Operational excellence is generally known as a management system integrated across critical functions that is geared towards continually improving operational performance. Functional areas such as health, environment and safety, quality and human resources are the focus of many corporate-wide operational excellence programs. Operational excellence also focuses on improving areas such as customer orientation, employee empowerment as well as process, and systems optimization. It is widely viewed as critical to sustaining business performance improvement.

Although it is difficult to find a universally accepted definition, or even common foundation in many respects, operational excellence remains a popular term in the business world. Many organizations have developed their own version of organization excellence, influenced by such individual factors, other similar institutions or even third-party service providers.

A mining organization is no different from other organizations in that adopting and implementing effective operational excellence programs can dramatically improve business execution and performance across regional or global interests. This paper brings together various perspectives of operational excellence and reconciles them for a useful composite for the mining industry.

While most agree that operational excellence should include normal functions in a manufacturing operation such as production, maintenance and engineering and processes such as quality, environmental and continuous improvement, many other factors for operational excellence seem to vary from perspective to perspective. Thus, programs that manufacturers engage in may seem the same, but may, in fact, be different in key areas. This may affect organizational performance in tangible ways. Management must buy into the company’s definition of operational excellence and be dedicated to achieving it. A review of many of the existing definitions of operational excellence, explicit or embedded as part of a program, seems to yield the following common factors:

- It should help organizations better execute their processes and services.
- It should be geared towards improving quality.
- It requires that the various operations should be aligned with the overall enterprise strategy.
- It should be geared towards continuous improvement.

A composite of operational excellence definitions suggest that it is:

- Geared towards helping the organization achieve sustained profitability;
- tied to strategic alignment and business objectives;
- tied to solid investment strategies;
- integrated as part of the culture, process, time plan and performance;
- a relevant performance measurement system;
- extended to include all aspects of the supply chain (including external suppliers);
- integrated with health, safety and environmental (HSE) aspects.

And, while the pursuit of operational excellence intuitively suggests that businesses should improve, it is very difficult to achieve given the difficult challenges facing companies today. Mining businesses face numerous pressures to perform in a global marketplace such as demand, energy cost, variable cost and pricing fluctuations as well as infrastructure challenges to further confound the environment. Companies generally must look to the following:
• Improving profitability.
• Maximizing existing and acquired assets.
• Optimizing value chain.
• Driving more efficiency from labor, transportation and other parts of the infrastructure.
• Becoming more agile to take advantage of opportunities.
• Expanding operations globally, extending best practices to new operations.
• Controlling costs and profitability with different pressures and price fluctuations.
• Managing environmental factors for different mine properties in different parts of the world.

Increasing regulatory requirements can further burden systems and processes. However, a company must be responsive in order to stay in business, requiring that its functions make further adjustments and drive more inefficiency out of the systems and processes in order to continue the drive towards operational excellence (Taylor, 2006). Safety and environmental responsiveness are not just seen as requirements to the regulatory environment but rather as a part of the fabric of the company and being responsible to societal and business stakeholders.

With all of these challenges, it is critical that mining operations improve across the entire enterprise in a way that drives business value. Therefore, mining companies must strive to be excellent beyond just financial dimensions. These companies must be excellent along other dimensions such as innovation, social responsibility and employee responsiveness as well as being able to respond effectively to a changing environment as a business operation (Chakravarthy, 1986). As mining companies continue to expand and change through organic growth or through mergers and acquisitions in places that they have never done so before, it is more critical than ever that mining organizations strive for operational excellence to be able to develop sustainable operations with reasonable standardization.

**A model for operational excellence**

The model presented in Fig. 1 is a composite of many existing definitions of operational excellence currently available. While this is a general model, it can be applied to the mining industry.

Operational excellence programs should include many interrelated and interacting components such as quality (Q), continuous improvement (CI), knowledge management (KM), human resource development (People), HSE compliance and management, and performance measurement within an aligned business. Processes, procedures, knowledge and other aspects of mining operations as part of a larger operational excellence program should be shared as best practices across the enterprise (i.e. across mines, mineral processing, freight, etc.) on a vertical or horizontal basis.

**Continuous improvement**

Continuous improvement can be generally described as a set of activities designed to bring gradual, but continual improvement to a mining process through constant review. These activities typically consist of waste elimination, cost reductions and other efficiencies (Blanchard, 2009). Continuous improvement enables mining companies to embed the principles of sustainability into their business. As mining companies look to improve their operations in the face of increasing global pressure and competition, continuous improvement programs have been undertaken by companies in an effort to remain competitive and improve their position.

To ensure that continuous improvement projects and initiatives are adding value to the company, a real-time performance measurement system must be coupled with continuous improvement programs. Real-time business intelligence can also be applied to greenfield projects to provide all layers of the business with an unprecedented view into the business performance in the mineral processing operation. With this business intelligence, people can make better decisions to improve performance by at least 3 to 5 percent. This enables operations to earn project payback in a shorter timeframe. A proper real-time performance measurement system that provides business intelligence is critical to showing the value of projects to the company, recovering investment as soon as possible and ensuring the strategic nature of initiatives and projects in a timeframe, resolution and reach that makes sense. It brings together the proper elements of finance, strategy and operations to effectively measure performance, to provide timely feedback to the right people and to enable performance improvement.

The mining industry is continually facing tough economic pressure (low market prices and high costs). To compete successfully, a mining company must use its assets in the best possible way. It must also have the best people and processes. Frequently, companies have turned to continuous improvement programs, formal or informal, that drive activities to solve problems that were not aligned with the original direction and were not clearly measurable in terms of benefit to the business performance. Through the careful use of real-time performance measures to support continuous improvement processes, additional productivity will be realized and sustained.

As global competition increases, manufacturing has become more strategic. Assets are becoming tools in broad global corporate strategies that need faster and better information to maximize profits beyond the pre-
Operational excellence involves all phases of mining.

vicious standard of cost reduction. Competition has come from developing areas of the world that had been off the radar of many companies. To remain competitive, companies must get the maximum out of their existing asset base. Continuous economic optimization and improvement remains critical.

In the past, the results of continuous process improvement efforts were measured in productivity terms, such as tons per day, and not in financial terms, such as revenue per ton or other pertinent metrics. Even if these were measured in financial terms, they were based on budgeted amounts that gave misleading direction when used in real-time. It is easy to see that these continuous improvement processes helped, but they can be improved. For example, in the mining industry, as assets are stretched to keep up with demand while minimizing capital expenditures, measures that provide information on incremental revenues per ton become more important because nearly each dollar in sales less the variable cost of production falls to the bottom line.

At the operator level, real-time performance measurement information presented in a meaningful and actionable way is critical to driving business performance as the front-line decisions typically have high value, especially in variable cost containment. At the plant management and executive management levels, performance measures that have a financial component become more important, especially if they are in real-time or so-called right-time. They provide management with the opportunity to respond to financial issues before being blindsided by a problem that only reveals itself after the financial reports are out.

Opportunities for continuous improvement in mining and mineral processing are vast and well-documented and involve the balancing of the value produced by control of availability and use of the plant assets. These include but are not limited to:

- Fleet management.
- Ore quality management.
- Crusher control.
- Mill load control.
- Labor management.
- Mineral processing.
- Energy management.
- Operator training.

Health, safety and environment

Many mining companies have global interests that vary in terms of environmental regulation and challenges. Opportunities for improvement in health, safety and environment as part of operational excellence in mining and mineral processing are vast and well-documented. They include:

- Air emissions management.
- Tailings management.
- Mine air management.
- Water management.
- Mine safety review.
- Supplier management.

These, and many other factors, are critical to a mining company’s ability to thrive in terms of short-term profitability and longer term sustainability of a viable and reputable business with society’s well-being in focus.

HSE factors vary from region to region in terms of regulation, impact on society and on firm profitability. Air emissions from smelting and roasting processes can have a significant impact on the environment and yet their regulation is very strict in developed nations and can be nonexistent or not enforced in less developed countries. There is, however, evidence that responsible manufacturers are getting ahead of the environmental regulation curve and are improving their emissions control ahead of regulatory changes.

Many mining operations are improving smelting control to lessen mineral content in the tailings. This has a dual impact on the business. First, less of the mineral product is wasted, in effect making better use of raw material inputs. Secondly, fewer minerals are deposited in the soil, which lessens the impact on the local environment.

Areas in lesser-developed parts of the world are undergoing substantial exploration and development with many new operations getting their start from junior and major mining companies. Standardization of best practices and processes is a critical part of the operational excellence foundation. Many companies have differing regulatory policies, depending on constraints of local government policies. When possible, operations strive towards uniform framework or systems of HSE across the operations, adopting or converging on the more aggressive approach.

Proactive mining operations are involved with local regulatory and academic constituencies to help monitor, form and train societal interests in HSE affairs. Some research even suggests that those companies proactively involved in improving their respective position in environmental affairs experience “superior economic returns,” (Thomas, 2001). Some mining companies have invested in local educational institutes and have invested in housing interests to benefit the local environment. Such activities by mining outfits are helping to improve society and their impact on the environment. Incorporating these and other practice across the operations helps miners strive towards operational excellence and sustainability efforts for long-term societal benefit.

Quality

Another important part of our definition of operational excellence involves the impact of quality
throughout the operations. The impact of quality on the business operation is widespread and can have a major impact on performance along many business related dimensions. Quality has impact throughout the operation including:

- Raw material quality.
- Utility quality.
- Final product quality.
- Ore quality.

Opportunities for quality improvement in mining and mineral processing are vast and well-documented, including:

- Ore quality management.
- Concentration water content.
- Mine air-quality.
- Final product quality.

Quality management is integral to operational excellence and must be tied to company profitability. Quality is connected to people, continuous improvement, performance measurement, human resource development and knowledge management. Mining operations are cognizant of this, integrating quality into ore management, intermediate product and final product analysis as well as various products.

Requirements for quality systems differ depending on the application. For example, quality requirements for grade-control programs will be different than greenfield exploration projects. Typically, laboratory information management systems (LIMS) play critical roles in measuring, analyzing and managing quality information and often is integrated with other systems such as mine modeling systems and production planning systems.

People
Clearly, employee involvement and empowerment in operational excellence programs are critical to success measured on many dimensions including organizational performance. Mining companies look to improve such functions as waste management and energy management through continuous programs with measurable economic goals and benefits. Success in these types of programs and activities requires a high level of employee participation.

The mining industry is battling a significant problem in the “graying effect” and on the decline of professionals and students in mining industry education programs. This has stressed the workforce in terms of mining experience and knowledge needed for efficient operations across multiple dimensions. Given the current economic climate, fewer people are generally engaging in mining-related educational programs. As a result, fewer new people are being introduced to the industry while senior mining employees are starting to retire. With the scarcity of mining talent and remoteness of many mining operations, organizations must now look for other ways to rally experienced people to deal with a multitude of issues.

With a strategic operational excellence program in place, a highly collaborative environment can be enabled by application integration (dissimilar operating systems) and incorporating visual content from multiple sources. This will allow people to work in a physically separated environment and allow plant interaction and optimization on a virtual basis. Figure 2 presents a conceptual schematic of a technology solution needed to bring together different mineral processing operations together. In this conception, grinding operations across the enterprise can be analyzed and improved in a central location by experts.

Managing change
Making changes in the way an operation is run in any of the operational excellence dimensions will likely have a resulting impact on people within the organization. Human resource management is one of the most important strategic areas in mining operations today. The human resource function is on the front line of helping employees deal with changes in the organization and is integral to communicating and maintaining the culture.

Organizational excellence changes can occur along any of previously discussed dimensions and the effects of the changes to the people in the organization can vary widely. Generally, the following should be undertaken in change management activities:

- Define what needs to change and the role of change agents.
- Evaluate climate for change and develop a plan.
- Find and cultivate a sponsor.
- Communicate change and prepare the path for change.
- Integrate the change in to the culture and solidify change leadership.
- Attain small wins and continually communicate.
- Measure change progress and integrate lessons learned (Mento).

Change management is critical to the successful improvements in mining operations as it relates to key dimensions of the organizational environment: people, process and technology. Change can manifest itself in larger reorientations to smaller incremental changes, requiring adaptive change management techniques and effort to effectively manage change with different magnitudes. Irrespective of change magnitude, communication is a critical success factor that must be supported and facilitated by management (Woodward, 2007).
Empowering employees

Employee empowerment is critical to making improvements in any dimension of operational excellence. In fact, empowered employees are critical to success of any business and changes in a business, especially in mining operations where operations are in diverse and remote locations.

Human resource analysis within the above context should also take place. As a company strives to improve its competitive position, the employee is being looked at as an asset that can be used to provide and drive more value through the plant. A company that is looking to improve and optimize performance should provide its workers with better information and more authority. Employees who know what their metrics are will be more apt to perform to them and will work as an integral part of the operational team.

As mining operations look to get more from their people resources, they must also institute performance management programs to improve the context and control of goal setting and improvement activities in the operation to improve performance against goals. Communication of goals and improvement mechanisms to attain goals is continuous and considered a requirement for these types of programs.

Knowledge management

Effective knowledge management is critical to the sharing and creation of innovation and knowledge within mining companies and is critical in developing new products, approaches, process improvements and other factors for attaining and maintaining a firm’s competitive advantage (Halit, 2005). Two main themes come to light in understanding knowledge management: dispersion or circulation of existing knowledge with a technology focus and management and creation of knowledge in terms of processes, social aspects, environment and its requirement for innovation.

The current manifestation of knowledge management in industry is really associated with knowledge sharing where existing systems are used to make old or existing learning/knowledge available and reusable for current workers to improve performance (McElroy, 2008).

While the creation of knowledge is essential to long-term performance improvement, it must be validated and tested within innovation, marketing, engineering or other appropriate functions in order for it to be useful to the company and focused on the business (Smith, 2005). However, this validation, or approval process, can sometimes function to limit creativity and, thus, must be properly guided and monitored. Firms must realize this and be open to different approaches to knowledge creation and management.

Knowledge creation, organizational learning and innovation rely heavily on social processes within the organization. Acknowledgment and support of this reliance is critical to knowledge creation (McElroy, 2003). However, because of its nature as a social process, it is very difficult to really manage knowledge creation and sharing of knowledge.

Knowledge management is critical to successfully implementing improvements to be more efficient as well as to be more innovative in mining organizations. Knowledge management efforts typically focus on organizational objectives such as improved performance, competitive advantage, innovation, the sharing of lessons learned and continuous improvement of the organization. Mining companies tend to rely on their technical staff to bring in new ideas and innovation. The main system for managing the knowledge management function tends to be through management meetings and is usually driven by its formalized business planning methodology.

Knowledge management efforts can help individuals and groups to share valuable organizational insights, to reduce redundant work, to avoid reinventing the wheel, to reduce training time for new employees and to retain intellectual capital as employee’s turnover in an organization. Some new technologies immersive virtual reality (IVR) help companies meet the knowledge-management, training and retention challenges they encounter in the face of an aging and dwindling industry workforce.

A lack of knowledge within an organization in a certain area tends to drive outsourcing programs and many times focus on legal, accounting and financial services (largely compliance), capital raising and IT/networking. In some instances, business planning is outsourced.

Performance measurement

Effectively measuring performance across a business is decisive to its success and its ability to execute its strategy across the operation. Operations of a given business can range from small, custom shops to multinational corporations spanning several product and business lines. In mining terms, junior operators can run smaller exploration and development businesses where larger multi-nationals can operate exploration, research, mine and mineral processing operations in multiple base mineral or precious domains on multiple continents.

Performance measurement crosses multiple domains and functions in mining companies and is essential to understanding, analyzing, improving and sustaining performance while striving towards operational excellence. Many mining companies use scorecard systems to assess strategic and operational dimensions of performance in addition to standard financial reporting systems and operational reports.

Corporate performance measurement has more recently been associated with measuring performance across an enterprise along multiple dimensions in addition to financial reporting systems using various systems, processes and tools.

Balanced scorecards aid in balancing short- and long-term objectives, using a measurement framework beyond traditional financial and accounting to also include shareholders, customers, internal processes, and innovation and learning. This provides a perspective that many companies use to measure the performance of strategic execution through many layers in the organization if analyzed and implemented properly. Scorecarding systems take many forms including those developed by Kaplan and Norton as well as other third-party and home-grown measurement and scorecard systems.

Scorecarding systems are usually historical in perspective (i.e. daily, weekly and other time frames) and are not easily actionable for users and usually are not well circulated among the different layers in the organization to aid in decision-making.
Managers and supervisors typically use operational reports that provide critical data such as production rates and amounts of various products and lines, raw material and energy consumption rates. Operational reporting systems are also used to measure the efficacy of the operation in terms of production related activities such as truckloads of ore moved, shovels processed, tons of ore crushed, concentrator throughput, electrical consumption per unit processed and other measures providing insight into operational and maintenance performance, including:

- Overall production.
- Production per product.
- Shovels.
- Ladles.
- kWh per ton.
- Btu per ton.
- Concentrate produced.
- Availability.
- Ore quality.
- And other measures.

These reports are typically evaluated daily, weekly and/or monthly and should be integrated from plant asset-based metrics to plant- and mine-level metrics and be available and used by all relevant layers within the organization.

This does not necessarily provide actionable measures of performance for strategic execution or even financial accounting performance in the mine or mineral processing areas of the operation. A significant problem in most mine/mineral processing operations is the lack of real-time performance measurement along financial and strategic dimensions in conjunction with operational kpis and process variable data. Newer process technologies have been developed to effectively develop and implement real-time strategic, financial and operational performance metrics for manufacturing operations domains. These technologies enable mining operations to measure performance along multiple dimensions in real-time and provide the critical decision-making information to all relevant domains in the form of easy-to-use dashboards and reports.

Figure 3 presents a conceptual model of strategic decomposition, dynamic performance measures of plant performance and business intelligence of the most important performance measures on a role-basis for each relevant layer in the operation.

**Conclusion**

Operational excellence encompasses many functions and areas in a mining operation and requires the involvement of many people in order to be successfully supported in the operation. Clearly, attaining proficiency and excellence in the six critical dimensions of operational excellence — performance measurement, continuous improvement, health, safety and environment compliance and management, quality, knowledge management, and human resource development — presents a big challenge for mining operations to ensure a thriving well-aligned business.

Operational excellence is about striving to be the best and showing this excellence in a way that the financial community looks at, admires and rewards. In order for initiatives and programs associated with operational excellence to be effective and thrive, complete buy-in and participation from the people who it affects is critical (Zorabedian, 2008).

**References**


