

The contextualization of lean manufacturing in the mining sector: foreseeable challenges to occupational health and safety

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Application of the principles of lean manufacturing in the context of mining raises challenges for occupational health and safety (OHS). Based on a review of the literature from 1996 to 2014, we characterize the motivations of mining companies for adopting the lean approach and identify the principal strategies and tools adopted as well as the documented facilitators, barriers and critical factors. The literature remains divided on the impact of lean on worker health and safety and reveals several scientific challenges. The implementation of lean mining is thus a delicate operation and major issues with regard to OHS prevention are foreseeable

Practitioner Summary: Recent applications of lean mining focus on the economic aspects of sustainable development. Occupational health and safety aspects, though considered relevant, remain to be included in lean mining. The scientific community needs to address this issue and provide clear recommendations to practitioners.

Keywords: lean, mining, lean mining, occupational health and safety.

1. Introduction

Organizational and generational changes, continued expansion of production and global economic pressures are pushing mining companies to dig down to ever greater depths to extract ore, sometimes as deep as 3,000 meters below the surface (Wood 2012). As a result, North American mining operations have become increasingly automated, since about 2010. The adoption of automation has been nevertheless slower and less widespread here than on other continents. According to many Canadian miners, human intervention will remain a necessity. Canadian mines thus face enormous challenges as well as huge opportunities to be addressed with urgency.

The Canadian public as well as governments both federal and provincial wish to see, among other things, increased job security and creation, in particular of value-adding jobs. They also wish to encourage businesses devoted to diligence and continued improvement in occupational health and safety. This means respecting the principles proposed by the International Council on Mining and Metals (2003) and designing sustainable mining operations, meaning operations in which value-added production is sustainable. It therefore makes perfect sense to envision the contextualizing of, among other things, the principles of lean manufacturing in the mining sector, which we shall call lean mining.

The goal of this study was to examine the existing literature pertaining to lean mining and to discuss the foreseeable occupational health and safety challenges implicit in this scenario.

2. Methodology

The literature search, covering the period 1996 to 2014, was carried out using several databases (Compendex, Inspec, Scopus, CRCnetBASE, IEEEExplore, Knovel, Proquest dissertations and theses, Worldcat, Springer online, Google scholar, Web of Science) and websites selected on the basis of their credibility in the scientific community and for the quality of the documents they contain (IRSST, NIOSH, Agence Européenne pour la Santé et la Sécurité du Travail, CSST, The South African Department of Labour, Kommission Arbeitsschutz und Normung (Germany), Inspection du travail et des mines (France), Australian Safety and Compensation Council, Ontario Ministry of Labour, Health and Occupational Safety, Ministère de la santé et des services sociaux and Ministère du travail (Québec), Health Canada.)

To start with, two articles were found using groups of several keywords in French, English and German: *implementation du lean dans le secteur minier*, *lean dans le secteur minier*, Toyota production system applied to the mining industry, human oriented lean mining, mining health and safety, mine health and safety management, transfer of mining technology, just-in-time in mining environment, *lean im bergsektor*. Fifteen

articles were then found using only keywords in English and French: leaner operation, lean (stockpiles, wastage, rework), lean (mining, mineral), JAT, purify, Honda system, human factors, safety, health, ergonomic, injury, increase, increasing, lean, mining, improve, improving, procedure, lean management, *épurer, santé et sécurité dans les mines*. By the snowball effect, the literature review was completed.

3. Results

As Hasle (2014) stated so aptly regarding occupational health and safety in lean practices, “The most remarkable fact about research outside the manufacturing sector is the non-existence of studies”, which includes the mining sector. A few businesses have nevertheless documented to some extent their experience with implementation of the lean approach, such as Vale (Steinberg and De Tomi 2010), Rio Tinto Aluminum (Dunstan et al. 2006), Boliden (Bäckblom et al. 2010). Table 1 summarizes the results of this survey of the available writings.

3.1 Motivations for adopting lean mining

The goal of adopting lean in the mining sector is to eliminate activities that do not add value (waiting, repair or rework, motion, over-processing, inventory, transportation (Dunstan et al. 2006)), and thereby reduce costs (Wijaya et al. 2009, Sanda et al. 2011, Sanda 2012, Liu 2013) or extract ore faster (Wei-Jian and Qian 2010).

3.2 Strategies and tools adopted

Mining companies adopt lean tools and technologies with the intention of:

- Increasing the reliability of mining equipment through redesign, improved standardization of work procedures (kaizen activities, brainstorming and employee suggestions) and maintenance (for example, single-minute exchange of dies or SMED techniques, value-stream mapping, 5 S and visual factory, total productive maintenance (TPM)) (Dunstan et al. 2006, Pal and Maiti 2006, Klippel et al. 2008, Bäckblom et al. 2010, Sanda et al. 2011, Sanda 2012);
- Continuous extraction, even for hard-rock deposits, by developing mining equipment capable of breaking rock (shearing techniques) and loading it over long distances using articulated conveyor belts that launch ore into vessels or trucks while securing the extraction zone to advance further into the deposit (Bäckblom et al. 2010, Steinberg et De Tomi 2010; Sanda et al. 2011);
- Optimizing the logistics chain using Six Sigma, Lean Six Sigma or postponement of differentiation (Dunstan et al. 2006, Steinberg and De Tomi 2010).

3.3 Facilitators

Sanda et al. (2011) showed that tacit knowledge about rock and its behavior transferred through experience and exchanges between miners is a source of resilience in the face of problems and could be a facilitator of the development of lean culture. The experience of Rio Tinto Aluminum has shown that gradual implementation of lean facilitates the achievement of desired results (Dunstan et al. 2006).

3.4 Barriers

Uncertainty and numerous sources of significant variability characterize the mining sector (Wijaya et al. 2009, Bäckblom et al. 2010, Steinberg and De Tomi 2010, Helman 2012), complicating the implementation of lean, although certainly not making it impossible, and some researchers have made recommendations in this regard (Yingling et al. 2000, Helman 2012).

3.5 Critical factors for success

In the case of Rio Tinto Aluminum, the role of mentor as played by the managers, their effectiveness in reducing the obstacles to change, and the fullness of their commitment to the implementation of lean culture have been criticized (Dunstan et al. 2006).

Table 1. Synthesis of the results of our review of writings on lean mining.

Motivations	Cost reduction Faster ore extraction
Priorities	Elimination of non-value-adding activities
Flagship corporations	Vale, Brazilian corporations, Rio Tinto Aluminum
Adopted strategies	Increasing equipment reliability Continuous extraction Optimizing the logistics chain
Tools adopted	Design/redesign of mining equipment Improvement and standardization of work and maintenance procedures (kaizen activities, brainstorming and employee suggestions), SMED, value-stream mapping, 5S and visual factory, total productive maintenance (TPM) Six sigma or Lean Six Sigma, Postponement of differentiation DuPont Safety Program
Facilitators	Tacit knowledge of miners Gradual implementation
Barriers to adoption	Uncertainty and variability
Critical factors for success	Role of managers

4. Discussion

Although occupational health and safety prevention is one of the 10 sustainable development principles of the Council on Mining and Metals (2003), clearly, in the recent applications of lean mining the focus is on economic considerations.

Nevertheless, recent studies of the impact of so-called lean management systems on occupational health and safety reveal many positive effects (increased worker participation and control over their work, emphasis on quality and hence better training of workers, broadening and enriching of tasks, increased autonomous teamwork, more egalitarian system). But negative impacts (increased workload, musculoskeletal lesions, stress and fatigue, reduced autonomy, work intensification, closer supervision, frequent overtime on short notice) (Westgaard and Winkel 2011, Saurin and Ferreira 2009) have also been documented. These contradictions are associated as much with differences in organizational culture, maturity of the implementation process, production philosophy and socioeconomic context as with the business and the level of participation of the workers (Saurin and Ferreira 2009, Koukoulaki 2014). Westgaard and Winkel (2011) as well as Hasle (2014) maintain that workgroup autonomy and social support as well as worker participation have protective effects on occupational health and safety. Koukoulaki (2014) notes that eliminating wastage and non-value-adding activities appears strongly associated with increased stress and musculoskeletal lesions apparently because of work intensification.

The literature proposes a very broad definition of lean management in action (Hasle 2014), at times vague and confusing (Taylor et al. 2013) and shedding little light on the tools being introduced, on how these tools are articulated or on their level of maturity, leading to considerable difficulties with scientific interpretation and making generalizing of conclusions practically impossible. « ...each study has looked at rather unique systems with little resemblance among them, so it is not possible to correlate specific lean elements with employee outcomes » (Hasle 2014).

Based on the “just-in-time” philosophy, lean management is in theory guided by two principles, namely elimination of wastage and respect for the individual. It should not lead to negative effects on occupational health and safety. Positive effects should be obtained while negative effects should be minimal and resolved without major difficulty (Hasle 2014).

In practice, researchers note that businesses often have chosen a few lean management tools from among a hundred or so and then applied them in isolation without cohesion between them and without really understanding the concepts underlying them (Longoni et al. 2013, Tortorella and Fogliatto 2014). The sociocultural factors involved in changing the organization of work are ignored, leading to poorly integrated, non-holistic and ultimately not sustainable lean practices (Yang and Yang 2013, Tortorella and Fogliatto 2014). The literature currently contains few in-depth case studies of real implementation of lean management (Taylor et al. 2013).

5. Conclusion

The adaptation of the lean management philosophy to the context of mining is just beginning. Although it promises gains in productivity, the implementation of lean management in this sector is complicated, given the uncertainties and variability characterizing mining activity. Tacit knowledge of miners, gradual implementation and unwavering commitment of managers will provide the foundation of success.

With respect to occupational health and safety, only the literature on lean management in the broadest sense or on lean manufacturing appears to shed any light. The results of the available studies are inconsistent, the scientific challenges are huge, and evaluative research on the results of implementation efforts is scant. For the time being, the implementation of the lean approach to mining remains a delicate operation.

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