

1993

Management of small mines

Sheikh Ateeq Ur Rahman
University of Wollongong

Recommended Citation

Rahman, Sheikh Ateeq Ur, Management of small mines, Master of Engineering (Hons.) thesis, Department of Civil and Mining Engineering, University of Wollongong, 1993. <http://ro.uow.edu.au/theses/2425>

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MANAGEMENT OF SMALL MINES

A thesis submitted in fulfilment of the
requirements for the award of the degree

Master of Engineering Honours

from

University of Wollongong



by

Sheikh Ateeq Ur Rahman, B. Sc

**Department of Civil and Mining Engineering
1993**

For

**MY Beloved Mother And Brothers Who Helped me during the Whole
Process of My Education.**

Abstract

The main objectives of this thesis can be expressed as follows:

- (i) To prove the importance of small-scale mining to the society and economy of a country,
- (ii) Why and how to manage a small mine by using different approaches,

Small mines play an important role in the socio-economic system of a country. They also provide employment to the people of remote and backward areas. A Small scale mining industry, like tourism, is a major source of income in many countries around the world and can be a good source of foreign exchange. Historically, most large mines started on a small basis which indicates that many major ore deposits are discovered by small mining companies.

Due to the importance of small-scale mining, it is not possible to ignore this important sector of the industry. It appears that majority of small mining units are malfunctioning due to a lack of proper and experienced management and due to which they receive less attention from governments and various mining agencies throughout the world. But, if small mine reserves are exploited properly, many areas in the globe can become prosperous and self sufficient.

The main objective of conducting this research was to identify the problems faced by small-scale mining operations and suggesting probable solutions. The research by the author indicates that in various countries very little work has been done on the management of small mines. Although attention was focussed on the small mining industry in the Asia-Pacific region it has been attempted seriously to cite a few examples from other countries such as India, Canada, and the US, where the small mining industry industry plays a significant role in the economy, to prove its importance.

Since, no experimental work was involved due to the nature of the project the attention was focused on a desktop study. It was also decided to emphasise small gold mines due to its importance and high unit value in the world market. The information collected during the process of this research showed that the areas like mine finance,

infrastructure, cost analysis, exploration, mine investment analysis, and different mining and processing methods should be addressed.

The author believes that further research should be carried out, in such areas as computer application, central milling facilities, labour training and education programs. The author also believes that an owner of a small gold mine should be properly informed by the state authorities and / or different mining agencies regarding pricing mechanisms.

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CF	Cash Flow Value occurring at point in time n years
DFC	Discounted Cash Flow
DCFROR	Discounted Cash Flow Rate of Return
IRR	Internal Rate of Return
NPV	Net Present Value
NSR	Net Smelter Return
PNG	Papua New Guinea
SSM	Small Scale Mining

CHAPTER ONE

**MANAGEMENT OF
SMALL MINES**

AN INTRODUCTION

CHAPTER ONE

MANAGEMENT OF SMALL MINES-AN INTRODUCTION

1.1 Introduction

The small scale mining industry has been receiving much attention during the last two decades in various parts of the world due to its impact on the development of industry and social culture, particularly in rural areas, and its most important impact on national economy. Although small scale mining is considered as a forgotten partner in most of the developed countries, because of the high labour costs and environmental restrictions, but still examples can be found in some developed countries like Finland, New Zealand and some states in the US which is considered as the most modern and developed country of the world. Small scale mining is also popular in many developing countries such as China, India, Sri Lanka, Chile, Iran, Turkey and Pakistan. The industry is playing a significant role in the socio economic system and development of these countries.

Minerals play important roles within the context of the individual country. They are a source of economic growth and formation of capital which is the basic need of every country for development and social welfare. Minerals are also an important source of foreign exchange and a good substitute for imports. Development of mineral resources make a country capable of saving the capital required to import other commodity from a foreign country, some times, not by cash and accept the hard and unacceptable terms of the supplier. This chapter presents the important contribution of minerals to the national economy in some selected countries along with a brief description of a small mining organisation. It has been tried in this chapter to present a standard definition of small scale mining.

The existence of small scale mining industry is attributed to small or geologically restricted deposit or a small market (Benkendroff, 1988). Small markets may exit because of the remote area where the demand of that commodity is not high or the necessary technical assistance is not available. Costs of mining operations can be another, and the most important factor, of small scale mining. It is not possible for the

government, large mining organisations or any other relevant mining agency to extend technical assistance to remote areas due to lack of necessary infrastructure.

1.2 Importance of Small Scale Mining

During the last two decades attention has been focused on the giant mineral extractive enterprises, the small miners (individuals and small groups) continue quietly to make a vital contribution to world exploration for, and supply of, essential mineral commodities. It is true that most, if not all, of the major producing mineral deposits and districts over the globe were discovered by independent prospectors and were, in many cases, first exploited by enterprises employing from one to fifty persons. In many underdeveloped nations, most production of mineral wealth is currently from small operations which constitute the discovery and initial development of mineral provinces and mining districts that, in many cases, has become the large mines and the major producers to supply the future requirements of expanding mineral and metal consumers. Due to the significant role of small scale mining in national economy and social structure, this sector of mining industry needs special attention of the policy makers and society to become the backbone of mineral supply process and also a potential source of future mineral wealth.

In many developing countries small-scale mining makes a major contribution to mineral production. For example, in India, 10 out of 54 major minerals are produced from small-scale mining operations. For another three minerals, 50 percent of the production is contributed by small-scale mining. According to a recent survey, 85% of all the working mines in India are claimed to be in the category of small-scale mining, which contribute 50% of the total mineral production. Table 1.1 gives an idea of average production per mine for 20 selected minerals for the year 1985 in India [Ali, 1986].

There are a large number of countries all around the world where small-scale mining not only helps in extracting minerals from deposits considered unworkable otherwise, it also satisfies the local demand of the consuming industries and stimulates forward linkage in the locality thereby bringing prosperity along with it. Not only in developing countries but a highly developed country like US has about 80 percent of the mines categorised as small mines employing less than 20 people. In the state of Colorado in US, 93 percent of mines are under small mine category employing fewer than 50 people and 80 percent employing less than 10 people.

Table 1.1 Average Production Per Mine In India (1985) [Ali, 1986]

	Mineral / Ores	Total Production ('000)	No. of Mines	Production per mine ('000)
1	Apatite & Phosphorite	944	14	67
2	Asbestos	29	77	0.38
3	Barytes	571	44	12.19
4	Bauxite	2,094	117	17.9
5	Chromite	536	19	28.9
6	Copper ore	4,209	15	280.6
7	Dolomite	2,278	122	18.6
8	Fire clay	555	236	2.35
9	Gold ore	450	6	75
10	Gypsum	1,200	74	16.35
11	Iron ore	43,118	285	151.3
12	Kaolin	703	190	3.7
13	Kyanite	31	10	3.1
14	Lead & Zinc	1,459	7	208.4
15	Limestone	47,219	548	86.2
16	Magnesite	428	19	22.5
17	Manganese ore	1,220	177	6.9
18	Silica sand	725	201	3.6
19	Sillimanite	180	10	18
20	Steatite	330	239	1.4

In Bolivia there are 4,000-4,500 small scale mines, Brazil 4,000, Peru 2,500 to 3,000, Mexico 2,500, Thailand 1,000, Malaysia & Indonesia 500 each and Burma 200. In China 10 percent of coal and 7 percent of iron ore comes from small-scale mining. Half of the coal in the US is contributed by small-scale operation. Table 1.2 indicates the percent share of small scale mining in mineral production all over the world [Ali, 1986]. Small-scale mining industry is also feasible under the following conditions:

- Small ore deposits with low value to the mineral not amenable to large scale operations.
- Spatially dispersed ore deposits.

- Spatially disperse demand for ore.
- Deposits requiring small investments.
- Deposits unexploited due to low grade reserves.

Table 1.2 Mineralwise percentage share of SSM worldwide[Ali, 1986].

Row No.	Minerals	Percentage
1	Antimony	25 percent
2	Asbestos	10
3	Barytes	60
4	Bauxite	neg.
5	Beryllium	100
6	Bismuth	neg.
7	Chromite	50
8	Clays	75
9	Cobalt	10
10	Copper	8
11	Feldspar	80
12	Fluorspar	90
13	Gold	10
14	Graphite	90
15	Gypsum	70
16	Iron ore	12
17	Lead	11
18	Manganese	18
19	Mercury	90
20	Nickel	neg.
21	Phosphate	10
22	Platinum	neg.
23	Sulphur	neg.
24	Talc	90
25	Tungsten	80
26	Zinc	11

Small-scale mining is useful for supply of minerals to small scale industries such as mini cement plants, graphite crucibles for the manufacture of pencils, heat resistant coloured tiles, insulators, potteries, pigments, glass ceramics, lapidary, etc. Even for large plants, it can play a useful role by providing minerals in small quantities for the purpose of blending. Old waste dumps having payable values can also be worked by small entrepreneurs. It suits small scale deposits with low mineral contents where resources are large but location or demands is spatially dispersed, small shallow mineral pockets where large scale operation is not feasible, deposits requiring small investment, deposits unexploited due to low grade reserves, deposits backed with poor infrastructural facilities, and deposits of strategic minerals to cut imports, etc. Too lean, too small and too difficult deposits have also been exploited by small-scale mining operations all over the world.

Small mines, unlike large mines, do not need major infrastructure or big organisation to run the day to day operation due to which small-scale mining operations are finding place in economically backward, underdeveloped or remote areas rapidly. Small mining operations are a potential source of employment to people of regions which have lack of agriculture or industrialisation sources. Governments in most of the countries want to develop their remote areas and this objective can be achieved either by setting up new industry or opening new mines, especially, small mines because smaller are more beneficial than larger. But better results can be achieved as production starts very rapidly due to short development time, unskilled labour finds more job opportunities, products can be sold in the local market and moreover raw material is available in the local market.

For example, the town of Voi in Kenya grew in 1975 due to mining of rubies and other precious stones on a small scale, and that in turn led to greater regional self-sufficiency. The introduction of brick making in Southern Botswana eliminated the use of expensive cement blocks for housing, and which made the local building industry independent of imports of cement from abroad [Wells 1984].

1.3 Need to Define

There is a noticeable lack of agreement on a definition of small-scale mining. This topic has been discussed in many international forums, but all efforts have proved fruitless. Since small mines are spread widely throughout the world and each deposit is physically, economically and politically different, due to which, it is almost difficult to gather information about these deposits regarding different properties.

But, in spite of these difficulties, it is very important to define small-scale mining due to its importance in the society so that this important sector of mining industry can be considered for further research, development and assistance. On account of limited technical, financial and physical resources, small scale operations need certain support from the government, financial institutions, equipment manufacturers, and consultants. The extension of these facilities would cover vital areas such as geological and back up information, infrastructural: manpower, water, transport and communication facilities, technical and managerial operational expertise, equipment leasing, necessary capital, marketing, taxation, environment preservation, vocational training of personnel deployed, beneficiation and custom milling.

1.3.1 Definition on the Basis of Different Possible Factors

Most people prefer to use quantitative methods of definition, while others want to adopt some measures of material output or throughput per unit of time as a criteria. There are different opinions about the upper quantitative limit and as to point of measurement. Proponents of other criteria hold out for degree of mechanisation as measured by output per man-hour or man shift, monetary units of capital investments in productive plant per unit of output or per productive worker, number of employees, or even continuity of operation. Some advocate a combination of the foregoing components of small-scale mining. There are two major components of small-scale mining, although, it is difficult to differentiate between them.

(i) Artisanal Mining

It is an old and primitive method, its techniques and technology can be traced back in the mists of pre-history. There is no noticeable change and improvement in this old method, which is characterised by the application of human energy directly on a one to one ratio to the physical production of minerals without multiplying that energy by mechanical means. It is astonishing to see that artisanal miners have devised methods and equipment to overcome the complex technical problems.

(ii) Application of modern concepts

Mining industry, recently, has undergone through a number of technical changes, the results of these changes are high production, more efficiency, less operating cost and more profit. Hydraulic excavators, wheeled loaders, trommels and jigs have replaced the old and simple equipment. These equipment are effectively used in small scale mining industry of many countries including Australia, New Zealand and Papua

New Guinea. Computer application is a new addition in small scale mining industry and this application has made the miner's job very easy. Micro-Computers, which are not beyond the limit of small enterprises, are used in various activities of small scale mining including grade control, reserve calculation planning, scheduling and feasibility studies etc. Most of these jobs are done on site by the help of micro-computers. There are a few drawbacks of these modern concepts that equipment are expensive along with high operating costs. Moreover spare parts are not available in remote areas due to which break down time is increased which affects production and efficiency. Skilled operators are required in order to operate modern equipment. These expenditures are beyond the limit of the small miners due to which small reserves can not be exploited properly.

1.3.2 Criteria of Definition

There are different criterion on the basis of which small mines can be differentiated from medium to large mines. It is interesting to note that different countries and mining agencies have adopted different definitions of small scale mining. The following is a brief list of factors on the basis of which small scale mining can be defined.

(i) Productive Capacity

Application of quantitative standards of productive activity is probably the most useful method of differentiating between size categories of mining operations. But this criteria can not be applied to precious metals including platinum, gold, diamond and other very high unit value minerals. For example, in order to produce one tonne of gold, a vast amount of material has to be moved by some of the world's largest excavating machines but production is very low as compared to metal mines or coal. If mining operations are categorised on the basis of productive capacity, then the world's largest mechanised mines would come under the rank of artisanal operations.

(ii) Number of employees

This is another criteria to define small-scale mining but this method too has certain drawbacks. Number of employees can not be the basis to classify mining operations. In most of the modern, large and most mechanised mines the labour force is less than in labour intensive mines but production is higher. Mining operations of certain categories of minerals are universally considered to be small operations.

Examples would include mica occurring in pegmatite from which the valuable minerals are hand sorted almost without exception.

1.3.3 Definition of Small Scale Mining

According to the report of “United Nations Department of Economics and Social Affairs”, any single unit mining operation having an annual production of ore of 50,000 metric tons or less, as measured at the entrance of the mines, is a small scale operation [Anon, 1972]. According to New Zealand and Australian standards, a small scale mining operation is one which has “limited ore reserve’ and produces less than 150,000 tonnes of ore per annum. US Bureau of Mines has adopted production basis and put the operations producing less than 400 short tonnes per day into the category of small scale mining. Mexico favours monetary basis and suggests gross income of less than \$ 800,000 per year from small mines. Bolivia has adopted production base definition. A mine capable of producing as much as 65 tonnes of concentrates per annum categorises the operation as small-scale mining. British Coal of UK has favoured the criterion of number of workers employed below ground. In Italy, small-scale mines are those operations where 40 workers are engaged and machinery aggregating up to 100 h.p. has been used. Some 80 percent of the US mines are categorised as small mines where less than 20 persons are employed [Ali, 1986].

A more specific definition would depend on local circumstances but given the above broad definition it is estimated that over 6,000 mines in the western world are considered small scale operations and together they make up approximately 10% of production excluding coal [Anon, 1989].

Indian Bureau of Mines has divided the Indian mines into certain categories based on pit’s mouth value (PMV) of the mineral produced for extending concessional rates for their technical consultancy to small operators. When the PMV is not more than Rs. 0.5 Millions per annum, the operation is categorised as small-scale. When PMV ranges between Rs. 0.5 to 5 Millions, the operation is medium size and for PMV exceeding Rs. 5.0 Millions, it is categorised as large scale. The PMV is calculated by multiplying the average of the production of the last three years by the all Indian average of PMV per tonne of that mineral.

It is clear from the above discussion that it is not an easy task to define small-scale mining operations, because many factors are involved in it. Most of these factors are suitable for different situations [Anon, 1972].

Consideration has been given to devising a multiple-factor definition along the lines of a mathematical formula which would utilise all significant criteria. One approach, for example, would be to assign arbitrary scale numbers to ranges of values appropriate to each variable. For each mine, as many as possible of the various scale values which could be determined on the basis of available data would be totalled and a simple mean calculated which would determine the size category of the mine. The formula could be refined to permit various degrees of weighting and in other ways made more sophisticated [Anon, 1972].

The process seems needlessly complicated, however, and perhaps more important, sufficient reliable data are not available, and are not likely to be for some time to come. Eventually, a system of this type may evolve for a particular country or area when the need arises for sophisticated and long term research into various aspects of the mineral sector.

The main aim of writing this thesis is "Management of small gold mines", but it is not an easy task to give a precise quantitative definition of small-scale gold mining. Gold deposits are physically more variable than other metalliferous deposits. It is difficult to fix a certain amount of gold as the basis of definition. It is, also, not possible to adopt a single definition based on productive capacity and number of employees.

1.4 Necessity for Efficient Management

Unlike the large mines, there is no need for the Board of Directors and line management. In the case of large enterprises, decisions related to technology, finance, planning, marketing, employment, costs and production are taken at different levels of the mining organisation in the presence of directors, presidents, general manager and other executives but in a small organisation the whole process is handled by one or two persons, especially, line management plays a key role in various decisions. But small scale mining operations can be managed effectively by a group of few people but multi skill is the basic requirement.

It is a fact that a mining enterprise exists to extract valuable minerals from the ground for the well being of the community, and to earn profit by extracting minerals with its value more than input resources. Generally, this duty is performed by Board of Directors, management at the site and the consultant engineer or his equivalent. The consultant engineer plans the future operations of the mine with the site management, following any guidelines laid down by the Board or General Manager. The site

management observes that the plans are put into effect, the consulting engineer looks after the progress, and suggests for further actions necessary to improve the performance. In order to understand "why effective management is necessary for small mines", it is important to identify the function of management. What are the duties of the manager? What kind of characteristics a manager must possess in order to manage a small mining organisation efficiently.

1.4.1 What Is Management ?

Management may be defined as the process of planning, organising, directing and controlling to accomplish organisational goals through the coordinated use of human and material resources. There are a number of definitions of management involved in the management science today. Most definitions of management do share a common idea-management is concerned with the accomplishment of objectives through the efforts of other people. The goals of most business firms, including mining enterprises, are to provide products and/or services for which they earn a profit. In order to accomplish their objectives it is necessary for managers to do the following:

Planning: Determine what is to be achieved.

Organisation: Allocate resources and establish the means to accomplish the plans.

Direction: Motivate and lead personnel.

Controlling: Compare results achieved to planned goals.

1.4.2 Management and Operating Philosophy

Most successful small operators are slightly conservative during the whole process of mining, ie. including deposit selection and other phases leading up to production. Mining probably requires a wider variety of disciplines than any other natural resource industry. Since the small operation does not need many disciplines full time, like larger mines, it is beneficial to retain those individuals with a special talent only on an as needed basis. Those typically considered are geologists, surveyors, safety specialists, mining engineers, metallurgists, mine contractors, mineral lawyers, mine accountants, hydrologists, electrical, mechanical and civil engineers. With recent tight economic conditions those still in business are generally competitive, motivated and

well equipped to put the small operator on the right track. They provide the small company with the facilities, materials and technology that have been available to major companies (Bruce, 1972). A number of marginal small operators called the do-it-yourself have the attitude that this type of talent is too expensive and not necessary. Just the opposite is true. A well planned venture can earn back the cost of good advice many times over, but a misguided venture may never succeed at all (Cope, 1981).

Small mining operations are well advised to adopt the operating practices used by mine contractors. They generally hire competent aggressive people, are quick to set up on a job, do completion in record time, and quick out with little wasted time. They employ very productive mobile equipment, easily erected and dismantled structure, and maintain close control on costs and schedules.

1.4.3 Managerial Functions

In a small scale mining operation every-body is a multi skills and has several areas of responsibility and tries to manage himself or herself by planning, organising, directing, and controlling his or her skills, talents, time, and activities. It is totally wrong to think managers only in terms of top level positions within large organisations. But actually, managers operate at various levels of different organisation, large and small business and non business. A bird's eye view of these different levels of management in a small mining company is given in Fig 1.1.

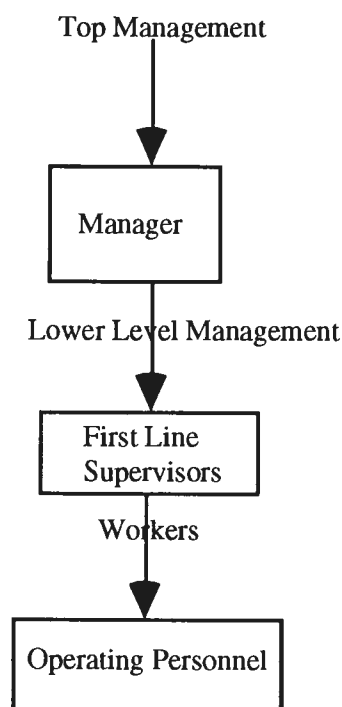


Figure 1.1 Management of small mining enterprise [Adopted from Solan, 1983]

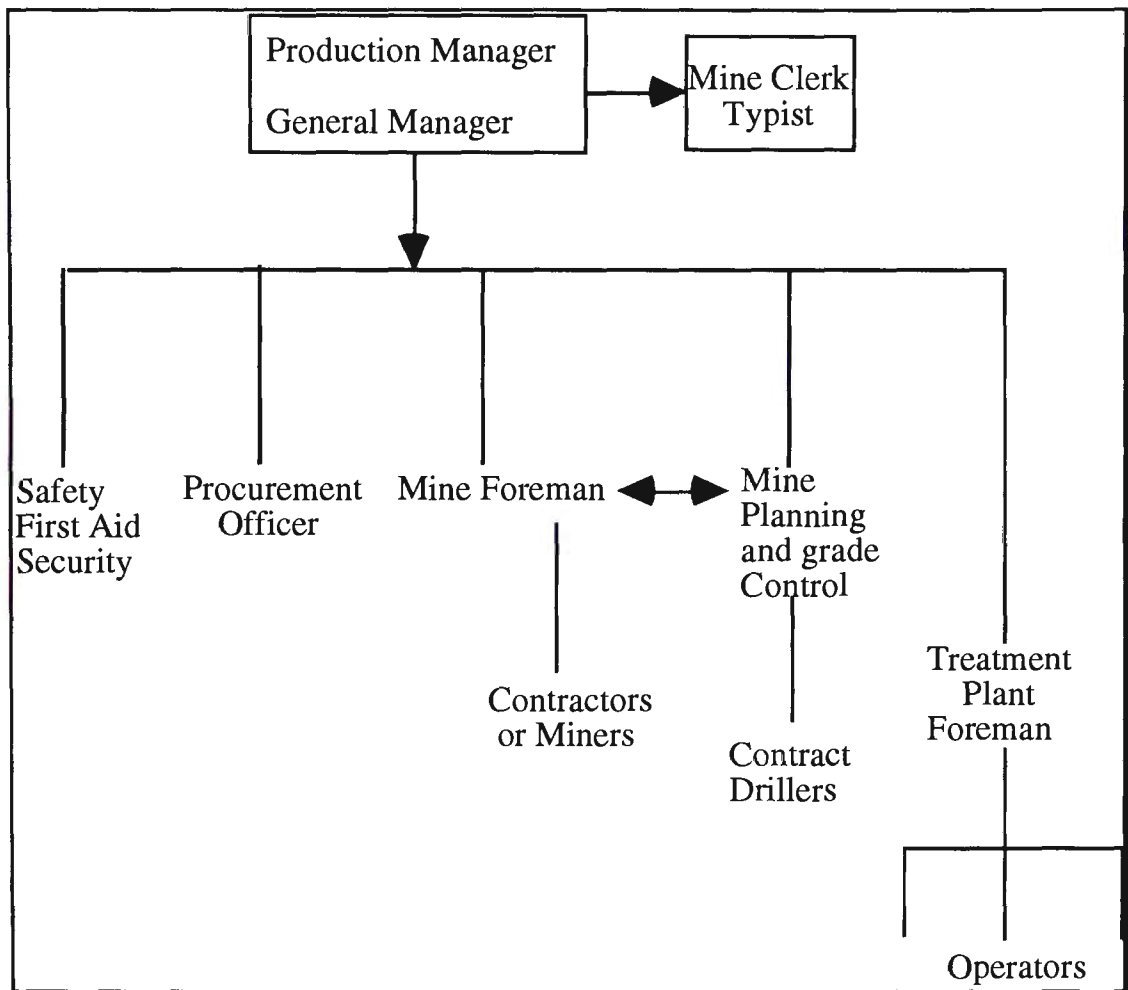


Figure 1.2 Management of small mining enterprise [Adopted from Solan, 1983]

(i) Lower Level Manager

Lower level manager, usually referred to as supervisors or site managers, are responsible to manage day to day development, production operation and employees in the performance of daily operations. Lower level managers are concerned primarily with the co-ordination of progress and activities that are necessary to achieve the overall goals of the organisation as identified by the top management.

(ii) Top Management

Finally, top management, referred to by such titles as presidents, executive directors or general managers, are responsible for providing the overall direction of the firm. Owner, or his agent, production Manager or General Manager can assume the responsibilities as top management in small mines.

Management has to be multi skilled in a small company which can be achieved by having a very flat organisation and having a team approach to task achievement. Production, planning, budgets and investment decisions need to involve all staff at least in the initial stages of preproduction. Involvement in decisions is the best means of communication. A small responsive team is in a better position to make decisions which may appear risky to a large organisation but to make such decisions management must be ware of the financial consequences of their decisions. Risky decisions, which normally give a higher financial return, can be managed by having a contingency plan and acting swiftly if things go wrong.

In order to give a final touch, a manager is person, at any level of organisation, who directs the efforts of other people in accomplishing goals. A manager is necessary in order to achieve the results wherever a group of people are working together and is the person who is responsible for making decisions concerning the use of a firm's resources to achieve better results and acts as a catalyst. The function of a manager is to establish goals, plans operations, and organise various resources. A multi skilled manager is required to manage the day to day operations of a small scale mining enterprise.

Successful gold mines are run lean and mean with flat structures and minimum employees. As mentioned above, multi skill is one of the most important component of the management in small scale mines. All the orders and memorandums are usually hand written and copied on photocopier in order to reduce double handling. Most successful small gold mines are heavily dependent on computer application which increases efficiency, profit and production. Production is scheduled together with required development and expected cost to produce a general chart and anticipated production schedule, cash flow and manning levels which are compared to actual on a monthly, three monthly, year to date and floating year average.

It is wrong to judge a manager on the basis of short term output. It is not correct to consider a manager effective if his or her unit is earning profit, or reducing cost, although it is one of the most important factors in small mining industry, or increasing the market share for the company's products, or other such measurable results. Although, these accomplishments are important to a business organisation, but a major challenge of any manager, is the development of people under his or her direction. This factor plays a major role in the development of a small mining enterprise as mostly mine labour is unskilled.

1.4.4 Management Function at Various Managerial Levels

The basic function of management planning, organising, directing, and controlling are performed by managers at every level within an organisation. But the amount of time and effort required for these functions varies according to the level of a manager within the organisation. For example, top level managers have to devote maximum time to planning as compared to low level ones. The first line supervisor must devote considerable time and effort in directing and controlling the work of others-accomplishing routine tasks.

As managers move to higher levels in the organisation, a greater percentage of their time is devoted to planning and less to directing. The amount of time spent on the controlling function is fairly consistent at all levels of management except for the very top executive level positions such as President or General Manager. General Manager is mainly concerned with over all control of resources essential to the very survival of the firm at this level of management.

1.5 Managerial Skills

A successful and efficient manager must possess and develop certain characteristics and skills in order to manage the organisation and employees properly. But the relative significance of each skill varies according to level of management and the place an individual manager occupies within an organisation. These important skills are explained as follows:

(i) Technical Skill

The ability to use specific knowledge, methods, or techniques in performing work is referred to as technical skill. Technical skill is considered vital for the effectiveness of lower level managers and supervisors because they are in direct contact with employees who are involved in day to day operation of the mines. The first line supervisor must provide technical assistance and support to the personnel within the work unit. The supervisor must possess good knowledge of mining techniques, rock mechanics, grade control and safety. As one moves to higher levels of management within the organisation, the importance of technical skills usually diminishes because the manager has less direct contact with day to day problems and activities. In the case of small scale mining this skill is very important for a successful manager because he is responsible for all the day to day mining operations.

(ii) Communication Skill

It is the skill of conveying necessary technical information orally or in written form to others in the organisation for the purpose of achieving desired results. It is a vital skill to the success of everyone, but most especially managers who must achieve results through the efforts of others. This skill is equally common at each level within the organisation. Communications are usually short, direct, hand written and copied in small mines where few employee work.

(iii) Human Skill

Human skill is the ability of a manager to understand work with, and get along with other people. Although this skill is essential at all levels of management within the organisation but especially at lower level of management where supervisors are in direct contact with the lower staff. A manager equipped with good human skill can create climate for effective motivation and leadership and this skill plays a very important role in organising small scale mining operations.

(iv) Decision Making Ability

This ability is the manager's skill in selecting a course of action designed to solve a specific problem or set of problems. This skill is very important for effective planning, especially, in small mines where managers are responsible for all responsibilities. They have to face, both, technical, environmental, and financial issues. It is not a common practice for small mine's manager to send directions by documents. But, instead, observe on the site and directs orally and immediately. He has to make correct decision according to the situations. A small mining company can only survive on the basis of effective decision making skill of managers. Effective decision making is an important skill for managers at all levels within an organisation, but it is more important to upper level managers than to lower level supervisor. Upper management's primary responsibility is to make effective decision, whereas lower level management is required to execute important decisions made by higher management.

(v) Conceptual Skill

It is the ability of the manager to understand the complexities of the overall organisation and how each department or unit fills into the organisation. This skill is extremely crucial to the success of top level executives for they must be concerned with the big picture-assessing opportunities in the environment and determining overall objectives, plans and strategies of operation. As one moves down the managerial hierarchy, conceptual skill become less important because other skills are more

important to the success of the lower level managers and supervisors. For instance, first level supervisors are able to refer to operating manuals to discover the capabilities of a particular piece of equipment whereas top levels must use their conceptual skills to determine what products will be produced with the equipment.

Professional managers recognise that they must develop and practice each of the managerial skills to be effective in accomplishing organisational and personnel goals. By looking at the importance of small scale mining economically and socially, it is very important to, systematically, manage this sector of industry, in order to increase production, efficiency and profits. There are many examples which show that many mining companies, which started their operation on small scale, were converted to large companies by adopting systematic management, latest technology and by the help of extensive exploration programs, easy approach to financial institutions and discovery of new mineral deposits in the vicinity of present ore deposits.

1.6 Factors Influencing Small Scale Mining

A number of factors must be taken into consideration while assessing the viability of small scale mining. Many of these factors are interrelated and influence the exploration, development and production of mineral deposits. Some of these important factors are exploration strategy, mining and mineral processing methods, socio-economic, political and environmental conditions.

Small scale mining activity ranges from very small operations that provides subsistence living (in many developing countries where small artisanal mining is practised) to the small companies of Canada and Australia in particular which usually discover and work relatively much larger deposits where revenue is such that subsistence living is the prime motivation.

Generally speaking, small scale mining approach is applicable to small or geologically complex deposits. Mostly ore deposits which are most applicable to small scale mining are high grade, near surface or alluvial type, containing precious or heavy metals. Exploration is not expensive and if the ore deposits are located near the surface they can be extracted without the help of sophisticated machinery. The produced ore can be easily upgraded by simple mineral processing methods, normally using the principle of gravity separation for precious and heavy metals to produce a saleable concentrate.

Small scale mining has not been the subject of large mining equipment manufacturers in past years, because small scale mining has not been considered a profitable business. But due to the extensive research on this sector of mining and the innovation of mobile and modular mills together with small scale trackless mining equipment, manufacturers have started to produce these mobile equipment and other small units necessary for small scale mining on low prices. This policy has motivated the miners to take benefit and use mechanised methods in small scale mining instead of old and artisanal methods.

The availability of this type of equipment means that small scale mining is now possible for a wide variety of minerals and is no longer restricted to certain minerals by a simplistic approach to mining and mineral processing. Also, small mines can operate in areas where high labour costs have inhibited their development in the past. Today, trackless mining methods are being employed in small underground mines using load haul dump units, diesel trucks and "mini" jumbos especially designed to operate in confined spaces. It is hoped that as trackless small scale underground mines become even more prolific greater demand will result in competitive pricing for this type of small scale mining equipment [Griffith, 1990].

The significance of small scale mining activity as an exploration tool for the mining industry as a whole has been appreciated on numerous occasions. Mackenzie [1982] stated that in Ontario during the period from 1951 to 1974 smaller enterprises incurred only 28% of the total mineral exploration expenditure, but were responsible for 62% of the economic deposits that were discovered. Although individual prospectors and small mining associations have traditionally made a significant contribution to the discovery of mineral deposits, legislation and government mineral policies are continually being introduced in many countries that discourage their important role [Griffith, 1990].

Unfortunately, exploration conducted in this manner is usually oriented to locating sizeable resources and in many circumstances the small deposits are either overlooked or considered "too small to be mined" by the organisation concerned. It is often very difficult to ascertain the size of a mineral deposit until it is mined and sometimes the size of a deposit may increase over the life of a mine as a result of on-going exploration and development work, changes in technology or economics. For example, 80% of the large gold mines in Zimbabwe first operated as smaller mines. In fact, the majority of successful large mining companies world-wide have grown out of small beginning, often on the basis small operation on a single property [Griffith, 1990].

Socio-economic, political and environmental conditions play a significant role in exploration and different activities of small scale mining. Political stability encourages small miners to increase the mining activities in order to boost the economy of a country. Certain governments have heeded the need for individual prospectors and small scale mining activities in their respective countries [Mchaina, 1987, Viewing, 1987]. Different steps have been taken by some governments in order to boost the economic situation of individual prospectors and small miners in the form of financial and technical assistance.

CHAPTER TWO

EXPLORATION AND FEASIBILITY STUDIES FOR SMALL SCALE MINING OPERATION

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2.1 Introduction

Exploration is the most important and basic concept in the whole process of mining. Feasibility studies and the later stages through development to production depend on the results of the prospecting and exploration. Exploration proves the occurrence of natural resources as well as the economic viability of ore deposits. There is confusion between prospecting and exploration as these two concepts overlap each other. It is very important for a mining company or exploration enterprise to distinguish clearly between these two concepts in order to avoid problems in the later stages. All mineral production ultimately depends upon the successful results of valuable mineral search by prospecting and exploration. It has become a trend, in recent years, to apply the term "exploration" to those steps of mineral search, where, highly sophisticated, specialised techniques and technology is used. Generally, the modern concept of exploration is applied to the searching for well-concealed mineral deposits. On the other hand, the term "prospecting" has been applied to the more traditional, less technological methods, employed by most individuals in searching for minerals.

Exploration is a very risky and expensive process starting from areal reconnaissance to mine valuation. It is very important, especially, for management of small scale mining to conduct all steps of exploration very carefully. Since most of the exploration programs do not result in finding ore deposits, the management of small scale mining should carefully consider the results of the previous step before proceeding to the next step in the series.

2.2 Prospecting and Exploration

Mining is an expensive, complicated and lengthy process. A detailed study of geology is necessary before a decision can be made to start this process. A detailed study of the stages in the life of a mine begins quite properly with prospecting and exploration. It means these two stages, prospecting and exploration, proceed to the later two stages of

mining, development and production. These two terms are closely related and transitional when concerned with locating and defining an ore body.

When discussing the exploration phase of small scale mining, a problem of definition arises due to the fact that exploration, short of the evaluation stage, is generally still very much the domain of the individuals or the small organisation-it is itself a small scale undertaking. Even in the economically most advanced countries, where sophisticated modern exploration techniques were developed, studies have shown a clear tendency for mineral exploration to become an increasingly skilled affair, in which the most successful practitioners tend to be individuals or small organisations. These organisations specialise in this activity, sometimes on their own account, more often on a contract or consulting basis. In the later case there can be no question of evaluating, developing or exploiting a discovery. In the former, owing to the high capital costs to be expected, the properties are disposed of to large mining companies for cash and a retained royalty interest only if the deposit is fairly small, and if consideration given to mining it [Stewart, 1990].

2.2.1 Role of Small Mining Companies in Exploration

While considering the importance of exploration for small deposits, it is interesting to note that most companies involved in the exploration business can be considered as small companies. Most of these companies undertake evaluation of small deposits just to assess feasibility, financial viability and later on hand over to owners of large companies for the rest of the mining process. These exploration companies do like to carry out development and production stages of mining because these two stages demand huge amounts of capital expenditure, lots of time, skill and effort. These demands are beyond the capabilities of these small companies. The smaller enterprises usually consist of companies with only one mine and limited resources, and small exploration companies that spend capital on exploration. On the other hand very few small exploration enterprises proceed towards development and production stages individually, but by partnership, venture, or funding by banks. The whole of this "go-no go" decision depends on many factors including evaluation of new data, changes in technology, recovery, market value of the product and available funding.

It is becoming very difficult for smaller organisations with less investment to work in different parts of the world, when maximum resources are required to undertake a new project. Many smaller companies have made major discoveries, some of which have resulted in large mining operations.

An analysis of metallic mineral exploration in Ontario during the period 1951 to 1974 shows that, although smaller enterprises incurred only 28 percent of exploration expenditures, their activities were responsible for 62 percent of the economic deposits discovered [Mackenzie, 1982]. Smaller companies make a significant contribution to discovery by re-examination of prospects and by exploration of and production from deposits considered too small for major companies.

A survey was conducted among the 41 major mining companies in the USA to determine the sources of their property proposals for the period 1970 to 1975. Approximately, 85 percent of all proposals came from individuals and small mining companies, something in excess of 40 percent being considered sufficiently interesting to examine and something like 5 percent in which a deal was made. Large companies both in the past and present take proposals by small companies seriously and they are, still, an important source of exploration projects [Yuill, 1985].

It can be seen from above explanation the importance of small exploration enterprises in exploration activities. By keeping this view in mind it is important to increase the efficiency of these small organisations. Government and other mining agencies, especially in developing countries, can provide substantial support to this sector of mining. The specific case is of small gold mines where primitive exploration methods are still used, and huge resources and a lot of time is wasted in some useless activities. What action could be taken in order to increase its efficiency? If small operations are successful, this sector can be very helpful in the growth of the economy.

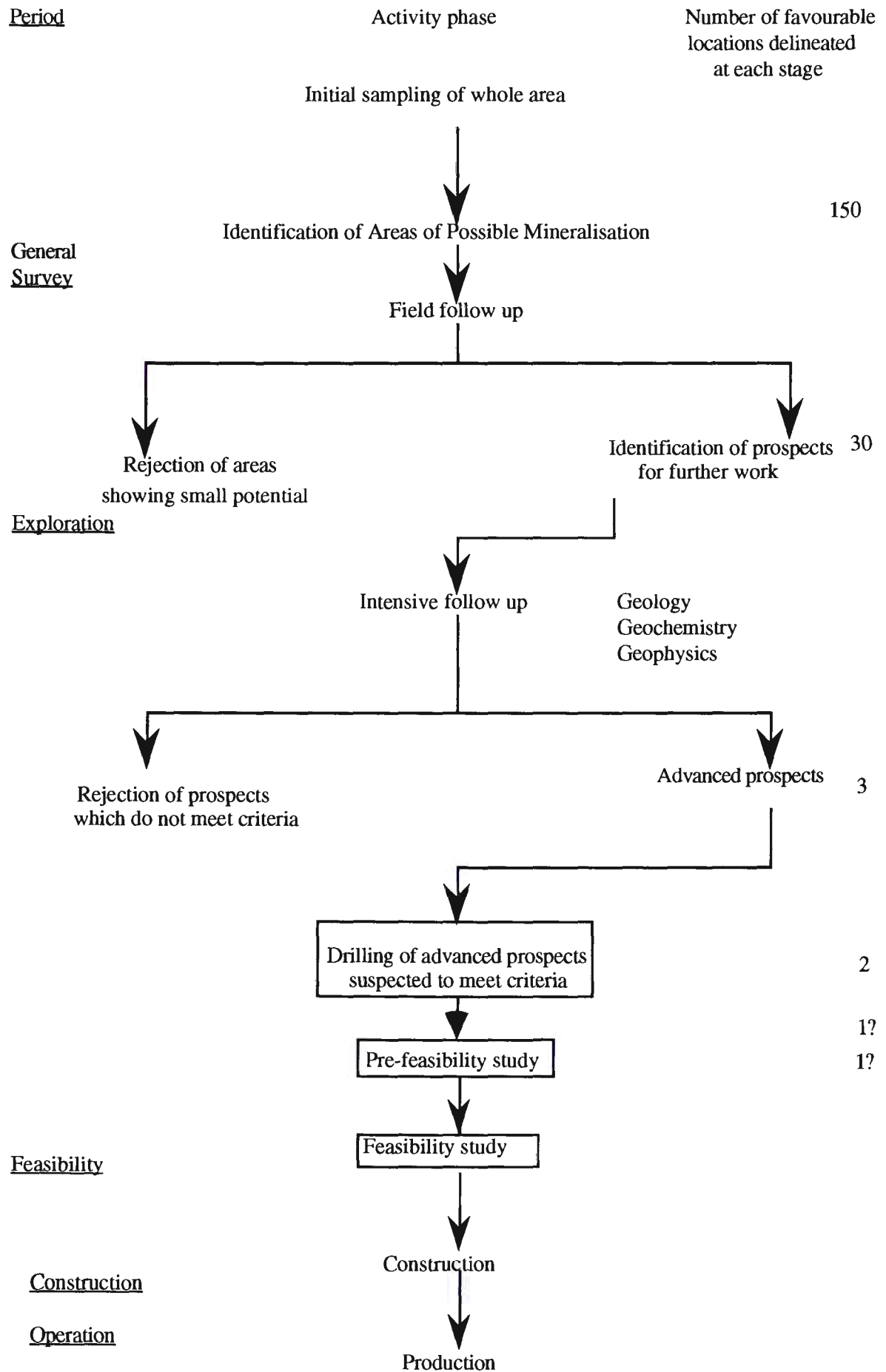


Figure. 2.1 Flow chart for discovery of a mine

2.2.2 The Prospecting Process

Prior to the middle of the nineteenth century, geologists did not involve themselves in the search of ores. Prospectors were involved in searching for ores and evaluation was made by panning and other simple techniques. Discoveries were by chance or made by following a trip of gold back to its source by panning stream sediments and it was one of the oldest and most effective techniques used by prospectors at that time. When the gold disappeared from stream sediments prospectors moved up the adjacent slopes, and continued panning the overburden until the load was found from which the gold was derived. A similar technique was used in the search for tin, tungsten, mercury and lead. The prospector used rule-of-thumb methods to locate the concentration of valuable mineral deposits. The prospector had a remarkable eye for landscape, colour variations and vegetation during their efforts to find mineral deposits.

The prospector usually worked in isolation and looked for the "float" from veins in the outwash gravels of streams or in the hill side soil, and the minute flakes of gold, or perhaps cassiterite, that had eroded from veins by weathering and stream action. It was the important capability of the successful prospector, to recognise significant minerals, as well as the discoloured and stained outcrops from which the metal values had been leached by the weathering process. The prospector developed a wonderful distinct ability, by experience, to identify minerals by scratching them with his knife or tasting them. This enabled him to judge the distance of travel and mode of formation of gold particles by examining their physical conditions.

2.3 The Exploration Process

A typical exploration program evolves from a generative stage which results in target acquisition, to testing and evaluation of the target, then to definition and delineation of the deposit discovered. When the deposit has been proved economically valuable and delineated, then, the next two important stages, before production, are pre-development and development stages. Before a concept or exploration target can be advanced to a succeeding step, it must survive tests of economic and geological viability.

A general flow chart which covers all necessary stages of prospecting and exploration regardless of, large or small deposits, and amount of capital is given in Fig. 2.2. The accomplishment of these stages depend on various factors including type of deposit, percentage of recovery, grade cash flow and market value of the product.

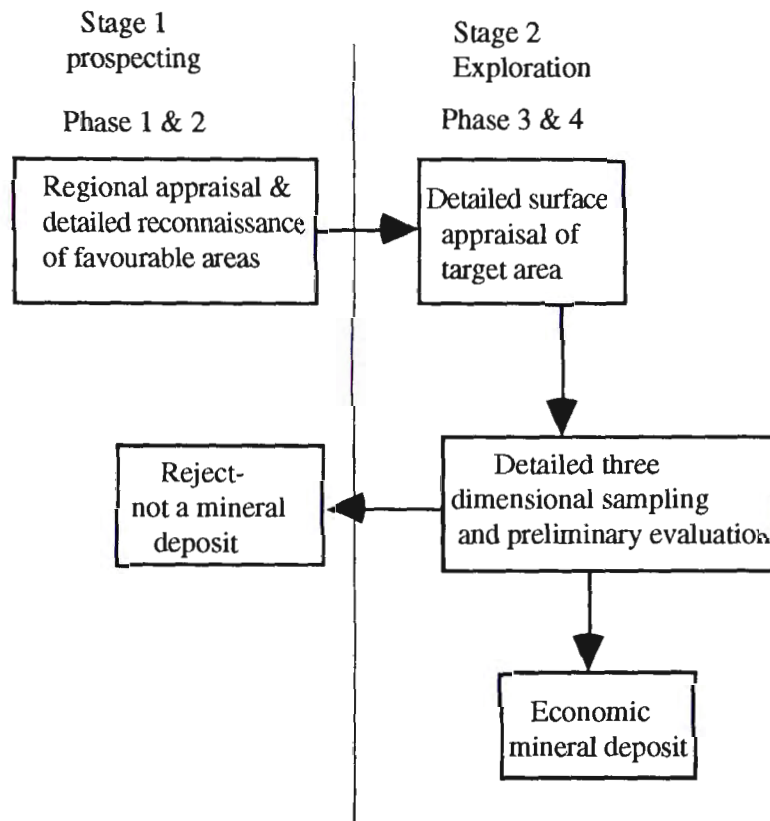


Figure. 2.2 Phases in regional mineral prospecting and exploration

It can be seen that the whole prospecting and exploration process can be divided into two stages, each of which is subdivided into two phases. Reconnaissance or generative stage has been more projected and emphasised in stage 1 of prospecting stage. The first two phases, along with the third phase, are also called grass-root exploration stages. This is the most important and crucial stage in the whole of the prospecting and exploration process.

This is a very risky stage due to lack of reliable data available about the ore reserve. This process is even more complicated for the management of small deposits which still use primitive exploration methods and are unable to prove the economic viability of the project. In this stage broad areas of geological provinces are selected for reconnaissance. The geological environment is explored in this phase in which details of the target are characterised and evaluated. If results are positive, it leads to the acquisition of land.

Stage 2 is the main exploration stage which is mainly related with target investigation. As more reliable data is collected, uncertainty decreases. In this stage, the target is subject to a series of geophysical, geological, and geochemical tests which define and identify the host rock, alteration and mineralisation. The success of this stage results in the discovery of viable mineral.

There are three main objectives of prospecting and exploration as we move from left to right in the Fig. 2.2. The first objective is to narrow the search by reducing the area under consideration from regional to areal in scope and then to target area to mineral deposit. Typically, areas decrease from 2500-250,000 square kilometres in phase 1 to 0.25 to 125 square kilometres square in phase 2 and 3, narrowing finally to 0.25-50 square kilometres in phase 4.

The second objective is to increase the favourability of the target area. The successful achievement of the above objectives give rise to the third and the most important factor of reducing the risk.

The discoveries provide the justification for the late stage exploration, during which approximate deposit dimensions, geometry, and tenor are established. Additional information for early stage engineering and economic evaluation can be obtained by delineating the ore reserve. Positive results of these evaluations lead to the pre-development stage, in which the transition between exploration and development typically takes place.

The role of explorationist changes to that of adviser during close-spaced drilling and the acquisition of metallurgical, mining and environmental data, which are required to complete the feasibility study. A time period of two to five years is estimated to complete the program design and the discovery of mineral occurrence, but it can take up to ten years due to limited budgets and the depth of mineral deposits. The ore definition and delineation phases currently take two to five years. Mine development may take from one to two years in "easy" situations and up to eight in "difficult" circumstances.

In the case of small scale gold deposits, it depends on the size, nature, type and mining methods. In the case of PNG and some other neighbouring countries where, still, primitive methods like panning are used it may not take so long to define and delineate the deposit.

But, if the examples of other small deposits are considered which are very small but their final products can be very useful for the market. Then, these deposits should be defined, delineated, designed and planned well before the development stage. The time

required before the development stage also depends on many other factors including, acquisition of land and finding necessary capital etc.

2.4 The Role of Exploration in the Mining Company

The mining company is involved in the development and production of mines and, more importantly, in the strategic decisions which lie beyond current operations. The most important problem faced by mining companies is the depletion of mines and methods of their replacement. This replacement factor depends largely on the discovery of new prospects. The discovery of new economic viable prospects depends on successful exploration due to high risk associated with exploration. Thus, success in mineral exploration is fundamental to the long term prosperity of the mining company.

2.4.1 Company Goals

Every mine operates to achieve certain goals including profit, growth and survival. Among these, profit is the most important incentive for long term or short term projects. Profit can be characterised as the success level of the company. Growth is the dynamic aspect of a mining company's development and in the long term, both profit and growth depends upon survival. The survival of a mining company depends upon the discovery of new resources because it can not survive upon its current resources which are going to be depleted.

The incentive for the search of new mines is guided by profit expectations and a survival need. The company may adopt some other alternatives too for its growth. It may integrate forward to further processing and marketing or it may diversify into non-extractive enterprises.

2.4.2 Company's Investment Alternatives

Management has to decide whether to spend on the new project and bring into production or on the expansion of an existing facility or other investment opportunities. There is a considerable difference between bringing a new mine into production or expanding an existing facility. Expansion of the existing facility, economically and financially, is safer than spending money on the new project, because a number of risks including, new regulations, escalating costs, and fluctuating metal prices are associated with it.

This is not an issue where return from developing a new opportunity is anticipated to exceed greatly the revenue from expansion. Management, also, has to decide between acquisition and primary exploration. In this case the average cost to find an economic deposit must be balanced against possible acquisition costs. Acquisition is a legitimate survival strategy. Typically, only deposits suitable for the survival of an organisation find their place in the market. There are infrequent sales where acquisition come onto the market at bargain terms. A well informed and efficient management, in these instances, can take bold steps to affect profits and growth.

2.4.3 Exploration Role

A company has three main resources of capital, technical and managerial skills and it tries to use these resources effectively to achieve its goals. The explorationist tries to work according to the strategy put forward by a mining company and selects areas, screens targets, acquire land positions, drills and discovers new resources.

The case is different with a small mining company due to limited resources and the low probability of economic discovery. Discovery of an economic deposit is very important for the survival of a small mining company. So, a small mining company uses its limited resources effectively in order to solve its survival problems. In the future it can shift its intention to forward processing and diversification.

The level and proportion of resources reserved for exploration by the mining company depend on the interest of the company for exploration. Data assembled by Mackenzie [1982] from the late 1960s indicates that the mining companies allocate from 5 to 40% of their post tax cash flow to exploration investment.

2.4.4 Role of Finance in Exploration Projects

The most difficult job for a mining company, large or small, is to locate and identify an ore deposit which has potential for development on the basis of maximum return. In the case of a small company, this precludes grass-roots exploration with its attendant high costs and the extended time required to develop a prospect to point of being a project. The small mining company, therefore must limit its search to known properties which, for various reasons, have been shut down or were never thoroughly developed at the time of discovery.

Acquisition of a property, its exploration and other mining activities need a lot of capital to fulfil all these requirements before a final decision can be taken for further processes. Finance is one of the most important problems regardless of the size of the mining company. Exploration is the initial stage of all mining activities due to which it is very difficult to find funding for exploration because ore deposits are not economically evaluated. Especially, in the case of small scale mining where tonnage is small as compared to large mines no bank or financial institution is ready to extend loans for this initial stage of mining.

2.5 Feasibility Studies

The development of a project, whether for a new discovery or the expansion of an existing operation within the minerals industry usually follows an uncertain path from initial discovery through to the point of commencing commercial operations. In either case, extensive investment of capital is required in an industry which is highly volatile.

During the development stage, a project passes through a number of stages including evaluation, planning, design, construction and commissioning. During the evaluation and planning phases, a project undergoes a series of feasibility studies, the purpose of which is to assess the viability of project, taking into account all relevant technical and financial aspects available.

A feasibility study is a comprehensive report on geology, metallurgy, mining, marketing, capital and operating costs prepared for the purpose of determining estimated earnings and cash flow in order to evaluate the economic viability of a property under examination. A feasibility study is prepared for a variety of purposes, at various stages of exploration and development.

This assessment is used as one of the various criteria to make a decision for further development, but its results are not enough to make such a decision. Several other technical and economic standards should be satisfied before taking a decision to proceed towards the following stages of mining. Feasibility studies are not only useful to measure potential profitability of project but also to identify critical areas in which further investigation and analysis are necessary to reduce the associated risks.

As a project is developed, it passes through a number of stages of assessment, each separated by a decision point, which determines whether or not the next stage of development is warranted. The chances of a project to "go ahead" usually increases as further amounts of risk capital are spent to improve knowledge of the project.

The feasibility study, therefore, is the most important and useful indicator used by the company to take appropriate course of action once a decision point has been reached. Since a feasibility study may be carried out at almost any stage of a project's development and since each project is unique, there can never be a standard approach to the feasibility study.

2.5.1 Objectives

The parameters of a feasibility study are almost the same for all mining projects. A feasibility study, in general, covers a number of activities ranging from conceptual studies and order-of-magnitude studies through to final design studies, and so on. It should be understood clearly that an amount of money is to be spent on such kind of a study in order to get certain technical and financial information. This information will become the basis of a commercial decision to proceed further with development or to reject the project.

The resources required to spend on a feasibility study depend on the policy of the company which in turn depend largely on the stage of development of the venture. The prime objective of a field geologist after identifying a deposit is to identify a source which satisfies his internal company's guidelines. Mostly these guidelines are determined by taking into account basic parameters such as preferred size of development, minerals sought and location.

If these criteria are satisfied then it is possible to develop a project concept and a basic feasibility study to be undertaken. This may involve the initial assessment of certain aspects such as tonnage and grade of the ore reserve, scale of operation, mining method, beneficiation techniques, infrastructure, transport and market conditions. The study would probably be based on subjective knowledge of similar projects.

In this situation, management has to decide whether or not to proceed towards further geological evaluation of the resource and starting preliminary mining engineering and mineral processing studies. In the mean time, management should try its best to get more technical information necessary to support the proceeding venture.

At the other end of the scale, a final feasibility study will be undertaken to provide sufficient information to enable the final decision to be taken on whether or not the company will commit to the project becoming a commercial operation. This is the most important and serious decision taken by management in the long sequence of events leading to the ultimate commissioning of a venture.

If a decision is favourable, huge amounts of capital will be invested in what is very risky game, especially, for a small mining operator. Therefore, all relevant information should be analysed very carefully before implementation. Information contained in a final feasibility study should be sufficiently detailed and reliable to ensure that the project will proceed unhindered in accordance with the proposed concept and that the cost estimates and project profitability have been defined within acceptable limits. Since feasibility studies have been based on ore reserves they should be both quantitative and qualitative in the proven category, and mining and mineral processing techniques should be well-defined and technology used be reasonably well proved.

At this stage of project evaluation, mine services, infrastructure and transport system should have been fully investigated and all technical problems have been overcome. The market for the final product should be researched in advance, so that the potential financiers can be briefed in advance about the prospect of the project. It is advisable to prepare satisfactory documents in order to protect the interests of joint venture partners in the venture, both individually and collectively, and to facilitate financing of the venture.

This will give some perspective of the degree of details to be considered by a company prior to a decision being taken to commit a project to being given the "go ahead" to become a commercial operation. The expected project financiers would also prefer to take into account the necessary and detailed information, in order to satisfy themselves that they are investing in an economically useful project.

CHAPTER THREE

FINANCING SMALL SCALE MINES

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3.1 Finance for the Mining Industry

In its simplest terms, finance is, "management of money matters". As an area within the discipline of business administration where it draws heavily on the related fields of economics and accounting, and to a lesser extent on marketing and production. The concept of finance for the mining industry relates to the provision of funds needed for the objectives of the business.

Providing the company with adequate funds to accomplish its objectives, and ensuring that these funds are provided on the best terms possible is a principle part of the finance function. However, the finance job is much broader than just that of supplying funds. The finance function is concerned with all the decisions that go into maximising a company's values by effectively using the funds, not just supplying them. For the mining industry, this includes such areas as mine valuation, acquisition and divestiture strategy, managing working capital, hedging financial risk, tax planning, and managing capital structure.

3.2 Basic Concepts and Sources of Mine Financing

Before proceeding to the next part of this chapter which is related to "How to raise capital for small gold mines and marketing", it is appropriate to mention major concepts and sources of finance. Actually, finance means "management of money matters", and in the case of the mining industry the aim is also to look for different sources to develop different projects for which capital is required. There are two main categories of these sources which can provide funds to the mining industry in order to start the new projects.

One of these categories is the owners or prospective owners of the business which can advance their own money to the enterprise as equity capital. The second is outside investors who provide funds to the enterprise in the form of debts. There is a basic difference of interests between these two categories. Generally, lenders who provide funds temporarily are ready to bear limited risk and expect limited reward from their investment. On the other hand, equity participants are ready to take the burden of

most of the risk involved in the proposed business and in return receive most of the reward.

3.2.1 Mine Development Cycle

Mining is a long, complicated and risky operation starting from the preliminary exploration stage to the production stage, and as result the nature and sources of funding is different for different stages. Consider the development cycle of a mining project starting with a traditional exploration stage (Fig 3.1). This chart can be termed as "Mine pipeline theory". By looking carefully at this chart it is obvious that people of different professions are required at different stages of this development cycle. Accordingly, as stated above different sources of finance are needed at different points in the pipeline. Figure 3.1 also shows the general sources of funding.

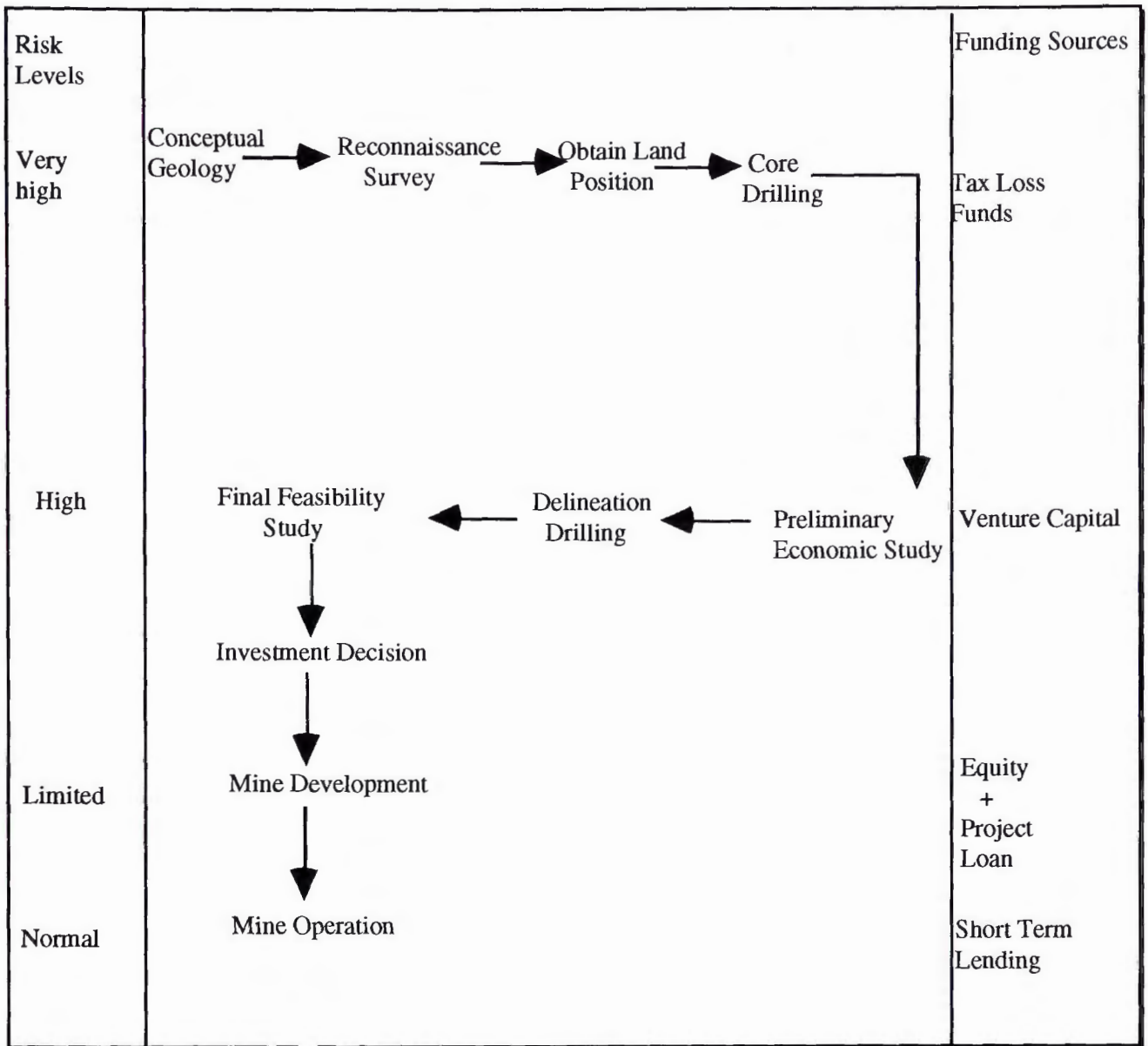


Fig 3.1 The mine project finance cycle[Arne, 1982].

3.2.2 Debt Financing

Debt financing is substantially suitable once the delineation work is finished, the mining and metallurgical design complete, the environmental permit in place, and the economic studies include that the project is both technically and financially viable. Since the level of risk has been reduced at this stage due to which it is more attractive for the investors.

Despite a number of alternatives available in the financial market, debt financing remains both the lowest cost (since the interest is tax deductible) and most flexible source of funding. Commercial finance companies, leasing companies, federal government agencies, local or state development authorities, commercial banks, and

insurance companies are ready to provide debt in one form or another. Each of these categories of lenders has its own objectives and interests and tries to deal with borrowers according to their interests.

(i) Commercial finance companies

Commercial finance companies tend to work on small and high risk credits, for example, financing a simple bulldozer or dragline. They are "collateral-based-" lenders which means that the finance company is more interested in the value of the single piece of equipment as its security, regardless of the overall financial situation of the borrower. Thus, retrievability and alternate uses of the machinery elsewhere are of prime importance.

(ii) Leasing companies

Leasing companies are involved in renting equipment rather than providing cash. These companies are ready to finance equipment from individual items through to complete plant under a variety of schemes. Tax considerations for the sponsor company are important here, since many deals hinge on who can take best advantage of the investment tax credit, accelerated depreciation, and residual value of the equipment.

Leasing companies are the best sources for a small mine as owners do not have to spend huge amounts of capital on purchasing new and modern equipment. At some later stages there can be an agreement between the leasing company and the mining company concerning payment of the rent, under which, the owner is allowed to pay rent when the production starts in the mine. Under certain arrangements, leasing companies are responsible for repairs and other breakdowns of equipment.

Various leasing structure are available in Australia for financing a range of plant and equipment, from processing facilities and major items of mobile equipment to small fleet vehicles. Such structures include direct leasing, leveraged leasing, and cross-border leasing. however, leasing structures are rarely used nowadays since tax benefits currently available do not provide sufficient justification.

Leasing has largely been replaced by innovative tax driven structure which are designed to maximise tax benefits and to create economic advantages to the project sponsor. Projects financed by tax driven structure include CITIC's share of Portland Aluminium smelter in Victoria, and CMIEC's share of the Channar iron ore project in Western Australia [Ballard, 1993].

(iii) Federal agencies

Federal agencies are also involved in providing funds to the mining industry, especially small scale mining in the Asia-Pacific region. The aim however is different to those of finance agencies as these federal agencies emphasise national interests by promoting those projects which are most suitable for the national economy. These agencies also prefer those projects which are small and in rural areas. In many cases the Federal agencies do not lend money, but rather guarantee the loan, so that the local banker actually handles the loan request and disburses the funds.

(iv) Commercial banks

Banks usually provide funding to the mining companies regardless of size and location but emphasise the economic and technical viability of the deposit. Structuring of a loan package can be considered once the project demonstrates an ability to generate a cash flow, sufficient not only to repay the interest and the principal capital to the lenders but also to provide a sufficient rate of return to the owners. Such loans are generally offered during the development or production stages of a project.

Banks, like other lenders, need to analyse and rigorously test the financial and technical risks of a project. This is only possible by analysing the "bankable" feasibility study. This feasibility study represents a detailed analysis of all aspects of a project, where technical and financial risks have been identified and a course of proper action has been suggested for their elimination or minimisation.

Banks place strong emphasis on the capabilities and experience of both project personnel and consultants who have been directly involved with the study's compilation. In many cases, rather than relying upon a strong balance sheet to provide assurance that the loan will be repaid, certain commercial banks with special expertise will carefully examine the operation itself to determine if it is technically and economically viable. Small mining companies lacking financial and technical resources may not be able to fulfil the costly requirements, bankable feasibility study, of the commercial banks in order to get sufficient funding for their projects.

Beyond the lending function, commercial banks also offer services which should be noted. Payroll preparation, handling of accounts receivable, money market investments, corporate trust activities such as payment of dividends and shareholders record keeping, financial consulting, and foreign exchange transactions are some of the day-to-day treasury activities which can be obtained at commercial banks [Arne, 1982].

(v) Gold loans

Another form of debt financing carrying a low interest rate is a gold loan, where physical gold is rented, converted by the borrower to cash by selling on the physical market with repayment to be affected in gold from future production. The interest on this physical loan will be low, basically to cover the risk of non delivery. Depending on terms (and the maximum term of the loan it is likely to be limited to five years) the rate of interest will vary between 2% and 5% a year. A gold loan essentially means fixing a portion of gold production at the gold price prevailing on the date of draw down. This action serves to reduce volatility of the earning stream.

The way a gold loan works is that the mining company wishing to raise money borrows gold from a bank. The company then sells the gold at as high a price as possible, to maximise the cash value of the gold which has been borrowed (and hence the amount of money raised). This sale is often carried out through the options and future markets to reduce the disruption to the spot market which can occur if the loan is for a large amount of the metal. Such phase loans are often advantageous to the company as it would only want to finance the construction of a mine on an ongoing cost basis rather than borrow all of the money at the outset and have to pay interest over an extended period (Kernot, 1991). There are great advantages both for banks and the mining companies. For banks it is a source of earning interest on a dormant asset. While for the mining company it is a means of borrowing for the development and production of a mine at low interest.

The gold loan repayments start immediately after commissioning of the operation and are supposed to be completed over a number of years depending upon the size of the loan and the production profit of the mine. Since, the gold which is repaid has already been sold by the company due to which the company counts the repayment as a source of revenue (although no revenue was shown in the profit and loss account at the time), the amount of revenue is calculated on the basis of price at which the gold was originally sold.

The best known gold loan in Australia is probably the Paddington gold project in Western Australia which was the first project gold loan transacted in this country. Since that time numerous gold loans have been made available for a range of projects, both large and small, including Kalgoorlie Super Pit, Jubilee, granny Smith and Mt McClure [Ballard, 1993].

3.3 Financing the Small Mining Enterprise

Most small scale mining operations around the world are managed by small, independent mining enterprises. A small, independent mining enterprise is an independently owned and operated business involved primarily in mineral development, from the exploration to the production stage. A small, independent mining enterprise is not dominant in its field and has no long-term financial backing. It is not a major producer of minerals, nor it is a petroleum company, a government organisation or a subsidiary of such organisation. A small, mining independent enterprise may or may not be listed on the stock exchange.

A small, independent mining enterprise is usually controlled by an independent entrepreneur, who not only conceives and carries out new projects, but is, also, affected by the success or failure of projects. Usually, a small independent mining enterprise does not have a large or constant cash flow which results in the necessity of a small mining enterprise finding necessary capital for its activities on a step-by-step basis. These small mining enterprises are actively involved in mining all around the world, and particularly in the Asia-Pacific region.

3.4 The Mineral Supply Process

Before mentioning the different alternatives available to raise capital by the small, independent mining enterprise, it is preferable to look at the mineral supply process. The whole process of bringing forth a new mineral supply involves a dynamic sequence of activities, ranging from the initial exploration for a mineral occurrence to the production of a marketable product. In order to locate a mineral occurrence, a series of geological, geophysical and geochemical studies are involved at the grass-roots exploration stage.

The uncertainty surrounding a mining-venture is high during the early phases of such activities, since only geological information is available and it is difficult to decide the economic viability of the venture on the basis of this limited information. Only a limited number of investors are ready to invest at this risky stage. Owners of small mines, generally, try to invest in these basic activities from their own sources to prove the economic viability of the venture in order to attract other investors.

Uncertainty diminishes as more and more information is gathered. Even if exploration efforts lead to the discovery of a mineral occurrence there is still uncertainty concerning the extent of mineralisation and probability of having located an economic mineral deposit. The expected return on investment at such a stage may well

be negative but the slight possibility of a very high positive return will make a number of financial sources available to an exploration company.

3.5 Financing Alternatives

Many small, independent mining enterprises are initiated with the investment of capital provided by an individual or a group of individuals. A small enterprise can not exist on the basis of such limited sources of capital. In order to expand the business and increase the activities, a time comes, when a small enterprise has to look beyond these sources. The major sources of capital available to a small enterprise are stock issues in the public market, investment partnerships and tax shelters, venture capital companies, banks and leasing companies.

The choice of a financing alternative by a small enterprise, however, does not depend solely on the nature of its activity or the needs and goals of different investors. It is more appropriate to have two or more alternatives at any stage. In such cases, the final choice will depend on a small, independent mining enterprise's goals and the relative effectiveness of a given source, as measured by the costs and difficulty involved in the process of raising capital from the different sources mentioned.

3.5.1 Financing Alternatives for Detailed Ground Investigation Stage

Reconnaissance work leads to the selection of anomalies which are favourable target areas for more detailed ground investigation. The activities at this stage include mineral rights acquisition and detailed geological, ground-geophysical and geochemical mapping. A small, independent mining enterprise usually finances this stage, but if enough information have been collected through previous work, then it can possibly convince other investors of the project's merits.

The level of risk is very high during these early stages due to the lack of enough geological information which results in external capital generally only obtained through negotiations with a small group of specialised and informed investors. This enables a small mining enterprise to make flexible financing arrangements tailored to the investor's financial and tax needs.

(i) Investment partnerships funds

Private placements can be useful in raising funds for high risk projects. Private placements are relatively simple and rapid way to raise capital without passing through lengthy and costly registration process as under Federal, blue-sky and provincial securities laws. Generally, the partnerships take place between a small mining enterprise and a small group of high-income tax bracket investors. As a result of this partnership, high income-tax bracket investors can transfer the tax advantages of mineral exploration to investors in the form of tax-shelters to compensate for the high risk.

A typical example of a partnership arrangement is the limited partnership. Under such an arrangement, a small, independent mining enterprise enters into an agreement under which it contributes property and its limited partnership contributes cash. The agreement provides that all intangible exploration and development costs should be borne by the participants contributing cash. The ratio of such contribution depends upon interest of the relevant parties involved in the deal.

This type of partnership is most beneficial for a small, independent mining enterprise because it authorises the management to control business matters of the enterprise independently. The limited partnerships, involved in such agreements, have to bear most of the risk of a venture. These risks can be offset by the tax-shelter provided and also by the substantial return in the case of a successful project. Investment partnerships can hence provide the small, independent mining enterprise with a source of funds otherwise not available.

(ii) Major mining corporations

At a later stage when enough geological information has been gathered, a small mining enterprise can raise capital from a large mining corporation. Under certain circumstances, it is sometimes possible for small a enterprise to submit a well-researched proposal to a major mining corporation for financing after a limited amount of exploration work has been done on a property. In this way, a small enterprise can benefit on the basis of a joint-venture agreement with a major mining corporation in the following ways. First, it can provide a small enterprise with cash flow. Second, major mining corporations has the financial means to bring a project to completion, thus eliminating for the small mining enterprise a major part of the problems involved in finding more capital for subsequent exploration and development stages.

Furthermore, a small mining enterprise can benefit from the technical know-how and operating experience of major mining corporations, which can prove to be

important if exploration leads to the discovery and exploitation of a mineral deposit. Because it is not the large mining companies' business to provide equity capital to small ones, the small enterprise must expect to hand over the management control of the project to large companies.

(iii) Public stock issues

Stock issues are appropriate only when a small, independent mining enterprise reaches the late exploration or development stages of a project. A few problems are involved in this alternative. First, regulation by government agencies seriously affect the feasibility, ease and costs of making public offerings of speculative mining stock. In fact, the prime objective of most securities regulations is to bound a small, mining independent enterprise to disclose complete and accurate material facts relating to a proposed stock issuance, in order to allow investors a realistic basis for appraisal and an informed judgement in a purchase decision.

Second, stringent access conditions to most stock exchanges have restrained their use by small, independent mining enterprises. As securities markets have matured, their role has shifted more towards secondary trading of securities and the small, independent mining enterprise has been effectively denied access to many stock exchanges. Indeed, stock-exchange listing requirement are now too stringent for many small enterprises to meet, especially those whose projects are not near the development stage. The consequences of not being listed on a stock exchange are important for a small, independent mining enterprise. It means that shares have to be sold in the Over-The-Counter Market, where a substantial selling effort is required, thereby raising the issuance costs for the small, independent enterprise.

3.5.2 Financing Alternatives for On-Site Exploration

The favourable results of grass-roots exploration and exploration drilling stages lead to subsequent stages of on-site exploration . The purpose of which is to provide information for estimating the size, grade, and other relevant characteristics of a gold deposit. Since risk is comparatively low and the level of confidence is increased, the following alternatives are available at this stage.

(i) Investment partnership

When a mineral occurrence has been discovered but the economic viability of the deposit is not clear and investment to be made in further exploration is still of a

speculative nature. Risk capital needed for this second phase exploratory and delineation drilling stage can be provided by an investment partnership. This is especially true when the general partnership (small, independent mining enterprise) puts high priority on management control, because limited partners have no voice in the day-to-day management of a partnership.

(ii) Major mining corporations

Major mining corporations usually prefer to enter joint-venture agreements with small, independent mining enterprises who have properties ready for the more expensive stages of the mineral supply sequence such as on-site exploration. If a small enterprise is unable to find other sources of development capital, major mining corporations are in a stronger bargaining position to obtain a controlling interest in the property.

(iii) Venture capital companies

A venture-capital firm may be ready to invest in a project at this stage. But such financial agreements can prove costly for a small mining enterprise due to the demand for high return on investment. Although, the venture-capital companies do not get involved in managerial operation of the project, they can impose restrictions with regard to the decisions which can affect the financial status of the project.

(iv) Public stock issues

When financial markets are in a buoyant phase and speculative capital is readily available, a public stock issue should be considered by a small, independent mining enterprise. In the past, small independent mining enterprises in some countries have been able to raise funds successfully in the public market for on-site exploration projects. Raising funds from the public is a long and complicated process compared to negotiations with small groups of investors. The legal, engineering, accounting and other issuance costs, as well as commission fees, can amount to a relatively high percentage of the money raised in the public market.

(v) Commercial Banks

Banks may be ready to share their expertise with companies, specifically in mineral economics and market analysis. This could be very helpful to the smaller mining/exploration company in deciding whether it should take out an option on a property, or even to help to formulate its exploration philosophy. Due to their contacts throughout the mining industry, bank mining specialists can provide advice to the small

mining company in its search for a partner, either to carry out exploration, or once a deposit has been identified, to provide the right fit from both a technical and financial perspective for the specific project's evaluation and development.

3.5.3 Development and Production Stage

The preparation of a detailed feasibility study for the development of a mine follows the collection of data in the grass-roots and on-site exploration stages. The feasibility study is the basis on which the decision to go ahead with the project is made. It is not appropriate to raise equity capital from one or a small group of investors at the development and production stages.

Firstly, these investors are not ready to invest the amount of money required for these capital intensive stages. It is preferable to raise large sums of equity from a very large group of investors, eg. through public stock issues. The main advantages of this source is that one or a few large holders are unable to impose restrictions on management. At this stage much of the geological uncertainty is removed overcoming much of the speculative aspect of a venture. Access to securities exchanges is easier, information is more readily available to investors, and the costs of public financing are relatively lower.

Although it may be impossible for a small, independent mining enterprise to borrow capital on the strength of its balance sheet, non-recourse financing may be available at the development stage. Indeed, once the economic viability of an ore reserve has been proved, a small mining enterprise can gain a non-recourse project financing loan. One of the main conditions to get project financing is the necessity to offer a completion guarantee, ie. a bridging guarantee which expires after a time sufficient to ensure the lender that the project operates as presented in the feasibility study.

The acceptance of guarantee by lender provided by a small, independent mining enterprise depends on the high level of equity interest. A small enterprise has to find a third-party guarantor in the case where equity participation is low and this third-party guarantor should be financially strong. Such guarantors are motivated by economic needs such as assuring a source of supply.

These guarantees should be secured by a small, independent mining enterprise without losing much equity in the project, or at worst, control over the project. A small mining enterprise can not complete its project successfully without borrowing capital

from certain sources. Indeed, the novice small mining enterprise, with no proven financial and managerial track record, with no outstanding assets or balance sheet, and which has a firm determination of keeping control of the project may very well find the task of securing financial backing impossible.

Banks are often appointed to act as financial adviser to a project, during the development stage, on a fee paying basis to both identify and advise upon its various financing alternatives, including the project's debt capability. Each mining project has unique characteristics which should be taken into account while developing a financial plan for the project.

Banks are, usually, very cautious with the technical and financial risks involved in a mining project and are usually unwilling to absorb these risks in extending loans to mining companies. These often relate to risks which can not be properly analysed, and also to uncertainties arising from insufficient data collection, for example in reserve estimation, metallurgical test work, potential environmental problems, unproven technology, etc.

Banks can supply debt funding in its various form. Domestic banks lend in Australian dollars or in external currencies such as US. dollars or Japanese Yen, where as foreign banks are limited to external currencies. Foreign banks can, however, make available Australian dollars through the use of a letter of credit on an Australian institution, which provides the funds. There are advantages and disadvantages to both domestic and foreign currency types. Withholding tax on loan interest payments is a problem for non-Australian dollar loans. Loans in external currencies can make sense, however, when equipment is purchased overseas, or product revenue is wholly or partially in an external currency. This will minimise exchange risks [Legg, 1984].

Small projects can obtain off-balance sheet or project financing. This method uses as security the assets of the operation and its cash flow expectations. There is no hard and fast rule regarding credit. Limitations will be imposed by various factors however, among which will be the strength of the project technically and financially, and also the cost of structuring such a loan.

Close contacts with banks even during the production stage are very useful for a small mining company because a bank's expertise can ensure that the project is performing technically as per feasibility study projections on which the loan structure was based. It can assist the bank in signalling potential problems in debt retirement, so that ratification measures can be adopted in good time with the full knowledge and cooperation of the lenders.

3.6 Marketing

A business organisation must sell products to survive and grow. Marketing activities directly or indirectly help to sell the organisation's products. Besides selling established products, they also generate financial resources that can be used to develop innovative products.

The highly complex, industrialised economy depends heavily on marketing activities which help to produce the profits that are essential not only to the survival of industrial business but also to the health and ultimate survival of the economy. Without profits, business finds it difficult to buy raw materials, hire more employees, attract more capital, and in turn, make more profit.

The concept of marketing is understood differently by different people. According to some experts "Marketing is the development and efficient distribution of goods and services for chosen consumer segments".

Or

"Marketing is the process in a society by which the demand structure for economic goods and services is anticipated or enlarged and satisfied through the conception, promotion, exchange, and physical distribution of such goods and services".

The market must be identified in terms of size, price, potential competition, possible changes in buyer's specification and long term demand. There is often a direct link between the market and project finance in terms of buyers taking equity in the project or providing loans against future supply of the product. It is imperative to exhaustively investigate the market at the inception of the project and to constantly update this evaluation throughout the life of the project. The market element of the project must be managed to avoid costly delay [Ansley, 1980].

The small operators generally lack market intelligence and marketing facilities. They are seldom aware of all the details of specifications needed by the mineral consuming industries. For example, very few people know the complete size ranges of dolomite and limestone required by the different steel plants and the range of quality and tolerance. A similar case can be seen in the gold industry. The majority of small miners do not know the different marketable products of gold which can be sold at a high profit and which is demanded by the refiners / smelters.

Similar comments can be made about the needs of other consumers. The major problem with small miners is that many of them are not qualified enough to suggest alternative specifications and to suggest the common needs of producers and consumers. It is therefore advised that information in this regard should be collected by state or federal authorities and pooled for dissemination. The relevant authorities should then make them available to the mine owners.

It is a common irony that companies are often spending a great deal of time and money to save a few cents per ton on operating costs while at the same time overlooking equal or greater savings on marketing opportunities. It is prudent for the small operator to acquire as much market information and expertise as he can. One aid in doing this is to develop a formal or informal association with a group that can help deal with some or all of the marketing problems, a small operator does not have the time nor talent to address. Ironically, a merchant knows the market place and may often be able to get a better price from smelters or buyers than the small operator himself can get [Chender, 1983].

3.7 Mine Product

The rule for determining the mine's final product is "the higher the gold and silver content, the greater return of metal at the lowest post-mining cost". As mentioned previously that owners of small gold mines should know the price trends of different marketable gold products, demand and other market conditions necessary to sell their products profitably. In the following paragraphs, the valuable form of gold along with its advantages and the different ways of marketing are mentioned.

(i) Dore Bullion

- It is the most advantageous form of gold due to following advantages.
- Highest return of metal.
- Lowest refining cost per ounce of gold and silver.
- Very compact and easy to ship in small quantities.
- Easy to assay.
- Assays between mine and refiners are comparable.
- Melt losses are very small at the refiner.
- Outturn of gold and silver 20-30 days for quick cash flow.
- Gold / Silver refiners can return or purchase metal soon after arrival at a nominal financing cost.

(ii) Placer Gold

This product can be shipped as is to refiners, but it is best to melt to a dore bullion to upgrade the purity.

(iii) Loaded Carbon precipitate

Most refiners accept this material providing that the precious metal content is high ie., 100-200 ounces per ton. However, the cost can be high, 5 to %10 or more per ounce because refiners have to do the melting and preliminary fire-refining mercury in the material can be a serious problem. It is best to strip or burn the carbon reducing it to metallic dore or melt precipitates on site.

(iv) Concentrate

This is the least desirable product. It is bulky, hard to ship, difficult to assay, and has the highest refining cost per ounce of gold. Smelters pay / return from 91 to 98% for gold and 94-95% for silver. The losses due to weight loss, assays, and assay methods can range from one half to three percent in addition to the returnable metal deduction.

3.8 Marketing the Mine Product

The following alternatives are available for small owners to sell their products:

- Sell to merchant who arranges everything, including sales.
- Have an agency arrangement with a merchant who arranges everything on your behalf, for a fee.
- Sell direct to a refiner who prices automatically and deducts charges from the proceeds.
- Toll refine, and sell the metal separately to a gold broker / merchant of your choice, using a pricing method suited to your need.

Before an alternative can be considered, market information has to be obtained by offering the material to refiners or smelters on a direct basis. In making such an offer to smelters-refiners the following information is required:

- A sample of dore or other mine product.
- Complete assay / analysis for all elements totalling 100%.

- Amount per shipment and frequency of shipment.

3.8.1 Dealing Direct With a Refiner-Smelter

Once the refiner has given management an indication of terms and management has the other related costs of getting it to their plant, management can compare one refiner against another. These terms can be improved by negotiation and material can be offered to a number of refiners / smelters. The mine should try to do its own first smelt-refine, if possible, and sell its own metal or receive early metal outturn with each segment of the business priced out separately. However, there is a point at which it is undesirable to do this, at about 20,000 ounces a year. The refiners can offer the following services:

- Purchase the contained returnable metals.
- Toll the material into saleable bars, if desired.
- Arrange transportation of concentrates and dore bullion.
- Insure the material while in transit
- Arrange for early outturn of gold / silver (at a nominal cost).
- Sell Some metal forward.

3.8.2 Comparing Smelter-Refiner Terms -NSR

To decide which refiner is best, all costs related to smelting-refining, transportation, insurance, early gold return costs and the time value of the payment date from the smelter have to be calculated to obtain the net smelter return (NSR).

3.8.3 Gold Leasing-Early Gold Return Option

To overcome the time lag between shipment arrival and gold outturn for payment, gold can be leased about three to five days after arrival at the refinery as given below. For mines producing under 20,000 ounces a year, it is probably less trouble to obtain early gold return direct from the refiner.

- From the refiner at a cost per ounce (15-30 cents per ounce).
- From a gold broker usually at a competitive cost 1.0 to 2.0 % a year.

3.9 Dore quality, Penalty Charges and Credits

A refinery normally requires the dore to contain not less than 70% gold and/or silver. The penalty charges are applied if elements deleterious to the refining process are present within the dore. The most common deleterious elements are iron, lead, tellurium and nickel. The application of penalty charges or the rejection of the dore shipment depends on the refining method used by the refiner. The customer should enquire of the refiner to obtain a clear identification [Cotton, 1993].

3.10 Precious Metal Return

Refineries return between 99.8% and 99.95% of the gold and 95% and 99% of the silver contained in the dore bullion to the seller, with the balance required to cover losses incurred in the refining process. The metal return offered by the refiner varies according to the quality of the dore. A high gold content normally ensures a high gold return and similarly for silver [Cotton, 1993].

3.11 Advantages of Dealing Direct with Smelters / Refiners

- The mine maintains control over assaying and sampling by talking directly to the refiner about assay / sampling techniques.
- Unusual losses can be dealt with on a one-on-one basis.
- Refiners can give advice as to the methods of refining dore at the mine for a cleaner product.
- A relationship can be built up between refiner and mine.

3.12 Dealing with Merchants / Gold Broker and Consultants

If the output of a mine is small and the merchants offer is very competitive, it is desirable to have a direct line of communication between the mine and smelter-refiner. It is not worthwhile to over emphasise a merchant who also is an investment banker house. There is practically no connection between the metal traders and investment bankers.

It is advisable to obtain financial data from the merchant on his company (annual reports, etc.). If the merchant is small, it is better to insist on dealing through

irrevocable letter of credit backed by a bank line of credit. A merchant broker can play a useful role for the small miner knows how to utilise their services.

Sometimes brokers approach the owners to pay cash for gold, at a 3% or so discount. It is advisable to avoid these, as there is never any need to sell gold at a discount. Before utilising a consultant's expertise, it is advisable to find out the efficiency of the consultant and how much he has sold and check references. It is useful to insist on dealing direct with smelters-refiners with the consultant's assistance.

3.13 Agency Agreements with Merchants

Merchants will approach the mining company to represent it for a fee for marketing mine products. The market conditions should be known before any contracts are signed with smelters or refiners. There is a lot of concentrate swapping, where a merchant offers the company's material to a smelter at high treatment charges while asking for an offsetting discount on his purchased material from the same smelter. This tends to happen when large amounts of material is to be produced, ie., 10,000 tons of concentrates or more per year.

3.14 Importance of Marketing in Small Scale Precious Mining Industry

The marketing aspects of a new precious metal's property is often not considered until the mine actually begins production. At this point it is often too late or too expensive to change the final mineral product and there is not enough time to do an effective marketing program.

The owners of small scale mining operations sometimes, do not, know the marketable product of gold (bullion or concentrate) which has more demand and can be sold at a profitable price without transporting a greater distance. Subsequently, the owners are ready to sell products at any price, even at discount, to get cash. Another problem faced by small mine owners is the extraction of high grade boulders or parts of a deposit leaving low grade boulders as tailing. If owners are fully aware of the market value of low grade boulders or nuggets, they are going to receive greater profit as low grade boulders can be further processed by using modern processing plant.

The main aim of a business is to satisfy its customers since the customer's satisfaction determines whether the enterprise will continue to exist. Marketing skills are important for mining companies because competition and customer demands

require both anticipatory and reactive supplies. This task covers sales, customer research, product planning and diversification, advertising, warehousing, and transportation in order to attract and hold the customer.

In conclusion it can be said that there should be some marketing training programs for small mine owners. These training programs or other informative sessions should be organised by the state authorities or other semi-government agencies. The small mine owners, especially in remote areas, should be fully aware of the different marketable products of gold, their uses in different industries, and demand and price trends. If state authorities can not organise training programs then at least there should be mobile teams to supply this information to owners.

CHAPTER FOUR

MINING TECHNIQUES AND MILLING FACILITIES

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MINING TECHNIQUES AND MILLING FACILITIES

4.1 Introduction

Once the ore reserve is discovered and economically evaluated, the next step is the selection of a suitable and profitable mining method and deciding about the ore dressing facilities. Selection of a mining method depends on many factors including geographical situation of a deposit, geological and stratigraphical conditions, grade, value of minerals, percentage of recovery, price of the product, market value and demand of end product, changes in technology and access to mining equipment. Since, this thesis is concerned with small gold mines so selection of a mining method for a small gold mine predominantly depends upon the factors mentioned above plus available capital because capital plays a unique role in the selection of mining and mineral processing methods. If some financial institutions are available to finance the project then it is possible to use mechanised mining methods regardless of ore reserve and grade of the gold.

Generally, the size, geological structure and physical properties of gold deposits are totally different than other metalliferous mines. It is not possible to explain and discuss in this thesis all the mining techniques and mineral processing methods, in detail, used for the extraction and dressing of small gold deposits. Moreover there is not much difference of mining and mineral processing methods between small to medium size gold deposits. It is a good idea to discuss the different mining techniques used in Asia-Pacific region along with the advantages and disadvantages of these techniques. These small deposits play a very important role in the development of these countries.

Formation and physical nature of a gold deposit is another factor to be discussed briefly here. Most of the gold deposits found around the world are placers. It is not use highly mechanised and sophisticated mining methods to extract these deposits due to the physical nature of these deposits.

Milling facility is the last step before the product is ready to be sold out in the market. Mineral processing for gold recovery from the gangue minerals is not as complicated as the recovery of other metal minerals, although, some hazards are associated with some methods of mineral processing.

It is the duty of management to decide the type of equipment which are technically and economically suitable to maximise the profit and minimise the operating costs and overhead expenditures. Due to the recent development in technology, mobile equipment are mostly used in the mining industry. These mobile equipment are also suitable for small-scale mining industry

4.1 Placers

Most placer deposits are formed by the weathering action. Detrital natural material containing valuable minerals in the form of discrete grains, after weathering from rocks, are deposited in stream beds. The mechanical sorting action of water flow tends to layer them below the fine sand and gravel. Most placers occur as unconsolidated sediments. Generally only the heavier minerals will be sorted and left.

Table 4.1 Specific gravities of different minerals

Number	Minerals	Specific gravity
1	Gold	15.5 to 19.3
2	Platinum	14-22
3	Cassiterite	6.6-7.1
4	Diamond	3.2-3.52
5	Garnet	3.15-4.3
6	Monazite	4.9-5.3
7	Magnetite	5.16-5.18
8	Zircon	4.2-4.7
9	Rutile	4.2
10	Ilmenite	4.5-5.0
11	N. B. Silica	2.6

It can be said roughly that the heaviest minerals are deposited first, while the lighter in the later stages. So, it is that gold is found in the foothills, and Zircon, Rutile and Ilmenite on the beach.

(i) Eluvial Deposits

These are the deposits formed by the deposition of particles close to their parent rocks. Eluvial deposits overlie, or are located very near to their source rocks. The

constant reworking of resitate minerals, which is a characteristics feature of fluvial and beach deposits, does not affect alluvial deposits so their grade is normally lower than equivalent ores in other placer environment.

(ii) Alluvial Deposits

These types of deposits are those carried away to river valleys, lakes, etc.

The minerals may be deposited in joints in weathered rock. For example, in Malaysia, solution joints in Limestone trapped the Cassiterite as it rolled along the river beds-otherwise the heavy minerals drop out on the inside of river bends or in deeper sections of streams and rivers where the water velocity decreases. This property of the rate of fall of a heavy particle in water being greater than that of a light particle is useful for natural concentration of minerals by rivers or wave action. But, sometimes this property becomes problem during mining operation because each time the heavy mineral tends to drop to the bottom of the sequence and left behind.

Placer deposits are formed by different types of natural processes ranging from chemical weathering to fluvial, marine, wind action, and combination of these actions. One or more cycles of erosion and deposition may have occurred. Placers formed under sub aerial conditions subsequently may become drowned by the sea and then covered with marine deposits.

Placers formed under sub aerial conditions, and beach and offshore placers that have become exposed due to lowering of sea level, often subsequently are covered with barren alluvium, eolian deposits, glacial debris and lava. In relation to mining, barren or near barren material overlying placers and the underlying bedrock, must be considered as integral parts of a deposits.

4.2 Factors Affecting Selection of a Mining Method

The next step after the discovery, delineation and evaluation of a mineral deposit, is the selection of a mining method, that is, economically, physically and environmentally adaptable to recover the mineral from the ground.

The major factors influencing the choice and characteristics of surface mining (as most of the small to medium range gold deposits are extracted by surface mining) are:

-
- (i) The thickness of overburden and physical properties of capping and enclosing country rock.
 - (ii) The thickness, shape, configuration and structure of the mineral deposit.
 - (iii) Its mode of occurrence (position with regard to ground surface, angle of dip).
 - (iv) Hydro-geological conditions of mining (these should be known in order to)
 - choose a rational method of dewatering the deposit.
 - estimate its cost.
 - select the high wall angles.
 - work out measures aimed at preventing landslides and water intrusions.
 - (v) Feasible technical facilities for surface mining work (i. e. the types of energy and equipment, mainly drilling, loading and transport equipment).
 - (vi) Climatic conditions prevalent in the area of mining operations. (These exert a definite effect in working soft ground which requires no drilling and blasting).
 - (vii) Environmental factors, such as the preservation of the surface overlying the mine, and the prevention of air and water pollutants.

4.3 Placer Mining Method

The methods for mining of placer deposit, based on the method of excavation, may be classified as follows:

- (i) Land based plant:
 - With hand tools and minor auxiliary equipment:
 - Drift mining
 - Shallow open cut surface mining
 - With bucket scrapers and wire line

- With equipment such as shallow open cut mining:

Dozers

Dragline

Shovel plus trucks

Small bucket wheel excavator plus trucks

Large powered scrapers plus dozers

- With water:

Ground sluicing

Hydraulicking

(ii) Floating plant

- Dragline and floating washing plant
- Bucket line dredge
- Hydraulicking dredge, barge or ship mounted

4.3.1 DRIFT MINING

This method is most useful for mining placers which are concentrated in relatively thin horizon at a depth that prevent excavation from the surface. The zone of concentration may rest on and extend into bedrock, or on a false bedrock, often clay, or be in intermediate horizon in a gravel deposit. The material mined by this method is gravel which is concentrated in a sluice paved with riffles. This concentrate is in black sand form from which gold is separated by dry blowing or amalgamation.

4.3.2 Hydraulicking Mining

This method involves loosening and disintegration of material in Situ by large quantities of water delivered under pressure through pipes and nozzles (giants) to disintegrate the deposit. This is followed by gravity flow of pulp into a downgrade channel and sluice box where heavy mineral is concentrated on riffles.

4.3.3 Dredging

This method is widely used in Asia-Pacific for exploitation of gold. In this method, material is excavated at the forward end by the bucket, elevated, washed, screened, and concentrated for recovery of valuable minerals, and discharged off the stern as coarse and small fractions. The end product is a concentrate consisting either of the valuable minerals and associated heavy minerals which are taken to treatment plant on shore, or in the case of gold, a clean amalgam is ready for retorting (distilling). There are two types of dredges

(i) Bucket Dredge

The bucket-line dredge is an extremely efficient machine for mining placers lying principally below the water level at the lowest unit cost. The basic rating of the bucket-line dredge is the struck capacity in cubic metres of one bucket with a new lip, combined with the maximum digging depth in metres below water level. Theoretical capacity is a function of bucket capacity and speed of bucket line which commonly is 21-24 buckets / minute. But it can be upto 38 buckets / minute with variable or two speed drives. The actual digging rate of a dredge is affected by the following factors:

- Quality of preventive maintenance.
- Organisation of replacement and repair work.
- Character of ground being dug (compact, loose, or partially frozen).
- The rate of swing.
- Rate of wear of bucket lips.
- Depth of ground which affects the recovery of stepping ahead or moving from one cut sideways to another.
- The amount and type of bed rock.

The principal factors governing physical application of a bucket-line dredge are as follows [Daily, 1973]:

(i) Adequacy of water supply in relation to character of material, particularly the percentage of clay or slime in the ground, and rate of loss by percolation through tailing

or bank. This is important in on inland deposit, where there could be the shortage of running water supply. This is necessary

- To make up that lose into tailing or bank.
 - To maintain the turbidity of pond water at the pump intakes below that which will adversely affect concentration of valuable minerals by gravity methods.
 - To remove high solids pulp from near the bottom of the pond on discharge it into tailing or other disposal areas. This factor is associated with deposits of high slime and clay contents.
- (ii) Character of deposit, degree of induration, size and number of boulders, buried timbers.
- (iii) Surface topography in relation to ground water level and surface grade.
The ideal topography is a wide valley floor having a gradient less than 1% and a vertical relief between surface and natural channel level of say 20% of total depth of ground. Relatively high ridges or humps on the surface are undesirable, as are piles of tailing from prior operations which must be cut down by hydraulicking.
- (iv) Shape of area to be mined, particularly minimum width. Because of physical operational limitations, selective dredging of the economics portions of the land delimited from prospecting can not be carried out.
- (v) Depth of deposit, topography of top of bed rock and character of bedrock.
The depth of deposit to be dredged, consisting of the portions that will be above and below water level, influences the size of the bucket and its range. The topography of the top of bedrock, and the depth to be dug into bedrock are important related considerations. A relatively flat, undulating surface of a weathered bedrock is an ideal situation.
- (vi) Overburden, thickness and type.
- (vii) Type and amount of vegetation that must be cleared from the surface.
- (viii) Fluctuation of water level.
- (ix) Climatic conditions that determine length of operating season, eg. formation of ice in cold climates and protracted periods of high water in rivers.

- (x) Offshore: depth of water, storm and current conditions and character of sea floor.

(ii) Suction Dredge

These types of dredges are designed for excavating materials lying under water and transporting the solids in a pulp or slurry through a continuous system to a point of discharge. They are designed to perform prescribed tasks under particular conditions, at lowest possible costs, which can be very low.

The principal uses for hydraulic dredges are industrial rather than mining, deepening and widening channels in rivers, harbours or canals; digging new canals, creating fills, developing marines and excavating sands and gravel for industrial purposes, principally aggregates.

4.3.4 Non Mechanised Techniques

Small-scale gold mining in Asia-Pacific, especially in Papua New Guinea, is generally at a very low level of technology. Most miners operate either very primitive wooden sluices or use pans, plates, pot lids or any other dish shaped object available. Although, small scale mechanised system has been introduced in Papua New Guinea, but still, less than 10% of total small scale gold production is obtained by mechanised operations.

The use of low water velocities in sluice boxes is a common problem and its main reason is the lack of understanding of the mechanics of the sluicing process. This is in part due to the very low levels of literacy prevalent in the mining communities and the lack of effective program for the miners [Blowers, 1983a, 1983b]. Recently, new aluminium sluices have been introduced in the market and these rely on higher wash water velocities to function. This operation results in higher throughput for the miners and consequently higher returns.

4.3.5 The Economics of Low Technology Techniques

Although mining industry was started on small-scale basis, and still a large portion of mineral production comes from this industry. But, there is not enough improvement in this industry due to many factors including lack of capital and necessary resources, size and nature of the deposit, demand of the end product, geological conditions, etc. All of these factors result in low technology methods in most parts of the world because most major mining companies in the world are looking for large deposit. So, that the ore can be mined quickly by the help of large equipment in order to sell the product at right time and in the right market.

Most of the people attached with this industry are poor, illiterate and unskilled. Although return is not very high with these non mechanised techniques, but still miners can produce some cash for the purchase of consumer goods. Again most of these miners have to work in various industries in order to supplement their wages. So, low technology techniques are very useful and profitable for miners because expenditures on maintenance and purchasing of new equipment are negligible.

Due to the low throughput methods being used the miners must work gravels of high grade in order to justify the hard physical effort required. According to a recent survey in Papua New Guinea according to which the current economics of many of the mining communities dictates that most full time miners would not work for returns which were consistently below K 5.00 per day. This generally equates to about 0.5 to 1.0 g of alluvial gold per day (depending on gold price and fineness).

4.4 Ore Treatment

In its ores gold is usually present as the metal, alloyed with metallic silver and perhaps copper. Its high specific gravity causes particles of gold to settle readily from pulp. Since gold is malleable due to which a grinding treatment which breaks gangue minerals may only flatten the metal without substantially reducing the size of its liberated particles. This differential grinding effect, by developing size differences, may assist gravity separation once the pulp is clear of the grinding section. Against this, the weight and malleability of gold particles causes them to be retained in a closed grinding circuit even after they have been adequately liberated.

In addition to “native” gold, the element may occur in forms of associations unfavourable to direct recovery by gravity methods. Metal sulphides such as stibnite,

pyrite and galena frequently contain inclusion of gold. Practically, it is not possible to grind these sulphides to the fineness required to liberate this finely disseminated gold, nor it would always be possible to trap it efficiently once it had been freed. The usual practice in such cases is to concentrate the gold bearing sulphides at a relatively coarse mesh-of-grind, regrind them, and then extract the gold by chemical actions. A third class of gold has its values combined in the form of telluride or sulphur telluride. These compounds are not malleable as they slime readily and their gold content is extracted by chemical methods.

The process selected depends, therefore, on whether the gold can be freed from its gangue at a sufficiently coarse mesh, or whether it is carried in a heavy sulphide which can be similarly freed. If the ore contains other valuable minerals, it may also be necessary to provide for their recovery.

While separating the base metal values the concentrate forms a significant percentage of the ore, only a few pennyweights of gold per ton exit in the average run-of-mine ore. Thus a large quantity must be handled in order to extract a very small amount of extremely valuable concentrate. If all the gold is carried in a small percentage of the ore, as is the case with auriferous pyrite, considerable handling of economies may be made possible by using froth flotation to separate this pyrite from the barren gangue at an early stage. If part or all of the gold is disseminated through a siliceous gangue, all the ore must be treated.

Gravity separation of gold is practised on strakes, shaking tables, and in sluices and jigs. Amalgamation with mercury is used in connection with this work. Froth-flotation can be employed to remove gold and sulphide minerals from a finely grounded pulp.

4.4.1 Cyanide Leaching Process

A number of small high grade gold and silver deposits have been uneconomical because of the high costs of mill construction, transportation and smelting. Processing of these ores must be simple, cheap, with satisfactory recoveries and be environmentally acceptable. Vat leach with direct electrolytic recovery satisfies these parameters. Some of the fines which ceased production due to different reasons are working by using this method.

4.4.2 Sand Leaching

During this process it is important that crushed ore should be brought to its optimum technical condition before cyanide process is carried out. Crushed ore should be liberated in such a way that no further grinding is required which is usually the most expensive item in the treatment. But if the ore particles are very fine they also create problems during the percolation process of cyanidation. The cyanide process proceeds in four stages and these stages are important according to the sequence:

- (i) Preparation of the ore to expose its gold
- (ii) Dissolution of gold from solids
- iii) Separation of gold-rich liquid from residual solids
- (v) Recovery of gold from pregnant solution

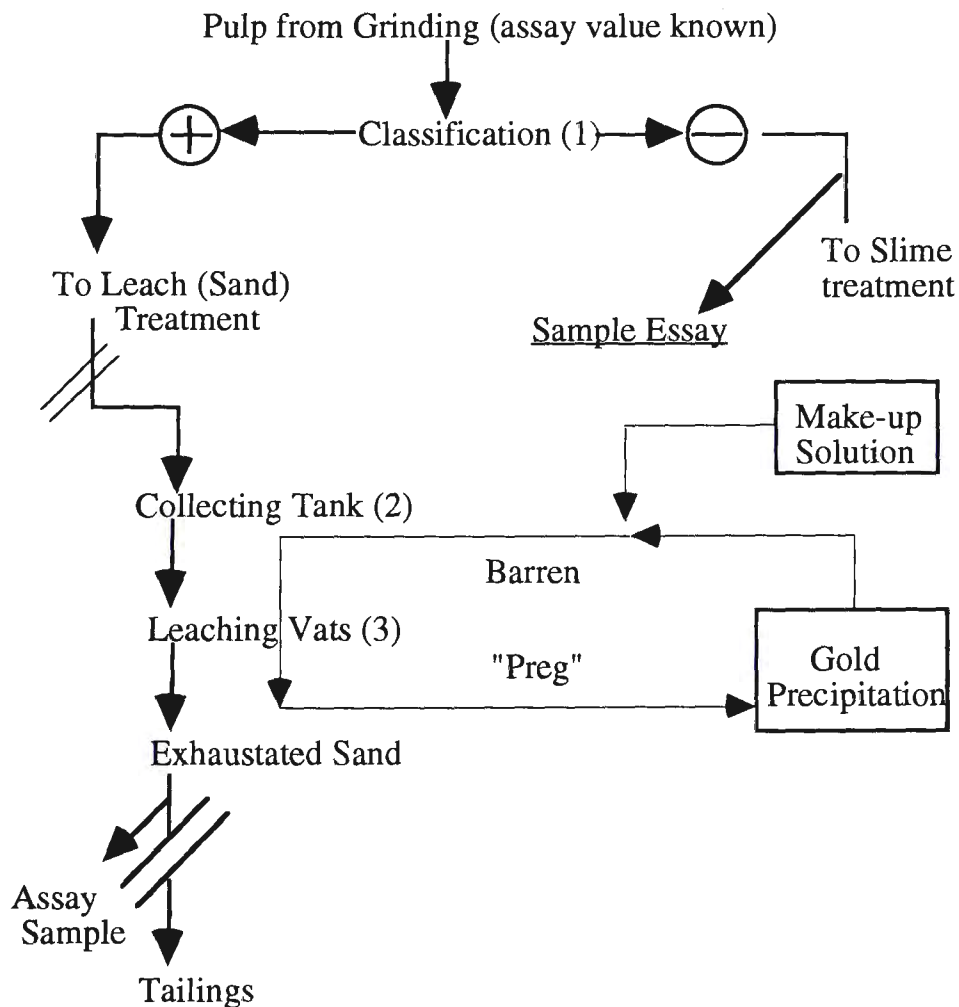


Fig. 4.1 Gold leaching flow sheet [Jain, 1987]

When the crushed ore is significantly coarse, cyanide-bearing solution can be made to percolate through moderately thick beds, with sufficient speed and searching power to dissolve and remove the bulk of exposed gold. The rate of percolation determines the number of days a bedded tankful of such crushed material must be treated, and hence the holding capacity (as capital investment) of a leaching plant for a given throughput tonnage. The porosity of the bedded material determines the rate of percolation.

If an unclassified mass of sands were bedded, the associated slimes and fine sand would obstruct the interstices between the large grains and thus interfere with percolation rate. This could in part be compensated by working with a thinner bed, by using vacuum to pull the leach liquors down through the beds, and by stirring these liquors into the upper layers of the bed. Leach treatment continues to have value in a variety of special application, notably with low grade ores, dump retreatment and low capital projects where simple home-made devices aid development finance. The general scheme of leaching treatment can be pictured as in Fig. 4.1.

4.5 Use of Biotechnology

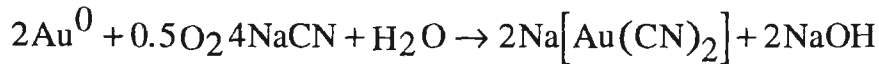
The use of biotechnology for the extraction of gold has been recently introduced in the mineral industry. This method is not only used for gold extraction but also for other precious metals. This technology has been successfully applied in various mine site pilot plants for the treatment of refractory gold concentrates. High grade extraction were achieved after bacterial oxidation treatment. More than 90% of the gold could be recovered after oxidation compared with approximately 50% for the untreated concentrate.

The extraction of precious metals from complexed sulphide ores by conventional method is a very difficult task. Direct smelting of such ores is highly energy-consuming, and is notorious for its environmental pollution problems. Selective flotation separation of these complex sulphides into individual concentrates followed by smelting the sulphide (s), which contain most of the precious metals, has the following objectives:

- Selective flotation separation of complex sulphide ores is very difficult [Natarajan & Iwasaki, 1985].
- There is considerable loss of precious metals (about 20-30%) with flotation tailing.

- Environmental hazards of sulphide ore smelting.

Oxide bearing non-refractory ore can be treated directly with a cyanide solution to extract gold.



The cyanide complex $(\text{Na}[\text{Au}(\text{CN})_2])$ is soluble in the aqueous leach medium, from which gold is absorbed on activated carbon, then stripped and electrowon [Chamberlain & Pojar, 1984]. Currently, high grade non-refractory gold deposits are becoming exhausted and lower and complex grade ore deposits have to be considered for gold production.

In order to avoid environmental problems, as mentioned before, associated with cyanide leaching, several alternative processes have been proposed for gold extraction. The most frequently studied process is based on the solubility of gold and silver in Thiourea [Schulze, 1984]. Thiourea is less toxic than cyanide, but more expensive, and less stable in the leaching process, therefore cyanide will remain the preferred extractant for precious metals. Chemical destruction of excess cyanide in the leach solution is based on alkaline chlorination, sulphur dioxide-air or hydrogen peroxide treatment. More recently, biotechnical processes have been developed for degradation of cyanide in mill effluent [Whitlock & Mudder, 1986].

When ore is refractory and the submicrometre sized gold particles are finely disseminated within the sulphide matrix, then only gold particles located on the surface of the sulphide ore will be dissolved by the cyanide solution. Furthermore, the heavy metals associated by the gold bearing pyrite and arsenopyrite will react with cyanide, resulting in excessive reagent consumption.

In addition, some refractory ores have organic content, which increases cyanide consumption and retention of gold by complexing, so that the efficiency of the leaching process is considerably reduced. Several alternative processes have been suggested for the treatment of these refractory ore, including nitric acid digestion [Fair & Schieder, 1987], Chlorination [Yen, Pinder & Lam, 1990], pressure leaching, roasting and bioleaching [Lawrence, 1990]. Bioleaching has the following advantages over the alternative processes listed above:

- It requires little capital investment.

- It is simple, and can be fully automated.
- It is applicable to low and high grade resources.
- It is environmentally benign, if operated properly

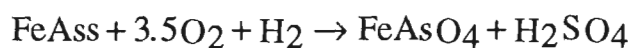
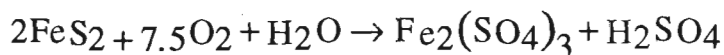
4.5.1 Leaching Bacteria

The principal micro-organism responsible for the oxidation of arsenopyrite, and pyrite is *Thiobacillus ferro-oxidans*. It is a motile, non-spore forming, gram negative, rod shaped ($0.5 \times 1.5 \mu\text{m}$) bacterium occurring singly or occasionally in pairs.

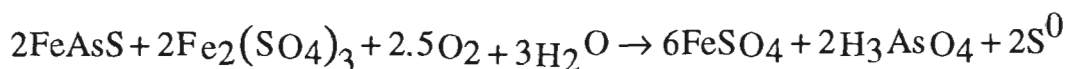
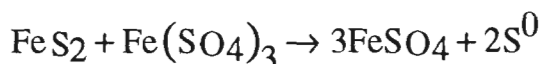
This chemolithotrophic bacterium contains energy for growth from the oxidation of ferrous iron and reduced valance inorganic sulphur compounds, and it uses carbon dioxide (from air) as the sole source of carbon for thesis of cell material [Torma, 1988]. The nutritional requirements of *T.ferro-oxidans* include $(\text{NH}_4)_2\text{SO}_4$, K_2HPO_4 and minor amounts of chloride, nitrate, calcium and magnesium.

4.5.2 Chemistry of Bioleaching

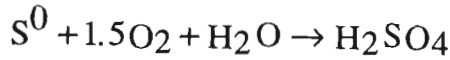
The metabolic oxidation of pyrite and arsenopyrite occurs by direct and indirect bacterial activity. The direct mode of bacterial leaching proceed via the reactions.



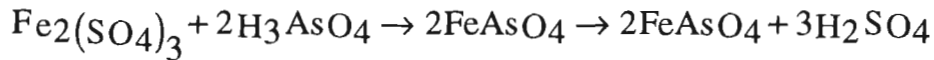
Where the indirect mode consists of



The elemental sulphur liberated as detailed in indirect mode will be oxidised to sulphuric acid by the bacteria



Ferric ion has a high affinity for the arsenic acid, which results in the formation of an insoluble ferric arsenate



During bioleaching of pyrite / arsenopyrite gold bearing minerals, the formation of elemental sulphur is possible, but in many instances detection of such accumulation is difficult because of reaction [Fair & Scheilder, 1987]

Both the direct and indirect modes of bacterial activity are electrochemical in nature. Therefore, it is possible to follow the process of bio-oxidation by electrochemical methods. It was found that the oxidation of pyrite by T. ferro-oxidans involves a number of indeterminate reactions, manifested by the peaks of a cyclic voltammogram [Choi, Wang & Torma, 1990] as shown in Fig. 4.2. Pyrite and arsenopyrite are semiconductors, and their activity may be dictated by the impurity levels and crystal defects related to n or p type semi conductivity.

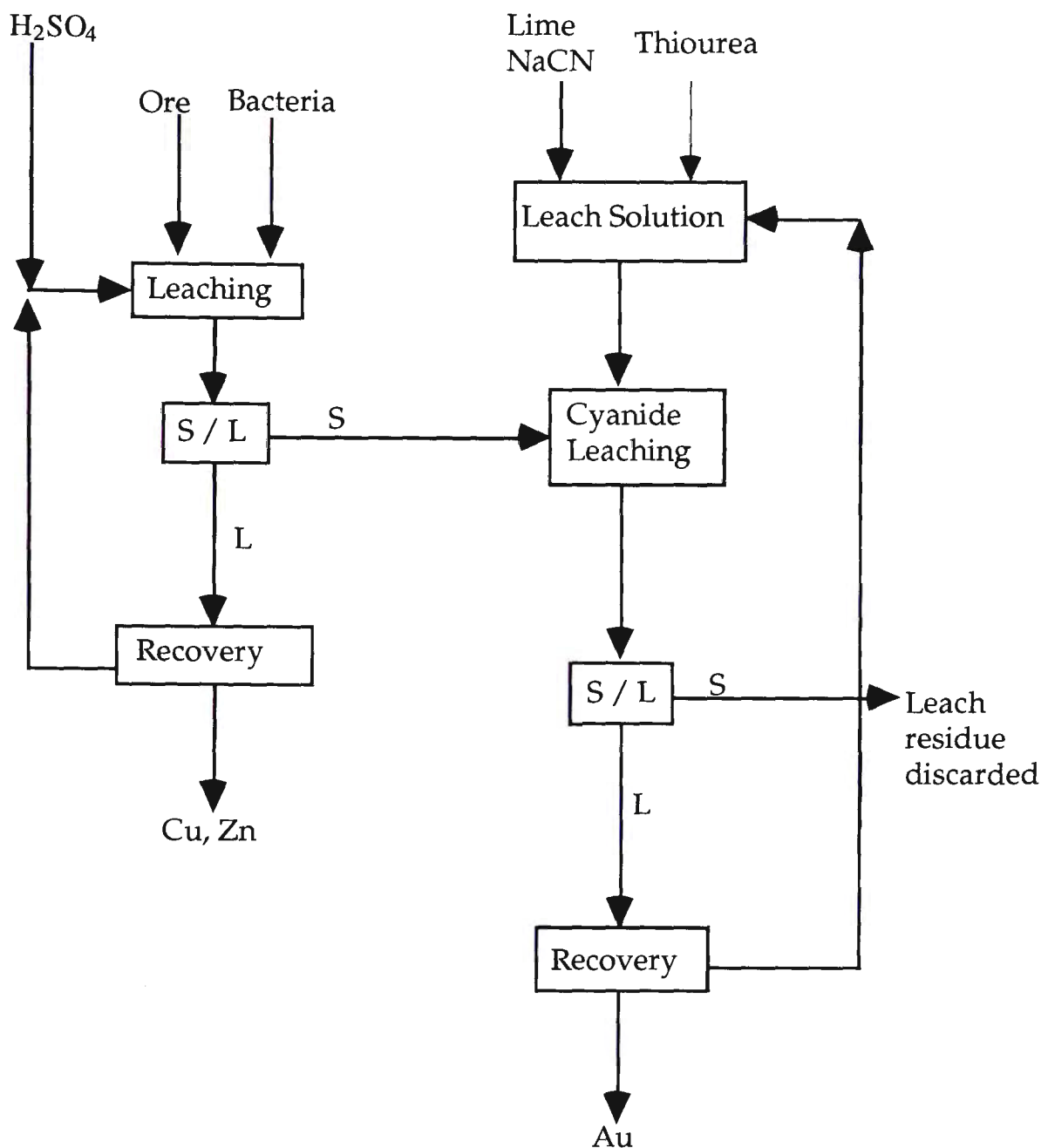


Fig. 4.2 Schematic depiction of bacterial preoxidation and cyanide leaching of arsenopyrite /pyrite refractory ores and recovery of gold from pregnant leach solution, s indicates solid phase, L liquor phase [Torma, 1988]

4.6 Optimum Mine-Mill Combination

In some areas, where the small mines operated while there was a central mill. Once it closed down, transportation to a more distant mill or smelter became too costly. But good market conditions have made some of these areas attractive again, since, a small mine can not justify its own mill but a combination of small mines in area may justify a central mill.

4.6.1 Multi Source-Central Process Facility

Due to lack of capital and expertise small scale mining operators are not able to establish milling facilities on the site. Therefore, the multi small mine-central mill concept is a new and very useful idea to solve the ore dressing problem of small scale deposits. In the following paragraph, some examples from United States are given to understand this concept clearly.

Several companies in the US have tried to establish central toll milling in older districts but have been unsuccessful primarily because small operations, on their own, can not be relied on to supply consistent feed. The only way most successful central facilities have assured consistent feed is to have control of the feed sources. Examples are the approach taken by uranium companies during the 1950's to 1970's on the Colorado plateau. Companies such as Climax Uranium, Energy Fuels and Union Carbide acquired large claim blocks containing numerous small uranium deposits. They then subcontracted or sublet these small deposits to as many as 150 individuals small operators. Some of these small operations produced as little as 45 tonnes. The ore was hauled on contract to central mills which were individually rated at from 306 to 1224 tpd. In some cases the mills were dependent on as much as 80% of the feed coming from company mines [Anon., 1966; White, 1978]. The multi small mine-central mill concept is presently more feasible in underdeveloped Asian and South American countries where the mining, socio and political climate is more attuned to the concept.

Another opportunity for the small miners is to seek small high grade deposits within or near a currently active large mining companies operations. The time and cost of discovery and exploration might be substantially reduced because current information may be readily available. The larger company may sublet or contract these deposits and mill the ore in its facility.

4.6.2 On Site Small Process Facility

Locating a small concentrator near the deposit is only justified if the economics are better than transporting to and processing in another facility. Several factors make a small facility cost prohibitive in comparison to a large one:

- (i) Per tonne operating costs are higher.
- (ii) Recovery is usually lower.

- (iii) Milling complex ores is more costly.
- (iv) Capital cost per tonne milled is higher.
- (v) Required more permitting in comparison to size.
- (vi) Required substantial quantities of water and power.
- (vii) Difficulties in finding a suitable tailing site near the mine and mill.

Before totally ruling out a mill on a small deposit there are other factors that a prudent small operator should consider. Sometimes a good balance can be achieved by transporting upgraded material to an established facility thus reducing transporting costs. Some ores can be upgraded by screening, ore sorting equipment, or rough gravity concentration. Other considerations are in-Situ and heap leaching, column flotation, or mobile "caravan mill".

4.6.3 Smelting and Refining

With few smelters in operation it has become more difficult for the small operation to sell their concentrates. Recent improvements in small scale precious metals leaching, smelting and refining have given the small operator the opportunity to produce a more saleable finished product. Also, some smaller precious metals refineries will take small lots of high grade concentrate and ore.

4.7 Discussion

Many smaller gold producers are the important contributors to world production and many of these producers produce certain precious minerals from vein type mineralisation. The development of this type of deposit presents both technical and financial problems. In many ways these problems are functions of the type of mineralisation and therefore apply to all sizes of deposits. Since smaller organisations can bring a deposit into production more quickly than large organisation, mainly due to their greater flexibility and less efforts put on investigations that are considered necessary by the large companies. It is also true to say, however, that the smaller companies are usually willing and able to start production at lower levels than a large

company could justify and, hence, the amount of exploration and development can be appreciably less.

Smaller operations do not differ much from larger operations in mining and processing. The main object of the operation, the maximum extraction of ore and recovery of mineral values, is the same but the methods may be different. The main differences are probably on the management side, where the lines of responsibility in smaller operations are usually very clear-cut, largely because of the minimal number of professional staff and the lack of inference from in-house technical expertise or consultants.

It is very sad to say that most small scale operations are inefficient in regard to both extraction and recovery and can be extremely wasteful as far as resources, both human and minerals, are concerned. Basically, this type of operation represents the worst features of high grading and, as such, can sterilise large tracts of ground that otherwise might have given rise to a well organised mining operation or operations.

Small scale mining does not need to be primitive, even at the artisanal level, and many small mine operations use modern techniques with a large degree of mechanisation and observe the best safety practice. In general, the difference between an efficient small mine and an efficient large mine lies in the size of the equipment used and the degree of mechanisation. Some mining methods, and therefore some equipment, are not suitable for the smaller producer or for vein type deposits as they have designed for large tonnage, often low grade, operations.

As, it has been mentioned above that if natural mineral resources are not exploited effectively, it is wasting of energy, capital and human resources. Since, most miners do not use mechanised methods due to lack of capital and information, the efficiency of operation is low and miners try to extract high grade gravels and leave low grade gravels in the ground.

It is suggested that there should be some cooperative societies organised and financed by the private sector or government to provide every possible help to small scale mining industry. These types of societies exist in Tanzania and many other countries, which, offer financial and technical assistance in the form of capital, recent geological data, and equipment hire on reduced rate. Government can play a major role in improving the mining techniques and equipment used for exploitation of small scale gold deposits. Government should, also, provide capital on low and easy interest to the miners, so that , they can purchase equipment for the effective exploitation of resources.

For optimum utilisation of resources, technology must be correct for the circumstances. It must allow machinery to work at maximum efficiency and require minimum maintenance. It must also be environmentally acceptable. Even, if equipment controlled by silicon chips gives the right answer, it should be used.

CHAPTER FIVE

COST BENEFIT ANALYSIS

CHAPTER FIVE

COST BENEFIT ANALYSIS

5.1 Introduction

Cost estimation is not an easy task in the mining industry as it is considered a very high risk industry. Costing is a very useful process in the economic analysis of any project in every industry. The results of costing are the foundation for budgeting and the calculation of profitability, tax and revenue etc.

Costs can be defined as resources used to achieve a given objective. Costs can be measured in the conventional accounting way, as monetary units that must be paid for goods and services, or in other ways such as hours of labour or litres of diesel fuel used to attain a production goal. Total costs are a function of production activities.

Capital and operating costs, and ultimately the profitability of a mining operation, are heavily influenced by the cutoff grade and production rate chosen in the design of facilities. The range of reasonable choice for these production criteria are limited by the amount of recoverable reserves at each cutoff grade as well as the distribution of mineralisation within the deposit. A knowledge of how costs and profits are affected as production parameters change is essential for evaluating discoveries, making design, and accurately predicting the financial outcome of a mining project.

If a given component of the cost changes in direct proportion to change in production activity, then it is defined as a fully variable cost. If a certain component of total cost remains unchanged for a given time despite wide fluctuations in production activity, then it is a fixed cost.

Expenditures for drill bits and grinding balls are good examples of variable costs (directly dependent on metres drilled for a given rock type, or tonnes milled for a given ore at a certain grind, respectively). The annual salary of mining engineer and a property tax bill are examples of fixed costs.

Every organisation has costs that may be classified as either fixed or variable (see Fig 5.1). It is important to recognise that fixed costs are only in relation to given time period, and within a given range of activity. A radical change in production system usually results in a new set of fixed costs.

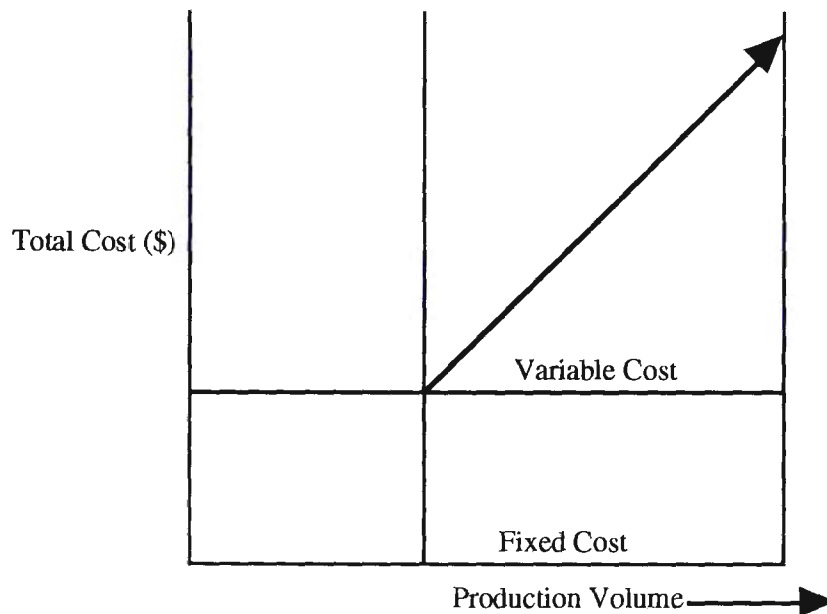


Fig 5.1 Fixed and variable cost [Recny, C. J]

Classification of costs is not an easy task. Costs often do not vary in direct proportion to changes in production levels, but are instead semi variable, exponential, or stepwise. Individual components of costs can also be influenced by more than one factor. Historical or projected expenditures are frequently stated in terms of unit costs. Unit costs are usually most useful to people who are directly responsible for incurring costs, and relate to measurable production activity, that is, cost per metre drilled, tonne mined or processed, or labour hour.

Since cost is one of the most important factors in the financial and economic evaluation of a mining project, it is better to mention, briefly, different types of costs together with their methods of estimation. Although the elements of cost are same for all mining operations regardless of the size of the operation, some elements are applicable or used more for large scale operations than small scale operations.

5.2 Types of Costs

The major costs used in evaluation of mining projects, budgeting, and financial analysis are.

- (i) Capital costs
- (ii) Operation costs

- (iii) Infrastructure costs
- (iv) Environmental costs
- (v) Maintenance costs
- (vi) Unforeseen costs

5.2 1 Capital Costs

Capital costs are the result of initial decisions taken by management on a project. If management decides to make the project capital intensive, then capital costs are high. But most of these decisions are taken by large mines which want to reduce high labour costs in order to increase production by making the project more efficient. There is always risk involved in capital intensive methods, in that, mines are unable to respond quickly to changes in technology and price systems.

Capital cost also depends on the selection of equipment. Open cut operations can use draglines, shovels, bucket excavators or scrapers. Small mines prefer to use small equipment which are cheaper and easily available in market, although funding of capital depends on financial institutions which are reluctant to lend due to high risk attached with small enterprises.

It is a false concept that capital cost per unit throughput is less with large scale equipment. Actually, smaller equipment with high sales volume can be manufactured on production lines where automation can give cost benefits. High competition is involved in high volume selling equipment.

Breakdown, accidents and downtime necessitate back up equipment or multiple units which may be idle for considerable time increasing capital costs. Small mines with shorter distances have a choice of large equipment for multi tasks or smaller dedicated equipment.

Second hand equipment in good condition is an alternative for small mines, which are unable to buy brand new equipment due to lack of capital. Another important factor regarding the equipment is, that since small mines generally prefer small and cheap equipment which can be replace or sell such equipment relatively easily. It can be concluded that small mines, normally, have a lower capital cost per tonne of ore than large mines.

Burmeister[1988] studied different projects to observe the estimated and actual capital costs [Table 5.1]. Of 21 projects where comparative data are available, Burmeister shows that 57% of them required capital expenditures which exceed their feasibility study estimates by more than 10%.

Table 5.1 Capital cost summary (All Figures in A\$ Millions) [Burmeister, 1988]

No.	Project	Estimate	Actual	% Change
1	Kidston	143.8	139.0	-3.3
2	Reedy	3.0	2.85	-5.0
3	Great Victoria	NA	3.0	
4	Nevoria	4.5	8.7	93.3
5	Mt. Percy	13.0	13.5	3.8
6	Paddington	34.0	33.2	-2.4
7	Sons of Gwali	NA	NA	
8	Porphery	10.5	9.2	-12.4
9	The Granites	30.5	31.4	3.0
10	Blubird	8.2	10.8	31.7
11	Harbour Lights	20.4	20.0	-2.0
12	Horseshore Lights	4.5	4.8	6.7
13	Bamboo Greek	15.0	16.0	6.7
14	Wiluna Tailing	7.0	7.2	2.9
15	Lawlers Tailing	1.39	1.50	7.9
16	King of the Hills	1.1	NA	
17	Pine Creek	37.0	33.0	-10.8
18	Canbelgo	0.65	0.80	23.1
19	Westonia	14.0	ON Budget	Nil
20	Golden Crown	18.2	Below Budget	
21	Galtee More	13.2	11.6	10.8
22	Cracow Tailing	2.8	NA	
23	Cork Tree Well	7.9	8.6	8.9
24	Great Eastern	5.0	NA	
25	Croydon	5.0	NA	
26	Lady Bountiful	1.6	1.6	0.0
27	Brilliant-Tindaals	0.335	NA	
28	Broad arrow	NA	On Budget	
29	Mt. Martin	2.0	2.0	0.0
30	Cowarra	3.3	4.5	36.4
31	Red Dome	NA		
32	Gwalia Tailings	5.0	NA	
33	Mt. Madden	NA	NA	
34	Howley Alluvials	NA	5.0	
35	Hawkins Find	NA	NA	
	Arithmetic Average	17.9	17.8	-0.6
	Maximum	143.8	139.0	
	Minimum	0.65	0.80	
	No. of Projects	22	22	

5.2.2 Operating Costs

Operating costs are incurred only when equipment is operated. Therefore, costs vary with the amount of equipment used and job operating conditions. Operating costs include operators' wages, which are usually added as a separate item after other operating costs have been calculated. The major elements of operating costs include:

- (i) Fuel cost
- (ii) Service cost
- (iii) Repair cost
- (iv) Tyre cost
- (v) Cost of special items
- (vi) Operators' wages
- (vii) Labour cost

(i) Fuel cost

The hourly cost of fuel is simply fuel consumption per hour multiplied by the cost per unit of fuel (litre). Actual measurement of fuel consumption under similar job conditions provides the best estimate of fuel consumption. However, when historical data are not available, fuel consumption may be estimated from manufacturers' data.

The cost of fuel depends on the unit cost and the engine consumption rate. As a general rule, fuel consumption can be estimated as 0.3 litres per hour per kilowatt of engine capacity. This consumption rate in turn is dependent on age/condition of the engine, duty cycle, idling time, operator skill and work area conditions. These machines / site specific items are reflected by the fuel job factor [Westcott & Hall, 1993].

$$\text{FuelCost}\left(\frac{\$}{h}\right) = \text{Engine(KW)} \times 0.3 \left(\frac{L/h}{KW} \right) \times \text{FJF} \times \text{UnitCost}\left(\frac{\$}{L}\right)$$

Where, FJF varies between 0.3 and 0.6.

(ii) Service cost

Service cost represents the cost of oil, hydraulic fluid, grease, and filters as well as the labour required to perform routine maintenance service. Equipment manufacturers publish consumption data or average cost factors for oil, lubricants, and filters for their equipment under average conditions. Using such consumption data, multiply hourly consumption (adjusted for operating conditions) by costs per unit to obtain the hourly cost of consumable items. Service labour cost may be estimated based on prevailing wage rates and the planned maintenance program.

(iii) Repair cost

Repair cost represents the cost of all equipment repair and maintenance except for tyre repair and replacement, routine service, and the replacement of high wear items, such as ripper teeth. It should be noted that repair cost usually constitutes the largest item of operating expense for construction equipment.

Life time repair cost is usually estimated as a percentage of the equipment's initial cost less tyres. It is then necessary to convert lifetime repair cost by the expected equipment life in hours to yield an average hourly repair cost. Although this method is adequate for lifetime cost estimates, it is not valid for a particular year of equipment life. As it can be expected, repair costs are typically low for new machines and rise as the equipment ages. Thus it is suggested that the following equation be used to obtain a more accurate estimate of repair cost during a particular year of equipment life [Nunnally, S. W].

$$\text{Hourly Repair Cost} = \frac{\text{Year Digit}}{\text{Sum of Digit}} \times \frac{\text{LifeTime Repair Cost}}{\text{Hours operated}}$$

(iv) Tyre cost

Tyre cost represents the cost of tyre repair and replacement. Among operating costs for rubber tyre equipment, tyre cost is usually exceeded only by repair cost. Tyre cost is difficult to estimate because of the difficulty in estimating tyre life. As always, historical data obtained under similar operating conditions provide the best basis for

estimating tyre life. Tyre costs are calculated by multiplying the number of tyres by the purchase cost of each tyre divided by the life of the tyre. Tyre life typically ranges between 1500 and 12,000 hours, with 4000 hours as an average. By incorporating allowances for the following in a tyre job factor, then site specific costs are calculated:

- Tyre type and quality
- Tyre maintenance conditions
- Travel speed
- Road surface condition and ambient temperature
- Prevailing work conditions
- Degree of overloading
- The number of curves and grades

In addition to the hourly charge for wear on tyres, costs are also associated with ongoing tyre maintenance usually expressed as a percentage cost [Westcott & Hall, 1993].

$$\text{Tyre Cost}\left(\frac{\$}{h}\right) = \frac{\text{No. of Tyres} \times \text{Unit cost}(\$) \times 1.05}{4000}$$

Where, TJF varies between 0.3 and 4.0.

(v) Cost of Special items

The cost of replacing high wear items such as dozer, and scraper blade cutting edges and end bits, as well as ripper tips, shanks, and shank protectors, should be calculated as a separate item of operating expense. As usual, unit cost is divided by expected life to yield cost per hour.

(vi) Operator wages

The final item making up equipment operating cost is the operator's wage. Care must be taken to include all costs, such as workman's compensation insurance, social security taxes, overtime or premium pay, and fringe benefits in the hourly wage figure.

(vii) Labour costs

Although big mines are more capital intensive, it does not necessarily lower labour costs. With big machinery unions have the opportunity to demand multiple manning, restrictive work practice and skill margins. It is difficult to manage a large workforce due to more demands, problems and extra overhead expenditures. Certain supervisors are needed to handle these matters of a large workforce which in turn can lead to industrial relation problems.

On the other hand, a manager of a small mine does not need to appoint supervisors in order to deal with workforce problems. He, himself, deals directly with all his employees and there is the opportunity to work just as a small team where everybody knows and trusts each other. In this case there is less need for supervision but more involvement, which, results in flexible work practice and higher productivity. At the same level of capital intensity the small mines should have an advantage. With high labour intensity small mines may be able to offset the higher labour cost with lower capital costs.

5.2.3 Unforeseen Costs

Even though the greatest care and effort is made in the estimation of costs in a project, it is quite surprising to find a project which has been completed without the pre estimated cost. Especially, in countries where the economic conjuncture is quite unreliable and unpredictable and where surprising devaluation of currency randomly and frequently occurs. It is therefore necessary to include one cost item "unforeseen costs" to the total project cost.

Of course the percentage of unforeseen costs compared to the project cost would widely vary according to the period of investment. It may be reasonable to allocate 10-20% of the total project cost as unforeseen cost in a project whose investment interval is 1-3 years. For a project of longer investment period unforeseen cost may be taken as 15-30% of the total project cost.

5.3 Case Study

Papua New Guinea and New Zealand have a very strong small scale gold mining industry. Although the nature, size, grade, economic situation and currency rate of these two countries are totally different. Again, it is possible to consider and compare real capital and operating costs existing in these two countries. Typical capital

and operating costs as in August 1990 are presented in the following tables. The costs presented are for a skid mounted, 1.65 metre diameter trommel plant with hydraulic riffles fed by a Komatsu pc 300, 30 ton hydraulic excavator. This combination plant has a rated capacity of 80 m³ per hour.

Table 5. 2 Basic operating parameters and assumptions [Hancock, G, 1991]

	NZ	PNG
Operating weeks per year	45	48
Plant utilisation %	80	70
Operating hours per day	10	10
Shifts per week	5.5	5.5
Exchange rate to US	1.57	0.94
Fine gold price(\$US 380 / oz)	\$595	K358
Alluvial gold fines	840	700
Effective corporate tax %	35	46.05
Exchange rate	KPNG / \$NZ = 1.67	
Average throughput and recovery		
Throughput (m ³ / hr)	80	80
Plant utilisation (%)	80	70
Operating days / year	288	315
Annual throughput (' 000 m ³)	1184.3	1184.3

5.3.1 Typical Capital Costs

The costs presented in Tables 5.2 to 5.4 assume the operating parameters outlined in Table 5.1.

5.3.2 Capital Costs for New Plant:

A capital cost breakdown for the establishment of new plant on a new mine site is presented in Table 5.2. Total capital costs are \$US500,000 (\$NZ785,000) and \$US527,000 (KPNG495,000) for NZ and PNG respectively. The higher PNG capital cost is basically a function of shipping cost and import duties. It is clear from these figures how the costs are affected by the introduction of taxes, customs and import duties, especially, in developing countries and these factors are the main barriers in the development of this industry.

Table 5.3 Typical capital establishment costs in \$US [Hancock, G, 1991]

	NZ	PNG
Property acquisition	31,850	10,650
Trommel plant (80 _m ³ / hr)	127,400	1149,000
Excavator (30t)	203,800	213,000
Light vehicles (4wd utilities)	38,200	47,900
Pumps and pipework	63,700	53,000
Site establishment	6,370	10,650
Electrical connection	15,900	32,000
Total capital costs	499,960	526,850

5.3.3 Average Annual Direct Operating Costs

Average annual direct operating costs are presented in Table 5.3. The main reason for this difference is the use of experienced but expensive expatriate manpower. This is continued for at least two years until experienced PNG operators are trained.

Table 5.4 Average direct operating costs in \$US [Hancock, G, 1991]

	NZ	PNG
Manpower (men)	3	13
Wages costs	61,150	170,000
Accommodation	0	42,500
Fuel	30,900	41,900
Oil (at 16% of fuel)	4,950	6,700
Repair and maintenance	25,600	50,500
Light vehicles	5,100	5,500
Electricity	17,800	2,100
Washup / refine	3,200	5,300
Rehabilitation	5,700	5,300
Land use compensation	5,500	9,600
Hydrologic control	7,650	2,100
Total operating costs	167,550	341,500

Table 5.5 Typical overheads costs in \$US [Hancock, G, 1991]

	NZ	PNG
Accountancy and legal	12, 700	21, 300
Management fees	25, 500	21, 300
Insurance	6, 350	10, 600
Total overheads	44, 550	53, 200

5.4 Importance of Cost Estimations

Any mine valuation requires time and judgement, and if these are limited, most of the effort should be spent on careful analysis of capital costs, operating costs, and the operating environment that influences such costs. A review of mine projects that have failed to yield the profits expected from the original evaluation shows that errors in predicting capital costs, operating costs, and mine productivity are much more prominent than errors in predicting metal prices and markets, taxes, and financial appraisal.

Accurate estimates of capital and operating costs are possible only when there is detailed knowledge of the physical quantities, labour and productivity to be attained. This knowledge is normally achieved only after a substantial portion of the design engineering works has been performed.

Preliminary cost estimates of moderate accuracy can be attained in advance of engineering by factoring known costs from similar projects, with allowances for differences in size, scope, topography, timing, isolation, climate, orebody shape, and mineralogical and metallurgical conditions.

5.5 Variation in Costs With Mine Size

It is clear that the size of a mining project, in terms of daily tonnage of throughput, affects the capital and operating costs to a major degree. Conventional accounting tends to consider costs as either fixed (constant regardless of mine size) variable (costs vary in direct proportion to mine size) or semi variable (a specific mixture of fixed costs and variable costs). In practice, virtually no costs are purely fixed, purely variable, or a specific mixture of purely fixed or purely variable. All

costs, to a greater or lesser degree, are semi variable, but the variation with mine size is exponential rather than arithmetic.

Thus, if we assume that a 1% increase in tonnage causes a 0.6% increase in costs, arithmetic costs variation projects a 100% increase in tonnage causing a 60% increase in costs. On the other hand, exponential costs variation projects a 100% increase in tonnage as causing a $2^{0.6} - 1.0 = 51.6\%$ increase in costs.

5.6 Capital and operating Estimation for Surface Mining Equipment

Fundamental to economic evaluation of a mining project is the provision of reliable equipment capital and operating costs. The majority of small scale gold deposits are exploited by surface mining methods, so, which it is very important to analyse the cost estimation of necessary equipment. Many estimation methods are available but is standard. The necessary data for these costs is typically provided by the suppliers of equipment, historical records from operating mines or from previous studies. Application of these costs are input to feasibility studies, budgeting and data for economic analysis of different mining options. Figures 5.2 and 5.3 summarise the costing process costing.

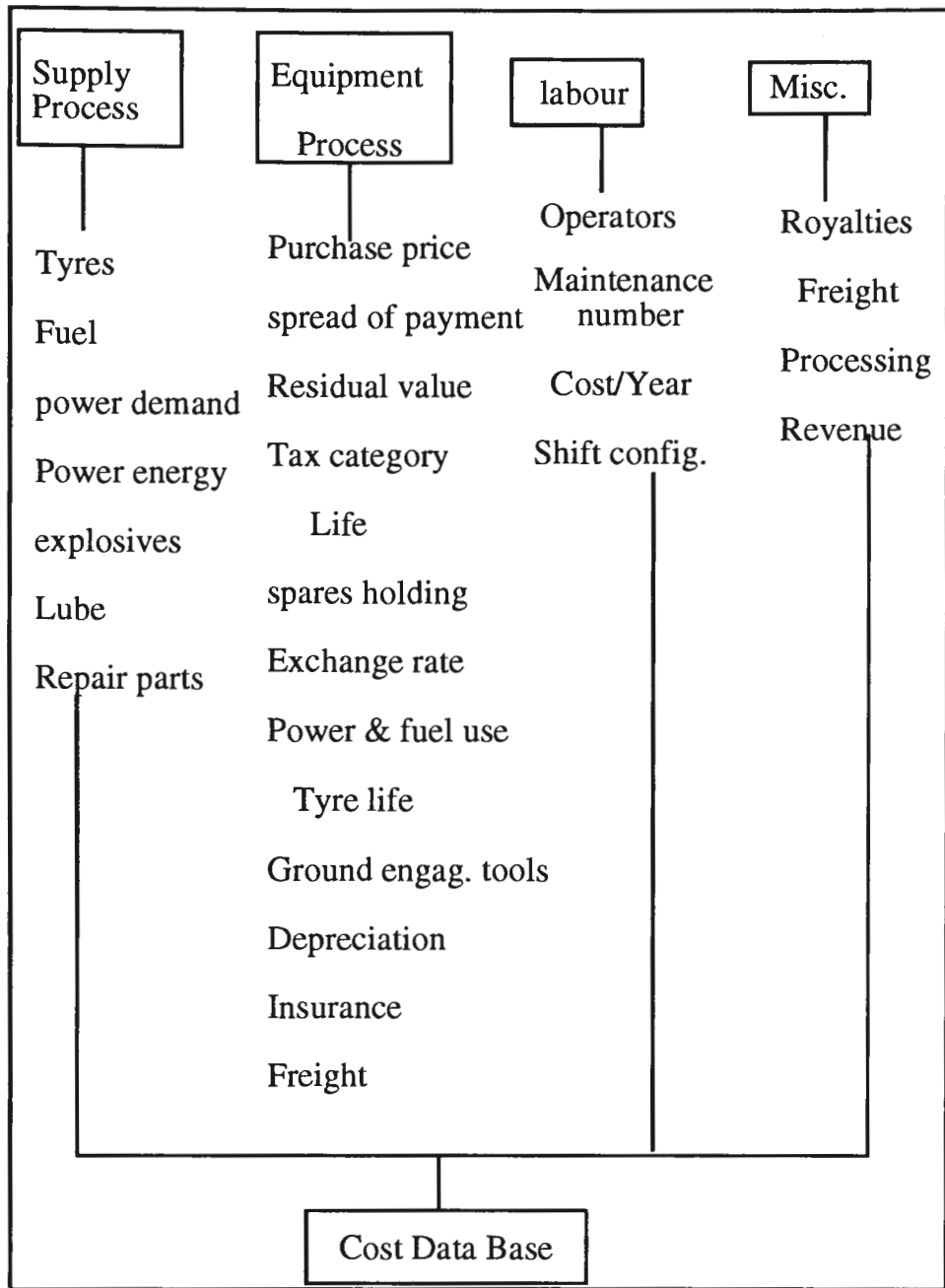


Fig. 5.3 Build Up of a cost data base [Westcott, and Hall, 1993]

5.6.1 Capital Costs

Capital costs are commonly estimated by three methods, or a combination of these:

- (i) A quick estimate where a "rule of thumb" is used such as dollar per tonne erected multiplied by the weight of the machine.
- (ii) Budget estimates from suppliers or manufacturers (which can have a plus or minus 20% variation to allow for exchange rate variation and a margins for negotiation).

(iii) Actual tender or contract bids which are definitive and binding.

The Method chosen should be commensurate with the type of study being undertaken. It is often desirable or necessary to determine the hourly ownership costs of a single item of plant and two methods are in common use. The first as proposed by many equipment suppliers is calculated from the sum of the straight line depreciation and a percentage of the annual average investment to cover taxes and insurance .

$$\text{Depreciation cost} = \frac{\text{Cost}}{\text{Life(hours)}}$$

$$\text{Taxes, interest, insurance} = \frac{\text{Average Yearly Investment} \times \text{Rate}\%}{\text{Annual Hours}}$$

Where, Average yearly investment is calculated from the delivered price

$$\text{multiplied by } \frac{(n + 1)}{2n}$$

where "n" is the life in years.

This calculation assumes a value of zero at the end of the machine life, and Rate% is the interest on the invested funds in the equipment, plus an insurance amount (typically 1-2%), plus any property taxes levied on the valuation of the equipment.

Table 5.5 gives typical operating life of mining equipment in hours. These refer to operating hours when the machine is manned and is consuming power. An important distinction should be made between "accounting life" and "operating life". Accounting life is used for tax purposes and represents how quickly the equipment can be written off for tax purposes. The operating life is the actual life the mine expects the equipment to operate at an availability satisfactory to meet production targets and at an economic cost.

Table 5.5 Expected operating life (Hrs)[Westcott & hall, 1993]

Item	Poor Condition	Average Condition	good Condition
Dozer			
Crawler	10,000	15,000	20,000
Wheel	8,000	12,000	15,000
Grader	12,000	16,000	20,000
Front End Loader	10,000	15,000	20,000
Hydraulic Excavator			
Construction	10,000	15,000	20,000
Mining	20,000	30,000	40,000
Scraper	8,000	12,000	16,000
Truck			
Bottom Dump	30,000	40,000	50,000
Rear Dump-small	15,000	20,000	25,000
Rear Dump-large	20,000	30,000	10,000
Drills			
Small	16,000	20,000	30,000
Large	60,000	120,000	150,000
Shovels	60,000	120,000	150,000

Another method is to treat the plant as if it were being leased. Lease rates include all of the above factors but more correctly account for the higher interest component of the cost earlier in the equipment life. For this calculation, the primary inputs are:

- (i) interest rate (i)
- (ii) present value (pv) and
- (iii) erms in years (n)

This allows the "capital recovery factor" to be calculated. This spreads a present value amount over a period of "n" years and produces a series of equal amount occurring at the end of each year for the period specified. This method is simpler and more realistic than the average annual investment method.

5.6.2 Estimation of Equipment Operating Cost

There is no standard method used to estimate operating cost of equipment, instead, costs are derived from certain factors and formulae. Costs are build up from first principles and are then cross checked with actual mine statistics. The steps involved in deriving costs are listed below:

- (i) Establish an estimate of the capital cost of the item of equipment.
- (ii) Dissect the machine into cost elements such as tyres, fuel, power and labour.
- (iii) Subdivide each cost element into component parts.
- (iv) Assign a life or utilisation to each component part and calculate the hourly cost.
- (v) Total all the components to achieve the total hourly operating cost.

Although, deriving costs from first principles is accurate, determining the costs and life for all components in a machine is quite time consuming and it is often difficult to get accurate information. In order to solve this problem, a set of factors or formulae may be necessary to estimate the hourly cost.

In order to derive factors it is assumed that any piece of equipment is just a set of spare parts. These parts have different operating life. By knowing the "standard" operating life (commonly 10, 000 hours) it is possible to calculate the total cost of parts expected to be purchased throughout this "standard" life and afterward the hourly cost of these parts is calculated. Since the cost of spare parts is somewhat in proportion to the original purchase price of the equipment, the above cost is calculated by multiplying the initial cost by a "repair factor" or maintenance parts factor and then dividing by the standard operating life to get an hourly rate.

This cost is adjusted according to the number of operating hours and operating conditions which may incur higher than normal or average operating cost. This method, although, provides useful derivation but reliable results depend on the judgement of estimating the repair factor and job conditions. For estimating purposes, operating costs are firstly estimated for typical or average conditions which are adjusted up or down depending on:

- (i) Material characteristics such as density, swell, abrasiveness and hardness.

- (ii) Job conditions such as operator skills.
- (iii) Labour factors including management, maintenance philosophy and proximity of spare parts and
- iv) Utilisation factors such as the annual operating hours.

Overall job conditions can be divided into three main categories:

(i) Good conditions

Material is relatively loose and free flowing. Equipment operates with considerable idling or low power. Wear items may have long life due to less abrasiveness. Low digging power is required and material heaps well into the bucket. Tyres wear out rather than fail due to cuts and abrasions. There is a ready supply of spare parts and the work force is relatively skilled. This type of condition is ideally more suitable for small mining units as they can not replace the spare parts often and most of its labour force is multiple skilled.

(ii) Average conditions:

Material requires blasting to maintain productivity. Some power is required to penetrate the bank and the material heaps reasonably well. Machinery has periods of full utilisation but there are still some idle periods. Wear rates are moderate. There is an average supply of spare parts and the workforce has average skill.

(iii) Poor conditions:

Higher power consumption required for blasting and often the material is bulky, irregular in shape and has poor fill factors. Machinery is often used at full capacity and tyres fail due to rock cuts and abrasions. Wear rates are high and component life is reduced. There are limited skills in the workforce causing higher repair costs. The equipment is divided into cost elements in order to analyse the operating costs correctly. Each of these cost elements are described in the following sections and listed below:

- (i) Power, energy and demand
- (ii) Fuel
- (iii) Lubrications

(iv) Tyres

(v) Repair parts (maintenance supplies) such as filters and hydraulic hoses

(vi) Wear parts (operating supplies), such as teeth and bits

(vii) Major overhauls

(i) Power-energy and demand

This covers the electrical power costs required to operate the machine and can be subdivided into an "energy component" as well as a "demand" component which reflects the required installed capacity of the power generation facility. This demand charge is a result of the cyclical loads of most mining machines and the electricity authority must be able to supply high power for short period of time.

(ii) Fuel

Fuel costs are based on the unit cost of fuel, and the fuel consumption rate. The unit cost of fuel typically falls between \$0.25 to \$0.35 per litre after allowing for rebates. The fuel usage depends on conditions of the engine, the duty cycle, operator skill and road conditions. Fuel consumption at 100% load factor approximates to 0.03 litres per hour per kW. Load factors range from 0.025 to 0.08. For example, a truck with a 1300 kW engine hauling under average conditions has a fuel consumption of $1300 \times 0.3 \times 0.35 = 137$ litres/hour.

(iii) Lubrication

If no detailed lubrication charges are available they can usually be calculated as a percentage of the hourly fuel cost. These proportions range from 15% for equipment with a relatively low proportion of hydraulic componentry up to 30-40% for equipment with a high proportion of hydraulic componentry. The consumption rate can be expressed as either litres/hour or Kg/hour and can be obtained from manufacturers or operational records. These are then multiplied by their appropriate unit cost.

(iv) Tyres

Total tyre costs are obtained by multiplying the cost of each tyre by the number of tyres and dividing by the hourly life. Tyre manufacturers give guidelines for calculating hourly life. The tyre life can vary from 1,500 to 12,000 hours depending on

site conditions. This is usually a base number of hours (4,000 is a common base) multiplied by a series of factors. These factors account for [Westcott & Hall, 1993]:

- (i) Tyre maintenance conditions
- (ii) Speed
- (iii) Surface conditions including temperature
- (iv) Road and work conditions
- (v) Amount of overloading and
- (vi) The number of curves and grades

(v) Maintenance supplies

Maintenance supplies are also referred to as repair parts. Two types of methods for estimation of maintenance supplies are presented. The first method is appropriate for large equipment and is to multiply the capital costs by a percentage and divide this by a number of operating hours per year. Typical values for the percentage range from 3% to 10%.

The second method uses a standard operating life of 10,000 hours and then calculates the maintenance repair parts cost by multiplying the initial capital cost by a repair factor and then dividing this by the standard operating life to get an hourly rate. This is adjusted if the number of hours is greater than the standard operating life and then further adjusted for job conditions.

(vi) Operating supplies

Operating supplies can also be referred to as wear parts or ground engaging tools. Wear items include bucket teeth, ripper boots, drill bits, cutting edges and so on. These are usually separately itemised as they are directly related to the ground conditions. In that case, lives are applied to each ripper boot, bucket tooth, etc. and costs are individually built up. This is the recommended approach for any detailed level of evaluation.

A simple method is to apply the Wear Parts Cost Factor to the capital cost (WPCF), using the same logic as deriving maintenance supplies, and adjust for job conditions (WPJF) [Westcott & Hall, 1993].

Where

$$\text{Wear Parts Cost (\$/h)} = \text{Capital (\$)} \times \text{WPCF} \times \text{WPJF}$$

(vii) Major overhauls

Major overhauls cover the cost of major component exchange or rebuild. This can be estimated as a percentage of initial capital cost (such as 15% every 12,000 hours) or as a build up of components and their life. For example, a truck could be subdivided into engine, transmission, body, frame, electrical and so on. The cost of each of these major components (or the cost of rebuilding them) can then be estimated with estimated life. This gives a standard cost per hour even though the actual expenditure may only occur when the damage or rebuild is implemented.

Alternatively, a simple approach is to assume that a proportion of the initial capital cost will require rebuild/overhaul/replacement after a specific period. Typically, for large equipment, this will be 15% of the initial capital cost every 100,000 hours [Westcott & Hall, 1993].

$$\text{Major Overhaul Cost (\$/h)} = \frac{\text{Capital(\$)} \times 0.15}{10,000}$$

CHAPTER SIX

INFRASTRUCTURE NEEDS AND COSTS FOR MINING PROJECTS

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INFRASTRUCTURE NEEDS AND COSTS FOR MINING PROJECTS

6.1 Definition and Infrastructure Needs

Infrastructure may be defined as anything necessary for the development and operation of a project, which is peripheral to the basic extraction, handling and processing of material. As depicted in Fig 6.1, infrastructure acts as a bridge between the technological aspects of a project and the outside world.

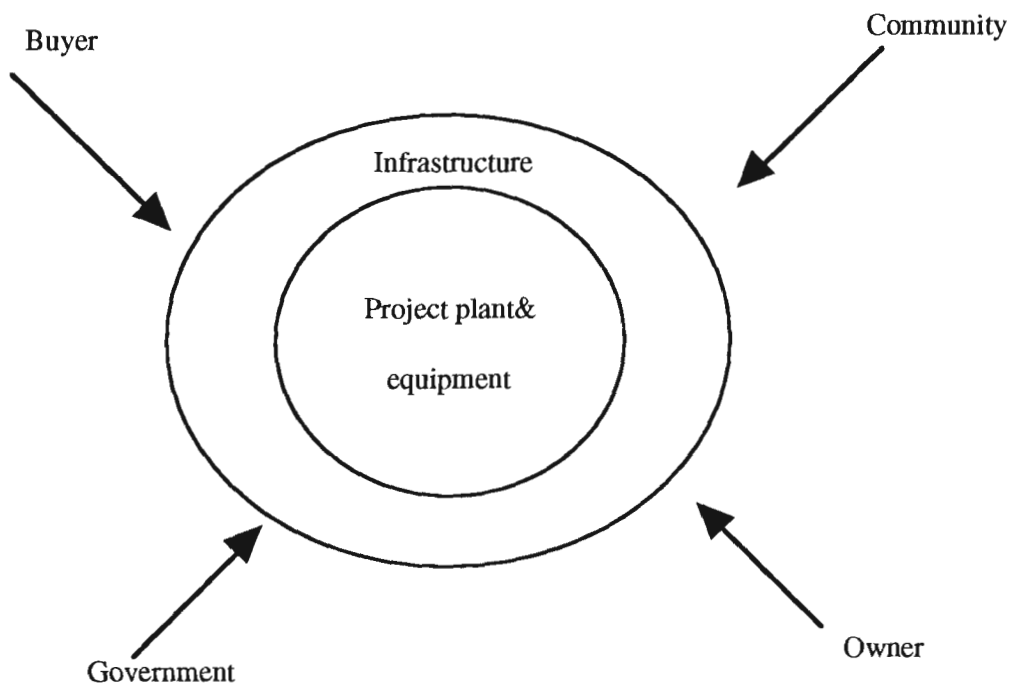


Fig. 6.1 Infrastructure relationship with other influences on a project [Groves & Gibbs, 1990]

Proper development of small-scale mining, in fact mining on any scale, requires some basic infrastructure such adequate and reasonable cheap transport and communication, power, medical facilities, engineering services banks etc. Since transportation charges are one of the heaviest items of cost, at times more than total production costs, it will have to be kept low if the minerals are to be supplied at reasonable prices in the market. Infrastructure is a very vast, costly and time consuming process. Therefore, the elements of infrastructure are grouped into four major types.

- (i) Urban planning
- (ii) Transportation
- (iii) Power
- (iv) Water supply

It is interesting to note that all natural resource projects need infrastructure and this need is a function of two factors, the nature of business and the geological location of the site. In the past provision of infrastructure formally remained the responsibility of governments, now whole burden has fallen on the shoulders of owners. But, again, in some developing countries, governments are responsible for the infrastructure.

Infrastructure needs for mining projects vary widely. For example, a plant expansion project at an existing mine in a near urban area ("urban / brownfield") is unlikely to present the same difficulties as a new mine in a remote location ("remote / greenfield"). A typical list of infrastructure needs for a mine is given in Table. 6.1 with comments indicating the variability of the impact, depending on the type of project.

Table. 6.1 Impact of infrastructure on project costs [Groves & Gibbs, 1990]

Infrastructure item	Remote green field	Remote green field
Railways		
branchline	minor	major
upgrading	minor	major
service yards	minor	significant
unloading load	significant	significant
rolling stock	significant	major
Access road	minor	major
Water supply		
pump station	significant	major
pipeline	minor	major
storage	significant	major
Power supply		
transmission	minor	major
substation	significant	major
distribution	minor	major
Township		
sub-division	negligible	major
utility services	negligible	major
housing	negligible	major
community facilities	negligible	major
Peripheral support		
workshop store	minor	significant
admin. amenities	minor	significant
services	minor	significant

6.2 Urban Planning

Sociological aspects of urban planning are crucial because the environment in which the mine staff reside directly affects the operational well being and thus directly affects the operational success of the mine resources. It is the most important duty of management to choose a suitable location for a township and it should be well planned, because urban planning is capital intensive and it is not possible or easy to change the whole structure and site of a township. It is a long term project and all facilities related with township are used until the end of mine life. The following aspects are generally accepted.

- (i) It is preferable to combine the housing and amenities for mine employees with an existing town rather than to build a new "mine only" town even at the cost of additional travel.
- (ii) The special circumstances of the mine staff and their families (eg. shift work, young families) should be taken into consideration while designing the housing facilities.
- (iii) Where a choice exists, small urban type amenities are preferred to large centralised ones.
- (iv) Incorporation of single accommodation within normal town development houses and flats rather than separate large barracks, although some hostel-type accommodation may still be required for transient workers.
- (v) It is, socially, preferable to combine the housing and amenities for mine employees within an existing town instead of building a new town.

Housing facilities are, generally, provided to direct employees and their families only. For preliminary purposes, these can be assessed as follows:

- (i) 70% will be married people, accommodated in houses
- (ii) 10% will be family members other than married men and will not require separate accommodation
- (iii) 20% will be single adults

The mix of housing with respect to size, standard and type is generally defined on a hierarchical basis with typically:

- (i) Senior management style
- (ii) senior staff
- (iii) A range of two, three and four-bedroom houses
- (iv) Single person quarters as self-contained flats

In general, discrimination in housing standards is being eliminated and, for initial cost estimates, reasonable building costs can be assessed by the application of unit costs for different house types based on house area. For many types of individual houses, transportable type units are favoured owing to the lesser requirement for site construction labour. Housing costs may be established by the selection of an appropriate unit cost/area/house type. Indicative constructed costs are shown in Table 6.2.

Table 6.2 Indicative housing costs [Garner, 1993]

House type	Area	Transportable (\$/	Conventional (\$/
Management	250	800	900
Senior staff	200	700	800
Staff house	200-120	700	700
Single person quarters (per person)	25-30	\$8,000-12,000	\$8,000-12,000

The developer has to provide housing facilities to indirect employees in addition to the direct workforce. Census figures, based on towns within reasonable reach of a major regional centre, indicate an indirect workforce of 50% of the direct workforce. Approximately 50% of the indirect workforce could be assumed to be family members of the married male direct employees.

In addition to providing housing facilities, it is also important to provide amenities. It is suggested that, in purely mine towns, more community facilities are required for women and small children as a substitute for the type of extended family and family friend assistance more generally available in longer established and more diverse communities. Typical amenities include,

- (i) Shopping centre
- (ii) Sporting facilities
- (iii) Swimming pools
- (iv) Parks

The management of small mines can not provide all these amenities as most of these are luxury and capital intensive for small mines. Since, a few persons are employed to work in small mines, it is not possible to provide all of these amenities but some of the above mentioned amenities are necessary regardless of mining operation because the small mines are in remote areas.

If management of small mine can not provide basic amenities for its employees, then, for example, in places where there are many small mines in the same area, it is possible to have central amenities which can be used by the staff, employees and their families. Generally, the costs of these facilities are provided by the mine owners. But in some cases state governments are ready to invest in these facilities if mining is one of the main industries of the country. On the other hand it is much better to set housing facilities near the existing town and use the common facilities.

6.3 Transportation

Transportation is an important element of infrastructure. It is used to carry both personnel and products. Roads are the main method used for transportation of both personnel and products. Good all weather roads are important prerequisites for the working of mineral deposits. Therefore in planning roads during different plan periods the potential and likely mineral areas should be adequately covered so that the provision of roads may help timely and quick prospecting and exploitation of the mineral deposits. Transportation can be divided into two groups.

- (i) Personnel transportation including the provision of roads and airport and
- (ii) Product transportation which could involve or have roads, railways, conveyors. Slurry pipelines and port facilities.

(i) Personnel Transportation

Design standards for access roads is the most important and crucial element of transportation and depends on the requirements, available capital and topography of the

area. State authorities are generally responsible for designing the standards of access roads. Access roads are typically design 6.8 to 7.4 metres wide, sealed with 1.8 metre shoulders, with a typical pavement depth of 300 to 350 mm depending on the subgrade.

(ii) Product transportation

Road transport finds application for short hauls and low annual tonnages. Flexibility, manoeuvrability and a greater grade capability are the main advantages of the road transport system. Road systems are particularly exposed to inflation in view of the high capital cost of replacement equipment and the labour intensive nature of the operation. The major capital cost is the fleet cost, fleet sizing being a function of haul distance and annual capacity.

6.4 Power

An industrial venture needs power, and it is necessary for small-scale mining also. Since, use of diesel power is much more expensive than electricity the natural preference is for electricity. Where power lines can not be drawn on purely commercial basis the mines will have to depend, out of compulsion, on diesel generator sets or diesel drive engines. However, in cases where mines occur in a cluster, it has been suggested that an industrial electric feeder line should be provided to a group of small mines by the "State Electricity Board", and the mine connection be provided under the rural electrification scheme where electric power may be provided at concessional rates as in the case of other specialised consumers.

Where such power lines are not available for remote areas the government may provide cash-subsidies to small entrepreneurs for purchasing generator sets. Provision must be made for the supply of electric power to both mine and town site. The high voltage transmission lines and associated switchgear / sub-station are design to the standards of the local supply authority and may even be installed by them at the owner's cost. Basic considerations in providing power for mine production and collateral operations are [Thuli, 1973].

- (i) Mining operations of any size normally use electric motors for driving all equipment except mobile service units.
- (ii) The electricity may be purchased or self generated, depending on the location, size and specific circumstances of the individual property.

- (iii) The major elements of the power system will be source, either an incoming transmission line from a utility in the case of purchased power or power plant itself-generated. Energy for the power plant may be water, hydrocarbon fuels, waste heat or nuclear, which will govern the type of prime mover selected.
- (iv) At the points of use, there will be starting and protective devices for each motor. In some instances, direct current will be needed and rectifiers of various types can be used to provide it.
- (v) The entire electrical system requires suitable switching and protective devices to prevent damage to the equipment in case of power failures or faults.

The decision of how to generate power can be critical to project economics and a number of alternatives should be considered. In remote areas, there may be no alternative to the on-site generation of power and particularly if process steam is required, this generally proves attractive. selection of the fuel, distillate, fuel oil, natural gas or coal will also impact on other areas of infrastructure cost.

6.4.1 Power Generation

With the establishment of the process requirements, an initial assessment of power demand can be made. The magnitude of the load may be helpful in deciding whether to connect to a state or Authority power system. Authority discussion on the availability and cost of power at the site will indicate whether transmitted power is a potentially viable option or whether alternatives need to be considered. If on-site generation is to be considered, the selection of plant is influenced by:

- Power requirements
- Steam requirement, if any
- Alternative methods of power and steam generation
- fuel availability and cost
- Control, operating and maintenance philosophies

6.4.2 Power Transmission

Power must be supplied to user facilities through a transmission and/or distribution system. This system consists of the main power station and many

substations where the supply voltage is dropped to the required working voltage. Selection of transmission voltage depends on electrical characteristics, transmission distance and economics. A transmission voltage of 11KV is frequently used but for long distance it can be 132 KV. However, 66 KV and 33 KV transmission lines have also been utilised.

Transmission line design has become highly computerised, with specialist companies offering design and construction services. Steel or timber pole structures are generally used and selection depends on the environment and life of the line. Typical transmission line costs are shown in Table 6.3. Higher costs relate to broken country, where steel (tower) structures are used and where access is difficult.

Table 6.3 Typical transmission line [Garner, 1993]

Transmission Voltage	Costs (A\$/Km)
132KV	90,000-100,000
66KV	45,000-50,000
33KV	20,000-25,000
11KV	12,000-15,000

6.5 Water Supply

Water is not only required for human consumption but is one of the most important elements for gold concentration by small scale mining. Water is especially needed in sluicing operations. The use of hydraulic sluicing to dislodge the gravel from a face is very rare, mainly, because of the lack of any pumping capacity and availability of water at most sites. Most operations occur in the river beds using natural water flows to move gravels through the sluice box. The gravels are usually fed into the box by shovel or spade. So, it is not possible to determine the exact amount of water required for sluicing operations.

Potable water requirements vary with locality, with factors such as climate, nature of soil, policy re metering and charging exerting major influences. The range of consumption varies from 400 to 1, 600 litres per head per day, with 1, 200 litres being a useful figure for preliminary evaluation.

6.6 Cost Estimation for Infrastructure

Cost estimate for mining development projects are generally derived by projection of a known cost base and cost factors. The certainty of the estimate increases as more project-specific details are developed. Estimates can be categorised in five groups.

(i) Type 1 - Order of magnitude

These are used to establish the broad viability of the project and, where appropriate, recommend more detailed studies be undertaken. They can also provide the basis of fiscal planning budgets.

(ii) Type 2 - Economic feasibility study

These are used to evaluate more fully the alternatives available, develop accurate financial studies, advance market negotiations and to establish areas that require more detailed investigations, or to positively reject the project.

(iii) Type 3 - Project commitment and funding

These estimates are used to obtain approval for the project to proceed with the allocation of appropriate funds. These estimates also form the basis of the initial project budgets during preliminary design and ordering of delivery items which require a long lead time.

(iv) Type 4 - Control estimates

These are used to confirm the scope and cost of the project and act as the basis for the project control and reporting systems. These estimates are usually undertaken when preliminary design has been completed, quotations for some of the major contract packages have been received, and government charges finalised.

(v) Type 5 - Definitive estimates

These are used to confirm the control estimate and provide the client with information that will increase his confidence in the final project cost. This estimate is undertaken when engineering is essentially complete, detail

design well advanced, equipment items ordered, and site work has commenced.

In estimating the costs for infrastructure, the technique is basically the same as for mining or processing equipment, ie, start with a factored estimate based on historical costs for road, rail, township, etc., and develop project specific details.

An additional challenge in handling infrastructure costing, however, is that frequently the infrastructure facilities are provided by others, eg. government, so direct access to and control of costs may be difficult for the owner of the project. For example, in some major projects the infrastructure costs associated with rail and port facilities are funded by a capital contribution by the project owner and / or a levy per tonne of product transportation / shipped. The quantum of these contributions is often influenced by potential to share with other project owners (ie. common user facilities) and by the policies of the various tiers of government and statutory authorities.

CHAPTER SEVEN

INVESTMENT ANALYSIS

ANALYSIS OF SMALL GOLD MINES

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INVESTMENT ANALYSIS OF SMALL GOLD MINES

7.1 Introduction

All mining projects are financially evaluated to establish the value of the operation, this may be done so that decisions can be made either to mine or not, during take over bids, legal reasons or any operational decisions such as modifying mining techniques, buying new machinery and mine expansion. Three basic aspects technical, economic and financial analyses are involved in the evaluation of a mining project. Where technical analysis is the most difficult and requires much effort. Financial analysis involves the assessment of cash flows which are projected for the life of the mine. It requires building a financial model to reproduce cash flows. All cash flow models follow the same basic principles, of obtaining revenue from the commodity, estimating operating and capital costs, royalties, depreciation and taxes resulting in cash flows and finally making a decision as to the validity of the project. The price of the commodity is one of the most important elements of project evaluation.

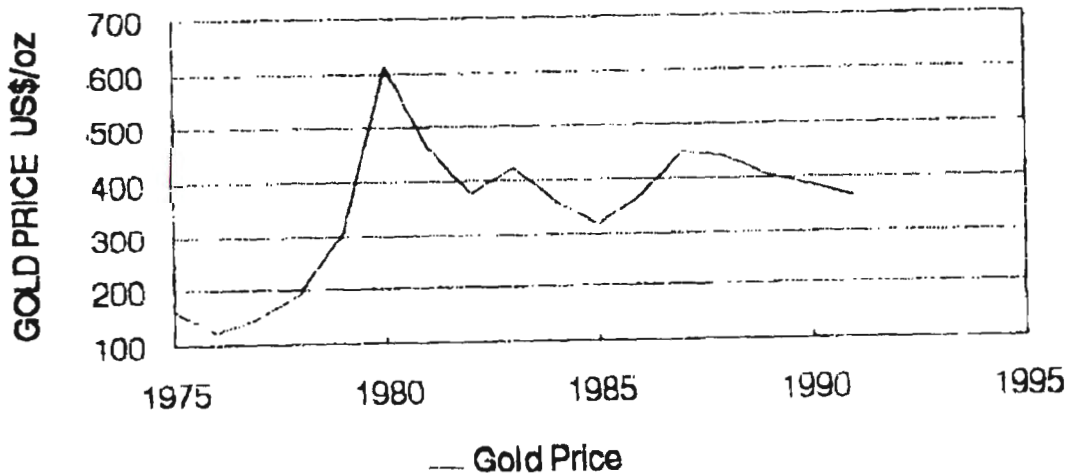


Fig 7.1 Gold price history [From personnel communication and reports of West, 1992)

The gold market is one of the most volatile of all commodity markets. Since the late seventies, significant and wide ranging price fluctuations have occurred over short periods of time as shown in Fig.7.1, creating many problems for gold producing companies.

Although some parameters are within the range of management but variations in gold price are outside the control of management. This volatility is even greater for Australian gold producers who must also contend with a floating \$A / \$US exchange rate as shown in Fig.7.2. Even though this is the case, one still has to be fully aware and must attempt to predict the value (worth) and viability of a project.

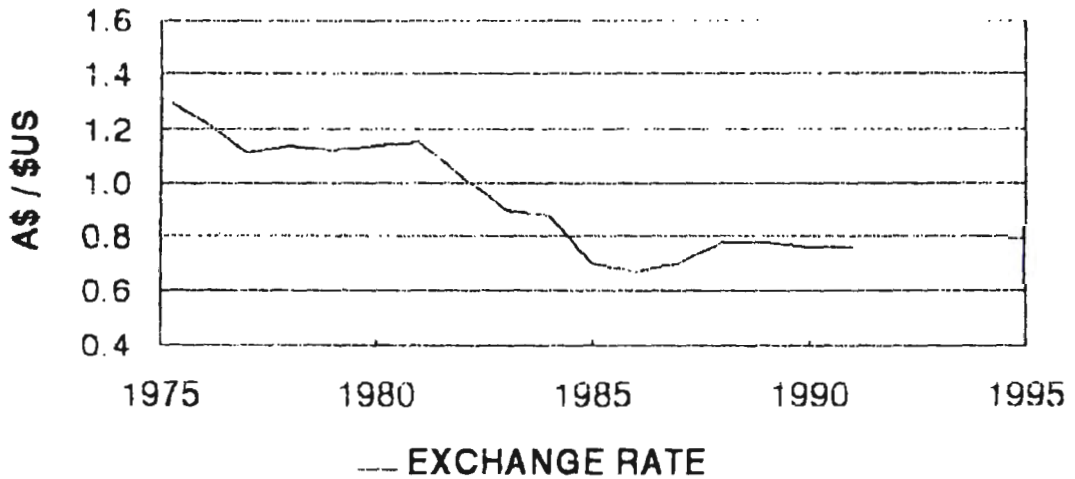


Fig. 7.2 Australian exchange rate [From personnel communication and reports of West, 1992]

It is very difficult to predict the future prices of a volatile commodity like gold due to many factors including the effect of market supply and demand. There has been considerable of variation in gold price during the last two decades. In the early seventies the price of gold was below US\$100 per oz, while in the late seventies the price increased to around US\$ 300 per oz, followed by an unpredictable rise in 1980 where the price doubled to an average of US\$ 614 per oz. The gold price then dropped to US\$ 460 per oz in 1981, and has basically stayed around the US\$ 400 per oz mark, with 1985 price dropping to the lowest at US\$ 317 per oz. Therefore, predicting of gold price for the next ten years will be an educated guess at best, spite of attempts to use various economic models in some instances (Gentry and O' Neil, 1984).

For the purposes of economic analysis, the mining company should be considered a decision making or planning organisation primarily associated with the exploitation of mineral resources. The objectives of this chapter are to discuss the nature and scope of data necessary for conducting a preliminary feasibility study of projects in the mineral industries and when reliable data has been collected or carefully estimated, to select the proper analytical technique or techniques. These will evaluate the economic feasibility of these projects and compare them with alternative opportunities. There are various reasons for economic analyses, some of which are the follows:

- To evaluate the actual engineering design of the development of a mineral deposit.
- The acquisition or sale of a working mine.
- A planned change in the mining or processing methods that consequently may affect the extraction rate (tonnes of ore per unit of time), the extraction level (tonnes of contained minerals per unit of time, as a result of change in cut-off grade), or other economic conditions under which the particular mine is operating.
- An assessment of value of assets for taxation purposes (mostly property and severance taxes).
- Re-evaluation of priorities in the allocation of investment funds by the firm.
- The evaluation for the purposes of bidding for leases.

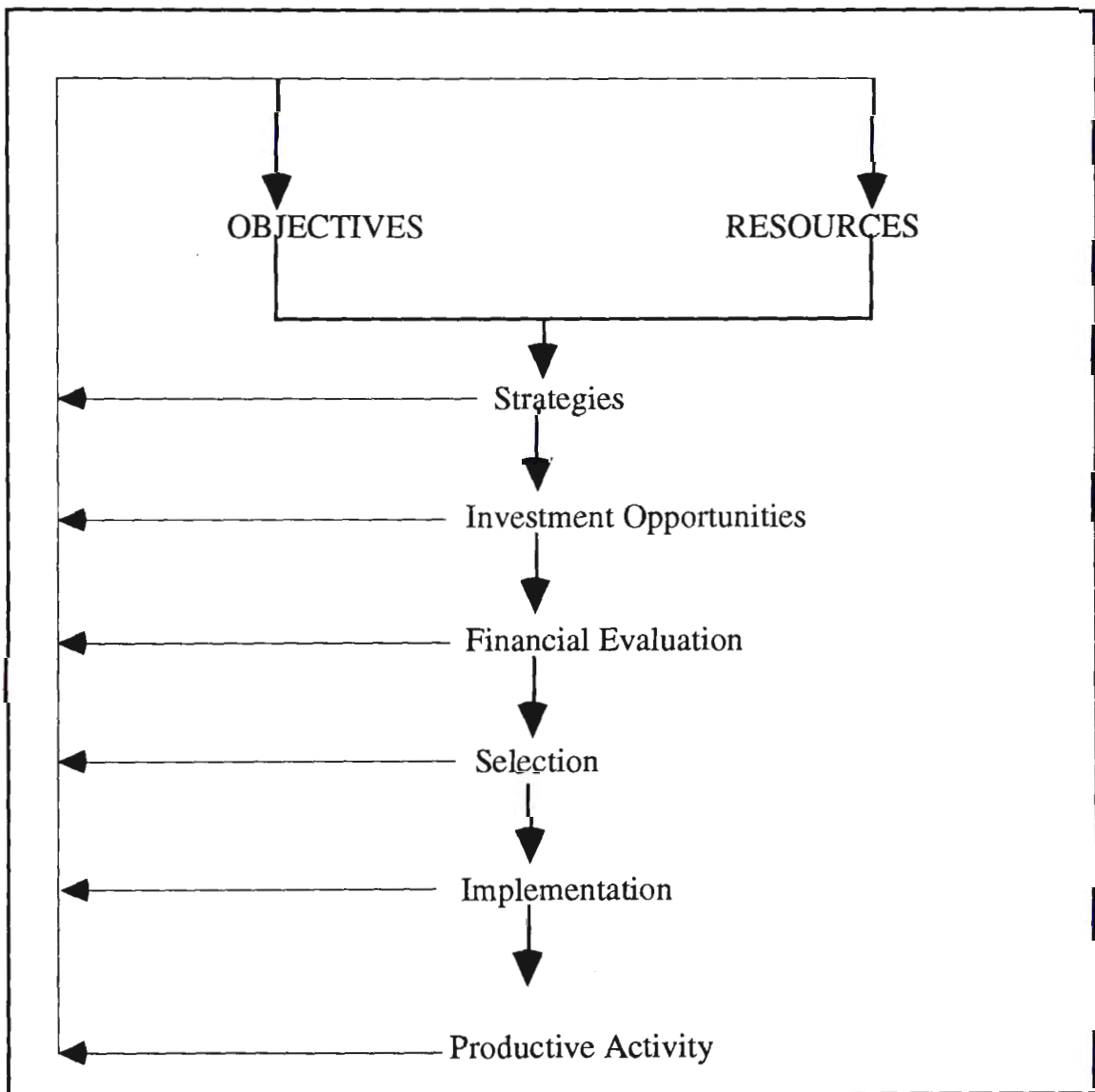


Fig 7.3 Conceptual mining companies planning framework [From personnel communication and reports of West, 1992)

The mining companies planning framework, outlined in Fig. 7.3 consists of the setting of objectives, the development of corporate resources, the channelling of resources through strategies to areas of environmental opportunity, and the evaluation, selection and implementation of investment opportunities. The relationship between objectives, resources and environmental conditions guide the development of corporate strategies (Mackenzie, 1984). There are generally considered to be three fundamental corporate objectives: profit, survival and growth. Corporate resources consist essentially of capital, managerial and technical skills. The mining environment has three basic components: exploration environment, a market environment and a government policy environment. All these provide opportunities and constraints in evaluating a mining project.

7.2 The Investment Decision Process

The starting point for the economic evaluation of an alternative to support an investment decision, as shown in Fig. 2.2, is the gathering and development of relevant experience and information. These may be generalised from a relative situation or may be specific to the alternative at hand. The balance of experience and information will shift from general to specific as an investment opportunity moves from its identification towards implementation (Mackenzie, 1984).

In many cases available experience and information provide the basis for estimating the future condition anticipated if a decision were to be made to proceed with the investment. Relevant estimates depend on the type of investment being evaluated but may include, for example, geological parameters such as ore reserve tonnages and grade, engineering plans associated with their application, mineral market forecasts of demand and price condition, and government policies relative to such forecasts as mining taxation, environmental controls, and provision of physical and social infrastructure.

Economic evaluation techniques are then applied to reduce these future estimates to a few indicators of the economic attractiveness of the alternative, termed investment decision measures in Fig.7.2. These measures are intended to portray the quantitative economic dimensions of the investment in terms of expected value, sensitivity, and risk criteria. At the same time attention should be given to non-quantifiable or intangible factors. Those discoveries which satisfy minimum acceptable conditions are considered economic deposits.

7.2.1 The Concept of Cash Flow

Project and venture, the spending of which usually has to be justified in terms of return or profit. Economic evaluation consists of comparing the costs of the resources and effort needed to finance these ventures with the value of the expected benefits. In order to make this comparison as many factors as possible are measured in the same units, those of money or cash.

Any project (or venture) involves a certain set of payments (cash movements). Some of these payments are made by the company to the project in order to run it. These are called cash-out items. Other payments are made to the company as result of the project.

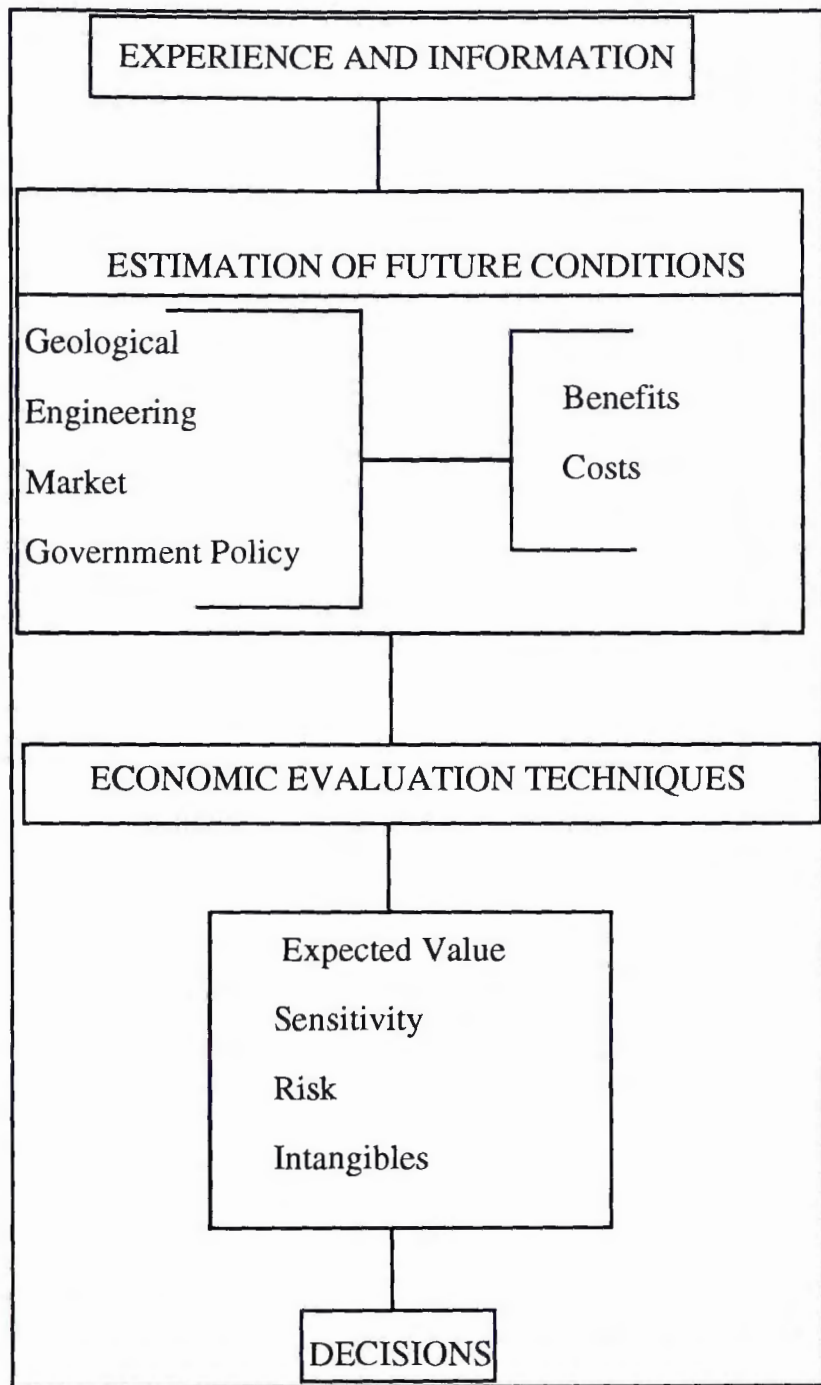


Fig. 7.4 The investment decision process [From personnel communication and reports of West, 1992)

These are cash-in items. The net result of the payments for any particular period, say, a year, will either be a cash-out or cash-in, which may be indicated by negative or positive sign, respectively. A series of such cash deficit/surplus figures for successive years represents cash flow of the project. Therefore, cash flow is the difference between actual cash benefits and costs for a specific time period. While special circumstances may require the estimation of cash flows on a monthly or quarterly basis, an annual period is usually suitable for evaluation purposes.

Benefits elements may include:

- Revenue from the sales of mineral products.
- Royalty payments for mineral rights.
- Salvage value for the sale of used equipment.
- The return of working capital at the end of a mine's productive life.
- Custom milling income.
- Realisation of tax credits.

Cost elements may include:

- Ongoing exploration.
- Expenditures.
- Capital costs.
- Operating costs.
- Royalties.
- Taxation payments.

The benefit and cost estimates should include all economic factors associated with an alternative and cover the total period of the project, starting at the present time and moving out into the uncertain future. Cash flow estimates of a project are of a great importance during the early years of a mine life. Sunk costs which have already been realised or incurred should not be included in the analysis since they have no direct role in the decision process. Therefore the economic outcome of an investment alternative is initially portrayed by the anticipated time distribution of cash flow, over its projected future life. The cash flow distribution represents the return on investment offered by the opportunity and, as such, a demand for investment funds.

In order to evaluate the cash flow distribution, the general estimates of metal prices and smelter payments, together with the individual deposit estimates of recoverable ore reserves, mill recovery, mine and mill capacity, capital costs, development period, and operating costs, are used to evaluate the cash flow distribution. Recoverable reserves and production scheduling should be estimated with the help of a computer aided orebody modelling program, using all available geological data. The expected mill recoveries along with the ore grades are estimated from the geological data, and possibly from bulk samples. Revenues are obtained from the sale of the commodity but if commodities are handled in foreign currency then it is appropriated to indicate the exchange rate.

The selling cost, smelter payments, freight and insurance may be estimated from existing mines working in a similar environment. All off lease selling costs are subtracted from total revenue in order to get net revenue. Operations cash flow is obtained by subtracting all operation costs including royalty and interests on loans from the net revenue. Allowable tax discounts like depreciation, on going exploration, and tax loses for the year are deducted from the operations cash flow to obtain the pre-tax profit. A flat rate of 39% is applied to the taxable income, which is paid to the government, yielding the net profit.

The operation cash flow is used again, where the taxation amount calculated is deducted to obtain the actual cash flow from operations. All capital cost outlays are deducted from this cash flow, then loan receipts if any are added to obtain the net cash flow, from which most economic evaluations are obtained. The capital outlays are capital expenditure, working capital, replacement capital, ongoing exploration, and any loan repayments.

Maximising benefits or minimising costs are the basis for evaluating projects by using normal cash flow analyses. Most mining projects are analysed from the point of view of maximising benefits, where equipment replacement decisions or production system alternatives are often evaluated from the point of view minimising costs. It is more appropriate to evaluate investment decisions for the purposes of maximising benefits.

Sometimes the results of the analyses based on cost minimisation can be misleading because minimum cost is only possible by shutting down the facility which is not a suitable course of action for any industry. Only when the revenue from each alternative are identical can minimum cost be safely used as a proxy decision variable. This means that the output of each alternative must be identical in quality and quantity.

All concepts of cash flow are tied together into a table, and repeated for each year of the project life (Table 7.2). The costing for each year of the project is affected by the time value of money concept which will be described later. Loan interest calculations, net cash flows and inflation are taken into account in the time value of money. Table 7.1 is used for each year of the project, and is commonly known as the Discounted Cash Flow (DFC) table in this thesis.

Table 7.1 Discounted Cash Flow [Adopted from Ikoku, 1985]

		YEARS 1 TO LIFE
	Total Revenue	
Less	Off Lease Selling Costs	
Yields	Net Revenue	
Less	operating Costs	
Less	Royalties	
Less	Loan Interest	
Yields	OPERATING CASH FLOW	
Less	Depreciation	
Less	Exploration	
Less	Taxes carried Forward	
Yields	PRE TAX PROFIT	
Less	Taxation	
Yields	NET PROFIT	
	OPERATING CASH FLOW	
Less	Taxation	
Yields	CASH FLOW FROM OPERATIONS	
Less	Exploration	
Less	Capital Cost	
Less	Loan Payback	
Add	Loan Receipts	
Yields	NET CASH FLOW	

7.2.2 Time Value of Money

It is a very basic concept in economic analysis that money has a time value—a given amount of money now is worth more than an equal sum at some future date. The long lead time between initial investment of funds in exploration and development of mines and the inflow of revenue when these mines are fully operative requires the incorporation of the time value of money concept in the analysis because of the different time aspects under consideration. The concept of time value is used in evaluation practice to allow for one important cost which is not considered in the determination of cash flows, the cost associated with investment funds being demanded [Gentry, and O'Neil, 1984].

The techniques which are commonly used to evaluate projects and compare different alternatives require recognition of the time value of money and understanding of the methodology for handling this concept, which is the proper use of interest

formulas and tables. Interest is the difference between the value of an earlier rather than later availability of funds. It is the price which is paid for the use of money on loan. The amount of the loan on which interest is paid is called the principal. The interest rate is the fraction of the principal that is paid per unit of time.

The actual interest rate depends on a number of circumstances among which the most important is the cost of capital which depends on

- (i) The risk involved
- (ii) Availability of capital
- (iii) Size of loan
- (iv) Duration of loan and
- (v) Whether the return is taxable or not

7.3 Parameters of Cash Flow

(i) Taxation

In every profitable operation there is one certainty-whatever the profit, the government is going to get a share of it. A mining operation, like any other manufacturing or service activity, faces various taxes from three different levels of government, federal, state, and local. Taxation is a major factor in evaluating mining project development. The availability or otherwise effective tax relief for project expenditures can have a crucial bearing on the decision with a project. The taxes are generally implemented to achieve one or more of the following objectives:

- Raising revenue
- Economic development
- Price stability
- Wealth redistribution
- Regulator medium

Cash flow is generally calculated on an after tax basis revenue. Revenue operating costs and capital expenditure are a before tax cash flow element where operating costs can be written off for tax purposes in the year that they occur. Capital expenditures are deducted for tax purposes in the form of depreciation allowance which are written off over a number of years starting in the year incurred. A flat rate of tax is

applied to the resulting taxable income, and in the case of all mining projects one straight value of 39% of the taxable income is used.

(ii) Off lease selling costs

These costs include smelting, freight, insurance and other sales charges. If the mine does not have a smelter, then contracts must be set up with nearby smelter facilities, they may get very involved for base metal, with different rates and penalties for each individual mineral in the project. Other sales cost include things like marketing and sales costs.

(iii) Royalties

In the case of mining, royalties are a payment which must be paid to the Federal government for the removal of a mineral from the ground on a yearly basis. Some royalties are based on rate per tonne of ore produced, others on a percentage of sales, and, occasionally, on a percentage of profit. Rates vary depending on the state and the mineral. For gold all states except the Northern Territory and Western Australia follow the same rule with differing percentages. The rule is X% of gross revenue refining, off lease transport and insurance costs. The respective percentages are as follows:

NSW	.4%
QLD	2%
SA	2.5%
TAS	2.5%
Vic	2.75%
WA	0

Western Australia does not charge royalties for mining gold, however in the Northern Territory two operations are used to compute royalty payments. These are 18% of post tax profit less depreciation and 5% of gross revenue minus off lease selling costs.

(iv) Depreciation

Depreciation is a non cash charge, deductible from the tax base, which represents a reasonable allowance for the exhaustion, wear and tear, and obsolescence of a fixed asset used in business or held for the production of income. This enables the firm to recover the cost of the depreciable asset during its estimated useful life. In

general, an item can be declared depreciable if it retains a reusable value over a period of time.

There are several methods of computing regular depreciation allowance, for example, straight line and declining balance methods are generally used in Australia.

- Straight Line

The straight line method of depreciation allows the deduction of an equal amount from the taxable income each year over the life of the asset. The procedure is to estimate the useful life of a piece of equipment and its salvage value, if any, at the end of such useful life. Salvage value is the amount of capital one would receive for a piece of plant or equipment once its service life has ended or the mine closes down. This is sometimes known as “scrap value”. Under Australian Tax Law there are three commonly used periods of depreciation years. Three years for small type equipment that have high wear rates, five years for most other equipment and machinery and life of mine for other mine setup costs like building and shafts.

The formula for the straight-line depreciation method is

$$D = \frac{c - s}{n}$$

Where

D= Depreciation allowance per year

S= Estimated Salvage Value

n= Estimated life in years

The straight line depreciation rate is $\frac{1}{n}$.

- Declining Balance Method

The declining balance depreciation method allows calculation of the annual depreciation at 150% or 200% of the straight line rate applied to the unpredictable balance of the assets, which is the book value. Since the salvage value is not deducted from the cost of the depreciable equipment, however, the total depreciation can not

exceed the total cost of the less its salvage value. The formula for the declining balance method is given in Equation 6.2.

$$D = \frac{F}{n}(C_u)$$

Where

F= Depreciation factor

C_u = Undepreciated balance for a given year

Although the rate is constant, it is applied to a declining balance each year. A larger depreciation deduction is taken for the first year and a gradually reduced deduction is taken in subsequent years.

7.4 Basic Financial Evaluation Concept

Valuation is defined as estimating or fixing of the value of a thing (the estimated worth), in our case a gold mining project. Cost and value are terms which must be explained first, as they are misunderstood frequently. Cost is defined as a price paid to acquire, produce, accomplish or maintain anything. Value is the measure of desirability or usefulness of ownership. Some of the types may be assessed, book, capitalised, cash, insured, market, replacement and salvage values. The worth of a property is the market value, which is the price established in a public market, by exchanges occurring between a willing buyer and a willing seller that are under no duress to do so. This value varies according to the economic environment at the time [Gentry, and O'Neil, 1984].

Three main approaches are used to determine market value, a cost approach, comparable sales and income approach, but not all are applicable or even used in mining ventures. Using the income approach, the value of a project is determined by estimating future costs and production. These estimations are then used to calculate the future amount of net earnings (cash flows) that may be generated from the project, which are then discounted to the present value using an appropriate interest rate. Using this approach the buyers would not be justified in paying more than the present value of the project.

If the project fulfils its estimated cash flow then the buyer would receive his original investment plus the interest which was used in calculating the present value. Most mining companies use the concept of cash flow analysis to evaluate their projects.

Another evaluation technique which is commonly used is sensitivity analysis, which is a means of evaluating the effect of uncertainty on the results obtained. This is done by varying the commodity price, operating costs and capital costs, and observing changes to the result.

7.4.1 Evaluating Techniques

Two main evaluation techniques those of discounted Cash Flow (DFC) and non-discounted cash flow, also known as Conventional Accounting Methods are used to evaluate mining projects. In DFC analysis the time value of money is recognised. Discounted cash flow rate of return, also known as Internal Rate of Return and Net Present Value along with Net Annual Value and Net Future value are the main techniques of DFC analysis. Accounting Rate of Return and Pay Back Period are the two main techniques used in Conventional accounting Methods. In the mining industry, IRR, NPV and Pay Back Period techniques are mostly used.

7.4.2 Net Present Value

The net present value or present worth is probably the most common evaluation technique in use. It requires a predetermined interest rate, representing the firm's cost of capital and any number of other factors (for example, growth element). The term present value simply represents an amount of money at the present time ($t=0$) which is equivalent to some sequence of future cash flows discounted at a specified interest rate. In other words this technique recognises the value of money and provides for the calculation of an amount at the present time which is equivalent in value to a series of future cash flow.

Expected net cash flows throughout the life of the project, either negative or positive, are discounted at this rate to a given period (usually it is the present, or year 0) and summed up. The rule of thumb is to accept projects that maximise NPV profit and reject all projects having negative NPV profit.

The greater the positive NPV for a project, the more economically viable it is. A project with a negative NPV is not a profitable proposition. If, however, a project is not concerned with making a profit, but with meeting a necessary objective at the minimum overall cost, for example, investment in pollution control to meet required standards, its NPV will be negative. The economic aim is to consider alternatives in order to reduce the negative NPV (net present cost) to as small a level as possible. NPV may be calculated using the following Equation.

$$NPV = \sum_{x=1}^n \frac{CF_x}{(1+r)^x}$$

Where

CF= Cash flow value occurring at point in time n years

r= Target interest rate

n= Number of years

NPV may be calculated by adding all Present value for each of the project years. Present Values are calculated using the following formula:

$$PV = \text{Cash flow that year} / (\text{Interest Rate} / 100)^{\text{Present Value}}$$

7.4.3 Internal Rate of Return

This is the average expected yearly return rate on investment for the estimated life of the project. The evaluation of IRR does not require the selection of a discount rate. The procedure is to find the discount rate which produces a net present value of zero. This is the rate of return of the investment opportunity.

$$\sum_{x=p+1}^n \frac{CF_x}{(1+r)^x} + \sum_{x=1}^p \frac{CF_x}{(1+r)^x}$$

Care must be taken in using IRR as an evaluating tool, because it may be considered useless if any debts are involved in evaluating the cash flow, or if two values exist, as would happen when the NPV goes from negative to positive, then negative again as in Fig. 7.5. For example if a loan is taken for a large percentage of the capital costing, then all the cash flows might be positive, not allowing the IRR to exist. An error may still exist if the present value for any of the years are not negative, causing the IRR value to approach infinity in some cases as shown in Fig. 7.6.

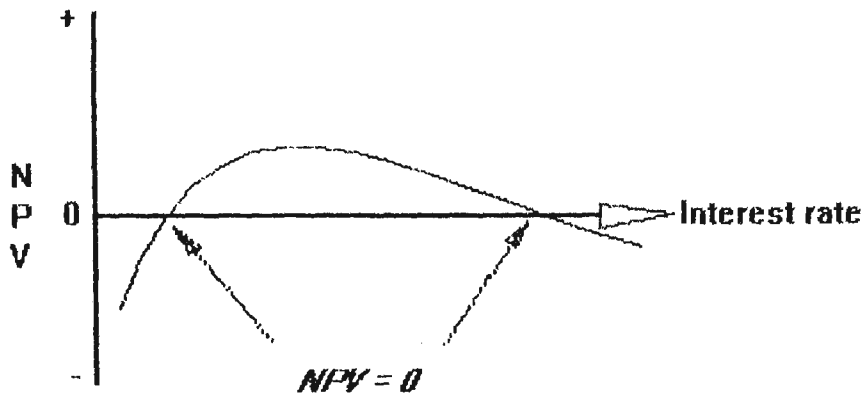


Fig. 7.5 Two Internal Rate of Return [From personnel communication and reports of West, 1992)

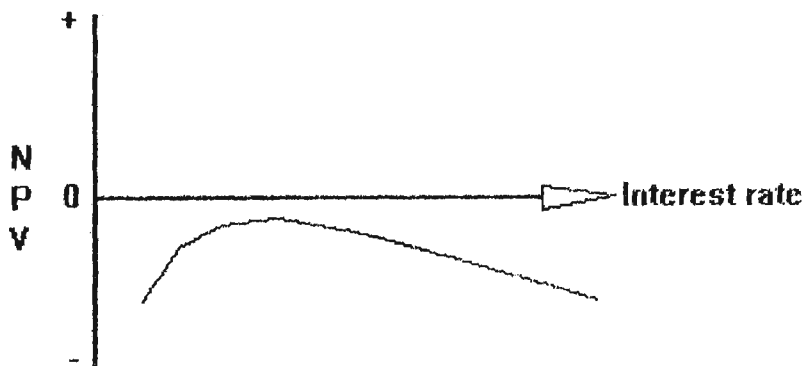


Fig. 7.6 No Internal Rate of Return [From Personnel Communication and Reports of West, 1992)

7.4.4 Pay Back Period

The payout period is the oldest and simplest project indicator. It is the time required for the cumulative net earnings to equal the initial outlay, that is the length of time required to get our investment capital back. The payout period thus measures the speed with which investment funds are returned to the business. It is determined by adding together each years cash flow forming the cumulative cash flow. When this cumulative cash flow value moves from a negative value and reaches zero, this time

period is the pay back period. This may be seen in Fig. 7.7, where the pay back period is when the cumulative cash flow line reaches zero value.

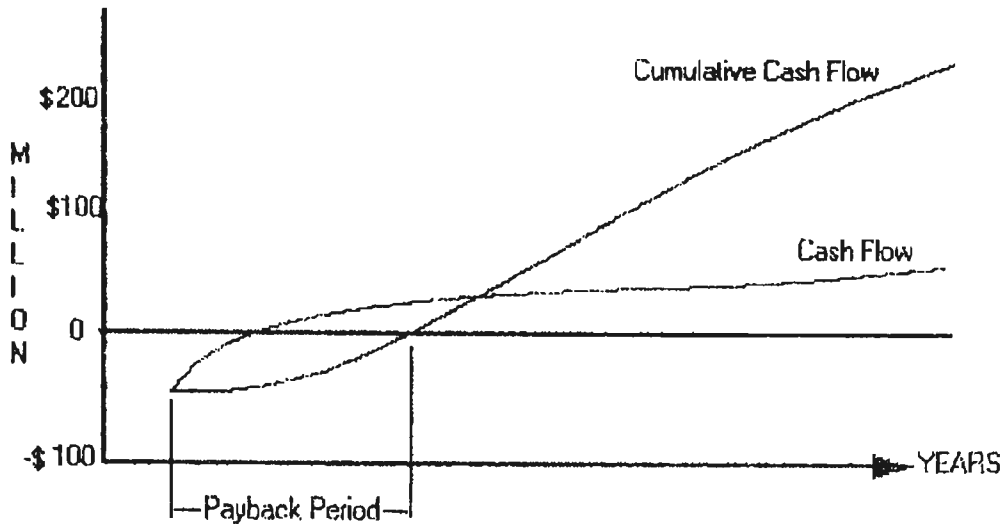


Fig. 7.7 Payback period [From personnel communication and reports of West, 1992)

This is a widely used technique, because it shows the investors when they will get their money, but care must be taken in using it, as it does not consider the cash flow beyond the pay back period. At the present time investors would be looking at a pay back period of approximately one third the project life, so for a ten year life, three and a bit years would be the accepted period.

7.4.5 Cost of Capital

The cost of capital is the weighted-average cost of investment capital, expressed as a percentage, from all sources. A good practice is that a company should not invest in a project returning less than its cost of capital. Therefore, the minimum discount rate for present value calculations is the cost of capital. The cost of capital is usually greater than the cost of borrowed money. When a company sells bonds at 5% interest to raise capital, it changes the capital structure of the company and increases the risks of the equity (stockholder) capital.

When the ratio of debt to equity increases, the cost of equity capital rises. The high leverage makes the equity in the business more risky and investors expect a higher return on their equity investments to compensate for the higher risk. The rate of interest increases as the proportion of debt to equity capital increases if all other things remain

equal. For this reason alone, it is not logical to consider the cost of borrowed money as the cost of capital. The cost is usually considerably greater. Projects should earn substantially more than the cost of borrowed capital to justify investment of capital.

7.4.6 Uncertainty

Assumptions which are made during the construction of a financial model should be realistic. The base case assumption should include estimates of all parameters but there is a possibility that these estimates can prove incorrect in practice because they are based on false assumption. These variations from the base case represent risk to the viability of the project. As a consequence of the risks involved, producers have to employ risk studies, which employ sensitivity analysis. Another technique to cover this risk is to employ price hedging strategies, which can substantially protect them from adverse movements in the gold price.

7.4.7 Sensitivity Analysis

The previous evaluation techniques all depend on estimates of expenditure and revenue in the future which are based on the best estimates which can be made at the time of evaluation. The investment analysis is then carried out using these "best guesses" and the decision maker in reviewing the results will be left with a feeling of some uncertainty. Sensitivity analysis is a means of evaluating the effect uncertainty has on the results obtained.

There are two principal formats, the first considers one parameter at a time and evaluates the impact on the project of a specific percentage variation, both up and down from the base assumption. This generates a table of say NPV's for the project, with values above and below the base case, for each percent tested. This technique can be done manually by varying the three escalators and also done automatically as can be seen in the sensitivity graph in Fig.7.8.

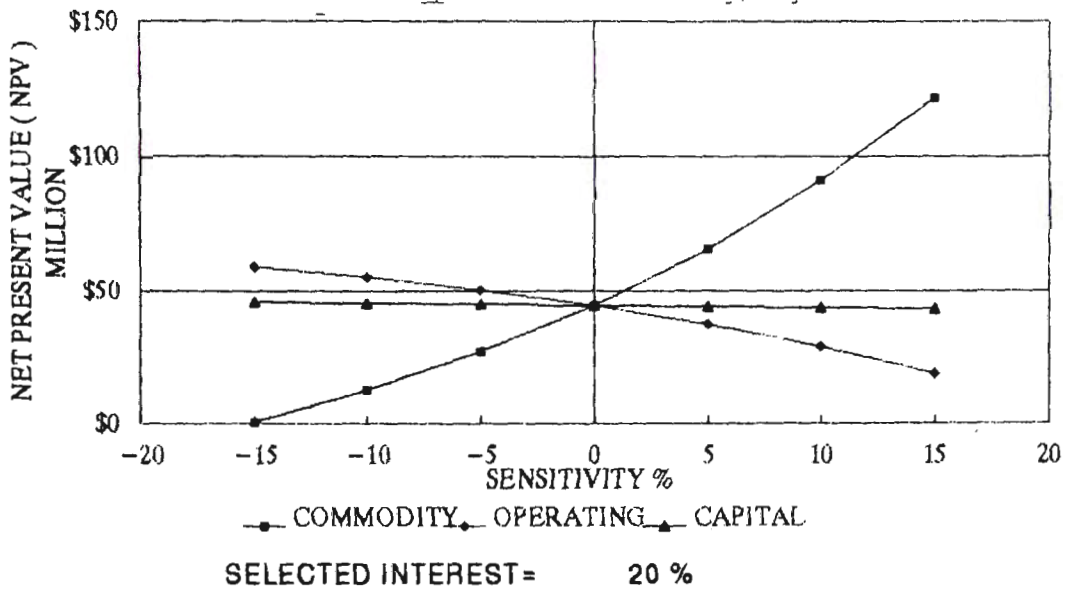


Fig 7.8 Net present value sensitivity [From personnel communication and reports of West, 1992)

The second principle of sensitivity analysis is an historical approach, which considers all parameters of the base case and considers how they might change for the better in the best case, and for the worst in a worst case situation. Many of the parameters are interrelated and the arrays of the best case and the worst case parameters must be internally consistent. This analysis will create three values, representing the most likely or base case, the best case and the worst case. These values should represent extreme limits of the actual outcome of the project.

CHAPTER EIGHT

CONCLUSION AND SUGGESTION

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CONCLUSION AND SUGGESTIONS

When sufficient capital is unavailable, geological conditions do not allow the adaptation of mechanised mining methods, the ore is in vein form, the deposits are dispersed, the grade is low, then the solution to all these problems is small-scale mining. Unfortunately, this sector has not been attracting much attention in the mining industry regardless of its importance. Mackenzie[1982] stated that in Ontario during certain period of time, smaller enterprises incurred only 28% of the total metallic mineral exploration expenditure, but were responsible for 62% of the economic deposits that were discovered. Not very far away, in Western Australia during certain periods of time, "nearly all of the newer gold mining ventures in Western Australia involved the so-called small or junior mining companies".

The small scale mining industry will be in a good position to play a major role in the future if enough attention is focussed on this sector of the industry, when most of the large mines are going to cease the production due to financial crisis and dropping of the demand in the market. It is suggested that instead of closing large mining units due to various reasons, they could be divided into small units, if mining methods and technology allow, and handed over to contractors or individuals involved in management. In other words, instead of one large lease, there will many leases. These leases or small units can be controlled by different contractors or by the skilled labour force.

If small mines are managed properly, they can become a good source of earning and can produce employment for hundreds of people. Changes in this sector can not only bring prosperity in the rural areas but also in the national economy. One thing which small-scale mining does quite effectively is to put funds into the hands of local people in rural areas. Small-scale mining also does more in encouraging other supportive activities in these areas.

There are also some negative aspects of small-scale mining which should be taken seriously. Such mining practices often mean an inefficient use of the nation's mineral resources. The small-scale miner's interests are short term. He may "pick the

eyes" out of a deposit and thus does not recover as much value as would be possible, as a result of such crude recovery methods the tailings could contain high levels of valuable material.

In order to bring widespread changes in small-scale mining so that the natural resources can be used effectively and small-scale mining can play an important role in the socio-economic system of a country, the following suggestions should be taken into account:

- Government encouragement should be by removing the plethora of restrictions, needless forms and regulations rather than the formation of advisory groups that, in general, have no practical experience of the industry or of its problems.
- Improvement of statutory monitoring to ensure safe and scientific mining.
- Provision of techno-economic aid to small mines for adaptation of large scale environmental control measures.
- Development of research and development facilities.
- Published data on the region wise mineral occurrences including topography.
- Geology, hydrology, power and transformation facilities should be accessible to small mine owners.
- Creation of a favourable economic climate by state agencies with reasonable tax and with tax concessions, and subsidies provided for the development and marketing of minerals from remote and backward areas.
- Government and banks should provide loans to small mine owners on low interest rates and on easy repayment conditions.
- Large mining units in the same area should extend help to small mines in the form of technical assistants, easy loans, milling and repairing facilities.
- Staff and workers should be multi-skilled in order to save expenditure.
- There should be training and safety programs for the mine workers.
- Government should provide infrastructure facilities including roads, power and water supply.

- Government should provide some arrangements for buying the products.
- Large manufacturers should manufacture small, cheap and mobile equipment suitable for the requirements of small mines.
- Leasing systems should be made easier.
- Unnecessary taxes should be removed.
- Import duties should be removed on the import of small equipment used in the small mining industry.
- Management of small mines should be efficient and well experienced to analyse and handle the difficult situations effectively.

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ACKNOWLEDGMENTS

The author would like to acknowledge the followings,

Prof. R. N. Singh, as both the Head of the Department of Civil & Mining Engineering and academic supervisor, for providing the facilities, his encouragement, suggestions and guidance during the progress of this thesis.

Mr. R. F. West, owner and consulting mining engineer of Wesral Mintec for his constructive suggestion on Chapters 3, 4, 5, and 7.

Asso. Prof. N. I. Aziz for his guidance from time to time.

Miss L. Middleton, research assistant in the Department of Civil & Mining Engineering, for assistance with proof reading of thesis.

Thanks are also due to my colleagues within the Department, particularly Mr. S. Borumandnasab & Mr. F.Sidrak, for their moral support.

Declaration

I hereby certify that the work presented in this thesis has been carried out in the Department of Civil and Mining Engineering of the University of Wollongong and has not been submitted for any other degree.

Sheikh Ateeq Ur Rahman