CHAPTER 2.7

Project Management

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Projects come in many shapes and sizes. Recent data show that more than 50% of projects have cost overruns and more than 40% have scheduling problems. The reasons behind these problems vary, but in most cases it comes down to poor project definition and preparation. Environmental concerns and the evolution of the associated actions and remediation requirements have also affected project management in the industry. Increasing social licensing issues also further complicate projects. These issues are evident worldwide, are difficult to estimate, and can greatly upset scheduling efforts.

Financing of a new project, particularly for smaller developing companies, depends on the availability of funds. Investors and major financial markets are demanding greater transparency, and many have special reporting needs, such as National Instrument 43-101 (2011) in Canada and the Australian Joint Ore Reserves Committee standards (JORC 2012). Although the definitions of various required studies are somewhat flexible, there are accountability issues. Investors are becoming more astute, all pointing toward the need for improved project planning, implementation, and a multidiscipline approach.

This chapter is intended to emphasize major concepts but is not a detailed look at all project aspects. Project management has developed into a professional art, requiring many special skills to successfully implement a project. We tend to mostly talk about new developments when discussing projects, which is the case in mining and will be the case in this chapter. However, a project can be a modification; a change of methodology; a change of philosophy; an operation suspension; a remediation; or another, less evident change. Project principles and organization are required for all types of these changes.

PROJECT CYCLE

Mining, by its nature, is a temporary activity, with a beginning, an operation, and an end; there may even be repetition of the same cycle as prices change or exploration and development provide added resources. All phases of the mining cycle require some level of planning and financing, and there is a need for a holistic, complete-cycle approach. The cycle is long, with major investments required over a long period of time before the cash flow becomes positive, as illustrated in Figure 1.

Exploration

The first group on the ground is comprised of exploration prospectors and geologists. They have the huge task of discovery and resource delineation. At the preliminary exploration stage, large areas are often evaluated by airborne or ground-based mapping or sampling surveys of the earth's surface done by prospectors and geologists. From maps and existing data, specific areas are singled out for more detailed studies. If valuable mineral potential is indicated, a "claim" is staked by way of an online, computer-based application system.

The second stage of exploration involves more detailed surveys, including mapping, sampling, and diamond drilling (often at great depths) to determine the size and shape of the mineral deposit. In addition, data collection for environmental studies begins at this stage. Some preliminary samples should also be taken for a preliminary metallurgical evaluation.

There is a tendency to become enamored early when mineral indicators are encountered. This excitement must be tempered as costs increase with further exploration and the reality of a resource base to justify further expenditures must be established.

A "mineral resource" is a concentration or occurrence of solid material of economic interest in or on the earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade (or quality), continuity, and other geological characteristics of a mineral resource are known, estimated, or interpreted from specific geological evidence and knowledge, including sampling. Mineral resources are subdivided, in order of increasing geological confidence, into inferred, indicated, and measured categories (JORC 2012).

For a resource to become a reserve, all aspects of a project must be addressed, including various modifying factors. The typical breakdown of inferred, indicated, and measured resources required for various study levels (conceptual study, prefeasibility study, and definitive feasibility study) is illustrated in Figure 2 and Table 1.

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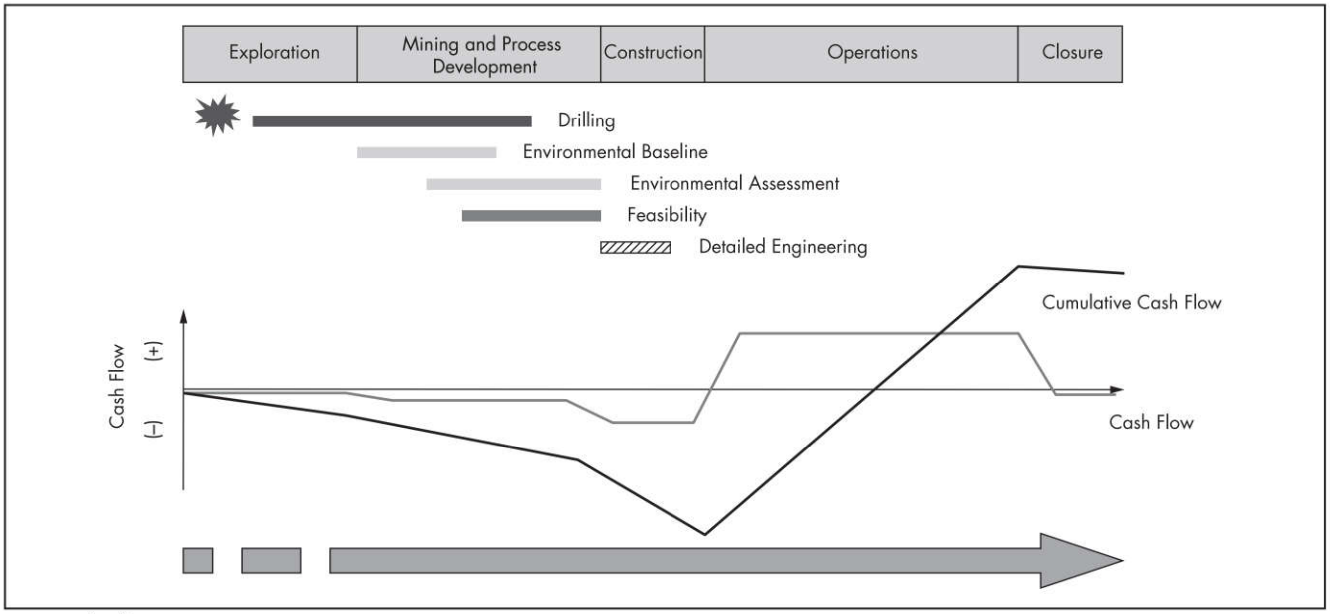


Source: Schnell 2013
Figure 1 Typical mining cycle

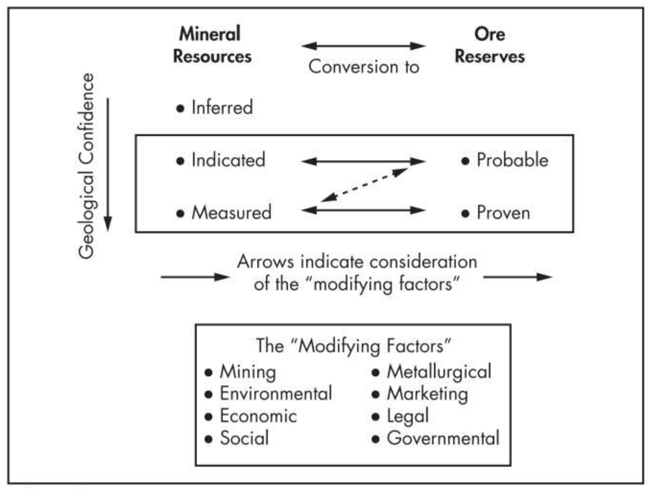
Mining Development

Mining is initially investigated based on preliminary ore-body knowledge and geological engineering data. Mine design can only be optimized once geology is sufficiently understood at the deposit and more local scales. Optimization is achieved through an iterative and collaborative process that takes into account the vast array of geological, mine engineering, scale of operation, cost, and processing factors. Ultimately, successful mine design and production scheduling deliver ore that is suited to the flow-sheet and plant requirements.

Process Development

Metallurgical data are initially collected from core or chip sampling through laboratory test work with input from mineralogical and geological logging. Flow-sheet optimization occurs after several stages of test work have taken place and is achieved through an iterative and collaborative process based on geology, feed grade, physical properties, throughput, and costs and is closely linked to the mine plan. Finalization of the flow-sheet and plant design requires a demonstrated environmentally acceptable method for tailings disposal and consideration for future closure and remediation.

As a project moves from conceptual study to definitive feasibility study evaluation, there is a growing degree of interaction among geology, mining, and processing, and these relationships become more complex. Common examples of such relationships include the deposit structural framework (faults, shear zones, rock mass fabric) that may influence mining; the alteration type and mineralogical associations, including contaminants that may influence processing; and the ore hardness, which may influence both mining and processing. Assessing the sensitivity of the ore reserves to the cutoff grade is a further example. This is an area that requires a good understanding of the relationship between the grade distribution and a range of mining and processing parameters (e.g., the selective mining unit size, head grade, and metal recovery). Poor handling of the geology–mining–processing interface usually leads to serious issues such as loss of value, missed opportunities, and project failure.



Adapted from JORC 2012
Figure 2 Moving a resource to a reserve

There is a tendency to focus on mineralogy, with a geological emphasis, but flow-sheet development and processing is most influenced by the gangue ore matrices. All testing also needs to look at other possible sub- or by-product options. Modern process development is more and more considering not only sustainability but also development of "comprehensive" extraction technology.

Construction

The construction phase will be variable, often with some preliminary construction or phased construction proceeding during the study phase. Part of this is due to needs for exploration

Table 1 Typical resource/reserve breakdown for study levels

Study	Inferred, %	Indicated, %	Measured, %	Typical Breakdown, Inferred/ Indicated/Measured, %
Conceptual study	70–100	0–30	—	80/20/0
Prefeasibility study	30–40	30–60	0–20	40/50/10
Definitive feasibility study	10–30	40–60	20–60	20/30/50

Table 2 Historical study nomenclature

Author	Date	Level I	Level II	Level III	Level IV
Taylor	1977	Preliminary	Intermediate	Feasibility	—
Hustrulid and Kuchta	1995	Conceptual	Preliminary	Feasibility	—
Barnes (reported from Australia)	1997	Resource calculation	Preliminary evaluation	Feasibility	Basic engineering
		Preliminary	Indicative	Definitive	
		Scoping	Preliminary	Detailed	
		Order of magnitude	Prefeasibility	Bankable	
Mackenzie	2006	Scoping	Prefeasibility	Definitive	—
Bullock	2011	Preliminary feasibility	Intermediate feasibility	Final feasibility	Basic engineering
Most common usage	2000–present	Scoping	Prefeasibility	Feasibility	Basic engineering

Adapted from Bullock 2011

or start of the mine pre-stripping development. Early in the project, there is a need to have a conceptual, holistic vision to avoid future demolition, prevent interference with mine development, and avoid environmental and social issues.

The construction phase on many high-investment or high-risk projects is phased to minimize capital investment, reduce risk, and allow for early production or long start-up cycles. These decisions need to be based on well-defined economic models, taking into account future production interferences and considering expansion options and flexibility as part of the facility design, reducing future investment.

Operations

Mine production involves the extraction of ore, separation of minerals, disposal of waste, and shipment of ore minerals. Additional exploration may lead to the discovery of additional mineralization that leads to expansion of the operation during the mine life. These expansions must involve the full cycle of studies, evaluations, and permitting processes that are required for a new mine development.

Closure and Reclamation

Mine closure is the last phase of the mining cycle. Shutdown and decommissioning involve the removal of equipment, the dismantling of facilities, and the safe closure of all mine workings. Reclamation, which in fact occurs at all stages of the mine life cycle, involves earthwork and site restoration, including revegetation of waste rock disposal areas. The final stage is monitoring, which includes environmental testing and structural assessments that commonly continue long after the mine is closed.

Mining is a temporary land-use activity. The goal of a reclamation plan is for areas affected by mining activity to host self-sustaining ecosystems that provide a healthy environment for fish, wildlife, and humans.

STUDY DEFINITIONS

The various stages of the project cycle are not absolute, and part of a cycle may be repeated several times before the project advances. It is important that the whole project team, the owners, and the investors have a common understanding of the language and expectations of each part of the project cycle. Each stage of the study needs to have an end, including a formal report, with a review process and approval for advancing to the next stage.

Terminology

In general, there is no international agreement on the terminology for each stage of a feasibility study, and there is no agreed-upon standard for quality or accuracy. Various publications do provide a set of standards that are becoming more widely used. Although it is convenient to refer to scoping studies, prefeasibility studies, and final feasibility studies, in reality the study process is iterative and increasingly detailed (McCarthy 2015).

There is a large variety of titles used for the various studies. Historically, the various studies were just categorized as Levels I to IV, with Level III signifying feasibility and Level IV representing basic engineering. Most common today are the terms *scoping*, *prefeasibility*, and *feasibility*. Various teams have used some poetic license to name studies, generally because there may be a gap in applying all required criteria (e.g., while waiting for environmental permits, social interaction, or even final resource figures). Table 2 lists the nomenclature that has been used by various authors.

Scoping Studies

A scoping study is carried out very early in the exploration phase as a basis for acquiring exploration areas or making a commitment for exploration funding. At this stage, the investment risk may be relatively small, but it is obviously undesirable to spend money on something that has no chance of coming to fruition.

The major risk at this stage is for a viable mining project to be relinquished due to an inadequate assessment. For this reason, it is essential that experienced people be involved in the scoping study. The intended estimation accuracy is usually 30%–35%, although some companies accept ±50%.

It is acceptable for scoping studies to be based on very limited information or speculative assumptions in the absence of hard data. The study is directed at the potential of the property rather than a conservative view based on limited information.

A sensitivity analysis, however, should present the likely range of possible outcomes so that decision making, including investment decisions that may follow a public release of the study results, is not biased to the optimistic end of the range. It is important in this phase to identify all the potential risks and determine what trade-offs are required to minimize these risks in the next phase.

Prefeasibility Studies

Prefeasibility studies are an essential part of mining projects as a basis for committing to a major exploration program following a successful preliminary geo-metallurgical program. These studies are used to attract an investor to the project or partner or as a basis for a major underwriting to raise the required risk capital. A prefeasibility study may also be prepared in full or in part by potential purchasers as part of the due diligence process. It is also necessary to provide a business case for proceeding to a final feasibility study.

The prefeasibility study must be prepared with great care by experienced people, and its conclusions should be heavily qualified wherever necessary. Assumptions and trade-off studies should be realistic rather than optimistic, because it is very difficult to bring management and markets back to reality in the event that the final feasibility study is significantly less favorable.

It is also very important to include *all* potential mining, processing, environmental, social, and location options with associated trade-off studies. At this stage, many options can be more easily and cost-effectively evaluated at minimal cost, whereas in the final feasibility study it is much more expensive. Failure to review a large variety of process options generally leads to "second thoughts" during the subsequent feasibility study or even during engineering, causing project delays and cost overruns. A single preferred go-forward process alternative is the objective of the prefeasibility study and is supported by a solid business case and risk analysis.

Final Feasibility Studies

The final feasibility study is usually based on the most attractive alternative for the project as previously determined in the prefeasibility study. Moving forward into a feasibility study with more than one option increases costs significantly. The aim of the study is to remove all significant uncertainties and to present the relevant information with backup material in a concise and accessible way. The final feasibility study has several key objectives, including

- To demonstrate with reasonable confidence that the project can be constructed and operated in a technically sound and economically viable manner;
- To provide a basis for detailed design and construction;
- To provide a Class 2 capital estimate, operating cost, and project schedule for the go-forward design case; and
- To enable the raising of funds for the project from banks or other sources.

The term *bankable* is sometimes used in connection with final feasibility studies. This just means that the study achieves a quality and standard that would be acceptable for submission to bankers. Whether a bank will actually lend against the project is another question, depending on many matters that are outside the control of the feasibility study team.

Whether the project design has been optimized in the feasibility study will depend on the time and budget allowed. Often a suboptimal—but acceptable—design is used as the basis of the feasibility study, with further optimization undertaken (or not) once the project has been approved. Outstanding issues and options at the end of the feasibility study will lead to cost uncertainty and (most likely) cost overruns.

The feasibility study is only one step along the design path. Much more work must be undertaken during the detailed engineering phase that follows project approval. The engineering work usually overlaps and is ongoing at some level through to project completion, commissioning, and early production.

STUDY COST AND QUALITY

Projects are costly—cost reduction is ever present, and studies are particularly heavily scrutinized because they occur early in a project and do not add to production. However, the cost of a study, its content, and its level of detail directly affect the final project, control costs, and help limit cost overruns.

Study Variables

A final feasibility study will cost approximately 3%–5% of the final project costs. Some mining companies will exceed this investment to reduce risk. In addition, innovative solutions or technology will increase risk and costs at all levels of studies. These costs exclude the exploration costs required to achieve a suitable reserve to support a project. Interestingly, companies may announce the start of feasibility study work, suggesting that the study will be positive—but undertaking a study does not guarantee positive results. Table 3 lists the typical variables that are used to determine study accuracy at various levels.

Costs

The earlier the team is assembled, the more opportunities there are for the team to challenge and affect the overall project budget. It is the combination of all disciplines early on that creates the balance needed to create a successful project. This signifies that early in the project, seemingly small decisions made by a small project group can significantly affect the final project cost. As the project progresses, the concepts are better defined, with costs increasing and making changes less possible.

It is normal to continue to question project costs and estimates. Experienced cost experts should estimate project costs, keeping in mind the estimate accuracy in relationship with the amount of work undertaken at each study stage. Project cost estimate reviews, known as "tollgate reviews," should be undertaken at each stage in an open, multidiscipline environment to vet the technical and economic concepts.

"Value engineering" is often used to achieve an optimum balance among function, performance, quality, safety, and

Table 3 Typical study variables

Factor	Conceptual	Prefeasibility	Feasibility
Objectives	To generate a range of viable options	To examine all options and select one option for feasibility	To maximize "value" and make a decision on mine development
Database	Limited, mostly assumed	Better, mostly assessed	Large to very large, calculated
Reserves	None	Probable	Proven
Accuracy, %	±30 to ±50	±20 to ±25	±10 to ±15
Typical duration, months	2–9	9–18	12–24
Typical cost, US$	50,000–200,000	0.5 million–1 million	1 million–5 million
Typical staffing, no.	2–6	5–20	15–50

Adapted from Bullock 2011

cost. The proper balance results in the maximum value for the project. This should really be part of the philosophy within each discipline as the project progresses. Be aware that the compromises made in such value engineering exercises will result in hampering or even preventing project goals from being achieved. In recent years, management at many companies has tried to help the project team better understand the business drivers. Decisions are then based on the key performance indicators for the project and any other key risk areas for the business.

Study Content

Most studies have similar content, adjusted in certain cases to emphasize project priorities. It is recommended that the main study volume be kept to a reasonable length—say, a thickness of 2 to 3 in. for a feasibility study to make it readable, with the details contained within a series of extensive appendices. A typical table of contents is as follows:

- Volume 1: Summary Report
- Volume 2: Geology and Ore Reserves
- Volume 3: Mine Planning
- Volume 4: Mine Plant
- Volume 5: Design Criteria, Mineral Processing, and Metallurgy
- Volume 6: Consultants' Reports
- Volume 7: Side Studies
- Volume 8: Environmental and Socioeconomic Factors
- Volume 9: Quotations and Proposals
- Volume 10: Project Planning and Execution
- Volume 11: Cost Estimates
- Appendices of all background information

ENVIRONMENTAL IMPACT STUDY

One part within the feasibility study is the "Environmental and Socioeconomic Factors" section. These studies need to start very early in the project cycle, even with the first prospector on the ground. The environmental impact study (EIS) is often done by a consultant who specializes in this type of work. It is becoming more and more important to establish the go-forward process option for the EIS. Changing direction later has the potential to delay the permit issue and the possible start of the permit schedule. A typical table of contents for the EIS includes the following but may require other specific areas in consultation with state and local authorities and stakeholders:

- Executive Summary
- Statement of Project Objectives
- Identification and Description of Project Alternatives
- Rationale for Selection of Preferred Alternatives
- Detailed Project Description of Preferred Alternatives
- Description of Existing Environment
- Description and Evaluation of Predicted Impacts
- Social and Economic Impacts to Local Communities
- Identification of (and Commitment to) Mitigation and Enhancement Measures and Appropriate Post-EIS Studies
- Impacts to Historic and Cultural Sites, Particularly Sites of Significant Importance to Indigenous Peoples
- Documentation of Public Participation Program
- Cost Analysis of Alternatives

PROJECT ORGANIZATION

Projects require a dedicated team assigned to various tasks. The team will change, expand, and add support groups as a project evolves. Oftentimes, key roles are not specifically identified or their function is not clear. It is critical that the right team members have lead roles during project evolution.

Organization

There is no single organizational approach to projects. Each project is organized to accomplish the work effectively and efficiently. Several factors influence the organizational approach to execute a project. The complexity profile of a project, the culture of the parent organization, the preferences of the project manager, the knowledge and skills of the team, and whether the project management office is in-house or outsourced are some factors that influence the project's organization. Most projects have similar functions that are important to successfully manage the project. These include

- The sponsor,
- The project manager,
- Project controls,
- Procurement,
- Technical management,
- Quality control,
- Commissioning planning, and
- Administration.

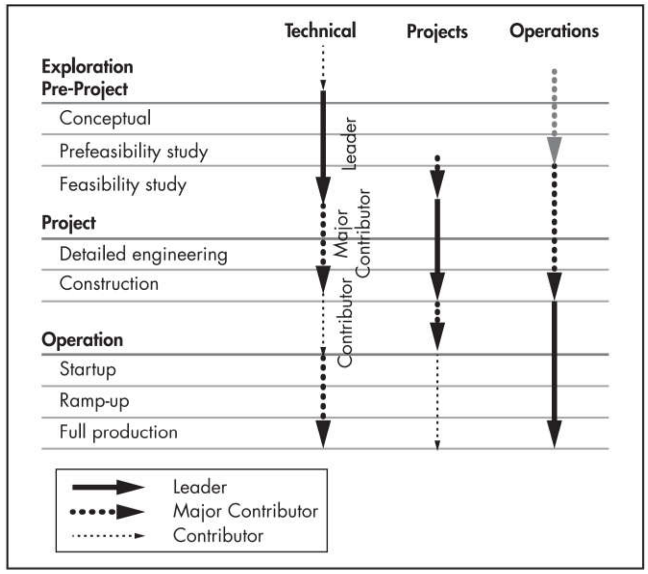
Most of these functions will continue throughout the various phases of a project. The primary leadership during a project will vary, with technical needs taking precedence early in a project until handover to the project engineering/construction/execution team and finally to the operator. Continuity is important, but the leadership should be appropriate at each stage. For example, operator input is vital, but a technical group leads during the conceptual study, prefeasibility study, and feasibility study stages. A suggested leadership model is shown in Figure 3.

Consultant Interface and Contracting

Engineering contracting, even when projects are carried out in-house, requires some form of contract between the owner and the engineer, consultant, and/or contractor. Service agreements range from fixed price to cost-plus arrangements. The former is generally preferred by purchasing departments, as this puts all the risk on the contractor but requires a high level of detail in engineering prior to award. A cost-plus contract requires careful control by the owner's team but allows for maximum project flexibility and less up-front completion of detailed engineering. Table 4 shows the available contract options for engineering that are also applicable to other types of services.

Test Work

Exploration requirements are addressed early in the project, and environmental studies are part of specialist programs for the EIS. Metallurgical and process studies are often minimized and shortened because they tend to affect the study schedule by being carried out after the geological results. As mentioned previously, it is at the prefeasibility stage that various options need to be reviewed, and in most cases this requires a wide range of metallurgical testing. It is important that samples be



Source: Schnell 2013

Figure 3 Project leadership roles

Table 4 Characteristics of engineering contract types

Type	Advantages	Disadvantages	Owner Influence	Comments
• Fixed price or lump-sum engineering	• Known capital cost • Maximum third-party liability	• Must have detailed scope • Change order dependent • Profit and risk costs added to project	• Minimal	• Good for established and well-known facility
• Engineering and procurement (EP) lump sum	• Initial cost estimated in proposal • Requires smaller owner team	• Needs good scope • Interface to construction difficult • Change order dependent • Construction errors are common	• Little influence by project team or its organization • Owner monitoring from outside only	• Profit built into lump sum • Engineering company strives to reduce its costs (to increase profit) by using vendor engineering, reduced details, and increased "field fit" construction • Difficult for modifications to existing plants • Generally, construction depends on a single general contractor
• Engineering, procurement and construction management (EPCM) lump sum	• Same as EP, except construction now integrated with engineering • Control only with EPCM costs	• Same as EP	• Same as EP	• Construction contracting is more flexible
• EPCM cost plus	• Maximum integration among owner, engineering, and construction • Availability of all systems and standards of engineering company • Available experts from within other parts of engineering company	• Requires owner control of EPCM scope and budget • Requires experienced owner team for project control • Target budget not available at beginning of engineering	• Owner control of project team • Maximum influence	• Profit is built into the hourly rates • Possible to integrate owner team into engineering team • This can be considered similar to in-house but under a third-party umbrella

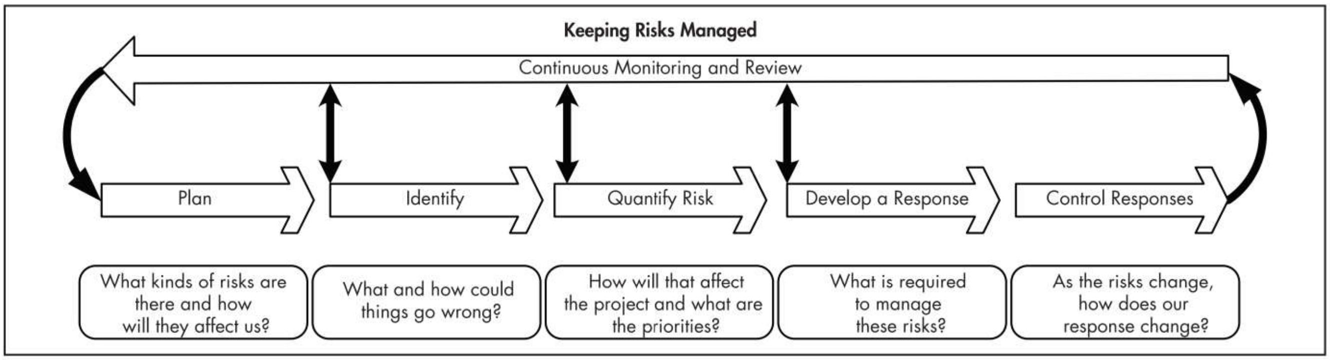
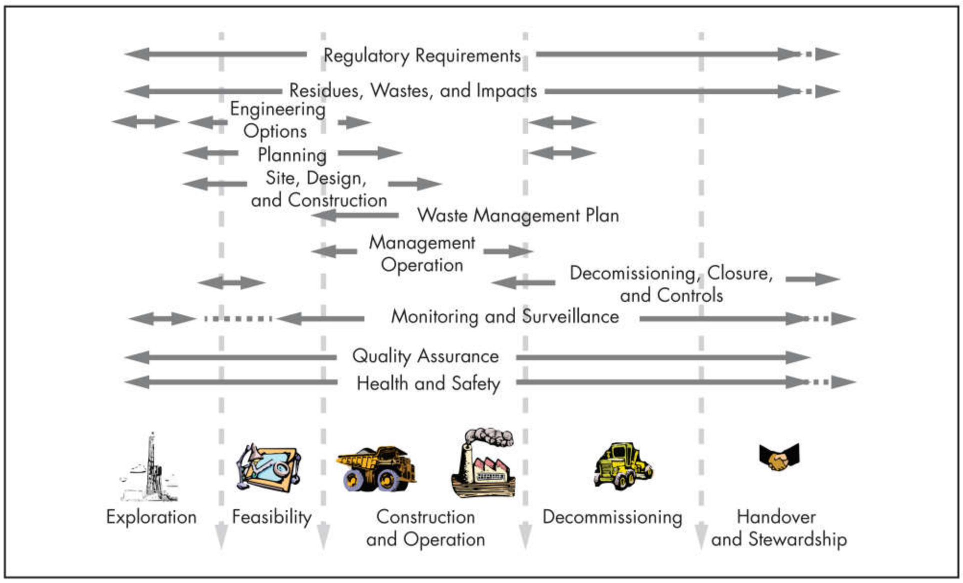


Figure 4 Risk management cycle



Source: Schnell 2010

Figure 5 Project development challenges

collected early, allowing for early mineralogical work aimed at metallurgy. Metallurgical testing covers many aspects, including the following:

- Grindability and work index
- Flotation and concentrate/tailings settling testing
- Acid and alkaline leaching
- Agglomeration and percolation
- Agitation leaching—batch and pilot
- Pressure leaching
- Heap leaching (bench and engineering)
- Recovery from solution using solvent extraction and/or ion exchange
- Precipitation/reduction
- Solution purification
- Resin in pulp—batch and pilot
- Resin in solution—batch and pilot
- Resin–ion exchange—batch and pilot

Most test work generally uses composite-type sampling, but variability testing from different parts of a deposit and different ore types is critical to avoid any future surprises.

Change Management

Changes during a project cycle are inevitable and require control. The completeness of prior trade-off studies and engineering will help reduce the magnitude and effect of project changes. These changes need to be effectively managed on both the technical side and the people side. A focus on the technical side ensures that the change is developed, designed, and delivered effectively. The discipline of project management provides the structure, processes, and tools to make this happen. A focus on the people side ensures that the change is embraced, adopted, and used by the employees who must do their jobs differently as a result of the change. The discipline of change management provides the structure, processes, and tools to make this happen.

Everyone working on a project needs to ensure that changes are communicated and subsequently controlled so that the project does not derail. Every project needs a formal change management system that evaluates the effect of a change on all areas—cost, schedule, safety, environmental permits, team morale, and so on. Project success depends on a fully developed project scope, and the investors' and stakeholders' needs must be met within the approved business case.

Risk

Mining has many risks that are continually evolving. Productivity, capital appropriation, and obtaining a social license to operate are now the top three risks faced by mining and metals companies globally (Elliott 2015). Currently, the industry faces low commodity prices, making productivity the most important issue. This will again change as the price cycle improves, but obtaining a social license to operate and environmental issues will continue to be long-term priorities. Assessment and control of risks are part of a successful project with a need to identify the risks, develop and quantify a plan, and develop response scenarios followed by control of the project. This risk cycle must be continually reviewed and modified to keep the project on track. A typical risk cycle is shown in Figure 4.

CONCLUSION

Mining projects and project management have many aspects that are not covered in this short chapter, but there are many capable consultants and professionals available to carry out the details required for each stage of a project. Mining projects are complicated and need to be systematically developed to improve the current trend of cost overruns, scheduling issues, and overall failure to deliver the business case. There are many parallel factors in a project, as shown in Figure 5. A project from initial discovery to initial production varies with the commodity, but it can take many years for a deposit to come into successful production.

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