed to a more efficient use of investment capital. DMT is represented at this event space by measuring instruments such as the IMAGER 5006EX (Figure 6c), the world's only high-precision, explosion-proof 3D laser scanner. The fully automatic GYROMAT can also record measurement data in real time and transmit it wirelessly (Figure 6a). With a diameter of less than 2.5 cm, the DMT SlimBoreholeScanner allows to record the number and condition of cracks in equally small boreholes and then visualise them along the entire length (Figure 6b). In contrast, geo-radar and ground radar provide high resolution searching of the ground to inspect road surfaces, power transmission lines and boreholes. Data from all devices can be combined, processed, and visualised by purpose for on-premises data platforms.

Figure 6. DMT's cutting-edge products a) GYROMAT b) SlimBoreholeScanner c) MAGER 5006EX

Optimisation of Mining Operations

In this context, DMT provides the MineSafe® platform which was developed as an in-house machine diagnostic system specifically designed for condition monitoring of machines and plants (pumps, crushers, large belt conveyors, vehicles, etc.) in the mining and processing industry. MineSafe can also be implemented as a customer-specific, controller-integrated system providing all the essential functions and components of a modern online condition monitoring system and is now available as such on Caterpillar's automation platform. The modular design allows for a wide variety of applications and a high degree of expandability thanks to the relatively simple integration of existing control systems. DMT is currently developing "MAMMA - Maintained Mine and Machine", which aims to significantly reduce the maintenance costs of machinery and systems in mining

operations by gathering, processing and clearly visualising all relevant data. This system allows for longer maintenance intervals and increased equipment availability. In the field of ventilation, systematic studies are carried out to implement adequate and adaptable practices by using "Ventilation on Demand-VOD" systems.

Whether it is the question of automating individual work steps or adapting entire process chains, DMT has positioned itself to provide tailor-made solutions and choices and support for the Clients during implementation phase.

Environmental Aspects

In addition to high productivity, Mining 4.0's objectives include security, increased efficiency, sustainability and transparency as the public's attention on the environment has significantly grown in the recent years. Negative environmental impacts due to the collapse or failure of tailings dams or similar events occurring on the mine sites impacting the environment have become immediate headlines recently. To avoid such events, continuous monitoring measures are required in addition to drilling planning. For this purpose, the DMT SAFEGUARD network platform has been developed by placing sensors in complex geo-monitoring systems with alarm functions to record ground motions, object deformations, vibrations, or geotechnical parameters. It does not matter whether the data is recorded and archived just a few times a day or more than 1000 times per second, and whether it is also temperature, water level, vibration, or video data. All information is automatically visualised according to the requirements and is accessible at any time via a decentralised and location-independent network portals. Based on SAFEGUARD, DMT is currently developing an all-in-one solution for waste monitoring under the "EIT RawMaterials" project "STINGS" and is successfully using it in a model plant in South America. This system detects ground motions using remote sensing techniques, as well as planning and installing a sensor network for geotechnical monitoring of waste. All measurement data is stored in a central database that enables complex models to be built to assess the safety of facilities and detect and warn of hazards at an early stage.

Mine Closure and Site Remediation

The life cycle of a mine is often combined with the improvement of the mine site following the end of the mining operation. Such processes are also known as "remitting funding". In many well-developed mining countries, mine operators have to allocate the monetary resources necessary during the extraction phase to ensure the regular upgrading of the mines in relation to the ultimate mine closure. The most obvious example of this is the management of water pumps in closed mines in the Ruhr and Saar region of Germany. Optimisation, automation, and digitalisation are tools used to ensure that the amount of monetary funds allocated to costs is not exceeded. As part of its water management activities, DMT compiles three-dimensional images of ground and surface waters, allowing mine operators to perform more complex analyses and calculations with "digital twins" of the groundwater. In this way, the effects of technical interventions can be predicted in different scenarios and correct measures can be taken. The SAFEGUARD system described above can also be used for continuous monitoring of indoor mining operations. By doing this, mining-induced ground motions such as slope failures can be detected and even predicted. The system is method independent and works with any data from geotechnical, surveying, geophysics, noise and vibration fields.

In addition, DMT with its global partners have developed a new system called CLOSUREMATIC which plans the closure and rehabilitation of a mine while it is still under construction. This digital product aims to eliminate the typical problems in mine closure such as loss of continuity upon changes in management and ownership, difficulties in cost estimation and

tracking, loss of closure-related data, poor coordination in closure activity and operations that compromise the goals of closure, inadequate consultation etc. The use of CLOSUREMATIC also reduces the closure related environmental and social risks. The guidance section (one of CLOSUREMATICs unique features) helps the operator to focus the actions to sectors that they are most effective and needed in a continuous manner. This has been designed in a way that the closure related actions and useful links to a knowledge base can be managed from the beginning of the mining activity even prior to mining at planning phase. Due to the precise descriptive nature of the closure process, the CLOSUREMATIC will probably be the most accurate tool in the market to estimate the costs of closure. This information can be used in determination of the financial closure related liabilities in the permitting process and also lowering the liabilities through development of a more developed and detailed closure plan.

PEOPLE

More than half of industrial companies in Germany have embedded “digital transformation” in their business strategy to simplify operations, increase sales and improve customer satisfaction. On the other hand, 30 percent of companies identify the insufficient digital qualifications of their employees as a major problem and thus a significant barrier to implementation. In addition, more than half of the companies criticise the need for a more open corporate culture in which “failure” is discussed in their companies.

These are the points where DMT, in collaboration with TÜV NORD GROUP's Digital Academy, stepped in to make employees the key to digitalisation. The core element of the employee motivation and motivation program within the company is a certified training course to become a "Digital Specialist". After all, the latest and greatest machines are only as good as the people who run them. The more digital the products, processes and machines become, the more important the education and training of employees becomes. For this reason, employees as well as managers should be prepared for a comprehensive digital transformation. The various training programs on this subject can be individually tailored to the needs and challenges of the respective companies in terms of content and duration. Due to this meticulous work, DMT’s parent company TÜV NORD was twice awarded the German Excellence Award 2020 in the "Education and Further Education" category, recognising the accuracy of the VR training of candidate experts in the fields of steam and pressure, on the one hand, and on the other hand, in the "Conversion" category. At this point, TÜV NORD and DMT can provide mining companies with tailored support solutions through courses such as using VR in the training and education of workers in both general and customer-specific mining equipment.

PROCESSES

Detailed analyses form the basis for further process optimisation. With its partners, DMT also provides consultancy services that serve to improve the performance of mining operations in terms of "Operational Excellence". The planning of equipment and materials, the control of cash flows and the management of personnel are challenging issues in terms of administrative responsibilities of mining companies. In terms of planning processes, using modern "ERP-Enterprise Resource Planning" software, accounting, shift planning, time recording, and invoicing automation are just a few examples of potential savings that can be achieved. For a company's production divisions, such systems offer advantages in material supply and storage. Through further analysis, it is also possible to timely identify materials that are required more frequently or that are particularly critical to a smooth working process. By doing this, countermeasures can be taken at the right time. As a result, there are fewer production delays, unnecessary material storage is avoided, and capacities can be lightened.

It has been pointed out before that the digital gadgets and inputs using the digital technology that have been taken for granted in our daily life for years have not yet been created or applied in mining on a large scale. In addition to the inability to provide internet signals throughout the area with relevant security standards in underground mining operations, it can be stated that even in open pit mining, communication over mobile data cannot be provided directly due to shadowing effects and dead spots. Co-synergies can be created by taking a holistic view of the existing and future necessary infrastructures. Accordingly, DMT, in collaboration with its global partners, supports and advises companies through its years of mining expertise and broad knowledge of far-reaching processes, providing one-stop solutions to help them meet the challenges of digital transformation.

CONCLUSION

In recent years, the continued digitisation of mining has brought about continuous changes in the way the raw materials industry discovers its resources, runs mining operations, processes products and ultimately delivers them to their customers. This article demonstrates DMT's Mining 4.0 concept, which is based on three pillars: "operations", "people" and "processes" and covers digital transformation holistically throughout the entire lifecycle of the raw materials industry.

Based on its long-proven ability to capture new developments and integrate them into its core competencies, DMT is passionate about the digitisation of existing products and services, but also very heavily on the development of new digital business models. DMT's aim through its stakeholders and partners inside and outside of TÜV NORD GROUP is to be at the forefront of Industrial Revolution 4.0 in the spirit of the 'Engineering-Performance' motto, to provide digitised, smart and connected solutions for the raw material sector, and thus assisting to shape the smart (autonomous) mining vision of the future. For this purpose, DMT has developed a modular four-step strategy, starting with the assessment of current processes within a company or operation (through a digital readiness assessment) and culminating in the implementation supervision of all services and solutions a customer needs for his successful digital transformation.

The mining industry like any other segments of the global economy faces new challenges in the coming years due to the introduction of many new ways and methodologies to deal with the traditional issues. The authors of this paper believe that the mining industry is in a unique position to manage the things in a completely new way as the world is rapidly moving into an era where the “artificial intelligence” and “internet of the things” will be a dominant force in decision making process. The winners will be determined by those who are able to participate fully in this innovation-driven period. One thing is definitely sure that the old and new operations will face similar challenges in implementing the ideas and innovations, but the ones who move with the time and trends will be ahead of the game. Therefore, choosing a right partner in this process is also a crucial decision in this new era.

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