Sustainable Development Practices and the Minerals Industry

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Abstract

The consumption of non-renewable mineral and metal resources is driven by society's need for the products and services that are derived from these essential raw materials. However, the global supply of minerals is finite and demand is expected to increase as a greater proportion of the world's growing population becomes more affluent. To meet this demand, mineral resource development will likely accelerate and mining will continue to shift from developed to developing nations where the vast majority of untapped mineral deposits are located. Mining projects carry a potentially significant social, economic and environmental footprint that, depending on how the project is managed, can have a positive or negative impact on current as well as future generations. The mining industry recognizes this challenge and has adopted business practices that address the problem of how to produce minerals in a sustainable and responsible way.

Introduction

For much of history humans have relied on minerals which, until the mid-19th century, were mostly extracted by hand from small mines. Large-scale mechanized mining operations began in Europe during the Industrial Revolution and since 1900 the rate of mineral consumption has grown almost exponentially [1]. Today minerals provide the basic raw materials for a vast array of manufactured consumer goods and services including innovative products that directly address some of modern society's most difficult environmental challenges. Examples include solar panels, high performance batteries, wind mill turbines, recyclable packaging, and energy efficient light bulbs. Mining also generates significant wealth and impacts economies on a global scale [2]. By some estimates mining's total direct and indirect contribution to global GDP is more than 45%.

Because minerals are critical for sustaining the built environment and modern economies, demand for them is expected to grow as global population grows. The UN predicts that the world's population will reach over 9 billion by the year 2050 and the highest rates of population growth are expected to take place in developing nations. At the same time the population demographic is expected to shift towards a more urban and middle class distribution [3] which will accelerate the demand for minerals and metals as rising affluence drives consumption of manufactured goods and services.

Regions where rapid population growth is expected to occur also host the vast majority of earth's remaining untapped mineral resources [4]. These regions include Africa, Afghanistan and parts of SE Asia. Many of these mineral rich areas are where geopolitical risk is high, technology is limited and infrastructure is poor. The confluence of these factors has the potential for creating significant and long lasting negative social and environmental consequences. The Democratic Republic of Congo is a prime example of such a region.

To insure an adequate supply of minerals for the present as well as for the future, steps must be taken to extend the life of earth's remaining mineral reserves. At the same time economic benefits must be maximized and social and environmental impacts minimized on multiple temporal and spatial scales. Achieving this outcome is immensely challenging and complex. It requires a new business philosophy that integrates social, economic and environmental considerations into core business strategies and in day-to-day operations. Elements of this business approach include adopting strategies that focus beyond the bottom line and the short-term quarterly or annual business cycle; efficient use of resources; cradle to grave material flow analysis to understand the entire manufacturing life cycle from mine to the post-consumer terminal point for manufactured goods; and designing processes and products to deliver sustainable social, environmental and economic benefits.

Sustainable Development and Mining

One of the most broadly accepted definitions of sustainable development is "… development that meets the social, economic and environmental needs of the present without compromising the ability of future generations to meet their needs" [5]. This definition states that for development to be sustainable it must generate wealth, advance social justice, and remain within the limits imposed by ecosystem and resource availability. It also states that development today must not compromise future generations. Our challenge is to apply this concept to mining in a practical and meaningful way.

Many argue that mining is not sustainable because it extracts non-renewable mineral resources and negatively impacts the environment. This is a simplified and one dimensional view of sustainability that is more relevant for renewable than non-renewable resources. There are other overriding factors that must be considered when applying SD concepts to non-renewable resources. Although single mineral deposits are finite, an uninterrupted supply of minerals is required to sustain today's technology-based society and to generate capital that fuels the growth of the world economy. Mining converts non-renewable mineral resources into capital that sustains social, economic and environmental activities that support human development. Mining, therefore, is unsustainable when the interaction between mineral resource development and economic growth, social development, and the environment is ignored [6].

It is important to acknowledge that the mining activity or operation itself is not sustainable but that mining can be managed in such a way as to contribute to positive environmental, social and economic outcomes. This is often referred to as the Triple bottom line, or the 3 pillars of sustainability which asks business to look past short term profitability towards the longer term objectives of environmental protection and resource conservation on a local and global scale; social equity and well-being for employees and affected communities; and economic prosperity for the business, its shareholders and its stakeholders [7]. Examples of how mining meets these triple bottom line objectives include: producing the raw materials that support human civilization; generating wealth through jobs, taxes, royalties, and upstream value that contributes to GDP; and contributing to the environment by adopting land use practices that improve biodiversity, protect fragile ecosystems and reduce water use [8].

In addition to the 3 pillars there are two more pillars that are unique to mining [9]. These are resource efficiency and health and safety (Figure 1). Resource efficiency is critically important in the case of mining because minerals have a finite life economically and physically. Therefore they must be extracted, processed and used as efficiently as possible. The goal is to extend the life of these irreplaceable natural assets and to extract their maximum value for human benefit without compromising current and future generations to meet their needs. This requires a sustainable mineral supply which can be accomplished by discovering and developing new resources, substitution of functionally equivalent renewable materials (i.e. plastics, composites) for minerals, more efficient use of the resource through improved mining methods and improved processing methods, and recycling. In 2011 approximately 40% of the U.S. metal supply was derived from recycling [10]. Mining can be a high risk occupation so worker health and safety is also core to a sustainable mining industry.

Figure 1: The five pillars of sustainability for mining after Laurence [9].

Commitment to Sustainable Development in the Mining Industry

The mining industry began the process of adopting sustainable development (SD) as a paradigm for driving business value and strategy in the late 1990's. Initially the focus was at the executive level and on crafting an industry-wide commitment to SD. The next phase of implementation involved individual companies developing corporate strategies with underlying visions and goals. The final stage, and perhaps most challenging phase, was to implement SD principles at the operations level where the daily pressures of running a mining operation may be in conflict with longer time line SD programs.

Not all mining companies or mining industry sectors have moved along this trajectory at the same rate so there is a wide range in acceptance and implementation of SD practices across the industry. However, there are some general trends that describe the industry's overall progress towards sustainability. For example, most large multinational metals mining companies have embraced SD and recognize that SD not only creates shareholder value but preserves the social license to mine. Other mining industry sectors such as industrial minerals and coal have also adopted SD and corporate social responsibility as core values and within these sectors larger companies tend to be the leaders. Small scale and artisanal miners, on the other hand, have not adopted SD to the same extent. In fact many artisanal miners fall on the opposite end of the spectrum: they often extract and process minerals using practices that are not sustainable, are harmful to the environment and hazardous to human health [11].

Industry Commitment to SD

About 10 years ago the International Council on Mining and Metals (ICMM), a consortium of 22 mining and metals companies and 34 global mining associations, started down the path of developing an industry-led commitment to SD. Through this process ICMM members voluntarily adopted publically stated principles and declarations, transparent reporting following standards set out by GRI G4 guidelines, and rigorous third party certifications such as ISO 14,000. ICMM conducts an annual assessment of the progress that each member company is making against these performance commitments including the integration of 10 principles and six supporting position statements into corporate policy [12]

At about the same time that ICMM was developing the 10 principles minerals professionals representing 12 leading technical professional organizations from across the globe came together to write and sign the Milos Declaration [13]. This declaration clearly states how the minerals professional community will contribute to sustainable development and further demonstrates the universal commitment to SD across the entire minerals community.

Individual Professional Practice Guidelines

To be effective the concepts of sustainability and sustainable development must be integrated into strategic decision-making processes as well as day-to-day operations. Operations level acceptance is critical because publically disclosed position statements, codes and principles declaring industry-wide commitment to SD are only as credible as the performance of individual operations. It is up to the individual mining professional who is responsible for day-to-day operations to insure that a plant or mine is operated sustainably or that a project is designed to contribute to sustainable development.

In many companies daily operations are managed against short term financial metrics and not longer timeline SD metrics. In fact it is not uncommon for plant and mine operators to have little understanding of how their daily decisions play into these goals. This gap can be bridged through clearly stated and shared operations specific SD metrics, by including SD related performance measures in individual performance goals and by giving individuals more accountability and responsibility for SD performance. The mining industry's success in improving health and safety outcomes demonstrates the importance of individual worker commitment to a safe mining operation. The same holds true for SD.

Mining Life Cycle Framework for Sustainable Development

The life of a mine consists of discrete phases or activities that together comprise the mining lifecycle (Figure 2). This lifecycle applies to all mined materials including coal, industrial minerals, metals, and precious metals. It provides a framework for both understanding and managing the environmental, social and economic impacts of mining at every stage of the mining project (Table 1)

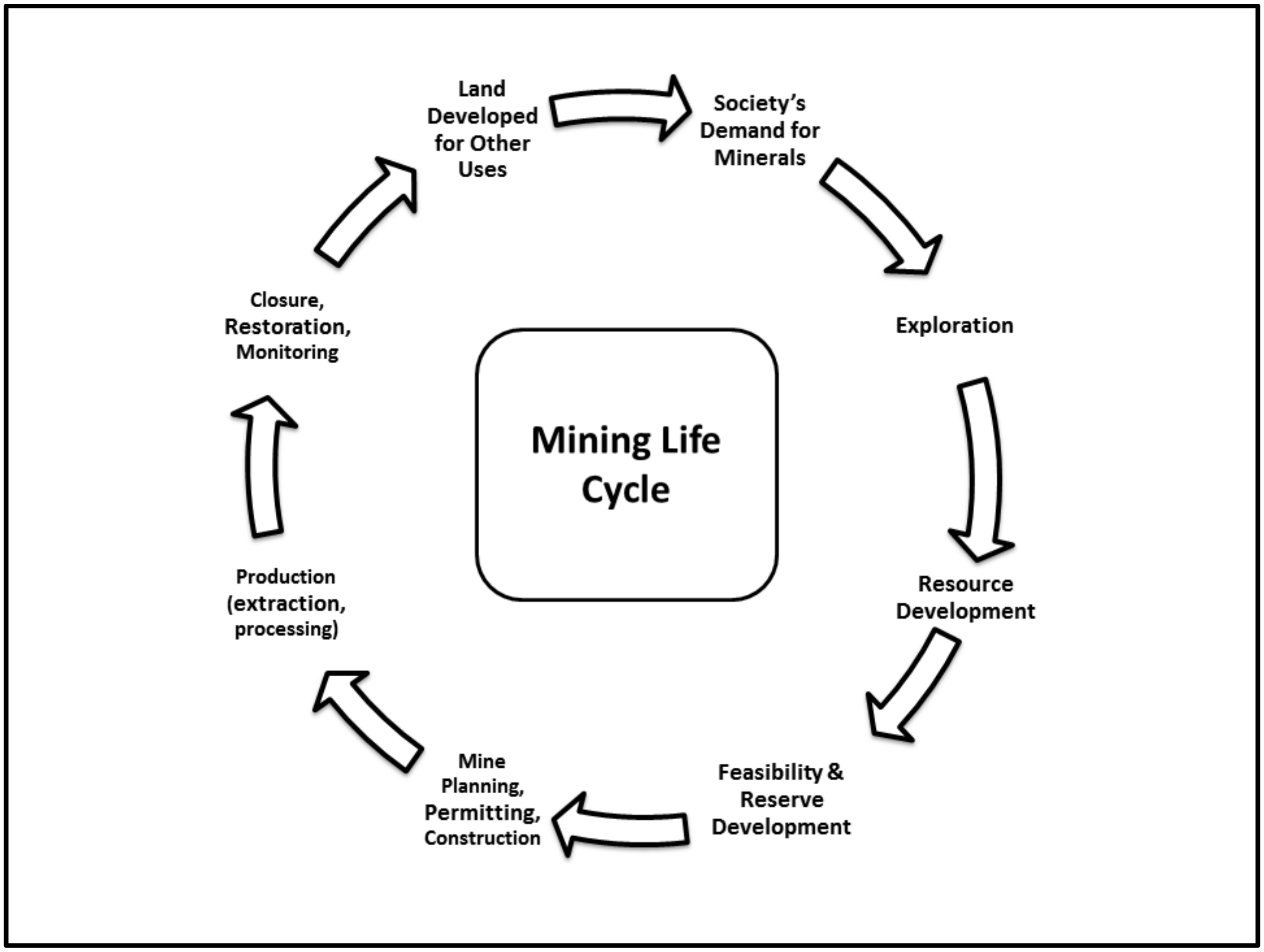

Figure 2: The Mining Lifecycle

<u>Exploration</u>

Exploration focuses on the discovery of new mineral deposits and typically takes place in two phases. The first phase involves searching for a deposit on the surface. It may begin with a geologist identifying promising areas and then searching for signs of mineralization. Prospectors rely on outcrops, stream beds and road cuts for clues to subsurface geology. Stratigraphic position, topographic elevation or geomorphologic features are also commonly employed prospecting tools. In addition to these simple tools, more sophisticated approaches such as geophysical surveys, remote sensing, and geochemical analysis may be used to gather information about potential mineral deposits. Once a deposit has been located, the second phase of exploration usually involves drilling into the subsurface to recover samples for testing. Typically a small number of test holes are drilled on a random or widely spaced grid pattern to confirm the discovery.

At this point the social and environmental impacts of exploration drilling such as noise, water contamination, soil erosion, disturbance of wildlife habitat, disruption of land use for other activities (i.e. farming, hunting, timber, community recreation) and disturbance of culturally significant sites must be considered. These impacts are important because, if mismanaged, the

Table 1: Mining lifecycle stages and impacts at each stage.

	Activities	Environmental Impacts	Social Impacts	Economic Impacts
Mineral Resource Development	Drilling, Feasibility, Mine Planning, Mine Design, Permitting	Land Disturbance, Vegetation Disturbance, Noise, Dust, Water Consumption, Energy Consumption,	Worker H&S, Community H&S	Jobs
Mine Development & Operation	Infrastructure Development, Overburden Removal or Underground Mine Construction, Ore Extraction	Land Disturbance, Noise, Dust, Asthetics, Water Consumption, Energy Consumption, Water Discharge, Air Emissions, Biodiveristy Protection, Resource Efficiency	Worker H&S, Community H&S, Capacity Building, Skills Development, Enhanced Community Services,	Jobs, Royalties, Taxes, Capital Investment
Ore Handling	Transport ROM to Plant (truck, pipeline, conveyor, other), Storage	Land Disturbance, Vegetation Disturbance, Noise, Dust, Water Consumption, Energy Consumption,	Worker H&S, Community H&S	Jobs
Processing	Crushing, Screening, Grinding, Separation, Concentration, Particle Size Fractionation, Physical or Chemical Removal of Contaminants, Drying	Waste Generation, Recovery and Reuse; Water Consumption, Contamination, Discharge and Reuse; Energy Consumption and Recovery; Air Emissions, Resource Efficiency; Noise	Worker H&S, Community H&S, Capacity Building, Skills Development, Enhanced Community Services (water, power, roads, schools, hospitals)	Jobs, Royalties, Taxes, Capital Investment
Transportation	Product to customer by rail, truck, ship.	Air emissions, Noise, Dust	Worker H&S, Community H&S	Jobs
Waste Disposal	Process and mine waste to, impounds, backfill or deep well injection	Land Surface Disturbance , Water Contamination, Aesthetics	Worker H&S, Community H&S	Jobs
Closure	Backfilling, Removal of Equipment, Removal of Buildings & Pipelines, Monitoring, revegetation	Waste Disposal, Biodiversity Protection, Water Discharge, Aesthetics	Worker H&S, Community H&S, Future Land Use	Jobs, Revenues from post mining land use (timber, agriculture etc)

company risks losing its reputation and social license to operate. This license is not a physical document but refers to acceptance of the mining company and its projects by the local community. The social license to operate is earned by developing and maintaining good relationships with all stakeholders and is based on open dialogue, transparency, timely responses to community concerns, and ethical behavior.

Resource Development

The next step towards bringing a deposit into production involves drilling the deposit on an increasingly dense grid pattern. Closely spaced drilling is required for estimating the size of a mineral resource which is defined as a mineral deposit of sufficient size and quality to have "reasonable prospects for economic extraction." According to this definition, which is used by most codes governing resource and reserve estimation, there are three pieces of information needed to evaluate the resource potential of a mineral deposit. These are tonnage and grade, and economic viability.

Methods used to estimate tonnage and grade include calculations based on maps, cross-sections and spreadsheets as well as calculations based on 3-D computer-generated geostatistical modeling techniques. Economic viability is determined by deposit depth, deposit continuity, distance to the processing plant, distance to market, access to transportation, availability of basic infrastructure (roads, power), and other cost factors. The economic assessment completed at this stage is very preliminary and serves to determine the feasibility of the project and the risk associated with continued investment.

Environmental and social considerations are also examined at this stage of the mining project. Often this is done through the formalized process of environmental and social impact assessment (EIA and SIA). EIA focuses on the project's physical and biological impacts on the natural environment while SIA focuses on the project's social impact on the local community.

Feasibility Studies and Reserve Development

Feasibility studies are detailed engineering and economic analyses that include mine design, cash-flow analysis (capital cost, operational cost, and revenue), mineral processing flow-sheets, closure plans, reclamation plans and plant design. Feasibility studies are used to delineate the reserve which is the portion of the measured or indicated resource that is economically minable. There may be additional drilling at this stage as well as continued environmental work including wetland delineation, submission of permit applications to appropriate local and federal agencies as well as baseline monitoring.

Mine Design, Construction and Production

Mine design and planning encompasses a broad range of activities that are mainly concerned with determining the size of the mine, mine layout, mining method, production requirements, and equipment needs. The mining process begins with designing a mine that takes into account the geotechnical aspects of the site. In the case of an open pit operation, the mining engineer designs the highwalls and ramps to reduce the risk of wall failure and ensure safe working conditions. The same considerations guide the design of underground operations.

The next step is to construct the mine. All required local, state or federal permits must be secured before this stage can begin.

Overburden is removed using scrapers, excavators or loaders. Once overburden is removed ore is extracted using a range of methods including loaders, dredges, drag lines, blasting or hydraulic mining. For open pit mines cut and fill methods are used whereby overburden removed from the first pit is stockpiled and then the overburden from each subsequent pit is placed in the previously mined out pit. The in-filled area is then sloped and graded in preparation for re-vegetation and final reclamation.

Construction of underground mines involves digging shafts and underground excavations to access the ore. The geometry, depth, and orientation of the ore body determine the mining method used for ore extraction. At this stage structures including headframes, hoisting-machine buildings, machine repair shops, and other administration buildings are constructed on the surface however most of the mine's footprint is underground.

<u>Closure and Reclamation</u>

After the ore has been removed, the mine is closed and the land is graded, re-vegetated and developed for a variety of post mining uses that, if managed appropriately, will bring long term value to the local community. Some common examples of land use after mining include wildlife habitat creation, community recreation areas, timber plantations, farming, hunting, agriculture and fishing. Community engagement is important throughout this process because communities are left with the land after it has been mined and the best outcomes occur when communities have a role in deciding how to repurpose the land.

Companies focus significant resources on this critical phase of the mining life cycle. In addition to re-vegetating the land, constructing ponds or creating wetlands they establish environmental monitoring programs of the site to ensure that there are no long term environmental issues after the mining project has finished. Mismanagement at this stage puts a company's reputation at risk.

A Vision for the Future

William McDonough and Michael Braungart in their 2013 book, *The Upcycle: Beyond Sustainability*, introduce the concept of constantly improving and moving from being "less bad" to becoming "more good" [14]. They call this the upcycle. Conventional eco-efficient approaches are aimed at reducing or minimizing damage with the goal of shrinking negative footprint. This is where many companies focus their efforts today. They do this because becoming more efficient generates positive results to the bottom line. However, even better results may be realized by going beyond efficiency and focusing on sustainable value generation through innovation that creates a "positive footprint" [15].

So how do we go from "less bad" to "more good"? How do we harness the value that mining generates and use it to not only solve real social, environmental and economic problems today but to create a better future for the next generation? The answer is not simple but there are 4 areas where the industry needs to shift or sharpen focus [16].

- People affected by mining must be treated fairly and with respect.
- Mining companies must create a culture of transparency by being more inclusive in engaging with stakeholders including NGOs.

- The industry must step up efforts to support social and economic development especially in underdeveloped countries where wealth tends to be concentrated in natural capital (minerals, oil, gas) while wealth in advanced economies tends to be concentrated in physical and human capital thus creating disparity between the two.
- As grades decline and demand for minerals grows, the industry must change the way it operates through innovation, new technologies and new processes.

It isn't up to industry alone to make changes. Other stakeholders must participate. Local and national government agencies must enact policies that support this commitment; the public must engage with open minds and with a willingness to participate in the process; mining professionals in both the private and public sector must innovate and seek new solutions to technical problems that are barriers to sustainability; non-government organizations and the international community must be at the table as well. Through collaborative problem solving the mining industry will meet the SD challenge.

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