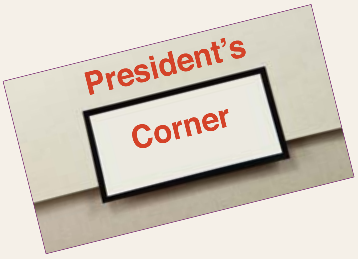

Trying to demystify Industrial Revolution 4.0.

There is much excitement in the air around 'Industrial Revolution 4.0' amongst information systems experts and data scientists, while on the other hand there is a fear of an impending tsunami of new technology which, if you don't ride on the crest of the wave, will leave a trail of destruction of conventional wisdom and systems, leaving the conventionalists behind in its wake.

Often, remarks are made about the 'inevitability' of Industrial Revolution 4.0, and the need to 'embrace it', by commentators and organizations that do not fully understand what it is, or what the real implications may be.

To create the mystique of this revolution, a new language has been developed which is baffling and incomprehensible to the uninitiated, talking about the Internet of Things, artificial intelligence, big data, cloud computing, blockchain, interoperability, and motes.

So, how do we demystify this in our world of mining, in order to ensure we are not swept aside, left behind, or abandoned as an industry populated by Luddites?

From Wikipedia, 'Industry 4.0 is a name given to the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing.'

This mouthful of cyber parlance merely indicates that Industrial Revolution 4.0 is about data, and how we use that data in improving the efficiency and cost of production, not only in manufacturing but in all sectors, including mining.

We have had data for many years. In a paper in the Association of Mine Managers from 1937 (MacNiven and Roberts: *Underground mule haulage*, Association of Mine Managers of South Africa, 1937) a study was done on measuring the productivity of underground mules, which were used as the primary source of power for what in those days passed for 'mechanized' haulage. Measurements included factors like food consumption, living conditions, temperatures, speed of walking *etc*. Less easy to quantify was the temperament of the animals. Of course, in those days, in order to analyse this data, it first had to be captured manually.

The difference between those days and today lies in the amount of data that is available, how it is collected and transmitted, and how it is analysed, as in all cases this is done automatically and remotely. This trend has progressed as the industry transitioned from the first industrial revolution (mechanization, water power, and steam power), to the second revolution (mass production, assembly line, and electricity), to the third (computers and automation), and to the fourth, based on cyber-physical systems.

Thus, the first issue to demystify is that this is not a sudden event, but rather a transition that we have been party to for quite a long time. Let us consider how this data has been collected in mining, by taking two examples. Firstly, mine survey data has typically been collected through measurement and recording, taking place whenever the surveyor is present to conduct such measurements. This data then gets translated through spreadsheets, and eventually finds its way to a reporting system, which typically reports at month end. It is then compared to other measurements which have been taken by other people (such as the shift supervisor), and because these were collated differently, these reconciliations are usually difficult. Secondly, mine ventilation data within a fire detection system is collected by a system which automatically triggers an alarm when a particular monitor underground detects smoke. What then happens depends on the reaction of a control room operator, who needs to make a decision. Often, the calibre of the person having to make the decision is such that perhaps the wrong decision is made, or the matter is elevated to a higher-level decision-maker, which causes a delay (which could be critical).

The two instances described here are completely unconnected, and one has no impact on the other. This may or may not be important, but if, for example, there is a communication system to people in the mine workings that automatically alerts them that there is smoke in the mine, evacuation could happen immediately.

Thus, a transition that is fundamentally important to understand is the interoperability of data systems, or in layman's terms how the data systems should be connected to each other.

Data monitoring has been very fertile ground for system salespeople, and has, in most cases, been blind to the interoperability issues, with the result that mines end up with a plethora of independent systems that do not talk to each other. This has resulted in the need for layers of data collation and interpretation, which allow a flow across systems and between layers, so that signals are sent to the right places for the right decisions to be made.

This gives rise to the '*Internet of Mining Things*', wherein, in a modernized mine, a complete map is required, or architecture, that defines what data needs to be collected, how it is to be collected, how it is transmitted, how it is integrated, and how it is analysed. Thus, given the level of data that can be collected, management needs to define what decisions it needs to make and at what level, and how frequently these decisions need to be made. Given that just about everything can be measured in real time, the amount of data available becomes excessive, and may become too much for it to be transmitted through to, say, a central control room, especially if it includes video data.

So, serious thought needs to be given to defining what data is required for production monitoring and control, and health and safety, and for what purpose. For a highly mechanized mine, this would be closer to real-time data on positioning, performance, and condition monitoring on machines, leading to the possibility of autonomous operations. On the other hand, for a multi-stope, conventional gold mine, the need may be for real-time health and safety monitoring, but for accurate end-of-shift reporting of mining production.

All of the above tends to put the focus of Revolution 4.0 on data and information. However, mining is a physical business, which is a complex system, and which has a clearly defined value chain. This implies that the focus for modernization of the mining industry needs to be on a balanced combination of people, processes, and technologies, and not an over-emphasis on one aspect in particular.

In terms of technologies, this includes not only focus on information technologies, but also on 'hard technologies' such as drill rigs, haulage systems, and rapid development systems, as well as improved comminution and metallurgical circuits, to deliver improved results. Indeed, various surveys of global mining companies on their view of modernization seem to indicate that these companies wish to concentrate on reduced dilution through in-pit or in-mine recovery processes, decreased environmental footprints, decreased energy costs, decreased water usage, appropriate automation, and condition monitoring for improved efficiency. These issues are all process issues, involving technologies and people, and are issues that are aimed at significant bottom line improvement for the industry.

While the issue of automation is high on the agenda of international mining operations, especially those in remote areas where labour is scarce, in the South African context it is relatively low on the agenda of conventional mining operations because of the possible socio-economic impacts as well as the complexity of the multi-stope operations. Instead, what is appropriate is the enhancement of operations, through providing solutions to operators and supervisors which make their work easier, safer, and healthier. This is where semi-remote operations, artificial intelligence, and augmented reality become the necessary focus areas, coupled with appropriate mechanization and real-time monitoring and control.

Augmented reality offers the opportunity for operators to conduct their work with immediate support for decision-making. For example, a poor ground condition that requires immediate corrective action can be dealt with immediately, through the operator having assistance from technical support *via* the augmented reality monitors that he or she can don. This then solves the problem of a long delay and production interruption while the matter is escalated to the right decision-making level.

Similarly, arduous and repetitive work can be done using artificial intelligence, applied through semi-remote operations, where the fatigue element and the need for the operator to work in an unsafe or unhealthy environment are removed. This then allows the operator to become more autonomous him/herself, by being able to think about the operation and the risks within it, and being involved in more satisfying work.

The Minerals Council states that 'Modernisation is not simply mechanisation and/or gradual implementation of new technology. It is not the replacement of people with machines. It is not a euphemism for job losses.

'It is a process of transition of the mining industry of yesteryear and today to that of tomorrow.'

The application of Industrial Revolution 4.0 to the mining value chain has some profound impacts, and is clearly a part of the modernization thrust.

First, because the value chain now becomes data-enabled, this implies that people throughout the value chain are themselves data-enabled. This has an impact on the requisite organizational structure in terms of the levels and points at which decisions are made, in real time.

Second, increased levels of modernization require more real-time control, which impacts on the point within the organization where critical decisions are made, and the skills required to make those decisions.

Third, implementation of augmented reality and artificial intelligence frees up operator time, for these operators to conduct higher skill work. This will require the definition of the skills required for these people.

The impacts of Industrial Revolution 4.0 upon people cannot be over-emphasised. This is in terms of the technologies which they will be required to work with and operate, and the requisite skills to operate in this environment. This applies equally to operators, supervisors, and management, and infers that skills, syllabi, and learning materials need to be changed for this new environment as it unfolds. It also implies that strong support in terms of engineering and data science is required.

Since so much emphasis has to be placed on people during the transition to Industrial Revolution 4.0, it is very clear that the people affected must be involved in the process of transition. This involvement needs to include both organized labour and the immediate communities. The importance of these dialogues lies in understanding what the concerns and expectations of these constituencies are, and how they can be accommodated in the transition. Clearly, in terms of tracking of people, for example, there are sensitivities that organized labour has concerns about, whereas tracking in terms of knowing where people are in an emergency and being able to communicate with them is of importance to all stakeholders. Other concerns relating to invasion of privacy and health monitoring data also needs to be addressed to the satisfaction of all parties.

Frequently, statements are made implying that Industrial Revolution 4.0 and automation will not lead to job losses. However, from a labour or community point of view, these statements need to be proven through joint, collaborative investigation and impact assessment.

The transition to Industrial Revolution 4.0 and modernization of our industry is therefore not something to be afraid of. Instead, it should be embraced as a means to keep our mines open, and to open new ones. This transition must be holistic and must involve all stakeholders.

The Institute is holding an increasing number of events around these issues, as exemplified by the New Technology in Mining conference in June. This will be followed by various other events to tackle specific issues. It is perhaps indicative of the focus on technology rather than people that the vast majority of abstracts for the conference received thus far are based on specific technology developments. Thus it is important that the people-centric approach advocated above becomes an equal, if not greater component of these discussions, dialogues, and debates.

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