A Study of Mining Taxation Systems

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Abstract

This study compares three mining taxation systems: royalty, profit tax and profitability tax, in a theoretical framework. It examines concepts and forms of taxation which are applicable to various nations, regions and / or commodities.

The study first reviews the economic characteristics of the mining industry and the principles of economic rent. Then, using a computerized model of a hypothetical project, the comparative impacts of the three tax systems are determined.

The following conclusions have been drawn from the study:

- In general, taxes are a significant cost to a mining project.
- A revenue taxation system (i.e. royalty) is easier to implement and enforce than either profit or profitability based systems.
- The profit and profitability based systems are less discriminatory against low quality deposits and marginally profitable operations than a revenue taxation system.

Résumé

Cette étude compare trois systèmes de fiscalité minière: royautés, taxe sur le profit, et taxe sur la rentabilité, dans un contexte théorique. Elle examine des concepts et des formes fiscales applicables à différentes nations, régions et/ou métaux.

L'étude revoit premièrement les caractéritiques économiques de l'industrie minière et les principes du loyer économique. Ensuite, à l'aide d'un modèle informatique et d'un projet hypothétique, les impacts des trois systèmes fiscaux sont comparés.

Les conclusions suivantes sont tirées de cette étude:

- En général, les impôts sont des coûts importants pour un projet minier.
- Le système de royautés est plus facile à mettre en place et à gérer que les autres systèmes.
- Les systèmes de taxation sur le profit et sur la rentabilité sont moins discriminatoires envers les gisements de basse teneur et les opérations marginales que le système de royautés.

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Chapter 1 Introduction

1.1 Mining Taxation Study Review

Mining taxation has been a major issue in mineral policy formulation for many years. It is indisputable that taxation policy has become increasingly important for three reasons. First, there has been a heightened awareness that resources are limited in quantity and, consequently, there is a need to conserve the resource base for society. Second, the exploration for, the development and extraction of, and the eventual depletion of a mine will cause environmental damages and disruptions as well as social and economic dislocations and inefficiencies. These environmental damages remain long after the departure of the extracting industry and its employees, bringing on demands for compensation. Third, too many and / or too few taxes cause inefficiencies in economic growth.

Much has been studied and written over the past decades. These studies of mining taxation have dealt with topics varying from the economic impact of taxation on mining projects, the comparison of tax legislations in different countries, as well as the structures and levels of taxation applied to different kinds of minerals. Some of these studies are briefly described below in chronological order.

Mackenzie and Bilodeau (1978) studied the effects of mining taxation on base metal mines across the major areas of Canada. The study analyzed the impacts of several taxation schemes existing in Canada in the '60s and '70s on the potential net value to society. It showed that important differences existed between the Canadian mineral taxation structures in the '60s and '70s. Three hypothetical mineral taxation systems were tested, replacing all other levies including federal and provincial corporate income taxes. It was found that the revenue and profit taxation systems induce a decrease in the number of economic deposits and net value to society. The rate-of-return taxation system did not affect the number of economic deposits nor the net value to society. It was also demonstrated that existing Canadian taxation systems of the '60s and '70s performed between the profit and rate-of-return systems.

Gillis (1978) studied the basic considerations involved in the design of mineral tax policy in seventeen countries, focusing on the mining taxation system in Bolivia. The study provided a thorough evaluation of impacts of the taxation system upon the mining sector, in terms of the system's effects on efficient investment in exploration, development, and production.

Bradley and Helliwell (1981) compared the efficiency of a mining profits tax with that of a royalty-based taxation system in the case of copper mining in British Columbia. The study showed that at low tax rates, there is little difference between the two tax systems, while at high tax rates, the royalty tax system is markedly less efficient.

Barnett and Anderson (1983) compared the taxation of uranium mining in Canada's province of Saskatchewan and Australia's Northern Territory. The study showed that, under the Canadian/Saskatchewan tax system, mine operators face a profit sensitive regime. In contrast, the Australian system is essentially a regressive tax structure which is typified by a declining average tax rate as economic rent increases.

Wilson (1984) examined the mining taxation arrangements, the impact of individual fiscal instruments as well as the total fiscal package on investor risk perceptions, investor returns and government receipts in Papua New Guinea, Indonesia and the Philippines. The investigation showed that the taxation regimes have clear potential for increasing government revenue shares for very little change in investor risk, or alternatively, increasing the attractiveness of projects to investors without reducing expected government revenues.

Cloete and Rensburg (1984) analyzed gold mining taxation in South Africa. The study briefly described the development of gold mining taxation and evaluated the impact of the system on gold mining companies by cash flow analysis. The results indicate that a resource rent tax encourages the conservation of mineral resources and reserves.

Campbell and Lindner (1987) discussed the effects of resource rent taxation on mineral exploration. The point of the study is that firms explore in order to obtain information which reduces the costs of risk and uncertainty associated with development. The cost of uncertainty is defined as the difference between the net present value of development given perfect information and the expected net present value of development without exploration information, i.e. with imperfect information. Similarly, the cost of risk is measured as the difference between the expected net present value of the deposit as a risky prospect and the amount of money that the firm would be willing to pay for the risky prospect. The numerical examples demonstrate that taxation has the effect of altering those costs and hence changing the value to the firm of information obtained from exploration.

These studies demonstrate that mining taxation issues are important and complicated, and it is essential to design a neutral mining taxation policy which can provide a favourable climate to sustain investment in the mining industry, thereby encouraging economic development and employment.

1.2 Objective and Scope of the Study

The objective of this study is to compare the structures of three taxation systems, namely royalty, profit tax and profitability tax, and to measure the effects of these mining taxation systems on a hypothetical mining project. The study seeks to provide a basis for a clearer understanding of the concepts of mineral rent, and of the complicated issues involved in the design and implementation of tax systems in the mineral industry.

There have been various taxes imposed on the mining industry for many years, such as lump-sum tax, excise tax, severance tax, property tax, profits tax, profitability tax, etc., which are applicable to different types of commodities in different countries. This study focuses on the three taxation systems mentioned previously regardless of country, region or commodity, since the essential concepts and forms of taxation, as well as the methods of study can been applied universally

The basic assumptions made for the purpose of this study are: (1) reserves are known with certainty, (2) a constant cost of capital or discount rate is used over the mine life, (3) maximization of present value is the only goal of the mining firm, (4) conditions which affect costs remain constant over the mine life, (5) a uniform grade is mined in each production year, (6) the rate of extraction is constant during the mine life, and (7) the firm is a price taker.

Parts of the study are undertaken with a spreadsheet based computer model to simulate the impacts of the three taxation systems on a hypothetical mining project. Three parameters, namely the cut-off grade, extraction rate and tax rate are varied individually, so that the optimal combination of cut-off grade and extraction rate for maximizing net present value can be reached given taxation system and a tax rate. The capital and operating costs of the project are based on O'Hara's (1978) cost functions.

1.3 Organization of The Study

Chapter 2 reviews the mineral supply process and economic characteristics of the mineral industry. Chapter 3 explains the basic principles of economic rent as well as the concept of mineral rent. Chapter 4 presents a detailed description of the three taxation systems. The general objectives and requirements of mining taxation policy are discussed as well. A numerical example is used to illustrate the application of each tax system. Chapter 5 examines a hypothetical case study, and includes a description of the relationship between grades and tonnages, cost estimation, and the evaluation of net present value. Chapter 6 compares the three taxation systems, and assesses the effects of taxation on the mining project. Chapter 7 concludes the study and suggests areas for further research.

Chapter 2 Overview of the Mining Industry

2.1 Mineral Supply Process

The mineral industry is a vital segment of the economy and one of the premier resource industries playing an important role in the development of new technology. One cannot imagine what the world would be without the mineral industry. The manufacturing sector, the high technology industry, the agricultural sector, and even the better known resource industries are all dependent, in some way, on the mineral industry.

Suppliers of mineral commodities must think about a series of fundamental economically related questions:

1. What kind of mineral products and how much of these should be produced?
2. How should the desired levels of production be achieved?
3. Who has the ability and is willing to pay for receiving an amount of available commodity at a certain price?

Success in the mineral markets depends largely on how the actions and decisions of mineral suppliers mesh with the needs and wants of the consumers.

There are basically three phases in the conversion process of minerals from unknown geological resources to marketable commodities: exploration, development and production. As shown in figure 2.1, the selection of environments for exploration is guided by information concerning geological, technological, social interest, market and political aspects.

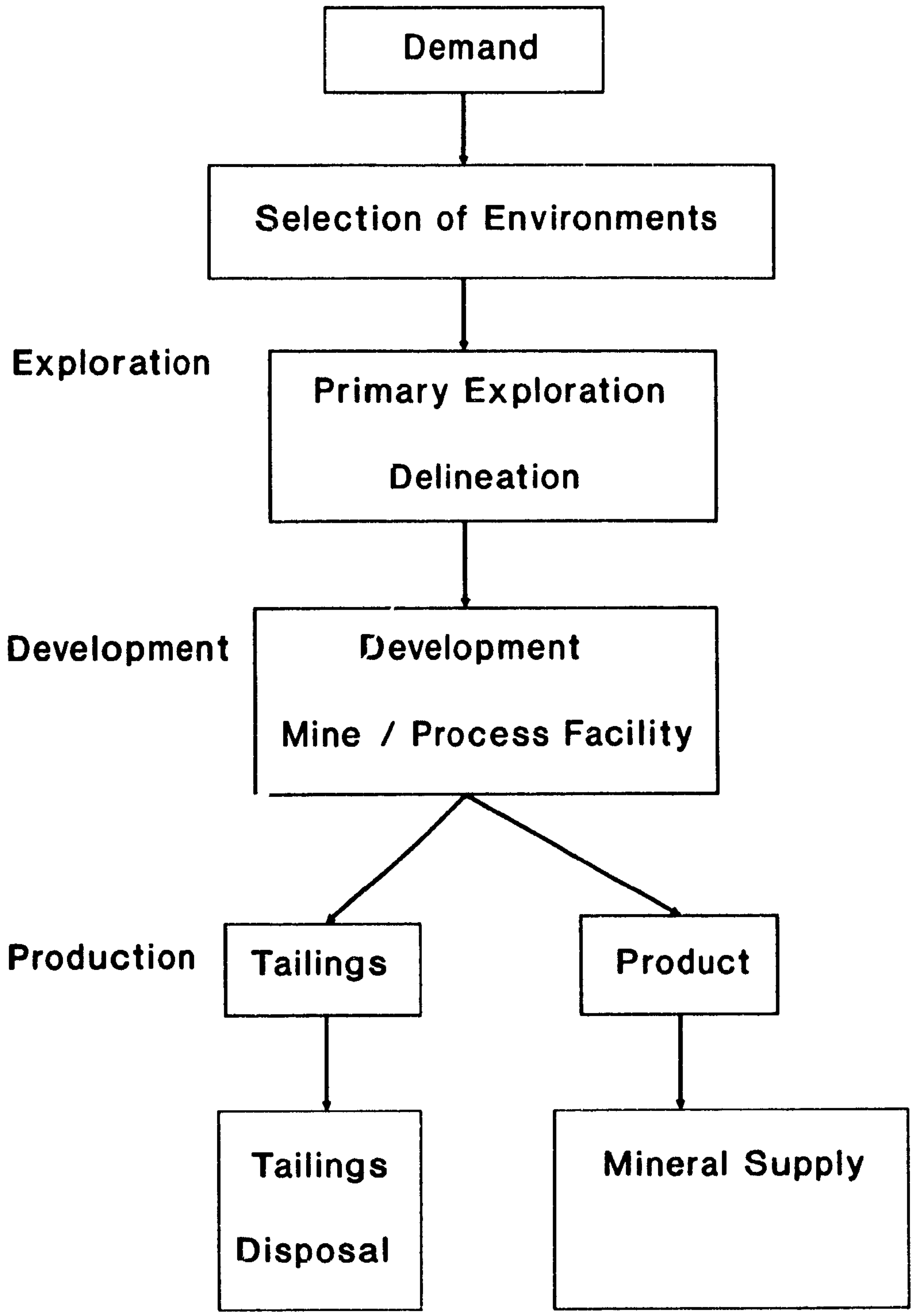


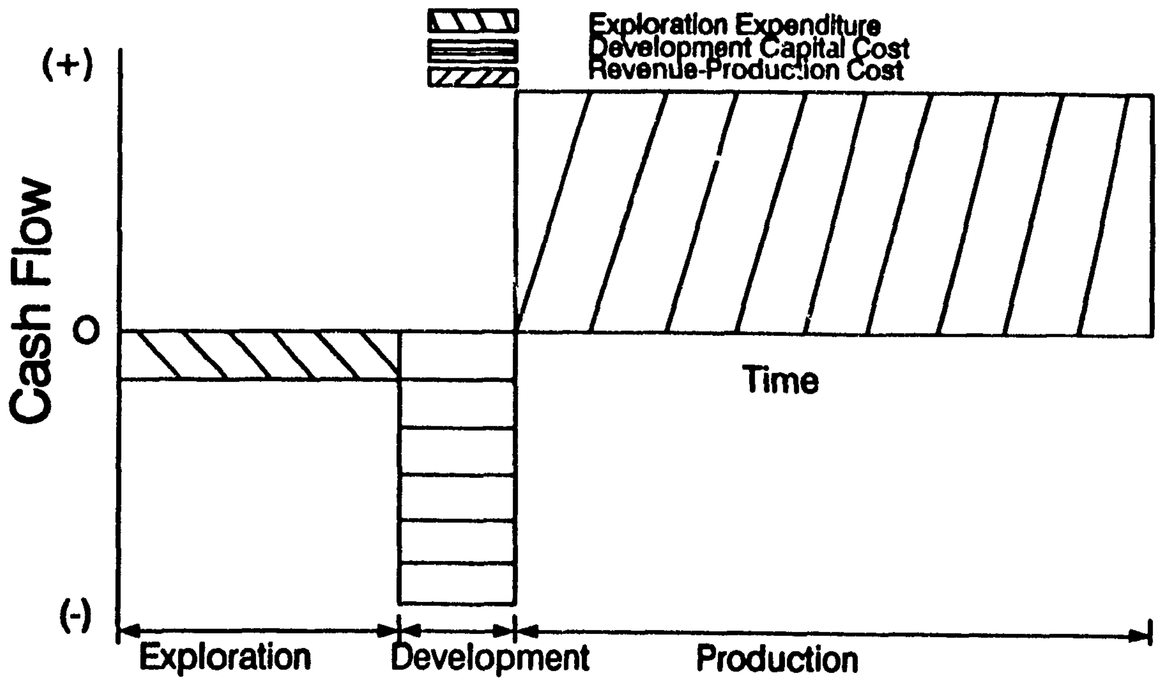
Figure 2.1 **Mineral Supply Process**

Exploration: The exploration phase is divided into two stages:

The primary exploration stage and the delineation stage. The primary exploration stage consists of selecting potentially favourable areas of land. A series of geological, geophysical, and geochemical tests are applied. Once mineral occurrences are found, further intensive studies are required to estimate the size, grades, tonnage and physical characteristics of these occurrences. The successful results of delineation would give rise to possible economic mineral deposits. Only those deposits which satisfy both minimum acceptable size and profitability conditions are known as economic mineral deposits and are developed.

Development: The development phase is less risky to some extent than exploration because at least the development is based on the discovery of a mineral deposit. The major tasks during the development phase are to install mining equipment and construct mineral processing facilities with the objective of establishing mine production. Mine development also comprises the stripping of waste for open pits, the preparation of stopes for underground mining, and the development of ore reserves. Though the time period needed for development of a mine is, in general, much less than that required to discover an economic deposit, the costs of the development per period of time is much more than the costs of exploration.

Production: The production phase includes drilling, blasting, materials handling to the processing facilities, filling of mined-out stopes, etc. In some cases, the production phase also includes processing, which consists of crushing, grinding, flotation and / or gravity separation, chemical processing, drying, and tailings disposal. Usually, the ore is upgraded to a concentrate at the minesite and needs to be further smelted and refined before reaching the ultimate market. The length of the production period is a function of the deposit size and capacity. As the production phase commences, a mine should start to generate a series of revenues from which the exploration and development expenses can be recovered. Figure 2.2 illustrates the time distribution of cash flows for a mineral project.



Source: Bilodeau, M. Mineral Project Evaluation Techniques and Applications, Seminar Notes, 1990

Figure 2.2 Time Distribution of Cash Flows for a Mineral Project

The mineral supply process is influenced not only by changes in demand, changes in the costs and prices of substitutes, changes in the relative costs of materials, fluctuations in prices, advances in technology, and so on ... but also by the degree of accessibility to the critical factors which are involved in the exploration, development and production phases. Because there are differences in the amount of information initially available, in the level of expertise for interpreting information, in access to technology and markets between mineral firms, each will have different initial opinions about the potential value of a deposit and will interpret results differently. Although most firms are averse to risk, they tend to bear varying amounts of risk. In general, the deposit which is the largest, with the highest grade, closest to surface and markets, and easiest to find and work is the first to be discovered, developed, extracted and exhausted. The increasing cost of mineral supply over time due to depletion is partly offset by advances in technology.

Mining taxes are another element adding to the cost of mining and affecting a firm's decisions related to investment and production levels. From the mineral suppliers' point of view, the stability of mining policy is particularly important.

2.2 Economic Characteristics of the Mining Industry

It is well known that the purpose of exploration is to find economic mineral deposits, and that a significant proportion of exploration takes place after the initial discovery, with the objective of ascertaining the size and quality of a deposit for the purposes of determining how best to exploit it and assessing its economic viability. Of course exploration and development involve a large amount of risk because the quality and quantity of mineral resources are initially unknown. The mineral industry must not only cope with high risk, but also with certain characteristics unparalleled in other sectors. These can be summarized as follows:

1. Variability of quality

Mineral deposits usually vary in chemical and physical characteristics both horizontally and with depth. The complexity of geological processes dictates that not all mineral deposits can be discovered, developed and evaluated using the same techniques and methods. Variability in the quality within individual deposits gives rise to planning opportunities in terms of cut-off grade and sequence of mining decisions. However, variability in the quality of mineral resources among deposits has a critical influence on a wide spectrum of policy and planning issues.

2. Fixed in quantity

Mineral resources are limited, which results in the limitation of the rate of production. The fact is that for every unit of ore mined from a particular deposit, there is one less unit left to mine. Diminishing returns economically limit the rate of production which can be achieved. Thus, additional exploration is necessary to maintain existing production levels

3. Fixed location

Mineral resources are unequally distributed among regions, countries and continents by type and by economic usefulness. Furthermore, a mineral deposit cannot be moved. In turn, the demand for mineral resources is not homogeneous throughout all of the world. Consequently, development, mining and some amount of mineral processing must be carried out where deposits occur. The same is true for a series of mine services such as transportation, power, water and social infrastructure. This geological fact explains why there is often a distinction between resource-rich regions and countries, and those areas which are heavy consumers of minerals, and that multinational firms, foreign ownership and international mobility of capital exist in the world.

4. Non-renewable resource

Minerals are non-renewable resources. Once they are removed from the earth, they are not replaced.

5. Risk

The most obvious risk in the mining industry is whether or not an economic deposit will be found and what size and quality it will possess. Another facet of exploration risk is that there is an uncertain time lag between initial exploration efforts and production, and long periods of time of negative cash flows. Thus, exploration risk is what is usually implied when saying that mining is a "risky business". There are some risks that are not peculiar to mining, which are the risks of wrong estimates of future prices and costs. All the above risks are hazardous because when mistakes in expectation are discovered, it is too late to withdraw the amount of capital committed. But it should be noted that there is a possibility that future prices turn out higher than anticipated as well. As in the other sectors, mining also has risks related to the future efficiency of management and to government policy. That is why there is always a requirement for the stability of government policy, especially in the mining industry.

6. Environmental effects

Finally, mineral exploration, development and production activities can have socially undesirable environmental effects. Pollution, destruction of forest resources, acid rain and issues related to health and safety are but a few of the problems that exist. It is necessary to pay much more attention to toxic waste management, land management and rehabilitation for the protection of our resource base and the environment.

2.3 Perspectives on the share of mining in GDP, Exports and Taxes

Mining is a source of national income, foreign exchange and fiscal resources. Thus, a number of countries around the world rely heavily upon it. Table 2.1 demonstrates the importance of the mining industry in terms of contribution to Gross Domestic Product, exports and taxes in countries around the world. Some countries are essentially dependent upon their mining industries. For instance, in Liberia, Jamaica, Gabon and Chile, mining is responsible for an inordinately high proportion of national income, export earnings and taxes. Thus, the proper design, formulation and reform of mining policy to sustain investment becomes even more important.

Table 2.1 Importance of the Mining Industry

(non-fuel minerals only)

Contribution of Mining to GDP, Exports and Taxes		Country
Mine production relative to GDP		
	0-2.5%	Brazil, Colombia, Finland, Mexico, Philippines
	2.5-5%	Indonesia, Peru
	5-10%	Canada, Malaysia
	10-15%	Bolivia, Chile
	15-20%	Gabon
	20-30%	Jamaica
	30% and above	Liberia, Papua New Guinea
Mining exports relative to total exports		
	0-10%	Colombia, Ghana, Indonesia, Mexico, South Korea
	10-20%	Brazil, Canada, Gabon, Mexico, Philippines
	20-60%	Malaysia, Peru
	60-80%	Bolivia, Jamaica, Liberia
	80% and above	Chile, Papua New Guinea
Mining taxes relative to total tax revenue		
	0-10%	Colombia, Indonesia
	10-25%	Chile, Malaysia
	25% and above	Bolivia, Gabon, Jamaica, Papua New Guinea, Liberia

Data selected from Gillis (1978).

Chapter 3 Basic Principles of Rent Theory

Since the 18th century, many economists have dedicated themselves to the study of economic theory and the relationship between inputs, outputs, costs and prices. Adam Smith, David Ricardo, John Stuart Mill, Alfred Marshall, etc., are some of the outstanding people who contributed to the formalization of economic theory, particularly rent theory. The following basic concepts and principles are from their penetrating quotations.

3.1 Classical Concept of Economic Rent

The concept of economic rent was developed and promoted by classical economists. Economic rent referred to the reward that a landowner could derive by virtue of simply being a landowner and without exerting any effort or making any sacrifice. By analogy, it could be taken to refer to the reward accruing purely and simply from the possession of any property. In principle, the government could tax away economic rent without directly affecting the reward or salary that anyone received for his effort or sacrifice, since rent is the reward that the owner of an asset can expect purely on account of ownership and without any personal sacrifice on his part. Thus, such a tax on rent might encourage the landowner to perform more productive activities in order to compensate for the reduced disposable income for himself. However, the reduction of disposable income might indirectly promote activities that could reduce the amount of salary payable to those who receive it for their efforts or sacrifice, at the margin.

According to Ricardo, economic rent is a surplus value over and above all costs, that is, the surplus value remaining after the use of any fixed resources and after deducting factors such as capital costs, labour costs and other sacrificial inputs which are necessary to undertake the productive activities. Figure 3.1 illustrates the relationship between economic rent and quantity produced on agricultural land.

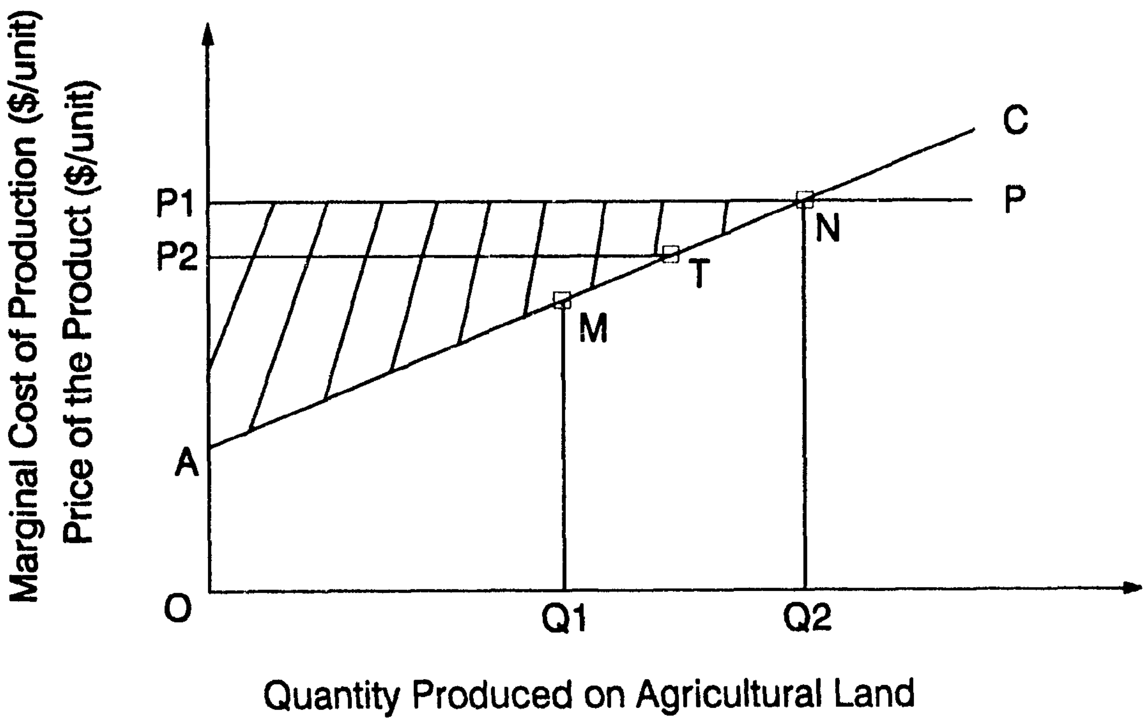


Figure 3.1 **Relationship between Economic Rent and Quantity Produced on Agricultural Land**

It is assumed that the agricultural market is perfectly competitive. Thus the price of the agricultural product is independent of the amount of production. This price is represented by the horizontal line P_1P. Consequently, it is easy to understand that marginal revenue is equal to price and average revenue. On this graph, AC represents a marginal production cost curve, or supply curve. When the quantity of production is equal to Q_1, the marginal cost of production is equal to Q_1M. When the quantity of production is equal to Q_2, the marginal cost of production is equal to Q_2N. It is obvious that as long as the demand for the agricultural product increases to force the extension of the land i.e. the quantity produced, the marginal cost of production will rise with any such increase, because the margin of cultivation will be extended to less fertile and more distant land. The margin of cultivation will only be extended up to the point where the marginal cost is equal to the marginal revenue, since any further cultivation on less fertile and more distant land would cause marginal cost to exceed marginal revenue.

When the price is equal to OP_1, the total revenue derived from producing OQ_2 units is area OP_1NQ_2, and the total cost of producing OQ_2 units is area $OANQ_2$. The economic rent of the agricultural land, according to definition, is represented by the shaded area AP_1N.

Economic rent is specific to a particular piece of land, and the amount of economic rent for this land depends on its fertility and location. The more fertile and accessible the land is, the higher the rent is, at a fixed product price. Also, the amount of economic rent depends on the price of the product. For example, if the price in figure 3.1 falls from OP_1 to OP_2, the rent will fall to AP_2T. The theory of economic rent on agricultural land is founded on the assumption that there is no opportunity cost associated with land, i.e. there is no non-agricultural use for which land could be used, thus there is no sacrifice on the part of the owner in allowing it to be used for agriculture. Also, it is assumed that investors will individually be inclined to increase the intensity of work or increase production on the land since there is rent accruing to the owner of the least fertile acre of land. As well, each owner will individually be inclined to allow his land to be used intensively, otherwise the rent he receives will be less than that from land of similar quality on which more intensive use is granted.

3.2 The Concept of Mineral Rent

Ricardo specifically extended the concept of economic rent to the reward of owning a mine. In general, the concept of mineral rent is the same as that of land rent. However, there are two important differences. First, the output in the case of agricultural land is considered as annual output, while in the study of the rent associated with mineral resources, the mineral output is considered to be the total output associated with the life of a mineral deposit. Second, in the case of agricultural land, the land at the margin of cultivation is the highest-cost land in production and earns no rent; the mine at the margin of cultivation may not be the highest-cost mine in production. A positive surplus, beyond production costs, is likely to accrue to an active mine, i.e. the mine will earn economic rent. This is because a potential developer has the option of postponement. His decision as to timing, rate, and intensity of mining activity depends on his expectation of costs and revenues, and on the rate at which he discounts the future.

For the purpose of extending the concept of economic rent to mineral resources, it is necessary to reconcile various classical views by making some assumptions. It is assumed that the property rights are held for each mineral deposit, so that there is no 'free-for-all' which leads to the disappearance of economic rent and the premature exhaustion of mineral resources. It is further assumed that the distribution and quality of mineral deposits, the future demand for minerals and the costs of production are known with certainty. Under the assumptions described above, minerals are gifts of nature whose extraction yields a return beyond the necessary factor payments to the capital and labour required for their discovery and extraction. A resource rent may be viewed as a particular kind of scarcity rent because of the depletion of natural resources.

Differential resource rents arise because some deposits are richer, closer to markets, or have lower extraction costs than do others. The relationship between mineral resource rent and total production from a mineral deposit is shown in figure 3.2.

Under the assumption of perfectly competitive markets, mining firms are price takers.

Consequently, mineral prices will not change as a result of changing conditions in a particular mineral deposit. The horizontal line P_1P represents the price of a mineral product. AC is the marginal production cost curve. According to the definition of the marginal mine, when the marginal cost of mineral production is equal to OC_1, a rent of C_1P_1 per unit of output is earned. When the marginal cost of mineral production is equal to OC_2, a rent of C_2P_1 per unit of output is earned.

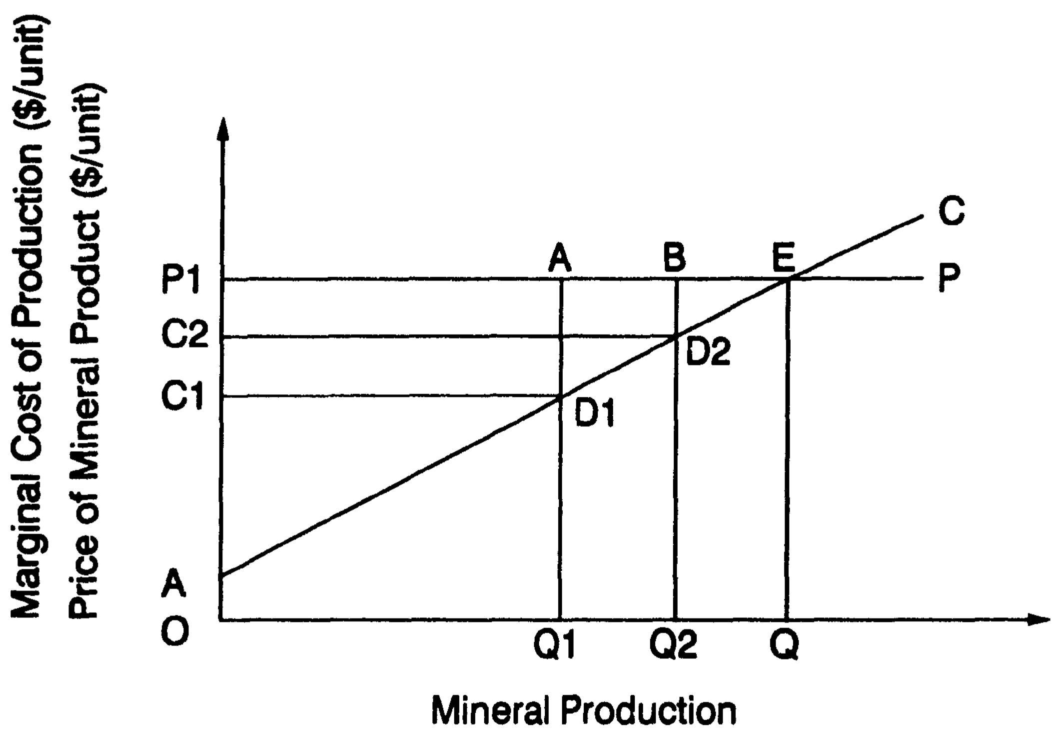


Figure 3.2 **Relationship between Mineral Resource Rent and Total Production from a Mineral Deposit**

There are two types of scarcity conditions. One is Malthusian scarcity, and the other is

Ricardian scarcity.

According to Malthus, the rate of production which can be realized from a fixed amount of resources is limited. This production rate, limited by diminishing returns, is called the intensive margin of cultivation and maximizes the returns to the owner. This type of scarcity condition can be reflected by the characteristics of total production costs. As shown in figure 3.3, total production costs initially increase at a decreasing rate, as the rate of production is increased. However, as the fixed resources get overused, the total production costs increase at an increasing rate.

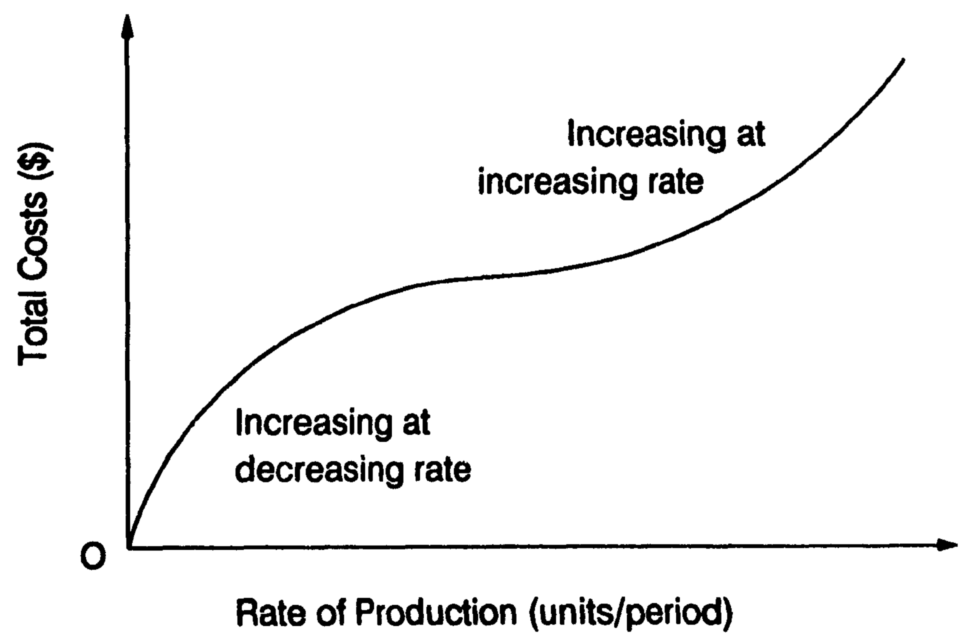


Figure 3.3 **Malthusian Scarcity (fixed land)**

According to Ricardo, neither land nor resources are fixed because the quality differs. Declining quality results in diminishing returns in output per unit of variable inputs. In other words, the total production costs increase at an increasing rate as the total production is increased, as shown in figure 3.4. Thus, the economic rent diminishes. The extensive margin of cultivation, i.e. the cut-off grade, defines the quality that is just worth working and defines a mining optimum.

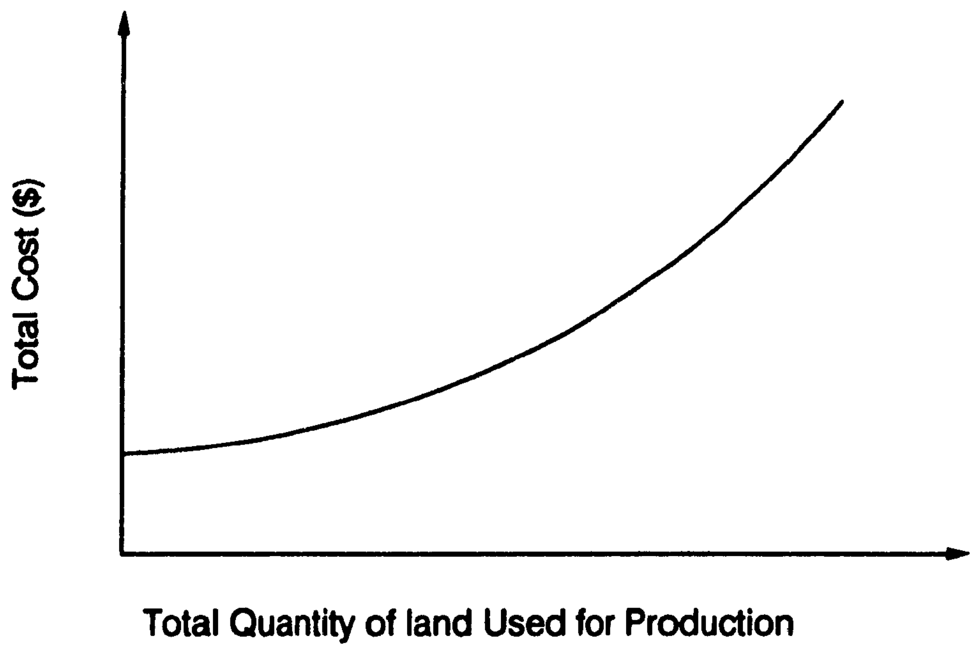


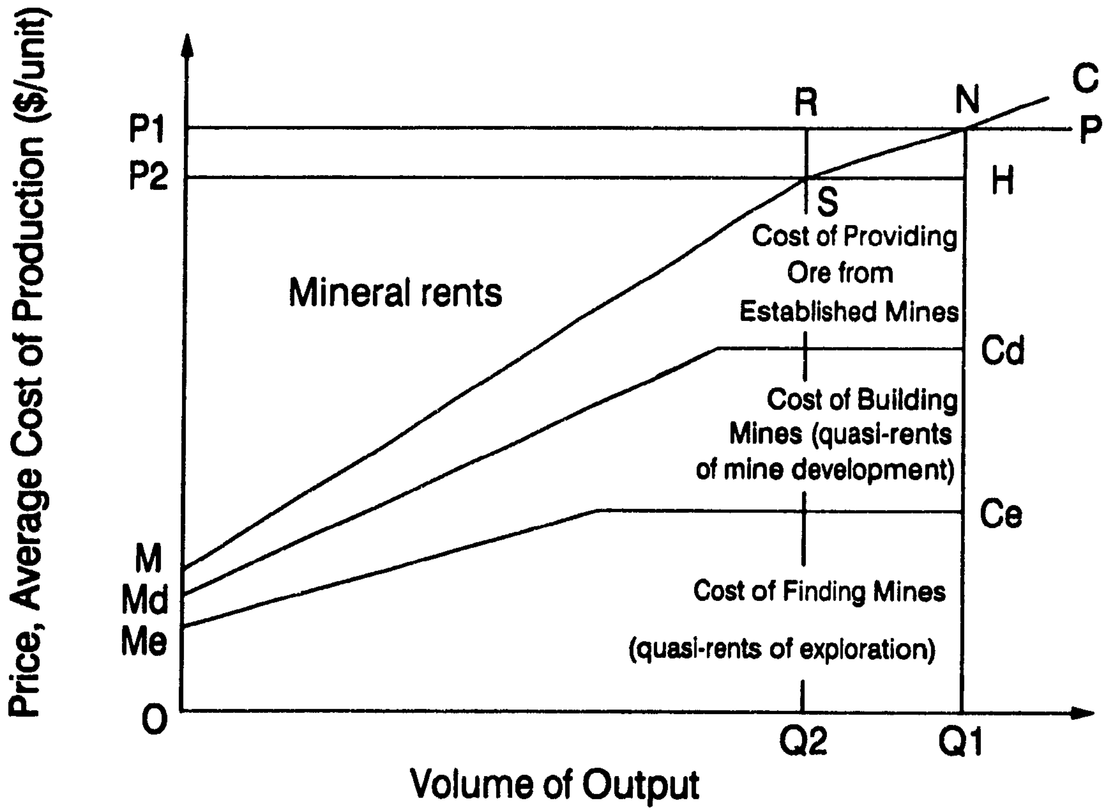
Figure 3.4 Ricardian Scarcity (fixed production rate)

Combining the concepts put forth by Malthus and Ricardo, the economic rent of a mine is a function of scarcity. As long as the quantity and quality differ, the economic rent will vary.

In the case of mineral deposits, economic rent comes from the use and depletion of the resources. The owner of the best quality resource receives the most rent. The owner of the resource at the economic margin, receives no rent.

Another concept related to economic rent is quasi-rent, which was introduced by Marshall. He observed that the excess income over the minimum necessary to hold some factor of production in activity is known as rent, and that in some ways, it is like economic rent, and in other ways, it is not.

According to Marshall, when rent is taxed away and its payment is, in the longer term, providing some incentive to a particular allocation of resources, this rent is defined as quasi-rent. In order to distinguish rent from quasi-rent, the average costs of mineral production could be viewed from three perspectives: the short-term average costs which relates to the variable cost of extracting ore from an established mine; the medium-term average cost which relates to the total cost of producing ore from new mines based on mineral deposits that are known; the long-term average cost which relates to the total cost of mineral production, including the cost of finding deposits. Figure 3.5 illustrates the relationship between rents and different levels of quasi-rent. As shown, an ad valorem tax at the rate P_1P_2/OP_1 would reduce total production from OQ_1 to OQ_2 and dissipate RSN of rent, but would not affect new mine development and exploration. However, a lump sum tax designed to remove a much larger sum (P_1MN + $OM_dC_dQ_l$) is completely deterrent to new mine development and exploration. Thus, the amount of taxes and the type of taxation may or may not have an effect on the different levels of decision, which depends on the tax base, i.e., economic rent or quasi-rent. Furthermore, it is useful to think in terms of the quasi-rent associated with mine development and mineral exploration.



Source: Garnaut, R. and Ross, A.C. Taxation of Mineral Rent, 1983

Figure 3.5 **Quasi-rents**

3.3 Mineral Rent and Taxation

In many countries, minerals are treated as belonging to the state, which is presumed to act on behalf of the public, and the taxes or charges on economic rents hold out the possibility of raising substantial amounts of revenue without distorting decisions on mineral production, consumption, or trade. Thus, as discussed previously, mineral rent is commonly thought to be a suitable base for the collection of taxes.

There are many types of tax on mineral rent. They may be lump sum charges payable when exclusive rights to exploit a mineral deposit are granted to an investor, they may be conditional payments, the amounts of which depend on the volume or value of mineral production, they may be proportional to annual profits, or they may be a function of the return on investment.

Although taxation on mineral rents would make those rents visible and identifiable, it is difficult in practice to design a tax system that is strictly neutral and collects the whole of mineral rent. In the real world, there may be some trade-off between the amount of mineral rent tax on each project undertaken and the total amount of mineral rent.

Chapter 4 Description of Mining Taxation Systems

4.1 The Objectives of Mining Taxation Policy

It should be observed that mineral taxation policy is a subset of an overall tax framework and its objectives should be compatible with the overall policies of the nation. Sometimes those objectives may conflict with each other. Hence the formulation of a taxation system depends on the importance placed on those conflicting objectives. It is apparent that there is no single optimum design of a mineral taxation system. The objectives and choices of taxation policy are based upon the economic conditions, historical mining operations, geological conditions, etc., which rank highest in terms of goals they fulfil, and lowest in terms of those they distort. Thus, any assessment of the present and potential role of taxation policy in economic strategy must be viewed in light of not only narrow sectoral objectives but also overall national economic and social goals. In the longer term, the basic objectives of taxation policy design for national development are as follows:

1. Fostering economic growth in per capita Gross Domestic Product.

2. Providing a fair and balanced fiscal and regulatory framework, such as reduction in income inequality, across households and between regions.

3. Protecting competition, encouraging investment and promoting improved technological performance.

4. Improving the general standard of living.

5. Facilitating enhanced mineral and metal export and giving access to new and traditional markets.

4.2 The Requirements of Mining Taxation Policy

It is understood that different interest groups will have different requirements for mining taxation systems. Many of these claims result from the fact that mineral resources are nonrenewable, fixed in quantity and varying in quality, and that the mineral industry faces relatively higher risks than other industrial sectors. Mining taxation policies should be equitable and fair to everyone, technically and administratively consistent, and neutral in effect on investment decisions. They should encourage the optimum use of resources and operational efficiency, and allow for the recovery of capital as well. They must also be easy to understand and to comply with, flexible in response to changes in economic conditions, and have low administration costs.

4.3 Numerical Illustrations of Mining Taxation Systems

Several mining taxation systems such as lump-sum tax, excise tax, severance tax, property tax, profit tax, profitability tax, etc. have been applied in various countries for many years. Only three broad categories of taxation systems are considered in this study. These are the revenue taxation system and the profit taxation system, both applied in Canada, and the profitability taxation system, applied to some extent in South Africa. The conclusions of the study have more general applicability since the essential forms of taxation are applied universally.

1. Revenue taxation system

The tax payment is x% of the annual revenue. Revenue tax is one form of severance tax which is also referred to as production or mining privilege tax. It is obvious that administration costs are relatively small compared to others since the taxes are a fixed proportion of the value of output (an ad valorem tax). In this taxation system, no costs, depletion, or depreciation need to be calculated. Thus, it is simple to understand and comply with, and valuation problems are relatively minor. On the other hand, revenue taxes add costs to the mine regardless of the size of the operation and the quality of the deposit. Because revenue taxes are levied on annual revenue and overlook any capital and operating costs incurred, this taxation system has some bias against deposits with low quality and low profit margins, which means leaving behind ore that could otherwise be extracted profitably in the absence of the taxes.

2. Profit taxation system

The tax payment is levied at x% of the annual profit which is generally defined as annual revenue less annual operating cost and depreciation allowance. In this system, there are two forms of tax payment. One is proportional (the tax is levied at a uniform rate) and the other is progressive (the tax is levied at an increasing rate). Only the former will be applied in this study.

The advantage of a profit tax system is that both the costs and the depletion of the resource base are considered. It is only when revenues exceed all costs that taxes are payed, which implies that the taxes are levied on a more equitable basis, and there is no inherent bias against low quality, small marginal mines. In applying the profit taxation system, operating losses are usually allowed to be carried backward and/or forward within certain years, depending on the tax regime of the country or province. The equatability of the profit taxation system provides a neutral environment for investment on any kind of deposit.

The disadvantages of this system are that the administration costs are high because accurate books and procedures must be maintained in order to apply the tax system correctly.

3. Profitability taxation system

This system is also referred to as the rate of return system. There are two methods of levying tax payments in this system as well. In the first method, the tax rate is fixed over the mine life and the tax is levied on the basis of operating profit as long as the return on investment is greater than the allowed cost of capital. In the second method, the tax rate is a function of the return on investment. One possible way of linking the tax rate to the return on investment is as follows:

$$t = a - a*b/IRR$$

t----tax rate expressed as a percentage of annual operating profit defined as annual revenue less annual production costs.

a----marginal tax rate, which can be varied within a certain range.

b----the threshold rate of return or allowed cost of capital.

IRR----before-tax return on investment.

As in the first method, the tax is levied on the basis of operating profit as long as the return on investment is greater than the allowed cost of capital. The difference is that the tax rate is progressive and depends on the return on investment. This last form is considered in this study.

The profitability taxation system has some unique advantages compared to the other two systems: first, this system gives tax relief when the return on investment is below a certain threshold rate of return, thereby eliminating the bias against low-grade deposits or small mines. Second, it encourages investment in marginal projects since tax payments occur only when the return on investment exceeds the cost of capital. In the application of the profitability taxation system, operating losses are automatically carried forward indefinitely.

Numerical illustrations:

A mine has a construction period of 2 years followed by a production period 10 years. The total capital investment of $50 000 000 is spread evenly over the two-year construction period. Annual revenues are $23 000 000 and operating costs are $13 800 000 per year. No working capital is required. The constant dollar cost of capital is 10%. Inflation is not considered. Capital costs are to be depreciated on a straight-line basis over the 10-year mine life when it is applicable.

Based on the information above, the application of the three mining taxation systems is demonstrated in tables 4.1, 4.2 and 4.3.

As shown in table 4.1, operating profit is equal to $9.2 million per year. A tax payment of $460 thousand in each year is levied on the basis of annual revenue under the revenue taxation system, which is obtained by multiplying the annual revenue of $23 million by the 2% tax rate. The net income in each year is equal to $8.74 million, which is obtained by subtracting annual operating costs of $13.8 million and annual tax payment of $460 thousand from annual revenue of $23 million. The after-tax cash flow distribution is shown at the bottom of the table. Net present value and rate of return are $994.64 thousand and 10.5%, respectively.

Table 4.1 Revenue taxation system ('000 $)

Time	0	1-2	3-12
Revenue		0	23 000
Operating costs		0	13 800
Operating profit		0	9 200
Taxes @ 2%		0	460
Net income		0	8 740
Capital costs	0	25 000	0
A-T Cash flow	0	-25 000	8 740

Net present value @ 10% = $994.64 thousand

Rate of return = 10.5%

Table 4.2 illustrates the application of the profit taxation system. The net income before allowance and taxes in each year is $9.2 million (annual revenue less operating costs). The taxable income of $4.2 million per year is obtained by subtracting annual operating costs and annual depreciation from annual revenue. A straight-line rate of 10% is used for the purpose of depreciation. The tax payment is $420 thousand per year, i.e. 10% of the annual taxable income of $4.2 million. The net income of $3.78 million per year is obtained by subtracting the annual tax payment of $420 thousand from the annual taxable income of $4.2 million. The annual after-tax cash flows are determined by adding back the amount of depreciation to net income and subtracting capital costs. Net present value and rate of return are $1197.77 thousand and 10.6%, respectively.

Table 4.2 Profit taxation system ('000 $)

Time	0	1-2	3-12
Revenue		0	23 000
Operating costs		0	13 800
Net income before allowance and taxes		0	9 200
Depreciation @ 10% SL		0	5 000
Taxable income		0	4 200
Taxes @ 10%		0	420
Net income		0	3 780
Capital costs		25 000	
A-T Cash flow	0	-25 000	8 780

Net present value @ 10% = $1197.77 thousand

Rate of return = 10.6%

Table 4.3 shows the numerical example under the profitability taxation system. The annual operating profit is obtained in the same way as in the other systems. Under the profitability taxation system, a tax payment is levied on the basis of operating profit only when the return on investment is greater than the allowable cost of capital. In this numerical example, because the return on investment exceeds the cost of capital after year 10, tax payments are incurred only after that year. The tax rate in each year is calculated by the formula t = a - a*b/IRR. Rates of 1.41% and 9.54% are obtained in years 11 and 12 respectively, by using a marginal tax rate of 70%. The tax payment in each year is obtained by multiplying the tax rate by the operating profit ($130.10 thousand and $877.32 thousand in years 11 and 12, respectively). The after-tax cash flow is calculated by subtracting annual operating costs, annual tax payment and capital costs from annual revenue. The net present value and rate of return are $3005.45 thousand and 11.4%, respectively.

Table 4.3 Profitability taxation system ('000 $)

Time	0	1-2	3-9	10	11	12
Revenue		0	23 000	23 000	23 000	23 000
Operating costs		0	13 800	13 800	13 800	13 800
Operating profit		0	9 200	9 200	9 200	9 200
Capital costs	0	25 000				
B-T Cash flow	0	-25 000	9 200	9 200	9 200	9 200
B-T IRR (%)				8.39	10.21	11.58
Tax Rate(a=70%)				0	1.41	9.54
Taxes		0	0	0	130.10	877.32
A-T Cash flow	0	-25 000	9 200	9 200	9069.90	8322.68

Net present value @ 10% = $3005.45 thousand

Rate of Return = 11.4%

From the illustrations above, it is obvious that the patterns of tax payments are different between the three taxation systems. In the revenue taxation system, there are tax payments as long as the mine generates revenues. Operating costs and return on investment are of no concern in the system. This can be seen in table 4.1. The tax payments begin in the first year of production and continue over the mine life.

In the profit taxation system, operating costs and depreciation are considered as tax deductions. Thus, the tax payments occur only when the operation yields a taxable profit. If declining- balance depreciation were used, the mine would pay less taxes in the early years of production, but more in the later years, which is always better from the investor's point of view.

In the profitability taxation system, the tax rate is a function of the return on investment. When the return on investment exceeds the cost of capital, the tax is levied on the basis of operating profit. As shown in table 4.3, there are no tax payments during the first seven years of production because the return on investment is below the cost of capital. Taxes are levied in the last two years of production. However, the amount of tax payments depends on the return on the investment. The higher the return on investment, the greater the amount of taxes paid.

Chapter 5. A Hypothetical Case Study

In this chapter, a hypothetical deposit is used to evaluate the effects of the three mining taxation systems described previously.

The chapter begins with a brief discussion of the evaluation framework. Then, O'Hara's cost functions (1986 version) are applied to estimate capital costs and operating costs. Finally, cut-off grade, extraction rate and tax rate are varied individually in order to examine the impacts of these changes on the hypothetical project.

5.1 Modelling of the Evaluation Framework

For the purpose of the study, the following specifications are assumed. There is a copper deposit with total reserves of 70 000 000 tonnes at an average grade of 0.6%. The deposit is characterized by a lognormal grade distribution of mining units of fixed size, with a variance of 1.0%.

The preproduction period is 2 years, the net smelter return and mill recovery are 85% and 90%, respectively. No ore dilution is assumed. The capital costs and operating costs per tonne are estimated by O'Hara's cost functions under specifications which are presented later (section 5.2). Mine capacities from 50 000 to 2 950 000 tonnes of ore per year are examined for purposes of optimization.

The price of copper is assumed to be an external parameter and is estimated to be 1989 U.S. $2,805/tonne by reference to the 1988 Canadian Minerals Yearbook (details in appendix

I). A constant cost of capital is used to discount the cash flows. Inflation at a rate of 4% is incorporated in the case study.

Figure 5.1 illustrates the basic working structure and organization of the model. The modelling task is accomplished with the use of spreadsheet software.

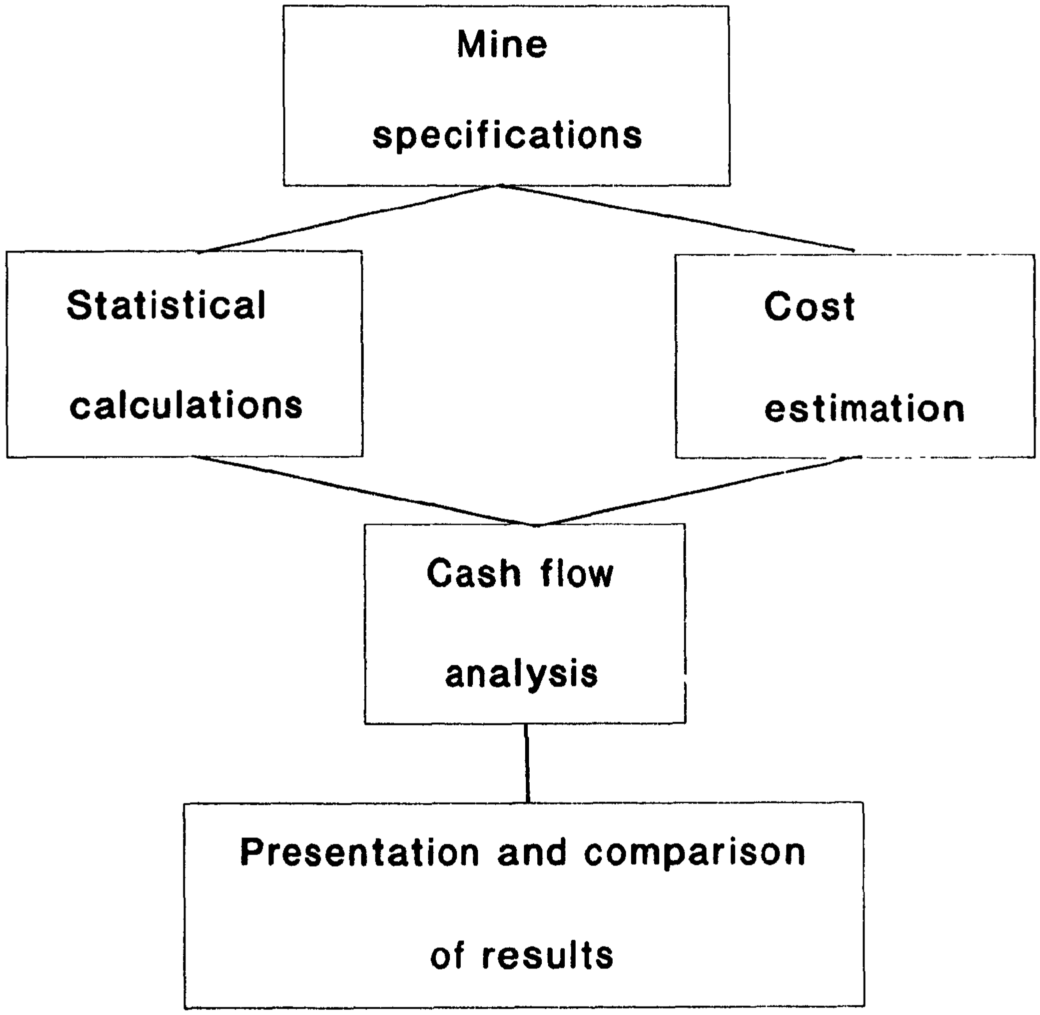


Figure 5.1 Organization of the Modelling

Statistical calculations: Based on the specifications previously stated, the relationships between tonnage and cut-off grade, and average grade above cut-off grade and cut-off grade are established. Tonnage above cut-off grade $t(g_c)$ is calculated using the equation:

$$t(g_c) = T_0 * T(g_c)$$

Where T_0 is the total tonnage of the deposit. T(gc) is the proportion of tonnage above cut-off grade (gc) and is derived from the formula

$$T(gc) = G[\ln(gc/m(0))/\beta + \beta/2]$$

where G(...) = 1 - F(...), where F(...) is the normal cumulative probability function; m(0) is the average grade of the deposit; β is the logarithmic standard deviation of grades of the mining units.

β is calculated by:

$$\beta^2 = \ln\{(\sigma^2/m^2(0)) + 1\}$$

where σ^2 represents the arithmetic variance.

The metal content above cut-off grade $q(g_c)$ is calculated by:

$$q(g_c) = T_0 * m(0) * Q(g_c)$$

where $Q(g_c)$, the proportion of metal content above cut-off grade, is defined by:

$$Q(g_c) = G[\ln(g_c/m(0))/\beta - \beta/2]$$

The average ore grade above cut-off grade $m(g_c)$ is defined by:

$$m(g_c) = m(0) * Q(g_c) / T(g_c)$$

Table 5.1, and Figures 5.2 and 5.3 show the relationships between tonnage and cut-off grade as well as average grade above cut-off grade and cut-off grade for this hypothetical copper deposit.

Table 5.1 Average grade, tonnage and metal content above cut-off grade

Cut-off Grade (%Cu)	$m(g_c)$ (%Cu)	$t(g_c)$ (t)	$q(g_c)$ (t)
0.000	0.600	70 000 000	420 000
0.100	0.705	58 380 000	413 028
0.200	0.868	45 360 000	393 540
0.300	1.032	35 840 000	370 020
0.400	1.197	28 630 000	345 996
0.500	1.365	23 604 000	322 266
0.600	1.517	19 670 000	301 980
0.700	1.683	16 723 000	281 400
0.800	1.832	14 231 000	264 306
0.900	1.999	12 334 000	246 582
1.000	2.151	10 773 000	231 714
1.100	2.300	9 499 000	218 358
1.200	2.461	8 330 000	204 960
1.300	2.637	7 455 000	194 922

As is shown in Figures 5.2 and 5.3, the amount of reserves available decreases as the cut-off grade increases, and the average grade above cut-off grade increases as the cut-off grade increases. But the grade-tonnage and grade-average grade curves do not show where the high and low grade reserves are in the deposit, nor do they show the boundaries between ore and waste.

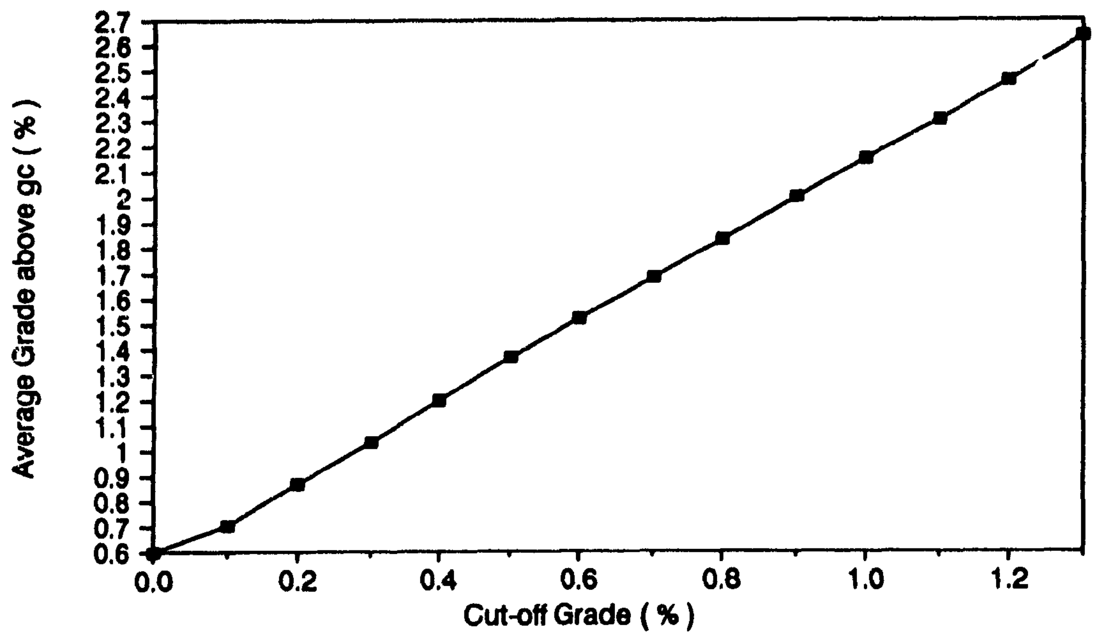


Figure 5.2 **Average Grade above g_c vs Cut-off Grade**

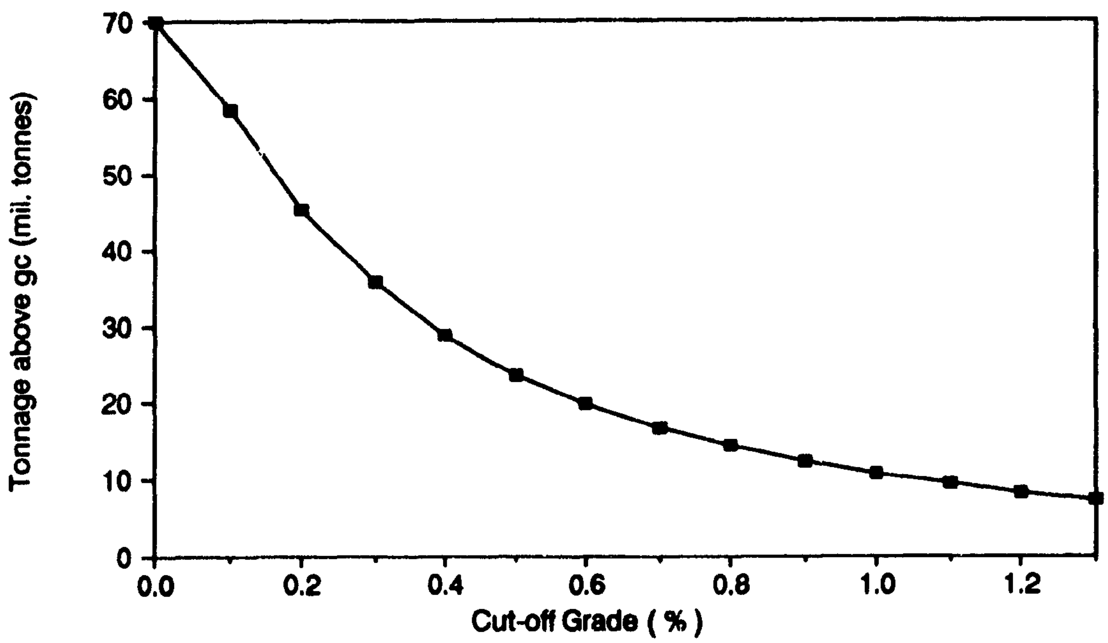


Figure 5.3 **Tonnage above g_c vs Cut-off Grade**

Cost estimation: Capital and operating costs are important factors both prior to and during the development and production phases of a mining project. O'Hara's cost functions (appendix II) have been used to determine these costs. The capital costs increase as the mine capacity increases, and the unit operating costs decrease as the mine capacity increases.

Cash flow analysis: Based on the statistical results shown previously and the cost estimates, the economic criteria, after-tax net present value and rate of return, are determined by cash flow analysis.

The analysis involves the determination of the ultimate profit-generating ability of the mine, the time required to recover the capital costs, and the probability of economic success of the project when relevant information is available. Therefore, cash flow analysis provides a series of economic indicators associated with the project, which are useful for decision-making.

The mine size is determined by the cut-off grade. The size of the deposit or the tonnage available decreases as the cut-off grade increases.

The data from table 5.1 show that as the cut-off grade increases from 0% to 1.3%, the tonnage available decreases from 70 000 000 to 7 392 000 tonnes. The mine life is constrained by the combination of mine capacity and cut-off grade.

The revenue, profit and profitability taxation systems are applied to the hypothetical copper deposit in order to evaluate the effects of mining taxation on the optimization of mining project variables. Table 5.2 illustrates the analysis format. The cut-off grade is 0.8%, the extraction rate is 2 850 thousand tonnes per year, and the tax rates for the revenue, profit and profitability taxation systems are 6%, 35% and 70%, respectively.

The tax rates chosen in table 5.2 are only for the demonstraion of the analysis format.

Table 5.2 Cash Flow Analysis Format

Cash flow chart ('000 $)

Time	0	1	2	3	4	5	6	7
Revenue				142795.809	148507.642	154447.947	160625.865	165937.227
Operating costs				54082.899	56246.215	58496.063	60835.906	62847.546
Operating profit				88712.910	92261.427	95951.884	99789.959	103089.681
Capital costs		122261.737	127152.207					
B-T Cash flow(cur.)	0.000	-122261.737	-127152.207	88712.910	92261.427	95951.834	99789.959	103089.681
Cost of capital(cur.)	0.144							
NPV(con.)	42777.684		IRR(cur.)	0.212				
B-T Cash flow(con.)	0.000	-117559.363	-117559.363	78865.454	78865.454	78865.454	78865.454	78339.685
Cost of capital(con.)	0.100							
NPV(con.)	42777.684		IRR(con.)	0.166				

A. Revenue taxation system

Tax rate: 0.060

Time	0	1	2	3	4	5	6	7
Tax payment	0.000	0.000	0.000	8567.749	8910.458	9266.877	9637.552	9956.234
A-T Cash flow(cur.)	0.000	-122261.737	-127152.207	80145.162	83350.968	86685.007	90152.407	93133.447
Cost of capital(cur.)	0.144							
NPV(con.)	18941.531		IRR(cur.)	0.175				
A-T Cash flow(con.)	0.000	-117559.363	-117559.363	71248.757	71248.757	71248.757	71248.757	70773.765
Cost of capital(con.)	0.100							
NPV(con.)	18941.531		IRR(con.)	0.130				
PV of Tax Payments	23836.154							

B. Profit taxation system

			Deprecia. base	249413.944	187060.458	140295.343	105221.507	78916.131
	Tax rate:	0.350						

Time	0	1	2	3	4	5	6	7
Depreciation				62353.486	46765.114	35073.836	26305.377	19729.033
Taxable income				26359.425	45496.312	60878.048	73484.582	83360.648
Tax payment	0.000	0.000	0.000	9225.799	15923.709	21307.317	25719.604	29176.227
A-T Cash flow(cur.)	0.000	-122261.737	-127152.207	79487.112	76337.718	74644.567	74070.355	73913.454
Cost of capital(cur.)	0.144							
NPV(con.)	-6406.876		IRR(cur.)	0.133				
A-t Cash flow(con.)	0.000	-117559.363	-117559.363	70663.753	65253.801	61352.393	58538.878	56168.150
Cost of capital(con.)	0.100							
NPV(con.)	-6406.876		IRR(con.)	0.089				
PV of Tax Payments	49184.561							

C. Profitability taxation system

Marginal tax rate(%): 70.000

Time	0	1	2	3	4	5	6	7
B-T IRR(con.)				-0.540	-0.181	0.003	0.105	0.166
t(%)	0.000	0.000	0.000	0.000	0.000	0.000	3.185	27.751
Tax payment	0.000	0.000	0.000	0.000	0.000	0.000	2511.730	21740.195
A-T Cash flow	0.000	-117559.363	-117559.363	78865.454	78865.454	78865.454	76353.725	56599.489
A-T IRR(con.)				-0.540	-0.181	0.003	0.102	0.149
A-T NPV(con.)	30203.721							
PV of Tax Payments	12573.964							

Presentation and comparison of results: The net present value is the major criterion for the evaluation of the project. The total discounted tax payments for the three systems at certain ranges of tax rate are compared with each other at the point at which the net present value is maximized. Finally, based on these results, the effects of the three mining taxation systems on the hypothetical mining project are measured and compared.

5.2 The Applications of O'Hara's Cost Functions

Definition of costs: According to economic theory, the costs of goods and services arise from the technology and the inputs used to produce them. The total costs of a mining project can be divided into two parts: total capital costs and total operating costs. Both of them are a function of mine capacity. In order to estimate total capital costs, it is necessary to define the type of operation to be established and the infrastructure required to support it.

There are three components of the capital investment required for mine development: the pre-production capital, the working capital and the sustaining capital cost. The pre-production capital must cover the costs associated with:

Mine access: pre-production stripping for open-pit operations, shafts and hoisting plant for underground operations.

Mine: equipment, site preparation, workshops, mine office, and stores.

Mill: crushing, grinding, flotation and drying facilities.

Infrastructure: railway, road, housing, townsite, power and water facilities.

The working capital is required to operate the mine and finance the time lag between costs and revenues.

The third component is sustaining capital cost. It is required for the replacement of equipment during the production period.

The operating costs can be divided into the following components: labour costs, material costs and utility costs. The total operating costs are the sum of these items.

The principles of O'Hara's cost functions: According to O'Hara, operating costs are related to orebody shape, mining method, milling process and general plant services; capital costs are related to size of mining equipment, mine development, plant-site topography, climate and accessibility, plant services and personnel housing. Different mine capacities will entail different capital and operating costs. In general, open-pit mines with high stripping ratios, underground mines with thin orebodies, mills with complex recovery systems, and projects located in isolated regions with severe climate, mountainous topography, and lacking access to existing roads, towns and electric power have high capital and operating costs.

For a more accurate estimation of capital costs and operating costs, O'Hara has itemized the operating costs by labour, material and power, and the capital costs by such components as mining equipment, material, mine development, mill plant, mill equipment, power supply and distribution, tailings storage and water supply. The total project capital costs and operating costs are estimated by the costs of the individual categories. It is obvious that the chief variable affecting costs is mine capacity. The application of O'Hara's cost functions shows that the capital costs increase as the mine capacity increases and the unit operating costs decrease as the mine capacity increases.

The specifications of the hypothetical deposit are:

Mining method: underground

Mining technique: room-and-pillar

Site preparation: level to hilly ground

Host rock: competent; rectangular shaft assumed

Concrete foundations: typical

Townsite requirement: no accommodations

Temperature: 5500 degree-days below 18°C per year

Grinding conditions: typical ore

Type: Base metal, low grade with copper

Tailings storage conditions: typical

Shaft depth: 300 metres

Stope width: 30 metres

Power supply: utility substation with 15 km line

Minesite access: 20 km dirt road

Under these conditions, the operating and capital costs are determined using O'Hara's cost functions (appendix II). The items and the values are recorded in Tables 5.3 and 5.4.

Table 5.3 Total Capital Costs of the Mine Project

Mine capcity ('000 t/y)	Hoist plant cost ($)	Mine costs ($)	Mill costs ($)	Utility and service costs ($)	Project overheads, total sustainining capital ($)	Total capital cost (1986$)	In 1989 $
50	302536	5718660	6581846	6029796	5496666	24129504	27142410
150	572972	10490495	11006531	7263827	8996848	38330674	43116795
250	788470	14399916	14079713	8180635	11661676	49110411	55242533
350	982086	17937217	16600425	8958708	13970815	58449251	65747458
450	1163271	21248016	18797635	9652512	16066330	66927764	75284632
550	1336297	24400407	20775546	10287714	18014233	74814197	84155797
650	1503512	27433082	22592037	10878929	19851783	82259342	92530572
750	1666370	30370655	24283215	11435449	21602529	89358219	100515843
850	1825839	33230006	25873406	11963636	23282520	96175407	108184253
950	1982600	36023340	27379930	12468079	24903290	102757238	115587918
1050	2137153	38759845	28815633	12952222	26473476	109138328	122765776
1150	2289877	41446656	30190363	13418732	27999748	115345376	129747861
1250	2441068	44089458	31511864	13869725	29487390	121399506	136557933
1350	2590959	46692868	32786359	14306916	30940680	127317782	143215190
1450	2739740	49260706	34018938	14731718	32363134	133114236	150000000
1550	3492961	53522407	35213826	15145313	34340600	141715107	159410222
1650	3651678	56038353	36374581	15548699	35715210	147328521	165724549
1750	3809046	58526489	37504227	15942734	37066253	152848750	171934056
1850	3965199	60988893	38605365	16328157	38395590	158283205	178047079
1950	4120252	63427380	39680249	16705612	39704840	163638332	184070869
2050	4274305	65843546	40730847	17075666	40995423	168919788	190011789
2150	4427447	68238810	41758894	17438818	42268596	174132565	195875453
2250	4579755	70614434	42765922	17795513	43525473	179281098	201666853
2350	4731297	72971550	43753299	18146149	44767054	184369351	207390445
2450	4882136	75311179	44722248	18491083	45994235	189400881	213050233
2550	5032327	77634243	45673868	18830638	47207824	194378901	218649828
2650	5181918	79941583	46609153	19165106	48408556	199306317	224192501
2750	5330956	82233964	47529005	19494753	49597097	204185775	229681228
2850	5479479	84512088	48434244	19819822	50774057	209019690	235118725
2950	5627526	86776598	49325620	20140537	51939995	213810275	240507481

Table 5.4 Total Operating Costs of the Mine Project

Mine capcity ('000 t/y)	Total labour costs ($/t)	Total material cost ($/t)	Power cost ($/t)	Total unit operating cost (1986$/t)	In 1989 $
50	32.05	26.19	3.36	61.59	69.28
150	20.90	17.96	2.42	41.27	46.42
250	17.20	15.14	2.07	34.41	38.71
350	15.15	13.55	1.87	30.57	34.39
450	13.79	12.49	1.74	28.01	31.51
550	12.79	11.70	1.64	26.13	29.39
650	12.02	11.09	1.56	24.67	27.75
750	11.40	10.59	1.49	23.49	26.42
850	10.89	10.18	1.44	22.50	25.31
950	10.46	9.82	1.39	21.67	24.37
1050	10.08	9.52	1.35	20.94	23.56
1150	9.75	9.25	1.31	20.31	22.84
1250	9.46	9.01	1.28	19.74	22.21
1350	9.20	8.79	1.25	19.24	21.64
1450	8.96	8.60	1.22	18.78	21.13
1550	8.75	8.42	1.20	18.37	20.66
1650	8.55	8.26	1.18	17.99	20.23
1750	8.37	8.11	1.16	17.63	19.84
1850	8.20	7.97	1.14	17.31	19.47
1950	8.05	7.84	1.12	17.01	19.13
2050	7.91	7.72	1.10	16.73	18.82
2150	7.77	7.61	1.09	16.47	18.52
2250	7.65	7.50	1.07	16.22	18.24
2350	7.53	7.40	1.06	15.99	17.98
2450	7.42	7.31	1.05	15.77	17.74
2550	7.31	7.22	1.03	15.56	17.50
2650	7.21	7.13	1.02	15.36	17.28
2750	7.12	7.05	1.01	15.18	17.07
2850	7.03	6.97	1.00	15.00	16.87
2950	6.94	6.90	0.99	14.83	16.68

The relationships between mine capacity and capital costs, and mine capacity and operating costs are illustrated in Figures 5.4 and 5.5. O'Hara's functions yield costs in 1986 Canadian dollars which have been converted to 1989 Canadian dollar amounts for presentation in Tables 5.3 and 5.4, and Figures 5.4 and 5.5. This conversion was based on an assumed average inflation rate of 4% between 1986 to 1989.

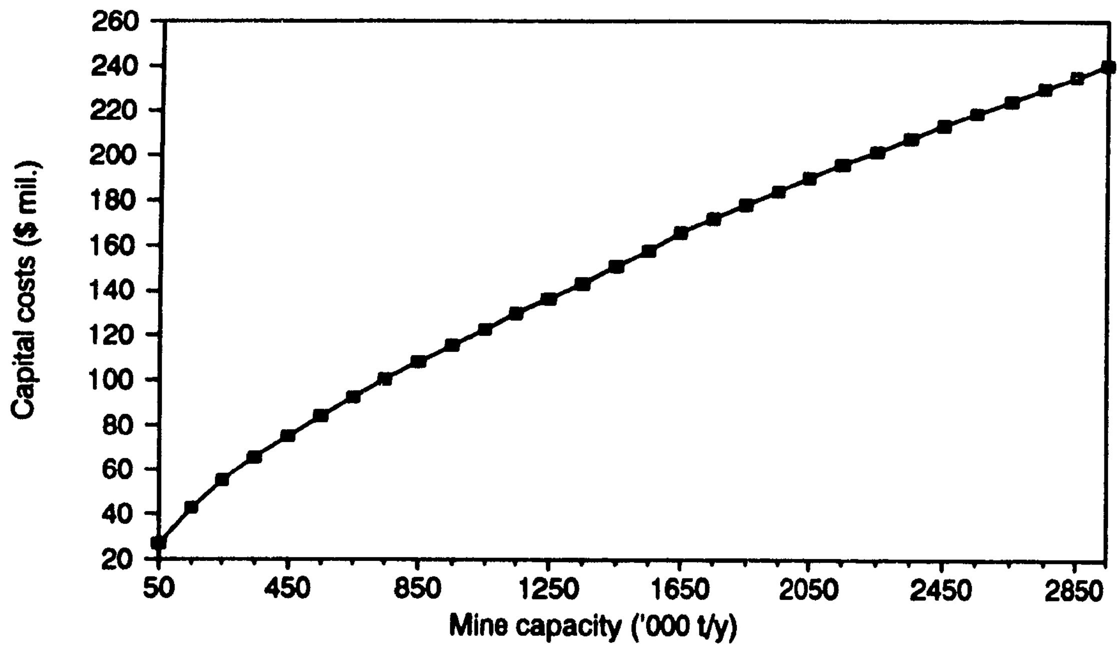


Figure 5.4 The Relationship between Capital Cost and Mine Capacity

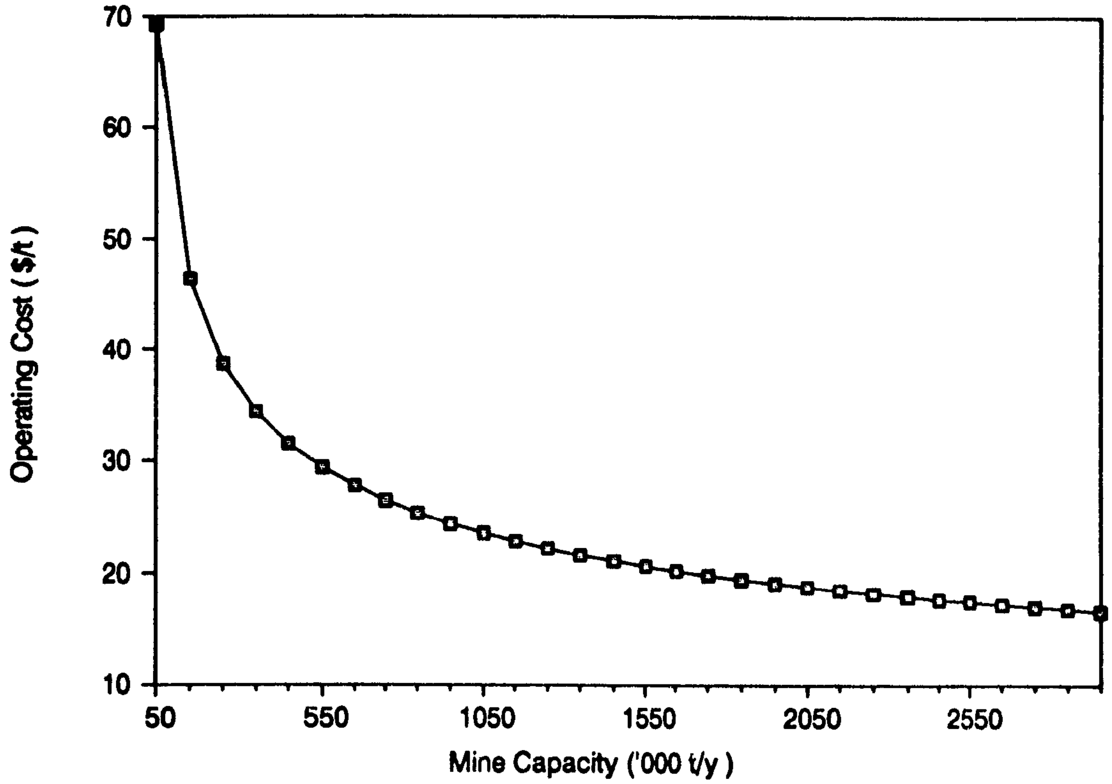


Figure 5.5 The Relationship between Operating Cost and Mine Capacity

As shown in Figures 5.4 and 5.5, capital costs increase as mine capacity increases; operating costs decrease rapidly as mine capacity increases at the lower range of the capacity scale and decrease slowly as the capacity increases at the higher range.

5.3 The Effects of Changing Cut-off Grade and Extraction Rate

A mine is faced with two related decisions to make before development and production. These are the extraction rate and the cut-off grade. Both the extraction rate and the cut-off grade determine the time period over which to extract the ore. However the extraction rate does not affect the total amount of reserves to be extracted. Therefore changing the cut-off grade and extraction rate affects the net present value of the project. This facts are shown in table 5.5.

Table 5.5 Before-Tax Net present Values of the Deposit

gc (%) Capacity ('000 t/y)	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30
1950.00	-9577.45	16304.40	31117.21	45339.55	50274.29	54022.36	55562.15	54838.97	55448.79
2050.00	-7804.83	17727.85	32205.85	45975.19	50450.39	53531.03	54319.83	53630.68	53412.95
2150.00	-6010.96	19145.18	32002.86	46091.01	49977.61	53088.90	53118.77	51908.66	51417.07
2250.00	-4644.86	20184.89	33509.69	46164.65	49422.45	51878.98	51891.43	49892.62	49405.88
2350.00	-3337.03	20973.42	33958.33	46185.93	48818.26	50586.97	50630.55	47844.64	47373.33
2450.00	-2493.44	21684.25	33965.04	45611.92	48156.76	49241.47	48751.72	45759.07	45313.79
2550.00	-1551.28	22030.06	33839.10	44981.00	46995.05	47975.42	46753.76	43743.11	42657.70
2650.00	-840.81	22220.16	33615.44	44262.69	45634.94	46645.36	44696.14	41680.68	39850.38
2750.00	-457.43	22403.09	33385.08	43538.02	44267.71	44914.15	42637.69	39624.02	37047.14
2850.00	-90.66	22357.17	32766.98	42777.68	42889.30	42866.92	40574.95	37046.37	34245.06
2950.00	252.52	21961.41	31901.34	41376.13	41495.84	40804.99	38504.70	34271.93	31441.40

* Optimum combination of capacity and cut-off grade

The impacts of changing cut-off grade

Cut-off grade is defined as a grade which is used to distinguish between the waste and the ore which can be profitably extracted under current technology and mining methods. In a previous discussion, it was shown that the available tonnage of reserves decreases and the average grade of the reserves above cut-off grade increases as the cut-off grade increases. For the purpose of maximization of net present value of the mining project, the cut-off grade is varied within a range of 0% to 1.3% by increments of 0.1%, with other parameters fixed in order to find the optimum cut-off grade for the specific deposit.

Regardless of the tax rate and taxation system applied, at a fixed extraction rate, the net present value of a mining project will increase as the cut-off grade increases from very low levels. The net present value will peak at a particular cut-off grade and further increases in cut-off grade will lead to a decline in net present value.

This concept is illustrated, for the hypothetical project, in Table 5.6. It is shown that if a revenue taxation system is applied at a tax rate of 6%, the optimum cut-off grade which maximizes the net present value is 1 2% for mine capacities in the range of 1950 thousand to 2050 thousand tonnes per year. The optimum cut-off grade is 1.1% for a range of the mine capacity of 2150 thousand to 2450 thousand tonnes per year. The optimum cut-off grade is 1.0% for higher mine capacities. The optimum cut-off grade at the higher range of mine capacities is less than that in the lower range because at higher production rates, the mine can sustain lower grade material and lower unit operating costs.

Table 5.6 Net Present Value at Different Mine Capacities and Cut-off Grades

Revenue Taxation System: Tax rate(%): 6.00

Cut-off Grade (%)	NPV (con.) Mine capacity at 1950 ('000 t/y)	NPV (con.) Mine capacity at 2050 ('000 t/y)	NPV (con.) Mine capacity at 2150 ('000 t/y)	NPV (con.) Mine capacity at 2250 ('000 t/y)	NPV (con.) Mine capacity at 2350 ('000 t/y)
0.50	-31246.41	-29968.88	-28658.12	-27720.61	-26841.36
0.60	-5680.21	-4685.58	-3686.19	-3023.59	-2589.64
0.70	9346.21	10046.20	10495.04	10681.12	10809.00
0.80	23772.80	24066.69	23900.60	23692.35	23431.72
0.90	29309.17	29181.84	28474.65	27689.25	26854.82
1.00	33637.34	32898.30	32208.46	30819.71	29352.18
1.10	35780.36	34350.45	32961.81	31546.89	30098.43
1.20	35789.11	34380.04	32506.29	30362.15	28186.06
1.30	35638.86	34365.73	32632.56	30484.07	28314.23

Profit Taxation System: Tax rate(%): 35.00

Cut-off Grade (%)	NPV (con.) Mine capacity at 1950 ('000 t/y)	NPV (con.) Mine capacity at 2050 ('000 t/y)	NPV (con.) Mine capacity at 2150 ('000 t/y)	NPV (con.) Mine capacity at 2250 ('000 t/y)	NPV (con.) Mine capacity at 2350 ('000 t/y)
0.50	-31638.80	-31070.55	-30602.75	-30261.66	-30003.34
0.60	-13369.68	-13273.69	-12987.23	-13224.86	-13329.47
0.70	-3490.81	-3403.88	-3983.22	-4405.81	-4857.42
0.80	5568.49	4597.03	3891.97	3169.12	1916.89
0.90	8182.07	6717.60	5454.09	4294.01	3111.41
1.00	9712.24	8573.01	6129.91	4376.59	2703.93
1.10	9331.05	7659.07	6025.16	4384.68	1017.67
1.20	8860.99	5973.37	2995.30	775.84	-1453.75
1.30	7149.28	4893.47	2675.77	459.46	-2324.84

Profitability Taxation System: Marginal tax rate(%): 70.00

Cut-off Grade (%)	NPV (con.) Mine capacity at 1950 ('000 t/y)	NPV (con.) Mine capacity at 2050 ('000 t/y)	NPV (con.) Mine capacity at 2150 ('000 t/y)	NPV (con.) Mine capacity at 2250 ('000 t/y)	NPV (con.) Mine capacity at 2350 ('000 t/y)
0.50	-9577.45	-7804.83	-6010.96	-4644.86	-3337.03
0.60	14436.34	15690.03	16631.13	17356.77	18127.41
0.70	25327.16	25967.23	26801.50	26647.71	26381.89
0.80	34059.54	34663.54	33774.66	33098.23	32570.69
C.90	35079.00	35052.87	35267.52	35470.31	33404.36
1.00	35849.39	34391.91	33196.96	32407.48	31680.13
1.10	34335.29	33943.82	33638.72	33356.99	33075.48
1.20	35519.06	31857.76	29082.28	26769.47	24617.80
1.30	28684.97	26935.43	25308.42	23733.36	22169.96

at y)	NPV (con.) Mine capacity at 2350 ('000 t/y)	NPV (con.) Mine capacity at 2450 ('000 t/y)	NPV (con.) Mine capacity at 2550 ('000 t/y)	NPV (con.) Mine capacity at 2650 ('000 t/y)	NPV (con.) Mine capacity at 2750 ('000 t/y)	NPV (con.) Mine capacity at 2850 ('000 t/y)	NPV (con.) Mine capacity at 2950 ('000 t/y)
61	-26841.36	-26375.36	-25804.88	-25450.69	-25382.65	-25331.22	-25303.36
59	-2589.64	-2233.40	-2185.65	-2288.19	-2397.90	-2712.62	-3341.40
12	10809.00	10534.83	10153.48	9674.41	9188.64	8353.85	7294.42
35	23431.72	22628.98	21784.16	20851.96	19913.39	18941.53	17388.42
25	26854.82	25963.08	24626.96	23103.71	21573.34	20031.78	18475.19
71	29352.18	27831.16	26389.59	24884.02	23013.34	20854.13	18680.21
39	30098.43	28083.11	25965.46	23788.15	21610.01	19427.59	17237.65
15	28186.06	25972.38	23828.31	21637.78	19453.01	16791.22	13948.62
07	28314.23	26117.39	23379.27	20498.91	17622.63	14747.52	11870.82

t y)	NPV (con.) Mine capacity at 2350 ('000 t/y)	NPV (con.) Mine capacity at 2450 ('000 t/y)	NPV (con.) Mine capacity at 2550 ('000 t/y)	NPV (con.) Mine capacity at 2650 ('000 t/y)	NPV (con.) Mine capacity at 2750 ('000 t/y)	NPV (con.) Mine capacity at 2850 ('000 t/y)	NPV (con.) Mine capacity at 2950 ('000 t/y)
56	-30003.34	-30134.66	-30025.67	-30393.47	-30760.91	-31130.00	-32034.77
36	-13329.47	-13771.93	-14312.39	-14781.95	-15262.86	-16757.53	-17731.92
31	-4857.42	-6275.53	-7102.59	-7985.59	-9225.56	-11148.50	-12454.83
12	1916.89	246.23	-936.63	-2168.44	-3396.94	-6406.88	-8102.01
01	3111.41	715.03	-1269.18	-2959.77	-4647.14	-6334.33	-8024.20
59	2703.93	1005.79	-631.94	-3804.71	-6857.41	-9041.59	-11227.69
58	1017.67	-1752.52	-3930.13	-6137.58	-8337.11	-10531.37	-12722.88
14	-1453.75	-3697.75	-5887.06	-8881.20	-13645.43	-16932.25	-19675.62
16	-2324.84	-7331.41	-10412.17	-13203.76	-15983.27	-18753.10	-21515.46

00

t)	NPV (con.) Mine capacity at 2350 ('000 t/y)	NPV (con.) Mine capacity at 2450 ('000 t/y)	NPV (con.) Mine capacity at 2550 ('000 t/y)	NPV (con.) Mine capacity at 2650 ('000 t/y)	NPV (con.) Mine capacity at 2750 ('000 t/y)	NPV (con.) Mine capacity at 2850 ('000 t/y)	NPV (con.) Mine capacity at 2950 ('000 t/y)
6	-3337.03	-2493.44	-1551.28	-840.81	-457.43	-90.66	218.34
7	18127.41	18320.87	18420.66	18524.32	18688.52	18818.66	18086.22
1	26381.89	26264.90	26335.51	26393.01	26005.54	24798.79	23774.61
3	32570.69	32245.68	32077.56	31895.35	31741.58	30203.72	28472.17
1	33404.36	31576.34	31572.33	29084.29	27950.27	26844.25	25744.76
8	31680.13	30966.49	30333.51	29671.50	29457.87	29532.27	26909.87
9	33075.48	30265.84	27451.62	24846.80	22382.63	20002.76	17663.16
7	24617.80	22553.80	23576.71	18598.75	16614.67	15865.75	15511.21
6	22169.96	20584.91	20272.55	20072.57	19798.57	19437.59	18975.28

The results are similar for profit and profitability taxation. Figure 5.6 shows the fact that, for a given constant mine capacity, tax rate, and taxation system, the net present value of the project increases initially as the cut-off grade increases, peaks at a particular point, and then decreases as the cut-off grade is further increased.

The response of the net present value to changes in cut-off grade can be explained by the fact that the reserves available for extraction change are inversely proportional to the cut-off grade, i.e. the reduced reserves shorten the mine life. The resulting decrease in net present value means a direct reduction of the national wealth created and inefficient use of natural resources.

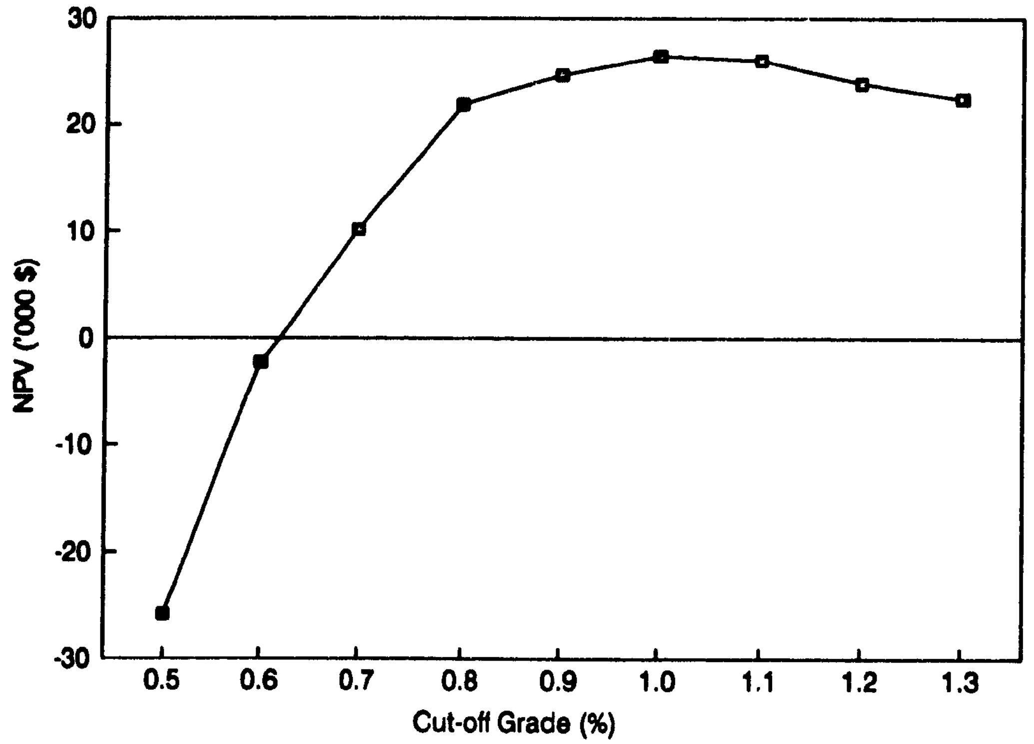


Figure 5.6 Relationship between Net Present Value and Cut-off Grade at a Mine Capacity of 2 550 000 tpy(Revenue Taxation, Tax Rate: 6%)

The impacts of changing the extraction rate

The selection of a rate of extraction is influenced by factors such as the prices of inputs required for the extraction process and the price of the product which is output For instance, the expectation of input price increases, such as wages may lead to an increase in the current extraction rate. The extraction rate decision is also influenced by the depletion of reserves. Increases in the extraction rate accelerate the depletion of reserves at a given cut-off grade. The optimum extraction rate is selected on the basis of maximum net present value.

Table 5.6 shows the effects of changes in mine capacity on the net present value at a fixed cut-off grade and tax rate with each of the three taxation systems. The general results are similar to those obtained from varying the cut-off grade. The net present value increases as the mine capacity increases up to a certain level after which further increases in the capacity result in a reduction in net present value. Figure 5.7 illustrates these results.

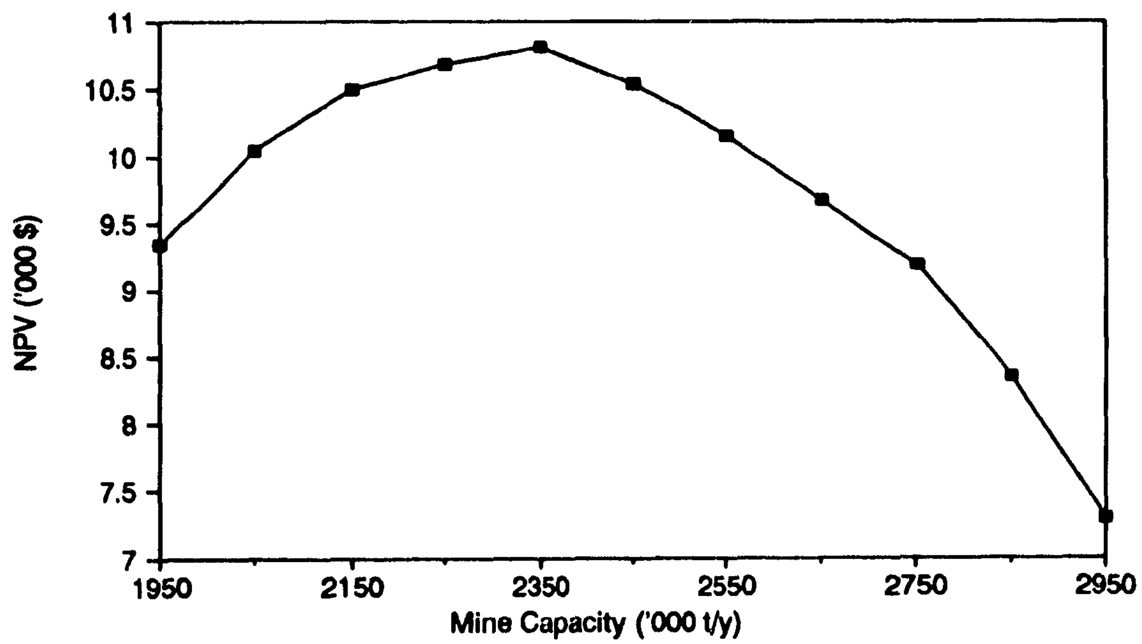


Figure 5.7 Relationship between Net Present Value and Extraction Rate at Cut-off Grade of 0.7% (Revenue Taxation, Tax Rate: 6%)

The net present value decreases as the extraction rate increases because the capital costs associated with the project more than offset the benefits of the shorter mine life.

5.4 The Impacts of Changing Tax Rate

A firm considering an investment in a mining operation treats any form of taxation as a cost of doing business in a particular jurisdiction. The taxes paid reduce the net present value of the project, making the investment less attractive. In this section, the tax rate in each mining taxation system is varied in order to evaluate the impact of a changing tax rate on net present value. Although it is obvious that any increase in tax rate will cause a decrease in the net present value of the mining project, the response of net present value to changes in tax rate differs among the taxation systems.

Table 5.7 gives the slopes of the net present value curves at particular cut-off grades for the different taxation systems. The slope of the net present value curves decreases as the cut-off grade increases for the revenue taxation system. However, in the applications of profit and profitability taxation systems, the slope of the net present value curves increases as the cut-off grade increases.

Figures 5.8 illustrates net present value trends as a function of increasing tax rate for the revenue taxation system. This means that the net present value becomes less sensitive to changes in tax rate as the cut-off grade increases.

Table 5.7 The Slopes of the Net Present Value Curves (Mine Capacity: 2 550 000 t/y)

Cut-off Grade(%)	Slope (Revenue Tax)	Slope (Profit Tax)	Slope (Profitability Tax)
0.6	36.32	46.73	23.20
0.7	35.53	52.64	48.24
0.8	34.80	59.04	82.95
0.9	33.55	62.05	107.50
1.0	32.38	62.50	113.41
1.1	31.18	65.17	124.09
1.2	29.87	63.81	148.93
1.3	28.92	68.23	143.90

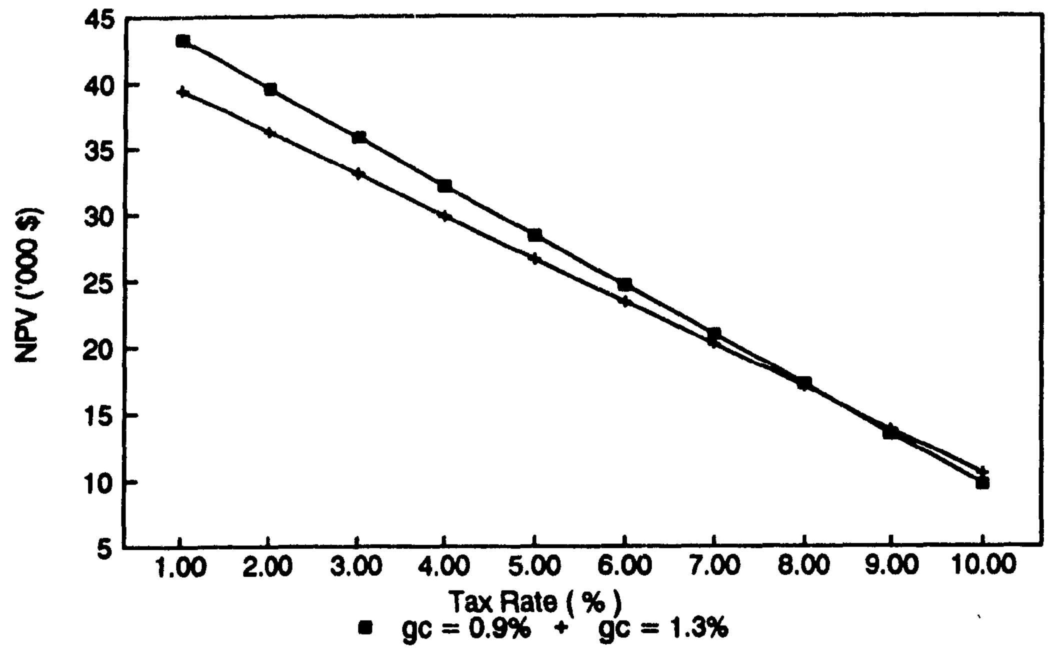


Figure 5.8 Net Present Value vs Tax Rate at Different Cut-off Grades(Cap. 2 550 000 t/y) (Revenue Taxation System)

For the profit and profitability taxation systems, the slopes of the net present value curves increase as the cut-off grade increases. This means that the net present value becomes more sensitive to changes in tax rate as the cut-off grade increases. Figures 5.9 and 5.10 demonstrate the results.

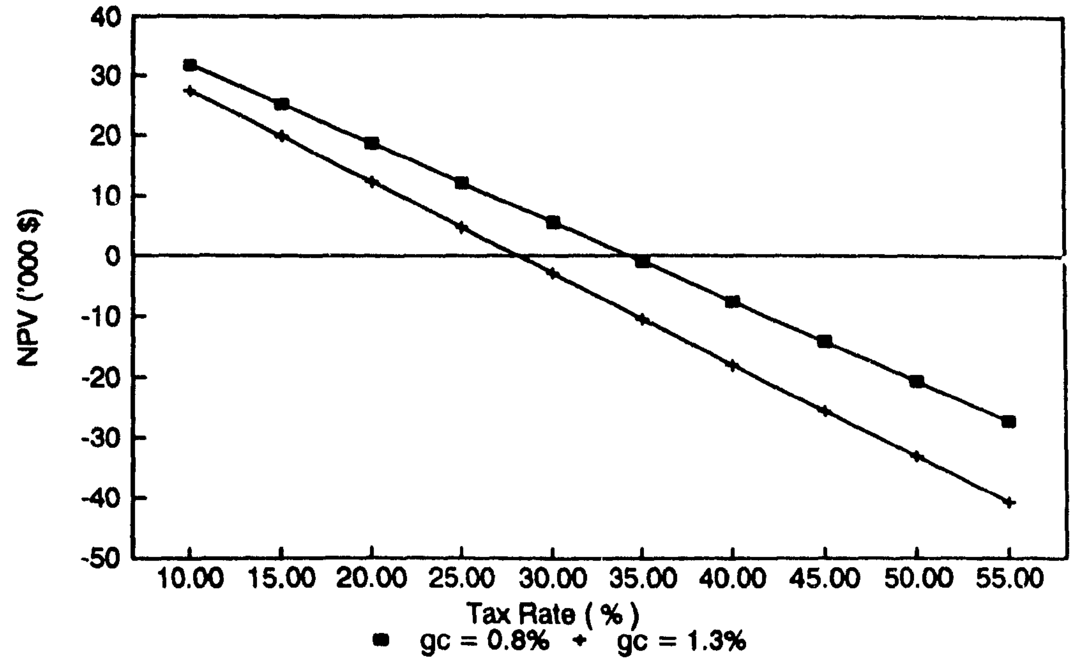


Figure 5.9 Net Present Value vs Tax Rate at Different Cut-off Grades(Cap. 2 550 000 t/y) (Profit Taxation System)

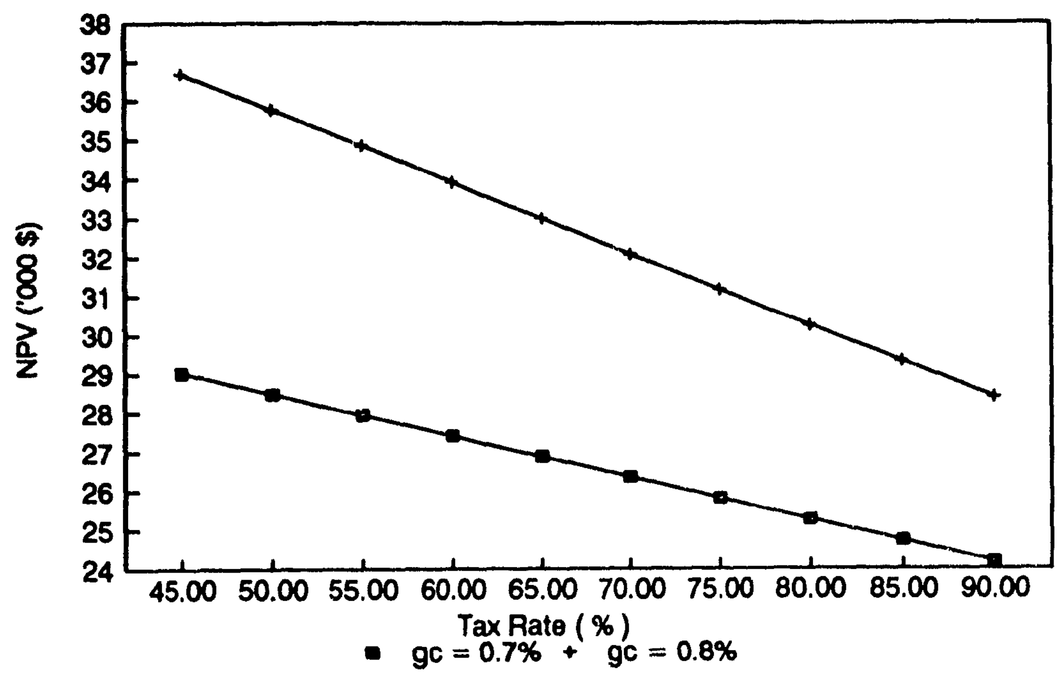


Figure 5.10 Net Present Value vs Tax Rate at Different Cut-off Grades(Cap. 2 550 000 t/y) (Profitability Taxation System)

Chapter 6 Comparisons of the Effects of Mining Taxation Systems on the Hypothetical Deposit

There is considerable variation in the types of mining taxation currently employed. Generally they can be divided into three broad categories: (1) Severance taxes which relate to output or revenue, (2) profit taxes which are levied on the profits and (3) profitability taxes which are a function of the rate of return of the project. In this study, the revenue related taxation system, the profit taxation system with a uniform tax rate and the profitability taxation system with a progressive rate of tax are applied to the hypothetical deposit in order to evaluate the effects of taxes.

It is well known that mining taxation policy is one of the most powerful instruments of government. A well designed taxation system acts to foster investments and perpetuate government revenue. The proper implementation of a taxation system should also have neutral effects on both the firm and the government. Using the environment developed in chapter 5, the effects of changes in tax rate in each taxation system are examined using various combinations of cut-off grade and mine capacity. The cut-off grade is varied from 0% to 1.3% in increments of 0.1%. The mine capacity is varied from 1 950 000 to 2 950 000 tonnes per year.

6.1 The Effects of Changes in Tax Rate in the Revenue Taxation System

The tax rate is varied from 1% to 10% in increments of 1% for this study. As it is shown, in figure 6.1, an increase in tax rate results in a reduction of net present value, given a mine capacity of 2 950 000 tonnes per year.

The change in tax rate also alters the optimum cut-off grade which is selected on the basis of maximum net present value. As is shown, the optimum cut-off grade is 0.9% when the tax rate is 1%, and this value increases to 1.0% for the tax rates of 6% and over This tax-induced high-grading effect may render less attractive projects which have low cut-off grades.

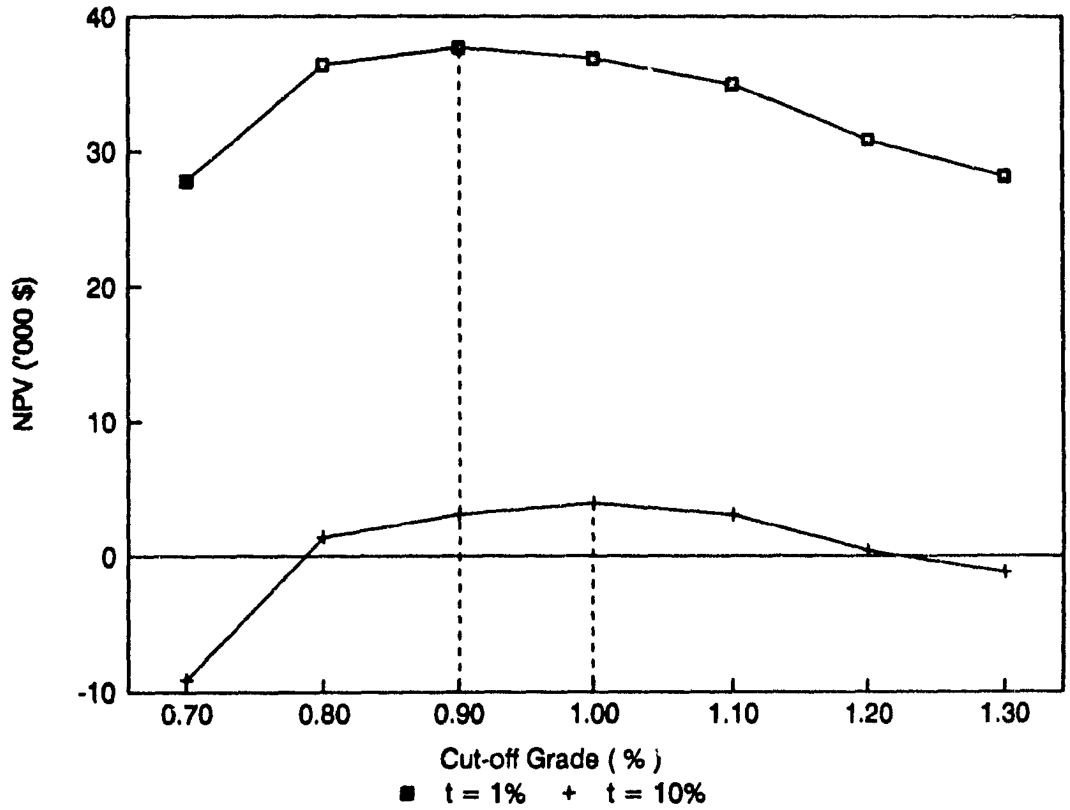


Figure 6.1 The Effects of Changes in Tax Rate in the Revenue Taxation System (Mine Capacity: 2 950 000 tonnes per year)

6.2 The Effects of Changes in Tax Rate in the Profit Taxation System

The tax rate is varied from 10% to 55% in increments of 5% for the application of the profit taxation system. As in the revenue taxation system, any increase in tax rate adds costs and reduces the net present value. The change in tax rate alters the optimum cut-off grade.

In Figures 6.2, 6.3 and 6.4, each curve represents the net present value associated with a different tax rate. When the mine capacity is 1 950 000 tonnes per year and the tax rate is 10% (figure 6.2), the maximum net present value is obtained at a cut-off grade of 1.1%. Increasing the tax rate to 40% and over, the maximum net present value is realized at a cut-off grade of 1.0%.

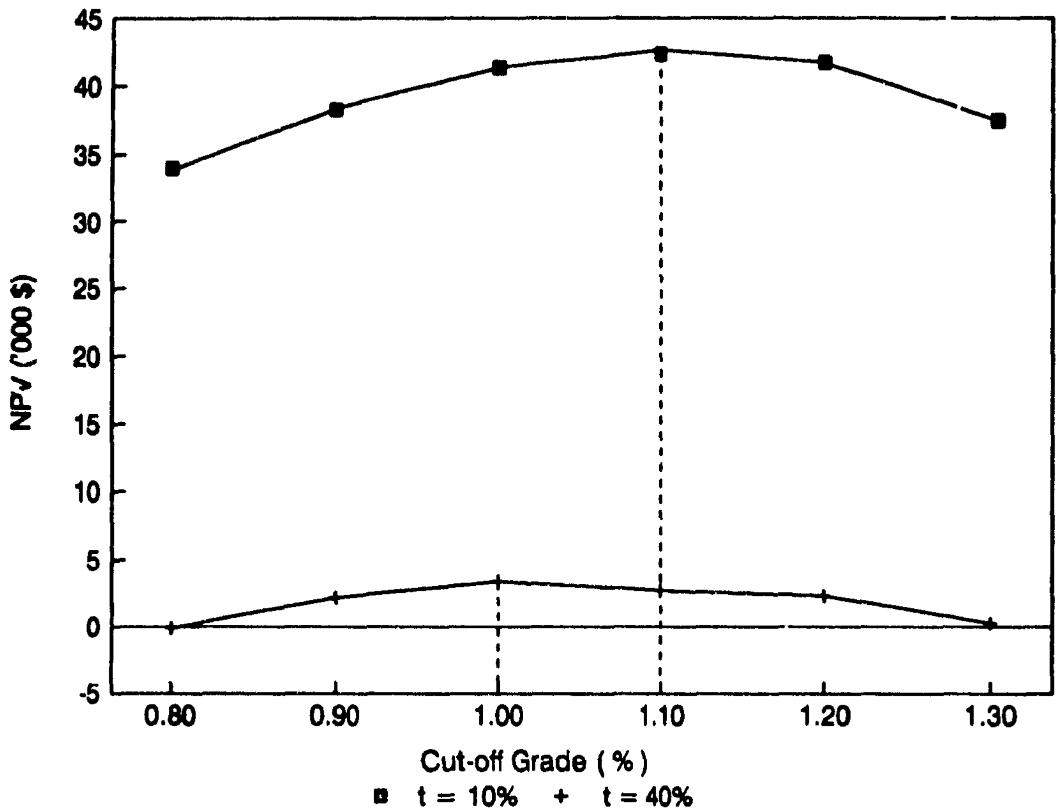


Figure 6.2 The Effects of Changes in Tax Rate in the Profit Taxation System (Mine Capacity: 1 950 000 tonnes per year)

When the mine capacity is increased to 2,350,000 tonnes per year (figure 6.3), a similar situation occurs. For tax rates under 30%, the maximum net present value is achieved at a cut-off grade of 1.0%. When the tax rate is increased to 35% and over, the maximum net present value is reached at a cut-off grade of 0.9%.

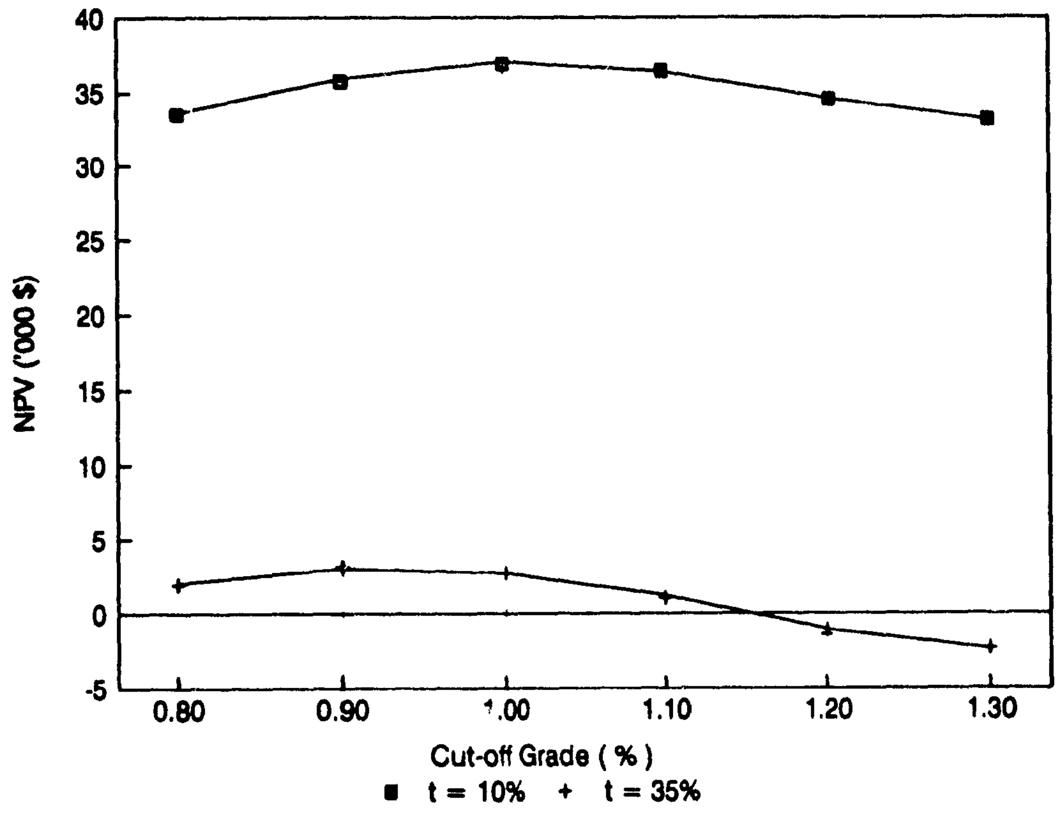


Figure 6.3 The Effects of Changes in Tax Rate in the Profit Taxation System (Mine Capacity: 2 350 000 tonnes per year)

When the mine capacity is increased to a relatively high level, for example, 2 950 000 tonnes per year, an increase in tax rate has little or no obvious effect on the cut-off grade associated with the maximum net present value, as shown in figure 6.4.

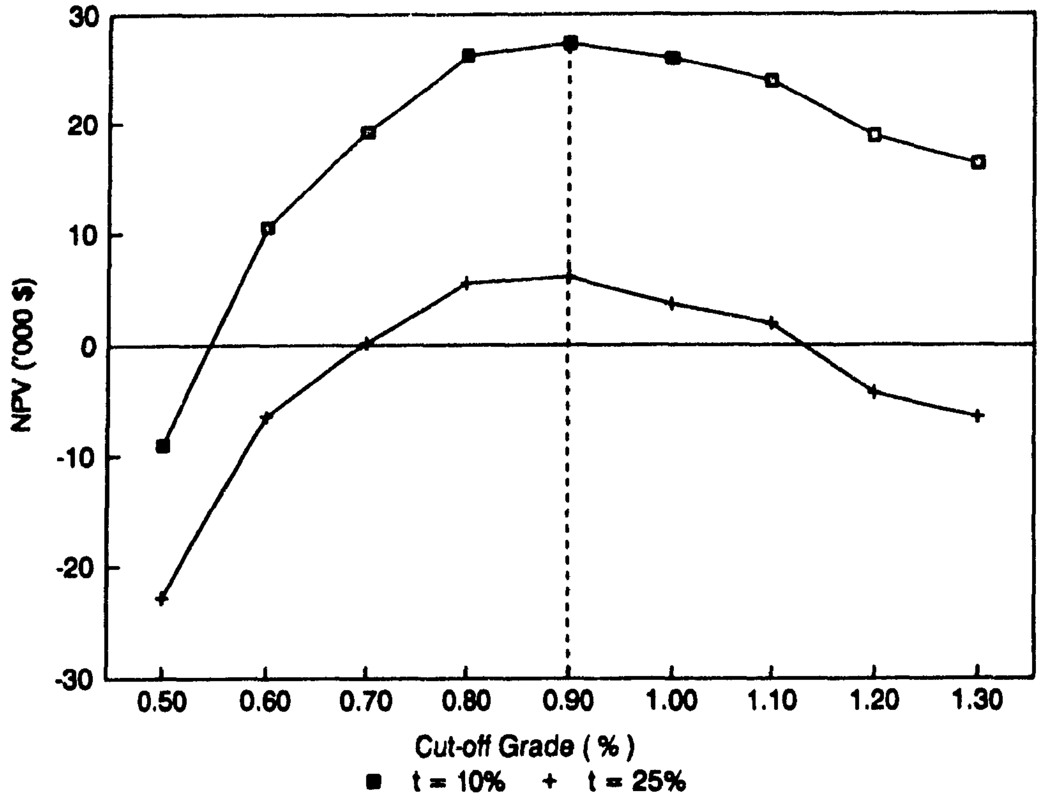


Figure 6.4 The Effects of Changes in Tax Rate in the Profit Taxation System (Mine Capacity: 2 950 000 tonnes per year)

The noted phenomenon of higher tax rates leading to lower optimum cut-off grades may be explained as follows. The reduction in net present value resulting from higher tax rates tends to be partly offset by decreases in cut-off grade, i.e. increases in reserves. However, in revenue taxation system, it does not consider the costs of the project, then the increases in tax payment will lead to mine richer grade materials.

6.3 The Effects of Changes in Tax Rate in the Profitability Taxation System

In profitability taxation, the tax rate is a function of the marginal tax rate, internal rate of return and threshold cost of capital. To study the change in tax rate in this section, it is assumed to be equivalent to a change in the marginal tax rate. In this case study, the marginal tax rate is varied from 45% to 90% in increments of 5%.

As shown in figure 6.5, the changes in marginal tax rate do not alter the cut-off grade that maximizes net present value.

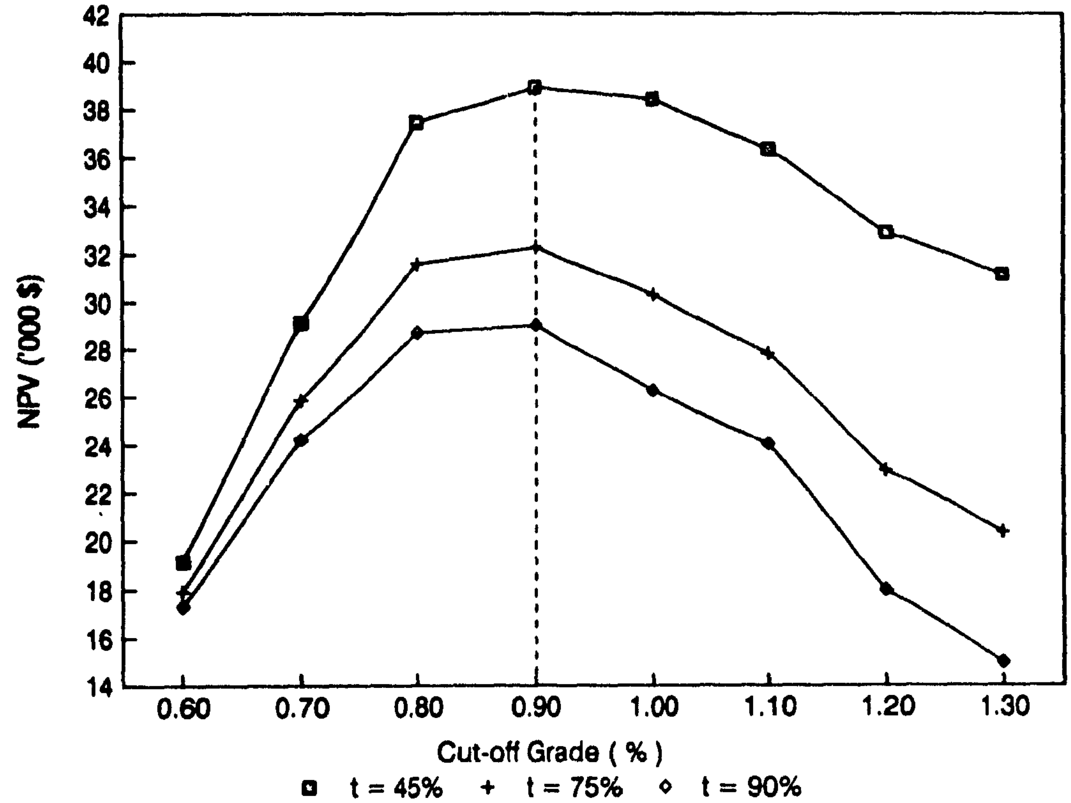


Figure 6.5 The Effects of Changes in Tax Rate in the Profitability Taxation System (Mine Capacity: 2 350 000 tonnes per year)

As is shown, regardless of the marginal tax rate applied, the maximum net present value is always realized at a cut-off grade of 0.9% for a mine capacity 2 350 000 tonnes per year. A similar situation occurs at other mine capacities, i.e. a optimum cut-off grade is not affected by changes of the marginal tax rate.

The comparison of the three taxation systems has shown that, for the revenue taxation system, increases in tax rates lead to high-grading operations because costs are ignored. The profit taxation system recognizes costs and, as a result, increases in tax rates lead to lower cut-off grade operations at relatively low mine capacities. This is favourable to small-profit mines and promotes conservation of resources. The profitability taxation system considers return on investment and does not discriminate against projects that operate at lower cut-off grades. An increase in marginal tax rate has no significant impact on the optimum cut-off grade.

6.4 Evaluation of Net Present Value at the Same Amount of Tax Payments for Different Taxation Systems

Apart from assessing the effects of changes in tax rates on the optimum cut-off grade for each taxation system, it is useful to compare the three systems on the basis of equal amounts of discounted tax payments. First, optimum cut-off grades for selected mine capacities are determined on the basis of before-tax net present value. Then, the tax rate is varied in order to generate the same amount of discounted tax payments in each taxation system.

The optimum cut-off grades for each mine capacity are shown in table 6.1. In order to compare the three taxation systems simultaneously, a range of cut-off grades from 0.6% to 1.3% is used.

Table 6.1 The Optimum Combinations of Cut-off Grade and Mine Capacity for Maximum Net Present Value

Before-Tax Maximum Net Present Value ('000 $)

g_c (%Cu)	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Capacity (t)	│	│	│	│	│	│	│	│
1 950 000	│	│	│	│		55562150		
2 050 000	│	│	│	50450400				
2 250 000	│	│	46164660					
2 450 000	│	33965040						
2 750 000	22403090							

As is shown in table 6.2, at each level of cut-off grade, for total discounted tax payments of $5 000 000, the net present values, under the revenue, profit and profitability taxation systems, are equal. However, at each level of cut-off grade, the rate of returns under profitability taxation system is higher than those under the other two taxation systems.

Table 6.2 **Comparison of Net Present Value at the Same Amount of Discounted Tax Payments for the Three taxation Systems**

			Tax Rate(%)	Tax	NPV	ROR (%)
gc = 0.6%	A.	t(r) =	1.21	5000004.16	17403085.23	12.23
Cap. = 2750	B.	t(p) =	4.65	5000004.27	17403085.12	12.24
('000 t/y)	C.	t(m) =	94.22	5000021.69	17403067.69	12.27
gc = 0.7%	A.	t(r) =	1.28	5000008.25	28965033.84	14.06
Cap. = 2450	B.	t(p) =	4.35	5000006.42	28965035.67	14.08
('000 t/y)	C.	t(m) =	45.45	5000007.02	28965035.06	14.13
gc = 0.8%	A.	t(r) =	1.33	5000013.02	41164641.56	16.28
Cap. = 2250	B.	t(p) =	4.07	5000012.14	41164642.44	16.31
('000 t/y)	C.	t(m) =	26.79	4999999.91	41164654.66	16.38
gc = 0.9%	A.	t(r) =	1.41	5000026.63	45450372.27	17.55
Cap. = 2050	B.	t(p) =	4.00	5000021.01	45450377.88	17.58
('000 t/y)	C.	t(m) =	22.73	5000017.72	45450381.17	17.67
gc = 1.0%	A.	t(r) =	1.47	5000002.80	49022353.21	18.80
Cap. = 1950	B.	t(p) =	3.95	5000004.11	49022351.89	18.83
('000 t/y)	C.	t(m) =	19.26	5000006.13	49022349.88	18.93
gc = 1.1%	A.	t(r) =	1.52	5000012.64	50562137.51	19.82
Cap. = 1950	B.	t(p) =	3.79	5000012.02	50562138.13	19.85
('000 t/y)	C.	t(m) =	16.49	5000016.27	50562133.87	19.95
gc = 1.2%	A.	t(r) =	1.57	5000015.76	49838953.63	20.49
Cap. = 1950	B.	t(p) =	3.81	5000000.63	49838968.76	20.51
('000 t/y)	C.	t(m) =	18.12	5000004.87	49838964.53	20.64
gc = 1.3%	A.	t(r) =	1.62	5000025.61	50448769.05	21.40
Cap. = 1950	B.	t(p) =	3.62	5000020.92	50448773.74	21.42
('000 t/y)	C.	t(m) =	13.08	5000017.43	50448777.23	21.53

A. Revenue taxation system
B. Profit taxation system
C. Profitability tax. system

This trend is explained by figures 6.6(a) and (b). The cash flow profiles of the project are similar when the revenue and profit taxation systems are applied. Under the profitability taxation system, however, the tax payments are further deferred due to the recognition of costs, which result in a higher rate of return. The deferred tax payments allow mining companies to recover their capital expenditures as early as possible and that is why the profitability taxation system is favourable to mining companies but not government.

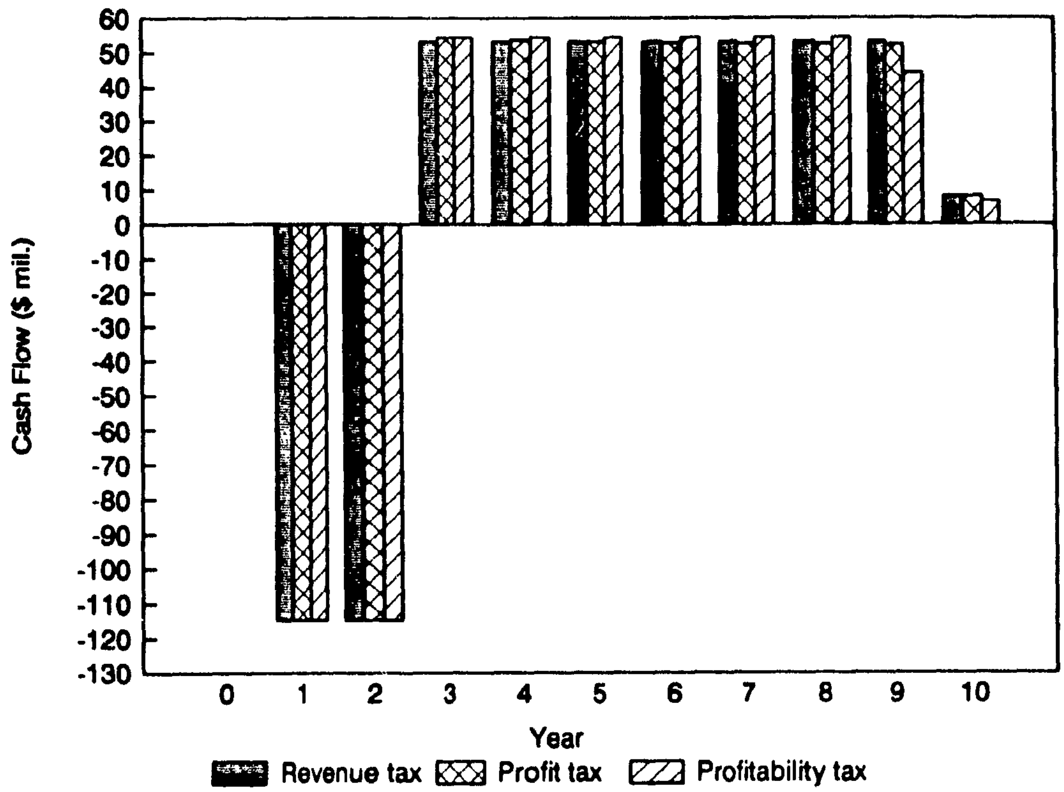
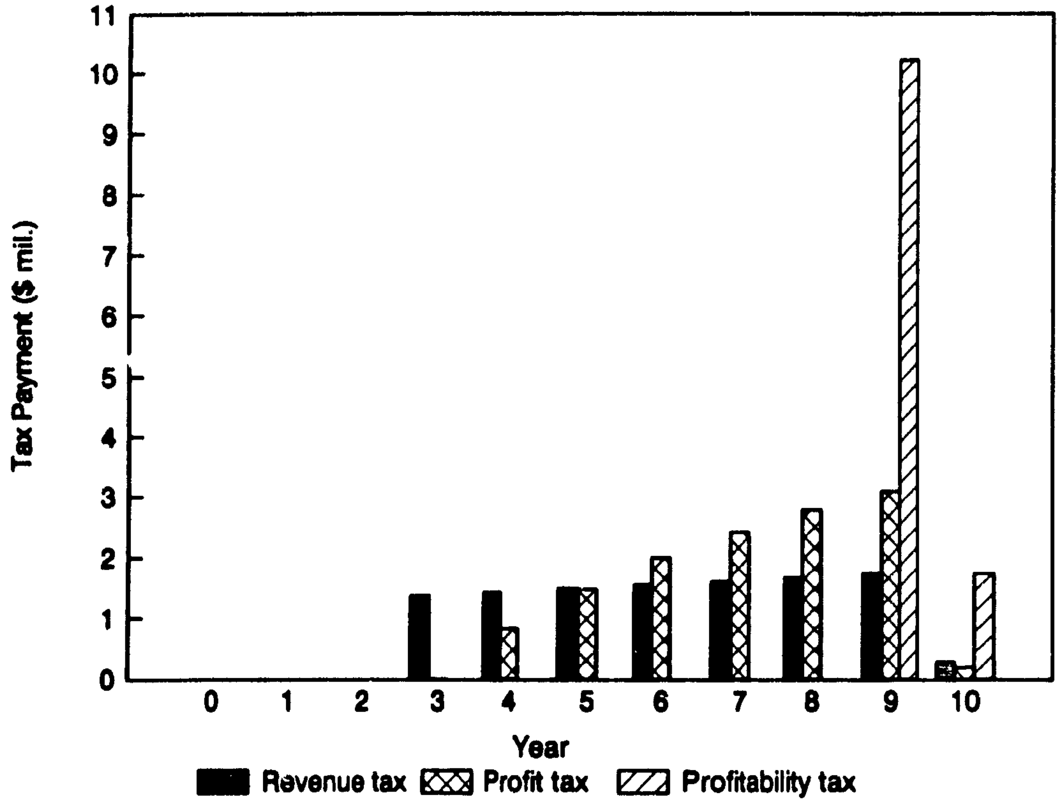


Figure 6.6 (a) Comparisons of Cash Flows at Cut-off Grade of 1.1% and Mine Capacity of 1 950 000 tonnes per year



(b) **Comparisons of Tax Payments at Cut-off Grade of 1.1% and Mine Capacity of 1 950 000 tonnes per year**

Chapter 7 Conclusions and Recommendations

7.1 Conclusions

1. The preceding analysis examined in detail the response of a mining project to the revenue, profit and profitability taxation systems. In general, any form of taxation is a cost of doing business. The taxes paid reduce the present value of cash flows, thus making the investment less attractive. Any increase in tax rate will decrease the after-tax net present value and rate of return for a given cut-off grade and mine capacity.

2. The cash flow distribution of a mining project varies according to the taxation system applied. When the revenue taxation system is applied, the first tax payment coincides with the first productive period. This is because the tax is levied on revenue regardless of the level of profit. When the profit taxation system is applied, the payment of taxes depends upon the availability of taxable income. When the profitability taxation system is applied, the tax payments occur only when the internal rate of return exceeds the cost of capital. From the point of view of the mining firm, it is preferable to delay the payment of taxes as long as possible.

3. As the rate of taxation increases, the optimum cut-off grade rises under the revenue taxation system, and decreases under the profit taxation system. When the profitability taxation system is applied, the optimum cut-off grade is unresponsive to changes in marginal tax rate. The profit and profitability taxation systems do not discriminate against low-grade operations or small mines.

4. For the hypothetical mining project studied, the net present value is less sensitive to

changes in tax rate as the cut-off grade is increased under the revenue taxation system. When the profit or profitability taxation system is applied, the net present value becomes more sensitive to changes in tax rate as the cut-off grade is increased.

5. The choice between tax policies is often complicated by a trade-off between the ease of administration and enforcement and the magnitude of the distortional effects caused by the complexity of the taxation system itself and the dynamic nature of the environment. It is clear that no single taxation system is perfect. In general, tax policies should provide the following characteristics: (1) ensure the stability of government revenue; (2) control external effects such as pollution and land reclamation; (3) be simple to understand and comply with; (4) be neutral on investment decisions of companies.

7.2 Recommendations

Since the revenue taxation system induces high-grading and increases the risk of mining because of its non-recognition of costs, the profit and profitability taxation systems should be major instruments for tax policy in order to reduce the discrimination and distortion on the low-grade operations and small profit mines. The tax rate should be adjusted according to the ore quality and mining techniques even if such flexibility may increase the costs of administration.

This study of evaluating effects of taxation systems on mining projects is based on a hypothetical copper deposit constrained by assumptions. Thus, some of the results and conclusions may be suitable only to this hypothetical deposit and may not be applicable to others. It is necessary to apply the three taxation systems to real deposits in order to assess the more general features and effects of taxation on mining projects.

Although the revenue taxation system leads to high-grading and does not favour the low profit-margin mine, and the profit and profitability taxation systems encourage investment in lower-grade operations and have no bias against small mines, the overall study remained superficial. A further study should apply the three taxation systems to real deposits divided into several size and grade groups. This would provide a more detailed insight on the effects of taxation systems on the wide variety of deposits that actually exist in nature.

Appendix I Copper Price

In the 1988 Canadian Minerals Yearbook, the copper price varies from a low of $0.85/lb to a high of $1.70/lb. The copper price in this study is determined as follows:

$$\{(1.70 + 0.85) / 2\} * 2.2 * 1000 = \$\ 2\,805 / t$$

1 kg = 2.2 b

1 t = 1000 kg

Appendix II O'Hara's Cost Functions

Capital Cost Relationships

Variables:

T Annual capacity - underground mines, and mills - thousand tonnes per year ore

M Annual capacity - open pit mines - thousand tonnes per year ore and waste

Valid ranges:

T (mine)	22.7 -- 3 400.0		
M	227.0 -- 11 340.0		
T (mill)	High grade ore	31.75 -- 4 765.0	
	Low grade ore	158.80 -- 9 525.0	

Mining Technique (MT):

1 Blasthole open stoping

2 Shrinkage

3 Cut-and-fill

4 Room-and-pillar

5 Vertical crater retreat

Mine and Mill Site Preparation (SP):

1 Level ground

2 Level to hill ground

3 Hilly ground

Host Rock Conditions (HR):

1 Competent -- Rectangular shaft

2 Incompetent -- Circular shaft

Concrete Foundation Conditions (CF):

1 Favourable

2 Typical

3 Unfavourable

Townsite Requirements (TR):

1 No accommodations

2 Partial accommodations

3 Full accommodations

Temperature Conditions (HT):

1 < 5 000

2 5 000-5 999

3 6 000-6 999

4 7 000-7 999

5 8 000-8 999

6 9 000-9 999

7 10 000-10 999

8 11 000-11 999

9 >= 12 000

(Degree days per year below 18°C)

Grinding Conditions (GC):

1 Soft ore

2 Typical

3 Hard ore

Ore Type (OT):

1 Base metal (BM), high grade (HG) with one concentrate

2 BM, low grade (LG) with Cu or Mo concentrate

3 BM, HG with 2 or more concentrates

4 BM, LG with Cu and Mo concentrates

5 Nickel (with copper)

6 Gold, HG free milling

7 Gold, HG refratory

8 Gold, HG with base metals

9 Gold, LG open pit

10 Uranium

11 Gravity separation, simple

12 Gravity separation, complex

Tailings storage Conditions (TS):

1 Favourable

2 Typical

3 Unfavourable

AR -- Access road

SD -- Shaft depth (m)

W -- Stope width (m)

TD -- Utility power line (km)

N -- Number of employees

V_s, V_R -- Volumes of soil and rock overburden to strip (m^3)

Functions (1986 $):

1 Open Pit Mining

* Site preparation

  SP

  1 $6\,929.4\ M^{0.5}$

  2 $10\,499.1\ M^{0.5}$

  3 $17\,428.5\ M^{0.5}$

* Waste stripping

  Soil $1\,396.4\ (1.1\ V_s)^{0.5}$

  Rock $14\,698.7\ (1.9\ V_R)^{0.5}$

* Shovels

  $14\,007.1\ M^{0.8}/SS^{0.2}$

  where $SS = 0.20069\ M^{0.4}(m^3)$ (Shovel size)

* Trucks

  $10\,482.5\ M^{0.8}/TR^{0.1}$

  where $TR = 10\,967\ SS^{1.1}(t)$ (Truck size)

* Ancillary equipment

  0.2 x (Cost of truck fleet)

* Drills

  GC

  1 $478.96\ M^{0.9}$

  2 $627.21\ M^{0.9}$

  3 $1\,011.14\ M^{0.9}$

* Maintenance facilities

  $446\,349.9\ M^{0.3}$

2 Underground Mining

* Shaf

  HR

  1 $262\,640\ SA^{0.25} + 1\,076.389\ SD^{1.1}SA^{0.25}$

where SA = $1.682\ T^{0.4}$ Cross-sectional area (m^2)

2 $235\,470\ D^{0.5} + 1\,697.470\ SD^{1.1} D^{0.7}$

where D = $1.476\ T^{0.2}$ Diameter(m)

* Multiple Shafts

  For T > 1 500, multiple shafts are required.

  N.B. Each shaft needs a hoisting plant

* Mine development

  $382\,354\ T^{0.9} / W^{0.67}$

* Hoisting plant

  $29\,224.8\ DD^{1.4}\ MP^{0.2} + 52\,047.2\ DD^{1.8} + 20\,990.2\ DD^{3.2}$

where DD = $0.0254\ (176.37\ T + 441.18\ SD^{0.5}\ T^{0.6} + 8.473\ SD^{0.3}\ T^{1.2})^{1/2.8}$

MP = $1.640\ VE\ (0.393701\ DD)^{2.4}$ Motor power

= $1.223\ VE\ (0.393701\ DD)^{2.4}$ KW

VE = $1.599\ SD^{0.5}\ T^{0.4}$ Rope velocity (m/min)

* Mine compressor

  $13\,677.0\ VL^{0.8}$

  where VL = $25.63\ T^{0.4}$ (m^3/min)

* Equipment

  $191\,182.1\ T^{0.8} / W^{0.6} + 251\,978.4\ T^{0.5}$

3 Milling Plant

	SP	
* Site preparation	<u>SP</u>	
	1	$84\,649.1\ T^{0.3}$
	2	$112\,865.4\ T^{0.3}$
	3	$169\,298.1\ T^{0.3}$
* Foundations	<u>CF</u>	
	1	$53\,240.2\ T^{0.5}$

2	88 733.6 $T^{0.5}$
3	159 720.5 $T^{0.5}$

* Primary crusher

592 543.4 $T^{0.3}$

* Coarse ore storage facilities

149 072.5 $T^{0.5}$

* Concentrater building

133 100.4 $T^{0.5}$ { 1 + 0.1(HT-1)}

* Fine ore storage facilities

GC	
1	32 369.3 $T^{0.7}$
2	48 442.3 $T^{0.7}$
3	58 264.7 $T^{0.7}$

* Mill equipment

OT	
1	47 769.8 $T^{0.6}$
2	31 846.5 $T^{0.6}$
3	69 644.2 $T^{0.6}$
4	35 827.3 $T^{0.6}$
5	69 664.2 $T^{0.6}$
6	124 227.0 $T^{0.5}$
7	372 681.1 $T^{0.5}$
8	212 960.6 $T^{0.5}$
9	97 607.0 $T^{0.5}$
10	709 868.8 $T^{0.5}$
11	13 394.2 $T^{0.7}$
12	33 485.5 $T^{0.7}$

4 Power Supply and Distribution

- Utility: 62 137.1 TD + 1 960 $KW^{0.8}$
- Diesel: 10 000 $KW^{0.8}$

where $KW = 37.556\ T^{0.8}$ for underground mines

$KW = 105.49\ T^{0.6}$ for open pit mines

5 Tailings storage

(include in milling plant)

TS	
1	40 817.5 $T^{0.5}$
2	70 986.9 $T^{0.5}$
3	124 227.0 $T^{0.5}$

6 Water Supply

31 846.5 $T^{0.6}$

7 General Plant Services

19 000 $N^{0.8}$

8 Access Road (9.1m wide road)

Cordilleran region	310 685.5 per km x AR
Other regions	186 411.3 per km x AR

9 Townsite

TR		
1	9 000 N	
2	14 000 N	
3	45 000 N	with fly-in program
3	100 000 N	otherwise

10 Project Overheads

25% of direct project costs

11 Working Capital

Typically 3 months of operating costs

12 Annual Sustaining Capital

Open pit mine system ASCC = 0.2255 M + 112 940

Underground mine system ASCC = 190.96 $T^{0.6791}$

Milling plant ASCC = 1% of direct milling plant costs

Operating Cost Relationships

1 Personnel (N)

- Mine — Underground

MT	
1, 5	34.627 $T^{0.7}/W^{0.5}$
2	7.019 $T^{0.7}/W^{0.5}$
3	8.735 $T^{0.7}/W^{0.5}$
4	3.432 $T^{0.7}/W^{0.5}$

Open pit — 0.852 $M^{0.5}$ + 0.067 $M^{0.7}$

- Mill

OT	
1, 2, 8	1.785 $T^{0.5}$
3, 4, 5, 9	3.318 $T^{0.5}$
6	2.772 $T^{0.5}$
7	3.822 $T^{0.5}$

- Maintenance

Underground

MT	
1,5	0.37 (N_{mine} + N_{mill})
2	0.26 (N_{mine} + N_{mill})
3	0.32 (N_{mine} + N_{mill})
4	0.29 (N_{mine} + N_{mill})

Open pit — 0.27 (N_{mine} + N_{mill})

- Services

TR	
1	0.050 (N_{mine} + N_{mill} + $N_{maint.}$)

2	$0.075\,(N_{mine} + N_{mill} + N_{maint})$
3	$0.100\,(N_{mine} + N_{mill} + N_{maint})$

* Administration

$$0.080\,(N_{mine} + N_{mill} + N_{maint})$$

2 Labour Costs (1986 $/t milled)

* Mine

	MT	
Underground		
	1,5	$1\,079.383 / (T^{0.5}\, W^{0.5})$
	2	$180.519 / (T^{0.3}\, W^{0.5})$
	3	$330.952 / (T^{0.3}\, W^{0.5})$
	4	$218.247 / (T^{0.3}\, W^{0.5})$
Open pit	$9.615 / M^{0.5} + 25.527 / M^{0.4}$	

* Mill

OT	
1, 2, 8	$65.448 / T^{0.5}$
3, 4, 5, 9	$121.318 / T^{0.5}$
6	$101.194 / T^{0.5}$
7	$139.448 / T^{0.5}$

* Maintenance $39.221\, N^{maint} / T$

* Services

TR	
1	$1.531\,(N_{mine} + N_{mill} + N_{maint}) / T$
2	$2.296\,(N_{mine} + N_{mill} + N_{maint}) / T$
3	$3.062\,(N_{mine} + N_{mill} + N_{maint}) / T$

* Administration (including head office allocation)

$$7.838\,(N_{mine} + N_{mill} + N_{maint}) / T$$

3 Material Costs (1986 $/t milled)

* Mine

Underground	MT	
	1	$38.134 / (T^{0.3} W^{0.3})$
	2	$18.734 / (T^{0.3} W^{0.3})$
	3	$29.662 / (T^{0.3} W^{0.3})$
	4	$24.458 / (T^{0.3} W^{0.3})$
	5	$42.621 / (T^{0.3} W^{0.3})$
Open pit	$12.759 / M^{0.3}$	

* Mill

OT	
1, 2, 8	$22.747 / T^{0.3}$
3, 4, 5, 7, 9	$25.118 / T^{0.3}$
6	$26.719 / T^{0.3}$

* Maintenance

$$3.969\ N_{maint.} / T$$

* Services

TR	
1, 2	$5.557 (N_{mine} + N_{mill} + N_{maint.}) / T$
3	$9.299 (N_{mine} + N_{mill} + N_{maint.}) / T$

* Administration (including head office allocation)

$$19.822 (N_{mine} + N_{mill} + N_{maint.}) / T$$

4 Power Costs (1986 $/t milled)

* Utility

Underground	$10.861 / T^{0.3}$
Open pit	$30.179 / T^{0.3}$

* Diesel plant

$$26.912 / T^{0.3}$$

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