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Towards Conceptualising Building Information Modelling for the Mining Industry

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Abstract

South Africa is a mineral resource-rich country with the largest concentrations of gold and platinum in the world. Yet the South African mining industry is facing an economic crisis. Some of the reasons for this crisis are: Low commodity prices, escalating production costs, depletion of economically ore grades, volatile currency, volatile exchange rates, difficulty to compete in the international markets. Thus, there is a need to develop an information and decision-making system that will cater for modern-era needs. Such a system would need to optimise production cost, while properly linking it to current and expected market conditions to enable synchronised and timely decision-making. This can only be done via a framework that is supported by relevant and timely information. This will need to include the following mine and market data (in both current- and anticipated-forms): Production rates; assessment of what is going on underground; incident reporting; scheduling; costing; market updates; inventory management; life cycle management. Such a system, named Building Information Modelling (BIM), was developed for the construction industry. This indicates that development of a Mining Information Modelling (MIM) may also address above-mentioned aspects, allowing for production improvements, optimal cost, less uncertainty and more efficiency – something that is difficult to attain via existing mining-software.

1. Introduction

South Africa is a mineral resource-rich country with the largest concentrations of gold and platinum in the world. This includes 80% of the world's platinum group metals, 80% of its manganese, 70% of its chrome, together with the world's largest gold deposits in what is named "The Witwatersrand Basin" (Chamber of Mines of South Africa, 2017). In terms of production, in 2016, South Africa produced approximately 141 metric tons of gold, 264 metric tons of platinum, 8.4 million carats of diamond, 0.3 million metric tons of coal, 16.3 million metric tons of chrome, 73.2 million metric tons of iron ore, and 15 million metric tons of manganese, together with job-provision to 0.46 million people (Chamber of Mines of South Africa, 2017). Yet the South African mining industry is facing an economic crisis. Some of the reasons for this crisis are:

- Low commodity prices;
- Escalating production costs;
- Reduced ore grades;
- Volatile currency;

- Volatile exchange rates;
- Difficulty to compete in the international markets

Of the above, lower commodity prices and volatile currency rates are primary factors. Indeed, an unforeseen combination between these two factors has aggravated the situation. However, it is important to note here that while global markets generally deal in United States Dollars (USD), South African Rand (ZAR) cost estimates and cash flows are generally prepared twice or at best, four times a year. Thus, South African mine production is generally planned by keeping in view specific market price and cost estimates at a specific point in time. However, there is a significant time lag between the production date and selling date. Therefore, the varying price of the product and volatile exchange rate adversely affect the accuracy of mine valuation and decision-making criteria.

Another factor is that South African mining industry production rates have dropped significantly since 2007: Whereas diamond production was 15 million carats in 2007, this dropped to 10 million carats in 2017; Gold production dropped from 260 metric tons in 2007 to 140 metric tons in 2017; Similarly, platinum production dropped from 310 metric tons in 2007 to 250 metric tons in 2017 (Chamber of Mines of South Africa, 2017). Aggravating this are declining production levels and ore grades, together with fast-rising mining costs (Müller & Frimmel, 2010). The reasons for this rise in mining costs are lower ore grades, increased depth of ore grades, increased prices of electricity etc. It is also important to understand that conventional mining methods are limited in their ability to economically exploit remaining mineral resources. Therefore, the design of today’s mines must address advanced risks, improved efficiencies and smarter applications (Braham, 2017).

Thus, there is a need to develop a system that will cater for modern-era needs, thereby enhancing mining capabilities without affecting job-creation. Such a system would need to optimise production cost, while properly linking it to current and expected market conditions to enable synchronized and timely decision-making. This can only be done via a framework that is supported by relevant and timely information. This will need to include the following mine and market data (in both current- and anticipated-forms): Production rates; assessment of what is going on underground; incident reporting; scheduling; costing; market updates; inventory management; and life cycle management. Such a system would need to be specifically-designed to enable real-time decision-making on individual and combined aspects of the latter data.

Such a system, called Building Information Modelling (BIM), has already been developed for the construction industry. BIM has since its development proven to be effective and cost-efficient throughout the lifecycle of construction projects. This indicates that development of a Mining Information Modelling (MIM) system may also address above-mentioned aspects, allowing maximum production, optimal cost, less uncertainty and more efficiency – something that is difficult to attain via existing mining-software.

2. Economic Related Problems in the Mining Industry

2.1 Commodity prices

Section 1 introduced the fact that South African mine-planning is generally carried out six-monthly or quarterly using current commodity prices, and that this fails to cater for future price changes which may affect the complete planning process. Figure 1 shows how commodity prices are changing.

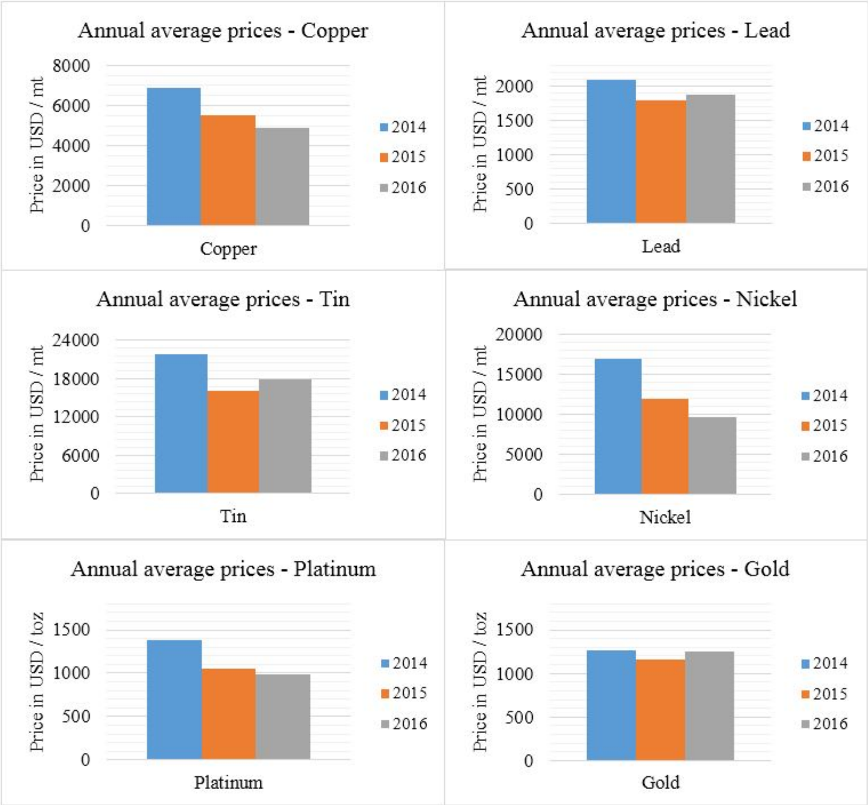

Figure 1.1 Annual average commodity prices
After (World Bank, 2017)

Figure 1.3 reveals that average prices of commodities change significantly over a one-year period. For example, the price of platinum reduced from $1 384 per troy ounce in 2014 to $1 053 per troy ounce in 2015. Since the commodity prices cannot be controlled as such, optimisation of the processes however, is an option to reduce costs and increase profitability. To illustrate this fact, an example is stated in the following paragraph.

South Africa produced 275.5 metric tons of platinum in 2015 (Chamber of Mines of South Africa, 2017). This implies that if the 2014 price and other factors had remained unchanged in 2015, the South African platinum industry could have earned R34.6 billion more in 2015 (i.e. 36.7% more than 2015's actual revenue). Furthermore, employees could have been remunerated R59.6 billion instead of R43.6 billion, and government might have received R0.98 billion instead of R0.72 billion in royalties.

2.2 Currency exchange rates

Section 1 introduced a further complication to production planning, namely the fact that the South African Rand currency (ZAR) is volatile. Figure 1.2 shows the ZAR vs. USD exchange rate changing daily during the period 8 February 2017 to 20 March 2017. As may be seen, over a period of forty days, it dropped significantly from R13.5/$ to R12.6/$. Currently, there is no comprehensive way to determine currency forecast in such a way as to aid smart decisions. This study proposes linking of MIM to real-time currency exchange rates, together with forecasts that are based on both expected and determinable future events. This will, in turn, provide basis for considerably-improved mine planning.

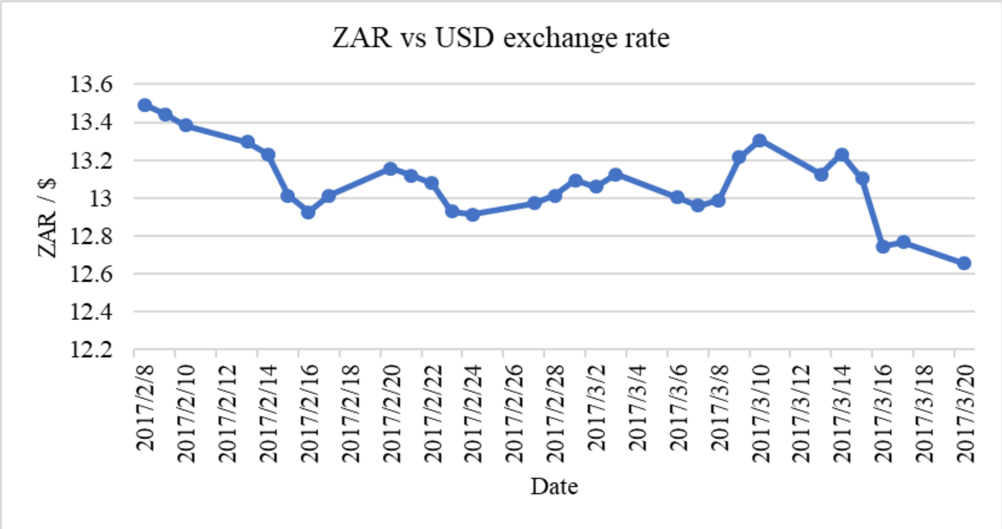

Figure 1.2 ZAR vs USD exchange rate
After (South African Reserve Bank, 2017)

3. Ore Grades and Mining Costs

Ore grades in South Africa have been in steady decline with the passage of time, which is not good for the economics of a mine. Lower ore grades mean less profit. Lower ore grades mean less profit. Figure 1.3 shows how the grade of gold has been depleted over time. Another factor which is to be considered while considering economic problems of the mining industry is mining costs. With the depletion of ore grade, the cost of mining is also increasing. As stated in section 1, these factors cannot be controlled however, with better planning and optimisation, mining costs can be decreased which will increase the profit. Figure 1.4 shows “All-in” cost of gold mining which has doubled over the 5-year period.

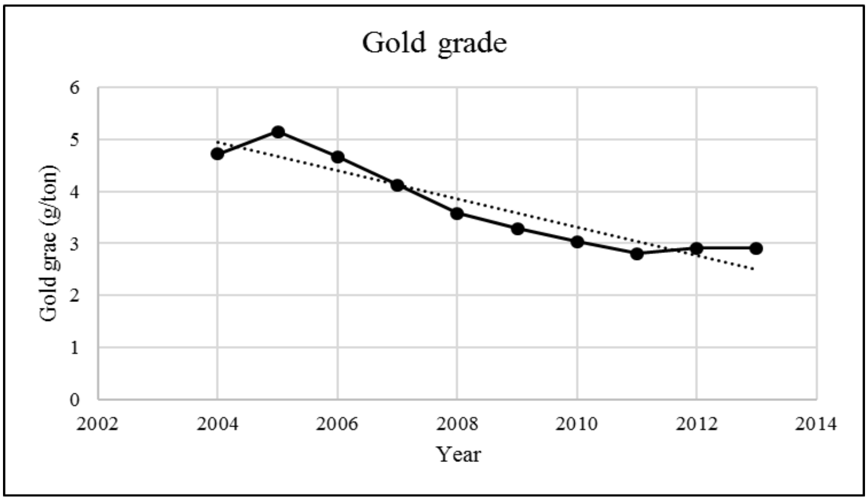

Figure 1.3 South African gold grade. After (Chamber of Mines of South Africa, 2017)

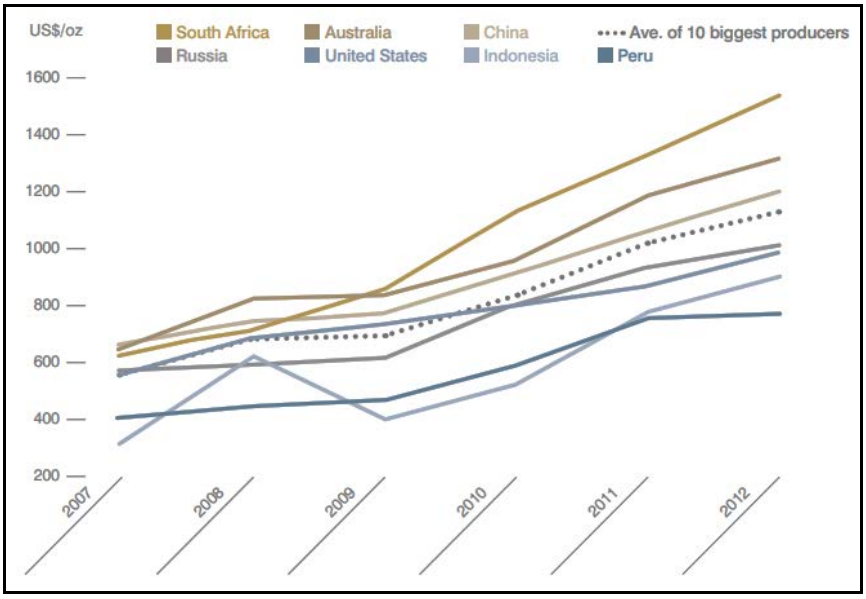

Figure 1.4 Production cost of gold in different countries. (Minerals Council of Australia, n.d.)

4. Mining Value Chain

As shown in Table 1, there are six phases in the mining value chain through which the final product is obtained. On the basis of these stages, a review on MIM requirements is presented in section 6.1 of this study.

Table 1. Explanation of stages of mining lifecycle. After (Guj, et al., 2017)

Stages of mining value chain	Explanation
Acquisition and exploration	In the first phase of the mining operation, land is acquired and exploration for the ore is carried out. Drilling and sampling is carried out and areas with high concentration of ore are highlighted.
Construction and development	In the next phase the construction of mine is started. The shaft is sunk and further development to reach the ore is done. Basic facilities like electricity, water supply, transportation system, ventilation system, etc. are also installed during this phase.
Mining and concentration	In Mining and concentration, the ore is extracted and initial separation from the waste is carried out.
Transportation	The ore is then transported to the refining plant through trucks, railways or ships for refining.
Smelting and refining	In this phase, the ore is heated and melted. A final refined product is obtained in this phase.
Marketing and sales	After refining and beneficiation, the final product is brought to the market and sold.

5. Building Information Modelling (BIM)

BIM is a technology and software creating 3D planning models that helps architecture and construction engineers in proficient designing, planning, construction and management of buildings. It considers the spatial relationships, geographical information, quantities and qualities of elements, material and equipment inventories, cost estimations, and project schedules, and enables team players to communicate, collaborate, simulate, optimize and operate the project throughout its lifecycle (Azhar, et al., 2008) and (Mihindu & Arayici, 2008).

Although BIM is a modern concept, this word was first coined in 1992 (Nederveen & Tolman, 1992). Since then, BIM has improved substantially, and its use is continuously increasing. The percentage of relevant professionals using BIM in the UK was estimated to be 13% in 2011, which has now increased to 54% (NBS, 2016). BIM can be used to create 3D, 4D, 5D, 6D and 7D models. A 3D BIM model with schedule and time constraint is called 4D model and if the cost dimension is added, it becomes a 5D model (ASHRAE, 2009). 6D BIM modelling is about optimising the energy consumption of the building and 7D model helps in management of the lifecycle of the building along with other 6 dimensions (Elsafadi, 2016).

5.1 BIM in the project life cycle

BIM is essentially a comprehensive way of producing, using and sharing the data in a building life cycle. This involves all BIM stakeholders, including owners, architects, engineers, designers, contractors and facility managers (Hungu, 2013). One of the important benefits of BIM is the accuracy of geometrical representation of parts of the building in an integrated data atmosphere (CRC Construction Innovation, 2007). The BIM project lifecycle is shown in Figure 1.5 and explained in the following paragraph.

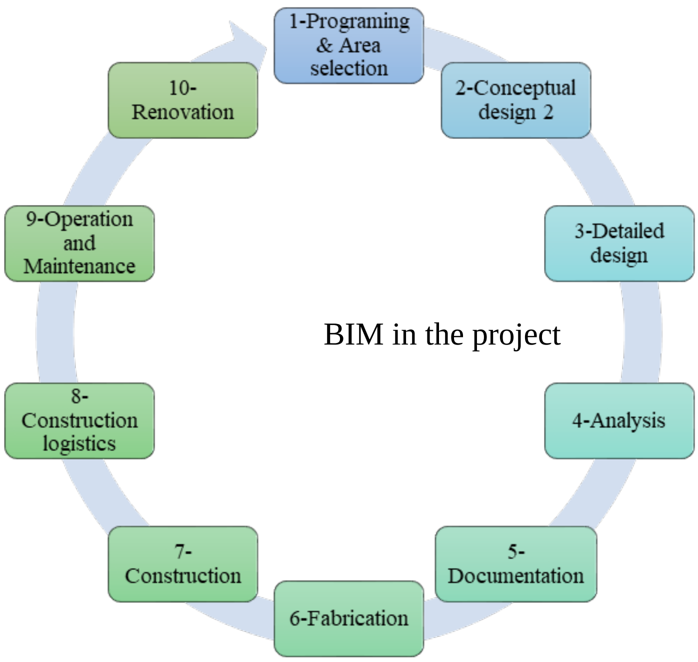

Figure 1.5 BIM in a project lifecycle. After (Dispenza, 2010)

1. Programming and area selection

   BIM helps in area selection, landscaping and terrain management. In an integrated BIM model, it is possible to shape the terrain according to the construction requirement and edit it until the most suitable model is obtained. BIM also assists understanding of environmental aspects concerning the building, such as sunlight direction, wind direction, weather conditions etc.

2. Conceptual design

   BIM provides visualization of different ideas that are submitted. It shows whether the ideas are practical or not, and what changes will be required at this early stage.

3. Detailed design

   In the detailed design, BIM helps in determining different structural properties of the building, such as strength of plinths and iron bars, gravity distribution, required capacity of equipment to be installed, etc.

4. Analysis

   The detailed design is then analysed to ensure that all user requirements have been met. Analysis is also done to visualise conflicts between different parts or installed equipment.

5. Documentation

   Documentation that is produced via BIM helps all stakeholders to better-understand the design. It also enables them to communicate with one another and discuss confusions in a more comprehensive way. A bill of quantities (BoQs) is also generated during this phase.

6. Fabrication
   During fabrication, drawings that were generated earlier are provided to the fabricator. BIM facilitates fabricator comprehension of the provided information through better (3D) visualization.
7. Construction
   During construction, there are often conflicts between involved parties. BIM facilitates resolution of such conflicts, thereby saving time and money.
8. Construction Logistics
   BIM allows detailed project costing and scheduling from the beginning of the project. It calculates material and equipment that will be needed for the building and adds its costs to the budget. In this way, the purchase of surplus material is prevented. Also, BIM's real-time scheduling and progress updates enable the team players to work in their respective places timeously and without delays.
9. Operations and Maintenance
   After completion of construction, BIM assists operation and maintenance of the building. This includes BIM provision of complete data on installed equipment, including operator's manuals, dates of purchase, vendor lists, maintenance schedules and warranty information. The single source of information in one package enables operations managers to manage all aspects of complete buildings and to correctly convey related information. The same feature enables operators to troubleshoot whenever there is an issue.
10. Renovation
    During renovation, BIM data files can be retrieved and material or equipment that needs renovation or replacement may be arranged. Associated manuals and vendor lists enable responsible parties to execute such projects in the best way possible.

5.2 BIM case studies

The following case studies (sourced from Autodesk Revit) highlight BIM benefits.

- Sundt Construction Inc., constructed Butler Water Reclamation Facility in Peoria, Arizona that started operation in 2008. The company saved 6000 hours on concrete rework and the use of BIM enabled the $135 million project to be completed in time. During the project, there were 84% fewer requests for information (RFI) due to the interactive nature of BIM (Autodesk, 2009).
- Shanghai Tower Construction & Development Company Ltd. constructed Shanghai Tower in Shanghai, China. The building was inaugurated in 2015 with distinction of being one of the world's tallest and greenest buildings. The building contains 121 stories of transparent glass, 632-metre height and 5.7 million square meters of building space. Due to the use of BIM, the team encountered no conflicts during construction and reduced building material requirements by 32% (Autodesk, 2014).

6. BIM to MIM (Mining Information Model)

The above-mentioned case studies reveal quantifiable benefits in using BIM. However, since BIM is a technology applied to construction rather than mining, bridging gaps between BIM and MIM will take time and effort. An aspect that could assist is Dundee Precious Metals mining company, who have implemented the concept of IoT under which communication and data from a mine is transmitted real-time. Dundee installed 45kms of fibre optics in its mine and used Wi-Fi for communication. Improved communication, real-time mine workers and equipment tracking, information regarding energy-equipment, equipment maintenance-requirements, and business intelligence using IoT enabled Dundee to efficiently use their resources which increased production from 0.5 million metric tons annually to 1.8 million metric tons and saved $2.5 million in operating costs (Prowse, 2014). This is just one part of applying modern-day technologies into one part of the mining operation. The value-add achieved by using IoT at the test site of Dundee Precious Metals mining company undergirds the impact it could make on the entire mining operation.

If a platform is developed that can capture real-time information, enable two-way communication, link to market prices, and assist smart-decisions, enormous improvement can be brought to the economics system of the mining industry. Benefits discussed above indicate that if it is developed for 21st century mines, it may become a game-changer that will take the mining industry from loss to profit.

6.1 MIM requirements

Using BIM as a basis, this section provides a gap analysis between currently-available software and proposed MIM requirements. Table 2 presents the requirement for MIM in each phase of the mining value chain. These requirements are established in a workshop with chief mine planner and senior business improvement of a platinum mine using a case study. This case study is included in a masters' report of (Javaid, 2018) which is accepted for graduation.

Explanation of these requirements is given in the following paragraphs.

- Acquisition and exploration: In the first phase of a mining operation, data related to exploration will be required.
- Construction and development: This phase will require mine design, construction scheduling, inventory management and construction progress reporting.
- Mining and construction, Transportation, and Smelting and Refining: These three phases (highlighted in Table 2) are combined as they have similar requirements. In these three phases, data related to planning and scheduling along with infrastructure planning and inventory management will be required. Infrastructure planning and inventory management will be required throughout the operation on real-time basis.

- Marketing and sales: For this phase, data from the financial model of the mine will be required. This data will be required from the first to the last phase of the mining value chain and has to be updated continuously, in real-time.

Table 2. MIM requirements in each phase of mining operation

Requirements in a mining operation in the light of BIM lifecycle (section 5.1)		Mining value chain					
		Acquisition and exploration	Construction and development	Mining and concentration	Transportation	Smelting and refining	Marketing and sales
Mining requirements	**BIM**						
Exploration data	1	✓					
Mine design	2,3		✓				
Planning	3,4	✓	✓	✓	✓	✓	
Scheduling	3, 4, 5	✓	✓	✓	✓	✓	
Infrastructure planning	Throughout BIM lifecycle	✓	✓	✓	✓	✓	
Inventory management	Throughout BIM lifecycle	✓	✓	✓	✓	✓	
Financial modelling	Throughout BIM lifecycle	✓					

6.2 Need for MIM

The mining industry is facing challenges, and one of those challenges is economic decision-making which needs to be more accurate, smart, quick and based on real-time information for the mine of 21st century. MIM will connect the mining industry to real-time information coming from the market on a continuous basis, so that necessary actions related to production and sales can be taken in real-time.

7. Conclusion

The aim of this study was to highlight the issues related to economic planning of a mine and to propose a possible solution. The conclusions drawn from the study are following:

- Mining projects need a depository of information throughout the mining value chain, from exploration to post mine closure, as a commitment to responsible mining;
- Commodity price fluctuation, volatile currency exchange rates and depleting ore grades are a challenge for the mining industry in South Africa;
- There is a requirement of a tool that can improve economic planning of mine; and

- MIM will improve the process of mine-optimisation by considering all processes that affect mining operation and decisions.

Although some aspects of MIM are not fully quantifiable at this initial stage (e.g. some parts of MIM information are still conceptual), the future of the model is optimistic. It may take time to develop proposed MIM facets, but this should not discourage associated research. Conceptualising MIM from BIM will face challenges and require perseverance. Yet by exposing existing gaps, this study's research provides insight into what is needed. In doing so, quantifiable encouragement has been given to the fact that even though much work is required, MIM is achievable.

It furthermore needs to be understood that working in silos is counter-productive in a 21st century collaborative environment. Most industries are taking advantage of technologies invented and used by other industries. Even the mining industry is taking advantage of other engineering disciplines such as telecommunication engineering, electrical and electronics engineering, mechanical and mechatronics engineering, etc. Clearly, the allegorical portrait of mining as a shovel is being eclipsed through extraordinary technology.

The same allegory applies to the construction industry. The fact is that prior to the development of BIM, the construction industry was plagued with multiple wastage and cost issues. BIM was conceived, but until research-analysis was able to quantify expected benefits, the concept could have been viewed as unreachable. Obviously, BIM development costs needed evaluation in relation to expected benefits. Obviously also, evaluation likely indicated that BIM development-costs vs. benefits were impractical in a one-company silo scenario. Thus today, BIM benefits many industries world-wide.

From a mining-industry perspective, some South African mines are more than one hundred years old. Their lifecycle is reaching completion and it is time for reclamation and rehabilitation. Yet a disturbing fact is that lack of adequate information on older areas of mines has inhibited reclamation and rehabilitation. If MIM had been available from project initiation stage, then responsible mine closure would have been substantially easier. Thus it stands to reason that MIM will enormously ease future mine closures through the volumes of on-line information that will be available. Furthermore, it also stands to reason that such information could extend the life of mines and enable implementation of future technologies.

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