

Envisioning the Future of Mining



Introduction

How does an industry over 5,000 years old view its own future? Public perspective sees mining as old, dirty, dangerous and environmentally contentious. Within the business, mining is on a precipice of exciting change. Volatile and emerging markets, new technologies, increased customer demands, a dynamic workforce and riveting business model change poise the modern miner to become different, to become smarter. Looking forward, mining companies will have critical choices to make about every aspect of their business. They can either innovate or stagnate. The most fundamental change will be in flipping the supply chain on its head, where the goal won't be to the push product out of the ground to dump on the market, but to respond nimbly to sophisticated customer relationships and market dynamics. Mining companies will have to lose the rigid and ironclad business models and practices of old and become fluid, flexible and agile enterprises poised to pounce on opportunity. This, we believe, sets the vision and imperative for envisioning the future of mining.

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I. Imperative: Volatility inside and out drives the need for a new vision

Mining enterprises, like many businesses today, see their marketplaces, customers and operations undergo a constant parade of changes and challenges. The volatile economy affects all, especially this particularly severe and destructive downturn we have been facing. With downturns in construction and industrial production (such as automobiles) in the West, providers of raw materials will find themselves with different demand curves than they were used to.

Globalization, both with the emergence of new buyers and new providers, changes the playing field for incumbents. Ongoing global industry consolidation (such as the Chinese steel industry buying mining companies to guarantee supply) drives business model change, with new company M&A configurations and government influence affecting outcomes. Industrialization in Asia and other growth markets creates new demand opportunities in commodities, but also fuels the rise of Asian mining and metals conglomerates. Price volatility exacerbates external market conditions, with contracts and market prices changing supply chain dynamics between ore suppliers and consumers. Management of commodity prices, exchange risks and capacity constraints is increasing in complexity and importance. Expansions and contractions in the market have also rocked supply situations for consumables (e.g. tires, explosives) and for heavy equipment.

The rising focus and publicity on environmentalism – and newfound focus on Corporate Social Responsibility (CSR) – creates pressure from governments, customers and shareholders, with mining being a prominent target for environmental outrage from all corners. At the same time, CSR is becoming a top priority among mining executives and mining employees and particularly to the prospective generation of future workers.

The number of skilled resources continues to decline and costs are increasing, with the number of upcoming retirees making the situation more difficult. Newer employees (e.g. Gen X, Gen Y, Millennials) have different attitudes and expectations that need to be taken seriously. Even when the next generation comes aboard, transferring the knowledge locked in the minds of the incumbent workforce will prove to be challenging. The enterprise's experts are dispersed and often unavailable.

Stoking the fire of this change is the speedy evolution and adoption of new technologies, changing how companies view and interact with their operations and markets. As problems such as inefficient scheduling, wasted consumables and labor-intensive activities all appear to be prominent operational issues, companies often ignore the underlying technological causes. The technology landscapes at the traditional mining company are now within their second and third generations. The technology footprints have grown diverse and chaotic. Managers feel like they're drowning in information while still unable to find the answers they need. Data is tracked in different conventions, systems and structures.

If there's one constant in the mining industry it is constant change, unpredictability and complexity.

In envisioning the ideal mining enterprise that tackles the issues of today and tomorrow, we must look beyond the mine and across the entire business.

How do we frame a vision for the future of mining?

The grievances and issues of the day begin to paint a picture of what is needed going forward. Too often, mining professionals focus on the mine itself, wondering how to dig more product out of the Earth rather than look at the big picture. Others resort to the same old, tired levers of traditional cost cutting that only provide short-term benefits. Smart leaders are thinking about their company's path forward. In envisioning the ideal mining enterprise that tackles the issues of today and tomorrow, we are prompted to ask several key strategic questions:

- How will mining companies use business innovation to transform the fundamentals of their operations, their customers and supply chain?
- How will we increase sales revenue and profitability by better synchronizing the entire demand chain and improving customer service?
- How can we reduce operating costs in our operations, management structure, resource strategies and suppliers? How can we improve overall return on capital?
- How can we leverage the role that technology will play in enabling new capabilities in the mining business?
- How will mining companies replace their aging workforce and find the next generation of employees eager to do the right work in a new era?
- How do we improve utilization of our critical production assets? How do we achieve overall load balancing across facilities, while minimizing sensitivity to disruption and risk?
- What role will mining companies take in leading the world in environmentalism and corporate social responsibility?
- How will mining companies reduce risk and ensure optimal safety and security of workers and assets?
- How will mining companies utilize a geographically dispersed workforce and skill-set while retaining local control and execution?

These questions and others begin to frame the discussion about the future of mining. Perhaps the most profound insight we can draw is that the smarter mine of the future will extend much further than the mine itself, leading a transformation to the entire enterprise of extracting, selling and delivering metals, materials and fuels.

“We must recognise that the landscape has changed and that we need to reinvigorate our focus on cost management and operational efficiencies. Importantly, efficient and predictable operations underpin our cash generation capability and establish the foundation to support further growth.”

Marius Kloppers, CEO Message, FY2010, BHP Billiton

II. Vision: The Future of Mining

In envisioning the future of mining, sometimes the question is “what will be different?”, and sometimes it will be “what will we do better?”

In envisioning a future state of smarter mining, the final image is neither concise nor discrete and may resemble a mosaic of new capabilities and business models more so than a monolithic solution or single transformation. The mine of the future will likely have areas that we can’t rightfully predict or imagine. At the same time, many (if not most) of the core mining activities, practices and competencies will be carried forward from practices today. Sometimes the question is “what will be different?” and sometimes “what will we do better?”.

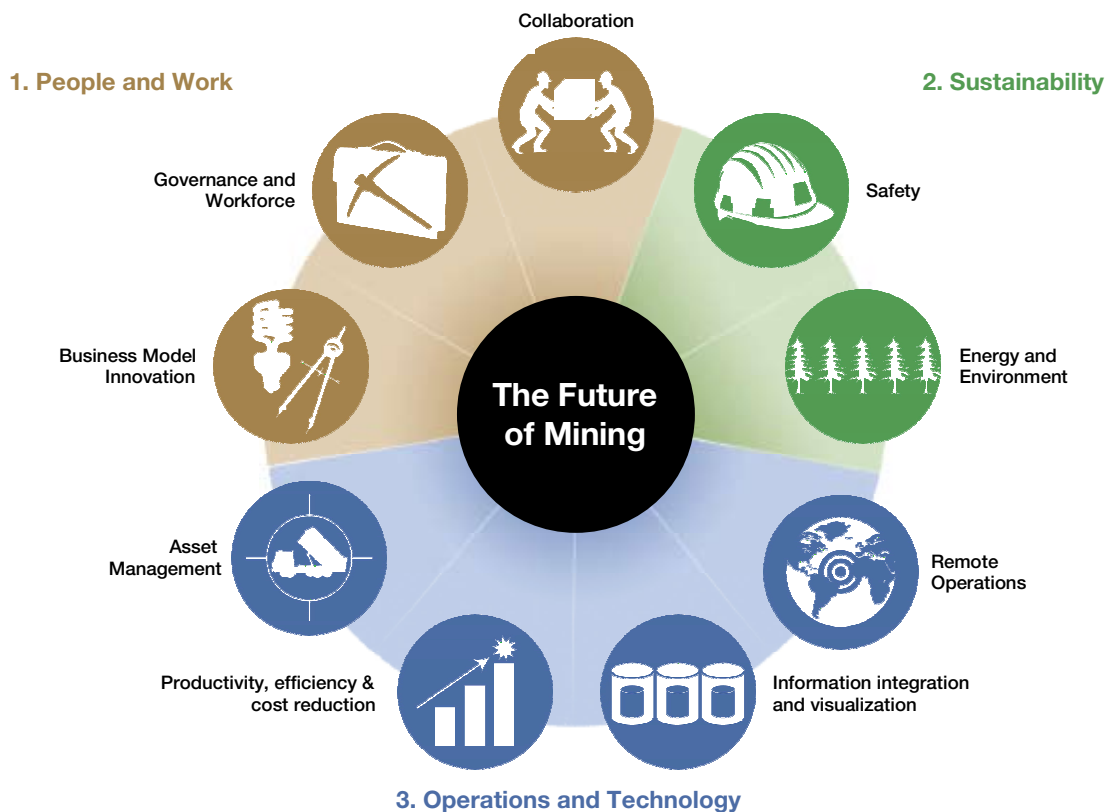


Figure 1: Strategic Areas of Focus for the Future of Mining

In a vision for smarter mining, we are also careful to cement our forward views in a stable and sensible base of reality, practicality and feasibility. For this, we identify practices and tactics in use today. While we find no one company as an exemplar for the future, we find the individual pieces in successful practice around the industry. In many ways, the future mining enterprise could also be described as the ‘perfect mining company of today’, i.e. a composite of all of the best and brightest operations being used currently. In some instances, ideas may come from outside the mining industry.

Listed below are nine characteristics of the future of mining, divided into three larger categories. For each characteristic we discuss a typical current state (with its companion problems and issues) and the capability or characterization of the future, often inspired by a best practice in use today. In general we focus on the “business of mining”, leaving other relevant future advancements (such as new technologies in geological surveying or ore extraction techniques) out of the scope of our discussion.

1. People and work

Many miners believe nothing can be changed: you have a mine, a railway system, a nearby port and that is it. This belief is untrue and many mining leaders are awakening to a new reality.

Business model innovation

The most significant – and most challenging – transformations mining companies will face are strategic in nature; making fundamental business model shifts that rail against conventional means of doing business. Currently, many mining companies view their business in terms of the ability to move material out of the ground and through the supply chain, all in hopes of finding customers to purchase their payload upon completion. Emphasis is placed on maximizing capacity and reducing costs at each phase of the supply chain. Inventory management and distribution then become a yield and price game, with profit margins often a mystery until the

goods are shipped. Many miners are strapped with the belief that there’s nothing that can be changed about a mining operation/logistics network: you have a mine, a railway system, a nearby port and that is it. This belief is untrue and many mining leaders are awakening to a new reality.

The new business model should focus on value, both for the organization and for customers. Mining companies will look to do more with less, optimizing their use of cash and capital and building flexibility. The focus will be to realign relationships to build financial solidity of suppliers, partners and customers. This, in turn, will build long-standing profitable relationships that will enable the company to transcend commodity-trading relationships only.

“We believe that our strong relationships with major customers, reinforced through long-term contracts, high quality products and a strong technical marketing strategy, will help us achieve this goal.”

- Vale Annual Report 2008

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Business model is commodity-focused and driven by amount of product produced
- Operational optimization is siloed and focused on each discrete phase of the supply chain.
- Geography constrains operations and is locally focused.
- Learning is from mining experience and the past.
- Business results are tracked and measured post-mortem.

The Future of Mining (Today's emerging practices to adopt)

- Business model is value- and relationship-focused and is driven by customer demand.
- The supply chain is viewed holistically and optimized as an integrated process.
- Operations become more geography-independent and a global perspective is taken.
- Mining companies also learn from other industries, partners, acquisitions and other sources.
- Business decision making is forward looking, based on smarter plans and advanced business analytics.

Imagine a new way where the old model is flipped on its head. Customer demand and needs drive capacity and resource planning. The mine adopts a new production discipline, best practices and supporting metrics that enables the company to focus on maximizing the throughput and profitability of the entire process. Integrated plans and schedules drive production orders in the most cost effective ways, enabling companies to react to manufacturing variability and changing business conditions, all while minimizing disruption. Production is optimized by order and schedule. Equipment turnovers and downtime are reduced. Global visibility breaks silo-based operations, enabling collaboration and connectivity across the supply chain.

Benefits of business model innovation in the future of mining:

- Mining companies break the chains of commodity-based trading relations.
- Business model is flexible and agile to deal with different market dynamics, economic conditions, customer demand and other forces.

- Profit margins are determined by value and relationship.
- Variety of operational options and tactics are greatly expanded to deal with ongoing business challenges.

One example of a company changing its model to make a smarter supply chain was one of the world's largest steel makers, capable of producing over 32 million tons per year. As most steel companies, their business model was one of "silos", separate business departments with separate functions and targets. The company wanted to break through these silos with streamlined processes and all focusing towards the single goal: customer satisfaction. They began a program to changing the typical heavy industry's mindset of maximizing throughput to starting from market demand. They re-engineered business processes to synchronize external and internal processes from suppliers through all divisions to customers, leveraging new end-to-end IT technology. This undertaking resulted in record Delivery Performance levels (95%) and at the same time significant reductions in inventories, metrics that are typically conflicting.

Governance and workforce

The smarter mining organization of the future will improve its utilization of governance and workers to drive change and improvement.

Organizational aspects of mining enterprises such as structure, leadership, policy, culture, careers and workers are key to achieving a smarter mining enterprise of the future. Mining companies today find themselves with an aging workforce and issues in attracting and retaining new quality leaders and workers for the future. Years of acquisitions and mergers have created management layers and legacy-driven, organizational silos that may inhibit efficient management as well as drive higher costs. The management and transfer of knowledge becomes especially important as operational execution becomes more about information and insight and less about the intuition and gut feelings of seasoned experts.

According to a recent study in Australia, mining companies are among the worst performers in an assessment of the corporate governance standards compared to other industry sectors. According to University of Newcastle Associate Professor Jim Psaros, the industry suffers from organization “immaturity”¹. He attributes this shortcoming to recent growth, where the corporate governance principles of the past did not grow fast enough to keep up with the size and complexity of the organization.

- Mining Governance Standards Slip, Mining Daily, July 2009

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Governance is informal and is different from location to location.
- Critical knowledge and intuition suffers attrition through an aging workforce.
- Mining deploys local workforces and struggles with finding the right skills.
- Leadership is multi-layered, dispersed, bureaucratic, costly and decision-making is slow and complicated. Administrative costs are high and unwieldy.
- Recruiting new employees is difficult as the traditional view of the mining business is unattractive.

The Future of Mining (Today's emerging practices to adopt)

- Formal, centralized corporate governance actions are in place and are supported by policy, measurements and incentives.
- Knowledge is captured and institutionalized and delivered to workers at the point of need. Knowledge strategies are proactive and pervasive.
- Global workforces and expertise are leveraged through virtualization and technology.
- Management organization is “lean and mean” with centralized organization and reduced cost structure, with streamlined and rapid decision-making. Administration is streamlined and cost effective.
- A youth movement eagerly gravitates towards mining as it is a high-tech, fast-paced industry that projects an image of environmentalism and responsibility.

Most mining companies have significant opportunities to improve their business by improving their organization and workforce. These areas need to be the focus of formal programs and investment. Too often, they are delegated to informal processes or ignored altogether.

Benefits of improved governance and workforce in the future of mining:

- The right employees have the best knowledge and the right time, driving better decisions, better execution and improving productivity and margins
- Cost reduction through streamlining and centralizing management and administration reduces costs while raising the effectiveness of decision-making and governance.
- Mining companies are able to attract a new generation of employees from across the globe.

Collaboration

We can envision a new mode where the mining company collaborates with customers and partners in new ways, becoming more intertwined and critical to their needs. This has the potential to extend the relationship, build customer loyalty, and even new revenue streams.

Many of the new strategies mining companies will adopt such as taking a holistic view of the supply chain, working with partners and customers, breaking organizational silos, sharing knowledge and expertise, and remote operations require a new view of collaboration. Collaboration among departments, geographies, phases of the supply chain, partners, customers, and suppliers becomes critical to building enterprise agility. Collaboration among individuals improves the sharing of knowledge, enables better decision-making, and better leverages experts who may be scattered throughout the enterprise. Collaboration among customers and partners can drive innovation and effectiveness unachievable within a single enterprise alone.

In many cases, there are potent new collaboration opportunities with customers. Some companies completely decouple relationships at the port where the material is dumped and left for the customer to pick up. Some iron ore producers, for example, have very limited understanding of the impact on how blends may affect steel quality. Others are beginning to bridge this gap by preparing certain blends, deploying their own shipping vessels for delivery to the customer, and even establishing global distribution centers. We can envision a new mode where the mining company collaborates with the customer in new ways, becoming more intertwined and critical to the customer's needs and processes. This has the potential to extend the relationship beyond commodity pricing, building customer loyalty and even new revenue streams.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- New programs, business models, techniques, products practices are developed in-house.
- Suppliers, customers and partners are kept at arm's length.
- Phases of the supply chain are isolated from each other, preferring to use a “throw it over the wall” approach to transferring work/product through the pipeline.
- Teams are isolated by location and do not communicate with a central control room or other mines.

The Future of Mining (Today's emerging practices to adopt)

- R&D and innovation are fueled by collaboration: across the company; through partners and vendors; through others both within the industry and beyond; and by forming coalitions, joint ventures and other ‘meetings of the minds’.
- Suppliers, customers and partners are collaborated with frequently to work on common issues, improve relationships, improve productivity and create better and more accurate plans (e.g. demand forecast accuracy).
- Teams collaborate with groups upstream and downstream to effectively control and streamline the entire supply chain.
- Teams communicate and collaborate across the enterprise and across multiple mines and sites. Activities are coordinated through a central control room or location.

Collaboration is more than a technological tool or organizational mandate. True collaboration requires an attitudinal shift among workers who need to understand how working collaboratively is beneficial both for themselves and the organization at large. Collaboration also requires new incentives and performance measurement to succeed. Organizations will need to invest in new tools and new skills for collaboration.

Benefits of improved collaboration in the future of mining:

- New sources of innovation are discovered, nurtured and leveraged.
- Issues and challenges are solved more quickly and more effectively.
- Institutional knowledge and expertise are leveraged to their fullest degree.
- Productivity and performance are enhanced.
- Customers and suppliers are drawn closer to the enterprise to improve results, service and satisfaction.

The Corporation has implemented a system of working together through alliances with companies and organizations that are world leaders in research and development. The objective is to speed up the integration of knowledge and innovation into mining processes, adding value to the business.

- Codelco Annual Report 2007

One leading example of extra-enterprise collaboration is the auto/steel partnership. The consortium consists of major US auto manufacturers and leading steel producers, and collaborates together on specific programs that drive innovation, technology advancement and efficiency across the steel-auto manufacturing pipeline. Although the participating companies are clear competitors and rivals, they've realized that they can achieve more for the entire industry (and themselves) by working together.

According to their vision statement³ they focus on "Using inter-company and inter-industry cooperative programs to ensure the success of the member companies" as well as "Proactively resolving governmental regulatory agency requirements and customer needs."

Their current initiatives focus on driving innovation in using steel in new automotive applications, such as stamping high strength steel, multiple light-weight steel applications and improving durability/quality (e.g. fatigue, corrosion, uniformity). The group also serves as a knowledge facility, with many projects focused on standards, documenting best practices and developing analytic solutions.

2. Sustainability

In the future of mining, safety efforts are bolstered by new technological approaches that stretch the safety net beyond what training and procedures can provide.

Today, sustainability is more than regulations, corporate philanthropy, or a marketing campaign. Sustainability and its larger umbrella concept of Corporate Social Responsibility (CSR), is now being integrated into a company's business strategy, operations and culture to drive business value, reduce costs and provide benefits for the business and society.

Most mines and mining facilities often encompass large areas, multiple levels and complex layouts. Workers, contractors and visitors are often surrounded by many dangers, from hazardous environments to potential collisions and accidents with machinery. When underground, mines can collapse, there can be ventilation failures and exposure to toxic mine gases, explosive gases and dust. On the surface, vehicle collisions, explosives, dangerous locations and the potential for human harm in material handling machinery (e.g. conveyers) pose more safety threats. The challenge is not only preventing dangers from occurring, but also being able to act on problems quickly and effectively when they occur.

In emergency or safety drill situations, it can be exceedingly difficult to learn quickly who has been evacuated, who is still missing and where the missing persons were last seen. While this critical information is gathered, rapid response can be delayed and incorrect and potentially time-consuming decisions may be made in directing rescue teams and managing accountability activities. Increasingly, Mining companies have to deal with safety improvement issues as part of a social 'license contract to mine' with municipalities, governments, or native groups (e.g. Aboriginal bands) and communities. In the future of mining, safety efforts are bolstered by new technological approaches that stretch the safety net beyond what training and procedures can provide.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Workers' safety is solely a function of training, procedures, policy and chance.
- Access, privileges, status and the management of employees is delegated to line managers and informal processes.
- Security information, if available at all, is restricted to individual security systems and/or vendors.

The Future of Mining (Today's emerging practices to adopt)

- New smart programs and technologies, such as location awareness technologies, GPS, RFIDs and collision detection/avoidance improve the safety of each employee both during daily business-as-usual and during catastrophes/accidents.
- Companies deploy sophisticated and automated Identity and Security Management programs that systematically and centrally track employees' access rights, location, duration, training, safety certification, permissions, compliance and site security.
- Security information is integrated and available to those who need it, including security and human resources.

Benefits of improved safety in the future of mining:

- Safer mines for workers, which reduce injuries and fatalities, which in turn reduce downtime, insurance costs and litigation, while improving employee retention, recruiting and morale.
- Certainty of which worker is located and for how long, with what training, safety certification and access privileges.
- Complying with implicit or formal social and governmental requirements for safety.

One refining company improved their safety through real-time personnel location monitoring. Their program involved employees wearing RFID tags that would send location information at frequent intervals, with the data uploaded to a control center. They integrated all these capabilities into a comprehensive location awareness and safety program. One innovative component is a real-time visualization engine that provides a rich graphical view of employee locations and associated metrics. In the event of an emergency or disaster, the system presents a real-time view of the location of employees in and around specific areas of the refinery. Having this view drastically reduces the need for rescuers to conduct sweeps of a particular area in search of unaccounted for employees. Staff can configure the system any number of ways to create new or temporary security zones along with conditional business rules that apply to the zones. By integrating the solution with security clearance data within its HR systems, the system can identify unauthorized personnel within a zone and automatically notify safety personnel, who can take fast corrective action to ensure the safety of the employees.

We will not mine if we cannot mine safely.

- Nicholas Holland, Chief Executive Officer, Goldfields Annual Report 2008

The company is also testing a variation of this approach to reduce accidents associated with the movement of overhead cranes, which represent one of the biggest causes of injury in the business. By integrating RFID position information, the crane safety initiative is designed to provide a collision avoidance warning to alert crane operators before accidents happen.

Energy and environment

It is time to take a proactive stance in energy and the environment to improve costs, attract new talent and make substantial societal change at the same time.

Energy and environment are emerging concerns within the mining industry, both within the ranks of its professionals and from the public. Government regulations are increasing (e.g. Australian Emission Trading Scheme, European Union Emission Trading Scheme, Kyoto Protocol, etc.), with carbon management issues coming to the forefront. Governments and public perception aren't the only pressures. According to a

2008 IBM Institute for Business Value study on Global Corporate Social Responsibility, a third of today's companies are required by their business partners (i.e. customers) to adopt or acquire new carbon management standards³. Regardless of whether environmentalism is considered to be a critical imperative or merely a hot topic, it is the right time to take a proactive stance in energy and the environment to improve costs, attract new talent and make substantial societal change at the same time.

For mining companies, "being green" will need to be more than a marketing campaign. New technologies and programs now exist that are able to manage consumables such as carbon, water and fuel from end to end, as well as providing new capabilities in performing trade-off analysis on productivity vs. environmental impact. These programs also may extend to footprint management, waste management, ecosystem risk management, mine closure and re-habitation, tailings placement management and stewardship management.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Green and CSR are considered stand-alone programs focused on marketing or corporate philanthropy with business value not formally defined.
- Meeting government regulations is managed with little automation or integration.
- Carbon, water, energy and waste are managed manually with little automation or integration.
- Mining is perceived by prospective employees, the public and the media as environmentally unfriendly.

The Future of Mining (Today's emerging practices to adopt)

- CSR is a formal and pervasive program that integrates into many (if not all) aspects of the business. It is formally measured and includes business value drivers in its scope, such as reducing energy expenditure, reducing regulatory costs and improving recruiting activities.
 - Meeting government requirements is tracked via a formal system of performance metrics and automated analytical tools.
 - Processes, information and analytical tools are used to proactively manage environmental and energy consumables, such as modeling carbon trade-offs, carbon trading, water management, fuel optimization and waste control.
 - The perception of mines is positive, attracting environmentally-aware advocates to work and support clean mining operations.
-

Benefits of improved environment and energy in the future of mining:

- Reduced energy costs.
- Reduced management costs and improved effectiveness in the management of consumables that impact the environment (e.g. carbon, water, energy, waste).
- Tighter compliance with regulations and reduced costs of meeting/monitoring regulations.
- Improved image, recruiting and public acceptance.

We manage this risk through implementing energy efficiency plans across our operations and developing energy efficient technologies... which reduces the energy consumption of ferrochrome smelting by over 20% compared to conventional processes. Long-term energy contracts are negotiated to reduce dependence on spot markets and we seek to diversify power sources and identify alternatives.

- Xstrata Annual Report 2008

3. Operations and Technology

The “heavy lifting” aspects of mining will improve in the future even whilst the core objective of unearthing product stays the same. New technologies will make the mine – and both its local and remote managers – smarter by becoming instrumented, interconnected and intelligent.

Asset management

Assets will be instrumented, interconnected and intelligent, reporting their location, their status and other key metrics remotely and automatically.

Massively capital-intensive, mining business performance is tied to the availability, maintenance, financing and deployment of assets. Every moment without the right equipment or transportation can have severe effects on productivity and profitability for miners. Repairs often create “double jeopardy” for mining companies as emergency fixes have high costs while the asset is simultaneously down and not producing revenue. Worse, repairs are typically performed reactively after the asset is down. In a traditional view, assets may only include items from a few categories, such as equipment, vehicles, or specific infrastructure. The responsibility for these items may have been lumped by their job function, financing scheme or their procurement categories. The issues of capital deployment, leasing, ownership, location and countless other factors make asset management as much a puzzle for finance as it is for operations.

The smarter mining enterprise will need a new view and approach to asset management. This new view encompasses the entire asset management life cycle (i.e. from needs analysis to disposal) and takes a wider view of asset classes (i.e. the way assets are categorized e.g. transportation, equipment, information technology, land) and how they each behave and contribute value differently. The future approach will also improve how well each asset management activity is performed.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Status and location of assets is managed through sight and manual tracking.
- As a strategic practice and business function, asset management is limited to a few asset classes such as equipment and transportation.
- Assets are managed by job function or financing scheme.
- Asset management is performed separately across sites or geographies and often involves manual or unconnected information, processes and systems.
- Asset management is separate from other business planning functions.

The Future of Mining (Today's emerging practices to adopt)

- Assets are instrumented and intelligent, reporting their location, their status and other key metrics remotely and automatically. "Predictive condition monitoring" is used where systems using predictive data modeling trigger maintenance orders before equipment failures happen.
- Asset management includes a broad array of asset classes, including land, fields, inventory, information technology, real estate, infrastructure, etc.
- The entire asset management lifecycle is planned for and analyzed/managed on many different dimensions.
- A centralized asset management program is deployed and used, leveraging sophisticated asset management practices and integrated asset management tools/technologies.
- Asset management is integrated with other business functions and systems, such as ERP.

Developing optimal asset management capabilities requires an attitudinal shift. In low-performing situations, managers might think in terms of cost such as reactive maintenance instead of taking a value-based approach that predicts maintenance and integrates reliability into the overall planning process. In this sense, asset management is no longer a practice of managing maintenance and equipment costs, but instead one of planning on how assets contribute to productivity and overall profitability.

An emerging trend within the industry is to improve uptime and reduce emergency repairs through condition and health monitoring. By enabling new methods in instrumentation and sensors, predictive analytics and remote monitoring technologies, mining companies will be able to track a 'living pulse' of their key equipment and assets. The machines and systems will monitor equipment health and use both onsite indicators and predictive analytical models to allow asset managers to repair or prevent breakdowns before they happen, employ more sophisticated maintenance schedules and reduce the time, expense and downtime that repairs entail. One major heavy equipment manufacturer is currently outfitting their fleet with this new technology and approach, shifting from a reactive 'health maintenance' mindset to one where equipment is viewed in its total contribution to 'production effectiveness'.

Benefits of improved asset management in the future of mining:

- Better utilization of assets to contribute business value and productivity
- Less downtime
- Lower MRO costs
- Improved finance strategies via smarter asset deployment, smarter purchasing/leasing decisions and ultimately improved return on capital employed (ROCE)

Productivity, efficiency, and cost reduction

Increasing productivity and efficiency will happen simultaneously with reducing costs.

Increasing productivity and reducing costs often present trade-offs for most companies. Mining companies of the future will need to improve both simultaneously without sacrificing customer service, safety or operational flexibility. Some traditional costs levers such as labor, supplies and vendor services can be adjusted through renegotiation, integration, virtualization and other strategies. More profound productivity and efficiency transformations can occur when fundamental business processes are redesigned to become lean or streamlined, and advanced analytics and optimization is used to support the decision making process.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Production scheduling is manual, performed with little visibility to the overall supply chain and heavily reliant on the individual skills of the scheduler.
- Few or poorly supported programs exist to promote quality and efficiency.
- Material blending and scheduling of production is based on manual analysis and the skill of the production supervisor.
- Hundreds or thousands of supply vendors are used with little central oversight. Different sites and departments run their own procurement activities independently of one another, duplicating purchases and driving up costs.

The Future of Mining (Today's emerging practices to adopt)

- Scheduling for the mine is integrated from mine operation to shipping, including blend design and dynamic order book allocation to stocks in the system wherever they are.
- Quality and efficiency programs, such as Six Sigma, are utilized to manage productivity and to define optimal processes.
- Production supervisors use advanced optimization capabilities to determine the optimal material blend option and scheduling production to optimize mine/plant throughput.
- Strategic procurement programs such as category management, strategic sourcing, supplier integration, procurement centers of excellence (COEs) and transaction optimization all work to reduce costs and wastes in the supply procurement process.

Benefits of improved productivity, efficiency, and cost reduction in the future of mining:

- Lower operations cost and improved margins.
- Greater production and revenue.
- Greater return on capital employed.
- More responsiveness and flexibility.
- Better delivery performance.

In the near term, we will continue to focus on reducing costs and maintaining our “Core Assets” to position us to benefit when conditions improve.

- Letter to Shareholders from James R. Moffett, Chairman of the Board, Richard C. Adkerson, President and Chief Executive Officer, Freeport 2009

Information integration and visualization

In the future, we can imagine scenarios where information integration, visualization and new modes of collaboration that wildly improves business performance

The traditional mining mindset is a “look and see” mentality. Aged experts rely on their intuition and gut feeling based on what they experience in the field and while sophisticated technology has permeated many of the operational aspects of mining, few have tied all of the information into comprehensive views of the mine(s) for insight-driven decision making.

The new vision for information in mines interconnects all entities in the environment including instrumented assets and equipment, transportation, people, supplies and plans into integrated views. Called visualization, this integration of information provides production and maintenance operations, analysts, field crew and other decision-makers with a real-time view of their entire operation via consolidated, synoptic interfaces. Alerts, alarms and triggers enable the mine to be hyper-responsive to change and challenges. Advanced analytics help miners predict and plan for the future, not just react.

One emerging practice for visualization relies on a new vision for the mining control room, and uses new technology techniques to integrate many sources of data without reinstalling or replacing different systems across the mine. These include using reference semantic models, industry standards, intelligent service oriented architecture (SOA) approaches and new, intuitive visualization dashboards and interfaces. The management of the mine’s operations also links to key business systems, such as ERP or sales forecasting, enabling the entire supply chain to be managed in synch across the enterprise.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Lack of information creates decision-making based on partial information, “guesstimation”, or bad/missing facts.
- Information about assets and people is manually gathered.
- Access to mining information is limited and is delivered on a time scale that hinders responsiveness.
- There are no integrated views of mine performance for monitoring, management or decision-making.
- Performance measures only scratch the surface of providing a quantitative view of most activities.
- Business information, such as financial planning or sales forecasting, is separate and unconnected to mine operation information and must be reconciled or accounted for through manual processes.
- Technology architecture is rigid, expensive to change and slow to upgrade to address new business capabilities.

The Future of Mining (Today's emerging practices to adopt)

- Decision makers have access to a timely and comprehensive set of facts and a single version of the truth.
 - Assets and people are instrumented with location-aware technology that provides real-time metrics on performance and status.
 - Information reflects the current business reality, delivered in real-time or right-time. Reporting and analysis of operations is real-time and can be predictive. Companies spend more time “looking forward” instead of reporting on the past.
 - Production operations and others are able to visualize their entire mining operations via intuitive interfaces that provide synoptic and detailed views of performance, including alerts and events.
 - A broad and rigorous set of key performance indicators are defined and tracked throughout the enterprise.
 - Operational data from mines interconnects and communicates with key business systems, enabling administration, finance, sales, service and other functions to respond to mining and supply chain events.
 - Technology architecture leverages new strategies such as SOA to become flexible, allowing new capabilities to be built and deployed rapidly.
-

Imagining information integration, visualization, and collaboration in the future

In the future, we can imagine scenarios where information integration, visualization and collaboration wildly improve business performance. For example, imagine an unexpected machine failure deep in the mine site. Sensors on the machine alert an intelligent control room thousands of miles away and provide diagnostics and performance metrics to a Remote Control Room production supervisor. The production supervisor then assembles a virtual team of experts to discuss the problem via multiple monitors in his control room. Experts from different mines across the globe are connected in real-time, as well as a maintenance repair person on the ground and a team of technical support experts from the equipment's manufacturer. Together, they discuss options and devise an approach to solving the problem. Recommendations and documented past fixes are sent from the Intelligent Analytics knowledge repository to onsite repair technicians.

The collaboration system informs other business users such as Finance and Sales of the machine downtime who are then able to adjust their production forecasts and to contact customers if need be. The event and solution are logged into the collaboration and knowledge system so that future problems can leverage this expertise.

Benefits of improved information, integration, and visualization in the future of mining:

- Make more accurate, timelier decisions that enable the mine to produce and function more effectively and respond to business changes better and faster.
- Enable technology architecture and infrastructure to be more flexible in responding to changing business conditions.
- Improve mine/plant throughput while increasing margins and improving customer service.
- Reduce IT spending.

A Norwegian petroleum company found great benefits by deploying an integrated information framework with the goal of identifying the methods, technology and work processes needed to integrate its operations. Previously plagued by unconnected systems and a lack of shared information, the company deployed an integrated industrial-semantic model based on a linkage of key oil and gas standards to create a flexible information integration and interoperability framework. Within this framework, nearly any system's data, regardless of its format, is accessible where it's needed most.

Using data from wireless sensors, which monitor subsurface conditions (such as the pressure and temperature at different points in the field, as well as the movement of gas or oil deposits), the solution will provide the company's engineers with the information they need to know when, where and how much to pump. Getting data feeds from its sensors in real time will give the company the means to make decisions for production optimization on the spot, without having to wait weeks or months to gather and synthesize information. The program has been a key enabler of their preventative maintenance strategy, which is designed to identify potential maintenance issues before they become critical and cause shutdowns. Algorithms will process this data to determine when proactive (or condition-based) maintenance should be performed.

The company expects to increase its overall production by 5 percent while reducing its operating and maintenance costs by 30 percent and expects a drastic reduction in shutdowns and the effects they produce. This model will also help the company to optimize turnarounds and shutdowns across all assets.

Remote operations

With the growing level of remote automation and computer-driven management, many operations managers) may find themselves asking “Couldn’t I run this remotely?”

Most mines are still run with a localized approach. Increasingly, mining leadership is finding that they are constrained in many ways locally, especially when trying to find qualified staff. At the same time, there is a shift in where more work is completed on the computer screen than in the field. With the growing level of remote automation and computer-driven management, many operations managers may find

themselves asking “Couldn’t I run this remotely? If we can mine on Mars, we can certainly mine without being at the site.” This leads to a philosophical shift from decentralized to centralized mining management.

Besides expanding the potential skilled workforce, remote operations and centralization provide other benefits. By moving control centers to centralized locations, mining performance can be measured across sites and locations. Measurement processes can be standardized and universally adopted. Knowledge and experts can be shared across the enterprise more easily via collaboration. Procurement programs can be unified across the enterprise for greater synergies and cost control. Customer relationships and production orders can be managed on a global scale.

In many ways, remote operations may best define the future of the mining enterprise. It requires the culmination of information, collaboration, smarter and leaner organization, governance and workforce, visualization and business model innovation.

Characteristics of the mining enterprise of yesterday and the future of mining include:

Mine of Yesterday (Conventional practice)

- Managers and teams are mentally and physically locked into local operations.
- There is little coordination or integration between sites and locations.
- Management, leadership and decision-making capabilities and structure are duplicated many times throughout the enterprise and maintaining organizational control is difficult.
- Staff must be on site.
- Equipment and transport are fully manned at location.

The Future of Mining (Today’s emerging practices to adopt)

- Sites across the enterprise are managed centrally and synergies and advanced capabilities are realized by unifying processes, information, control and knowledge.
- A lean, centralized management function achieves improved control of the enterprise. The reduction of redundant management reduces costs while making governance and coordination more streamlined and effective.
- Leadership and staff can be located in ideal locations independent of mine sites.
- When appropriate, automated, robotic and remotely controlled equipment and transportation are used to improve productivity, safety and boost employee retention.

Benefits of remote operations in the future of mining:

- More expansive resource pools are available at different cost structures.
- Redundant expenses are mitigated.
- Greater control of the enterprise.
- Synergies, efficiency, prowess and speed realized through unified processes, information and knowledge.

The future in action today: Remote Operations in the future of mining⁴

One mining company, with a site located in the deep Northwest of Australia, has taken on an acute technology focus that includes the development of a remote operations center (ROC) that will eventually control trains, drills and tracks from as far as 1,300 km away. This company chose one of their many mines as a test bed for innovation, such as testing automated trucks, automated drills and blasts and automated logistics applications (e.g. driver-less trains, autonomous haulage systems).

The ROC will house around 350 employees who will oversee, operate and optimize the use of key assets and processes, including all mines, processing plants, the rail network, ports and power plants. Operational planning and scheduling functions will also be based in the ROC, which features an operational control room, office block and supporting infrastructure. Having maintenance, rail, HR and all other departments located together will improve managing the operation's scale. As a difficult place to live and raise a family, the remote mines suffer high employee attrition. The ROC will improve staff retention dramatically. These types of initiatives begin to show how mining can transform itself in innovative new ways for the future.

In an industry that often thinks in 25-year time frames, this depiction of the smarter mining enterprise of the future may seem more immediate than far reaching. In light of the challenges facing the mining industry today, future leaders will likely be those who speed their path to future capabilities, leaving the reluctant and slow-to-change in the dust.

III. Forging your vision

Purposely break from conventional mining thought processes and tradition; elicit provocative, adventurous, trailblazing and transformative points of view.

Just as every mining interest is unique, each mining company must craft their own vision of the future to adapt to its own distinctive operations, business challenges, strengths and opportunities. As each enterprise is mature or weak in different areas, defining a future vision becomes an exercise in self-analysis and setting priorities. Ultimately, the vision should cast a unique profile for the company, combining areas of competitive differentiation and excellence while also leveraging widely accepted best practices and tactics.

While establishing a vision is a critical step, real change can only be enacted through purposeful transformation activity. In this sense, a carefully crafted vision becomes a destination and the journey to get there is a sequence of small changes and steps, each moving the enterprise forward while achieving short-term goals. Mining leadership should start with a thorough understanding of their challenges and internal environments via a rigorous and thoughtful look inward. The vision should define clear goals and business capabilities. Tools such as business component modeling can help achieve this analysis and pre-existing industry models can be leveraged to ensure that all areas of the business and best practices are covered.

Tools such as a mining-specific component business model can help leaders envision their future operations. It provides a comprehensive and relational view of the enterprise that ensures all areas of opportunity are analyzed and discussed.

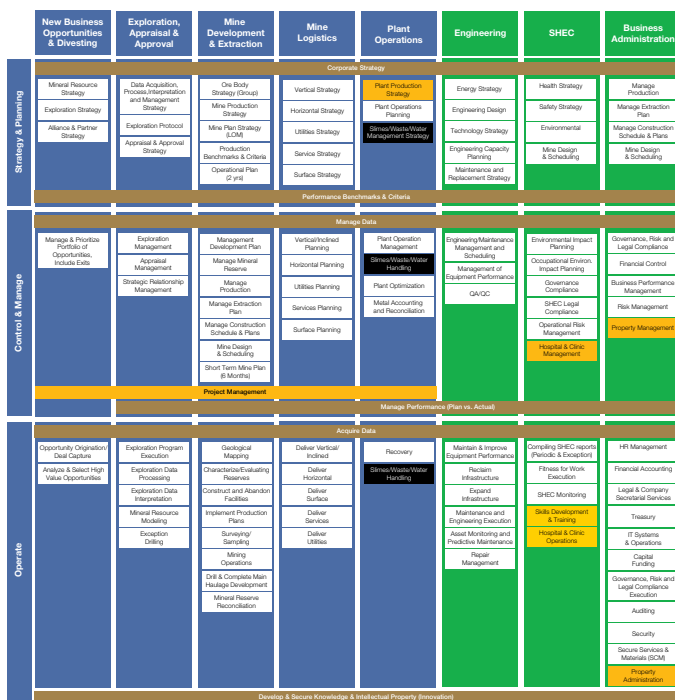


Figure 2: IBM Business Component Model for the Mining Enterprise

Upon defining the vision, leadership should look to understand gaps between their existing state and their proposed vision. Closing these gaps sets the basis for transformation work, aligning projects and initiatives along short- and long-term timescales to achieve specific results, capabilities and benefits. This plan is often called a roadmap.

Mining companies looking to establish their own vision for their future should be mindful of several factors that can help drive success:

- Purposely break from conventional mining thought processes and tradition; elicit provocative, adventurous, trailblazing and transformative points of view.
- Provoke, recruit and engage different stakeholders from across and outside the enterprise to contribute to the vision, including different functional areas (e.g. operations, IT, sales, finance), geographies and managerial levels.
- Focus on gaining consensus, excitement and advocacy for the vision at every step of development.
- Glean, leverage and learn from partners, vendors and other industries to broaden the scope of possibilities and to cull innovation from these sources.
- Follow the money by creating rigorous and comprehensive financial justification with a business case to fortify decisions and to gain commitment.
- Communicate more and share the vision in new ways across the enterprise. Stop using the traditional passive means of communication (the same video or presentation) and find new ways to engender energy and momentum with leaders and staff alike.
- Be smart and pragmatic when setting direction. While examining all angles from the wildest to the most conservative, choose change techniques that can fit with the style, appetite and resources of your organization. style, appetite, and resources of your organization.

These steps describe the beginning of the journey. Making the first step requires initiative and courage. The “champion” or leader of creating the vision will be tasked with energizing and motivating the organization. This begins with a purposeful and pointed conversation about business today and the future.

IV. Conclusion

The challenges facing mining enterprises today are pushing leaders to abandon the traditional ways of thinking about their business to discover and explore new practices that will improve the business of mining. The future of the mining enterprise is characterized in all aspects of the business, from improving people and leaders, to engaging new business models and processes, to employing new techniques in developing insight, knowledge and working remotely. Most of all, the mine of the future is smarter. It responds to change faster. It is agile and flexible. Leaders looking to establish their own vision for the future must begin first by taking a critical – and sometimes painful – look inward to their own operations. Understanding their own priorities and matching them with newer practices and ideas can result in a re-imagined mining business that is both best in class and competitively differentiated. The true beginning of this change starts with an energized conversation about the future. And then, the journey begins.

“The Corporation’s current innovation projects point to substantially improving processes in current mining operations, generating high impact in productivity and environmental care and protection, as well as employee and operation safety. Without losing sight of the need to optimize operations, the company has strongly emphasized the search for new processes and technological breakthroughs to respond to the future challenges in the mining business.”

- Codelco Annual Report 2007

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