Application challenges for information and automation technologies in an underground mine in Brazil

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Abstract

Organizations can establish a value-added sustainable strategy by increasing asset utilization. WLAN infrastructure in underground mines tends to be a consistent platform for reliability in data/information management, and assertive governance practices. It enables remote monitoring, registering and data transfer from a control room, avoiding unnecessary human exposure in risk zones while adding agility to operation and maintenance related processes. A series of challenges must be considered so that onboard electronic systems combined with information technology infrastructure can become part of the operational strategy. Leaders must effectively manage to adapt organizations to new standards. This study aims to discuss the challenges related to implement information and automation technologies in an underground mine in Brazil. Data collected in a base metals underground mine is the basis for utilization, reliability and productivity analysis of computerized drilling equipment operating under severe conditions. The study concludes that searching for state-of-the-art operational practices demands a cultural change in organizations, followed by a redefinition of peoples' roles and processes, so technology can provide full integration and be used as a management platform for decision-making.

Keywords: underground mining; underground drilling; underground infrastructure; information technology; mine automation.

1. Introduction

The technological evolution of equipment and systems used in underground mining is a positive contribution to operational management. Efficiency, safety, and reliability are fundamental aspects that can be added through utilization of automated equipment integrated with information technology for mine management (KOPPE, 2007; SACHS, 2009). Higher efficiency in mining corresponds to higher sustainability (SECCATORE *et al*., 2014).

Flexibility of the system used to adapt to different applications, suppliers, and scenarios supports the management of internal and external risks and uncertainties in the project (MAYER & KASAKIDIS, 2007). According to Freitas *et al*. (2014), mine planning and scheduling software with inputs from conventional optimization algorithms or conditionally simulated models may be used as risk resilient mining strategies in relation to ore grade uncertainty.

Organizations can establish a value-added sustainable strategy by increasing asset utilization (TOO, 2010). Communication through the WLAN internet instead of paper reports may represent a significant gain in agility and reliability in operational data transfer. In Brazil, the use of automated equipment in underground mining is still limited to a few mines. Usually, the information technology infrastructure available restricts the capacity to efficiently manage the equipment's performance indicators.

The human factor is critical when it comes to technology transition in mining operations (SECCATORE *et al*., 2014). Qualified labor results in improvements in mining operations, safety conditions, and the work environment (KOPPE, 2007). According to Levy (2010), technology can change the nature of work faster than people can change their skills.

In this scenario, this paper aims to discuss the challenges related to implementing automation and information technology in an integrated manner for operational data management in Brazilian underground mines. Operational data have been collected from a base metals underground mine with the objective of analyzing utilization, reliability and productivity of computerized drilling jumbos.

2. State-of-the-art

As a reference case of state-of-the-art integration of operational data in underground mines, it is possible to cite a chromite mine located in Finland, where the management strategy adopted by the mining company is oriented to the highest level of automation available in the market.

The mining method is the overhand *Sublevel Bench Cut and Fill*. This method is effective in preventing subsidence events and provides good ore recovery. The capital equipment fleet operates with a high level of onboard technology. Computerized systems provide many levels of automation and data handling to all stakeholders involved in the mine management. In this context, computerized machinery for all operations such as face drilling, production drilling, mechanized rock reinforcement, remote controlled LHD's *(Load Haul and Dump)*, and automated core drilling rigs, combined with remote monitoring systems, are part of operational reality.

The infrastructure is WLAN based for high capacity and agility data transfer and online access, integrated to rig's onboard computer systems. The ERP *(Enterprise Resource Planning)* system used as the management platform *KaTTi* is the central part of the integrated net and involves several systems for planning, production, maintenance, smelting, 3D mine viewing, geology, and general management.

This system was built based on the market's cutting-edge standards, such as *Visual Basic* and *Oracle* databases. Moreover, it can operate in a Windows environment and generate Excel format analytical reports and documentation for governance practices, allowing editions and updates to follow needs that may appear and adding flexibility to the mine management.

3. Application study at an underground mine in brazil

The tests with the electronic drilling jumbo have taken place in a base metals mine with open pit and underground operations. The underground mine has a complex structure of shafts, ramps, production drifts, and stopes. The mining method adopted is *Vertical Retreat Mining*, which according to Germani (2002) offers advantages related to subsidence control and higher mineable resources recovery. Maximizing recovery of reserves represents a great opportunity for the mining industry in terms of improving the sustainability of operations (GOMES *et al*., 2014).

Due to the need to ramp up mine development, a study of the utilization of computerized drilling jumbos has been proposed. This work presents the results of tests done in the mine with this type of equipment together with software for data management. The objective is to discuss aspects related to utilization, reliability and productivity of computerized systems under severe operational conditions.

Five electrical hydraulic drilling jumbos (Rig#1 to #5) and one computerized rig (Rig#6) have been utilized. A Summary of technical features is presented in Table 1:

	RIG#1	RIG#2	RIG#3	RIG#4	RIG#5	RIG#6
Control System	Electric-Hydraulic	Electric-Hydraulic	Electric-Hydraulic	Electric-Hydraulic	Electric-Hydraulic	Computerized
Number of Rock Drills	2	2	2	2	2	2
Nominal Rock Drill Power (kW)	20	20	20	20	20	18
Hole Length (m)	3.70	3.70	3.70	3.70	3.70	5.20

Table 1
Technical information of drilling jumbos.

The onboard electronic system in Rig#6 controls the entire drilling process, registers operational data and simplifies operation. Software *Underground Manager* (Figure 1) offers the possibility to create drill plans and further analysis of each drilling round by using a *pen drive* for data transfer.

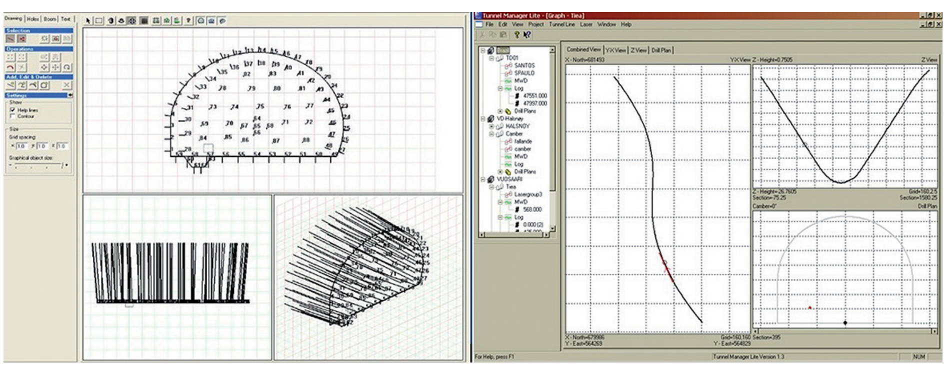

Figure 1
Underground Manager,
software user interface.
(Source: Adapted from Atlas Copco Rock Drills AB – Underground Rock Excavation Division, 2012).

Operational data from drilling jumbo fleet used in mine development were collected during 10 weeks, between 28 September 2011 and 30 November 2011. During the test period, according to the operational procedure, information was transferred from operators and maintenance technicians, through individual radio devices, to production planners located in a control room at the central office.

Workers are responsible for managing the dispatch and keeping the planning software updated. Results shown in this study have been collected from the planning software used in the mine in spreadsheets format.

4. Analysis

Laurindo *et al.,* (2001) states that organizational impact from IT implementation must be evaluated with focus on organizational targets, effectiveness and business-oriented strategic alignment.

Effective integration of the mineral value chain, based on automation and information systems, depends on proper definition of *key performance indicators* (KPI's) and systematic measuring of related variations throughout the entire process (NADER *et al*., 2012).

Approaches such as Mine Productivity Estimation and Management Methodology (MPEMM) to increase production efficiency by the identification and removal of losses in the mine production have been implemented and have achieved production improvement in practical applications by managing the discrepancies in the KPIs (BRANDÃO; DE TOMI, 2009).

In this specific study, KPI's were defined to evaluate drilling jumbos in operation in the underground mine. According to Pinto & Xavier (2001), *Availability* can be described as the ratio of possible working hours to calendar hours (Equation 1). It is an important indication for reliability analysis.

$$\textbf{Availability} = \frac{\text{Possible working hours}}{\text{calendar hours}} \tag{1}$$

According to Veloso (2009), another KPI for asset management is *Utilization*, which can be defined as the ratio of worked hours to possible working hours (Equation 2).

$$\textbf{Utilization} = \frac{\text{Worked hours}}{\text{Possible working hours}} \tag{2}$$

Working hours, in this paper are based on the operational characteristics of the jumbos' total time for tramming, boom and feed positioning and effective drilling. Results related to both indicators described above are shown below in Figure 2:

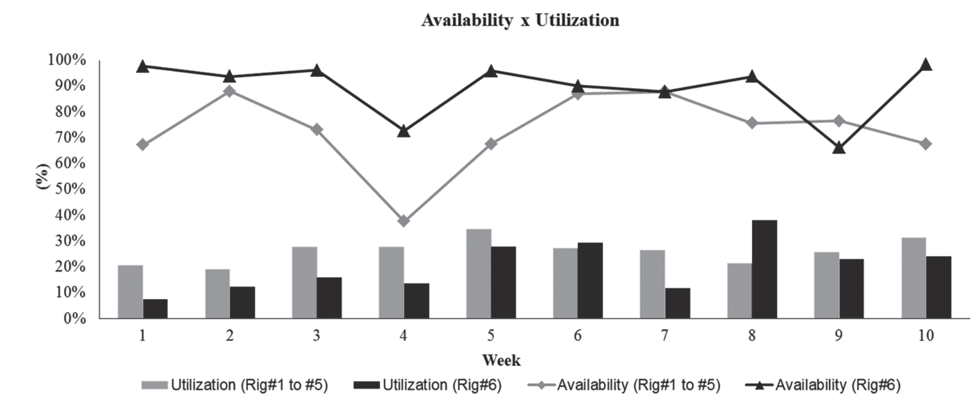

Figure 2
Comparison of availability and utilization between the electrical hydraulic jumbo fleet (Rig#1 to Rig#5) and the computerized one (Rig#6) from 28 September 2011 to 30 November 2011.

Up to week 4, there was observed a lack of proper electrical panels to meet the power supply requirements of the computerized jumbo (Rig#6) in several headings to be drilled. Operators were afraid of using the new onboard technology available in the electronic rig. Both factors contributed to low utilization during this period. By the end of the tests, high acceptance and even preference for the high technology rig was observed. Failures related to the cabin air conditioning system and to a hydraulic cylinder of the Rig#6 jumbo's jacks had a negative impact on availability during Week 4. Both are not related to the computerized system.

Another relevant performance indicator for a reliability analysis is the so called *Mean Time to Repair* (MTTR), which according to Pinto and Xavier (2001), represents the maintenance team's ability to execute the repair itself. It can be expressed as the time spent executing the maintenance (in hours) divided by the number of repairs done during the period (Equation 3).

$$\textbf{Mean Time to Repair} = \frac{\text{Hours of repair}}{\text{Number of stops for repairs}} \tag{3}$$

According to Veloso (2009), Mean Time between Failures (MTBF) measures the reliability and shows the frequency of failures during a certain period. It is calculated using the hours worked divided by the amount of failures in the period (Equation 4).

$$\textbf{Mean Time between Failures} = \frac{\text{Worked Hours}}{\text{Number of failures}} \tag{4}$$

Figure 3 shows the results for the analysis of MTBF, MTTR and number of failures for each drilling jumbo during the test period.

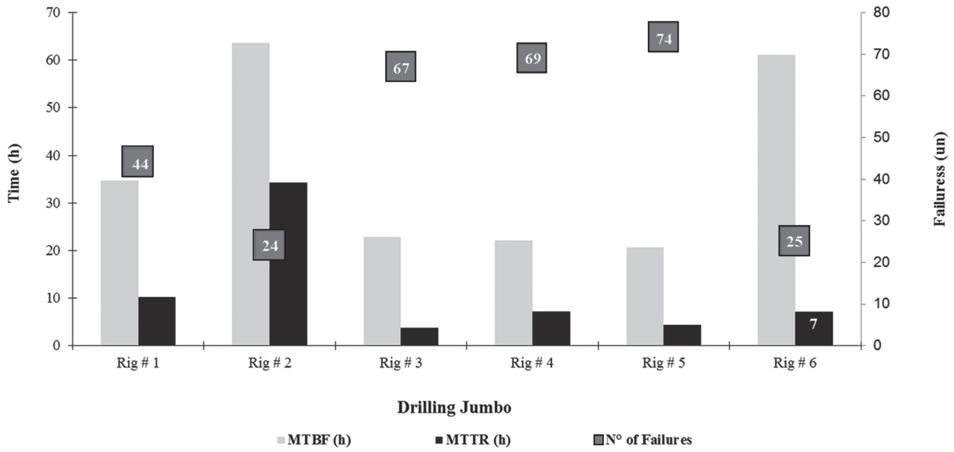

Figure 3
Comparison of MTBF, MTTR and Number of Failures between the electrical hydraulic jumbo fleet (Rig#1 to Rig#5) and the computerized one (Rig#6) from 28 September 2011 to 30 November 2011.

It is possible to understand that the computerized rig performed at a high level of reliability compared with other drilling jumbos. Even working under severe conditions of humidity and temperature, the onboard computerized system of Rig#6 did not experience any failure during the entire test period.

Regarding productivity analysis, *Nominal Drilling Speed* was chosen as KPI. It stands for the ratio of total drilled meters per drill rig in a certain period to total drilling time (worked hours). This indicator is directly related to drill plan design considerations, such as the hole's length and amount of holes. It is also related to utilization, rock drill nominal capacity, maintenance procedures and drilling tools condition.

$$\textbf{Nominal Drilling Speed} = \frac{\text{Total Drilled Meters}}{\text{Total Drilling Time (Hours worked)}} \tag{5}$$

In order to evaluate drilling productivity, Table 2 below shows drilled meters, drilling time and the nominal drilling speed for each drilling jumbo.

	Drilled Meters (m)	Drilling Time (h)	Nominal Drilling Speed (m/h)
Rig # 1	5,816	183	31.72
Rig # 2	4,786	107	44.73
Rig # 3	15,667	334	46.87
Rig # 4	14,415	305	47.31
Rig # 5	14,493	310	46.78
Rig # 6	14,376	245	58.66
OVERALL	69,553	1,484	46.86

Table 2
Productivity data collected for each drilling jumbo.

Computerized drilling jumbo (Rig#6) showed the highest productivity of all drilling jumbos in operation. Some difficulties were observed in obtaining the right parameters from the topography department to navigate the computerized drilling jumbo (Rig#6) properly inside the drifts and utilize its full capacity in terms of drill plan management, precision and productivity in a systematic manner.

Operational information was transferred from operators and technicians through individual radio communication devices. This represents susceptibility to deviations on data communication and further analysis.

5. Conclusions

This study showed that information and automation technologies represent an opportunity for the integration of people and processes in an underground mine. Paper reports can be replaced by automatic registering and processing, making compiled information available with more agility and reliability.

It offers a higher level of control over asset utilization in order to evidence opportunities for improvement. This allows more assertive governance practices and leads to a more transparent management of all stakeholders' interests in any mining project. Some points can be highlighted as key conclusions from the study:

• Onboard electronic systems are reliable, even operating under severe conditions of humidity and temperature. Data transfer reliability could be higher if WLAN communication infrastructure were available in the mine;

• Effective information management depends not only on technology available but also on established operational processes. It represents an opportunity for higher standards in governance and physical asset management.

• Training is a key factor to integrate information systems into planning, topography, operation and maintenance related processes. Natural resistance to changes demands a consistent and clear approach from managers and suppliers from the conceptual stage of the project to assure a value added operation.

• A longer period of tests and consequently a larger amount of data, combined with a more detailed variability analysis, should provide more consistent conclusions.

Therefore, the search for the state-of-the-art in automation and information technology management demands a cultural change in organizations, followed by a redesign of processes and people's roles, to allow technology to provide full integration and be used as a management platform in decision-making processes.

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