T-3663

U.S. COPPER PRODUCERS ACHIEVE COST COMPETITIVENESS THROUGH OPERATING EFFICIENCIES OF THE 1980s

by

Dana J. Cassidy

T-3663

A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfullment of the requirements for the degree of Master of Science (Mineral Economics).

Golden, Colorado
Date 3-13-89

Signed: Dana J. Cassidy

Approved: Dr. Franklin J. Stermole
Thesis Advisor

Golden, Colorado
Date 3/27/89

Dr. John E. Tilton
Professor and Head
Mineral Economics Dept.

ABSTRACT

This study demonstrates how discounted cash flow analysis is used to evaluate the economic effects of changes in the U.S. copper industry. The economic analysis alternative service-producing projects and the economic analysis of new mine developments is addressed from the viewpoint of the improving copper mining economics. These service and income generating project analyses emphasize breakeven cost or price per unit of copper produced to achieve a specified discounted cash flow rate of return (DCFROR) on invested dollars. This approach is not emphasized elsewhere in the literature, especially for service alternative analysis.

An analysis approach to account for the impact of downtime risk on the economics of providing service in alternative ways is presented in this paper. The sensitivity of new mine development project economics to changes in projected copper price cycles is also analyzed. It is shown that both discount rate and copper price cycle have an impact on the optimum strategy to maximize project economics.

Finally, since most minerals are sold around the world in contracts written in U.S. dollars, the U.S. dollar and foreign currencies are shown to have

significant potential impact on the economics of foreign mining projects. This exchange rate impact in turn can affect U.S. mining operations because of the supply and demand effects on worldwide production of copper and other minerals that directly affect copper and other mineral prices.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Cu	-	Copper
Ag	-	Silver
Au	-	Gold
opt	-	Ounces per ton
DCF	-	Discounted Cash Flow
ROR	-	Rate of Return
NPV	-	Net Present Value
PW	-	Present Worth
Depltn	-	Depletion
O.C.	-	Operating Cost
SX-EW	-	Solvent Extraction - Electrowinning
stpy	-	Short Ton per year
i*	-	Minimum Rate of Return
CF	-	Cash Flow
COLA	-	Cost of Living Adjustment

ACKNOWLEDGEMENTS

I would like to thank Dr. Frank Stermole for his time and help in developing the ideas of this thesis. With his insight and the input from Dr. John Tilton and Dr. Thomas Kaufmann, I believe the content of the paper can make a contribution to the field of economic evaluation in the minerals industry.

I would also like to thank my employer, ASARCO, Incorporated, and Larry Eagan, manager of the ASARCO Globe Plant, Denver, Coloado, for recognizing the importance of continued education for the working professional.

Chapter 1

INTRODUCTION

1.1 Background and Objectives

As copper prices steadily declined through the early 1980s, remaining copper producers had to restructure operating and financial plans to profit at a $.66/lb. selling price that had stabilized from 1984 through 1986, (Figure 1.1). Strategies that affected mining, milling, and smelting all contributed to total cost reduction. Changes in labor agreements affected costs, as well as how mines and plants would operate in the future. Technological advancements integrated with long-term investment decisions have made possible a stable, low-cost production scenario for U.S. producers.

The objective of this thesis is to demonstrate how discounted cash flow analysis has been used to evaluate the economic effects of changes in the U.S. copper industry in the last ten years. The economics of alternative service producing projects and overall economic analysis of new mine development, domestic as well as foreign, will be evaluated. Service and income generating project analysis demonstrate the relationship of economic results to breakeven cost or price per pound of copper to achieve a specified DCFROR on investment capital.

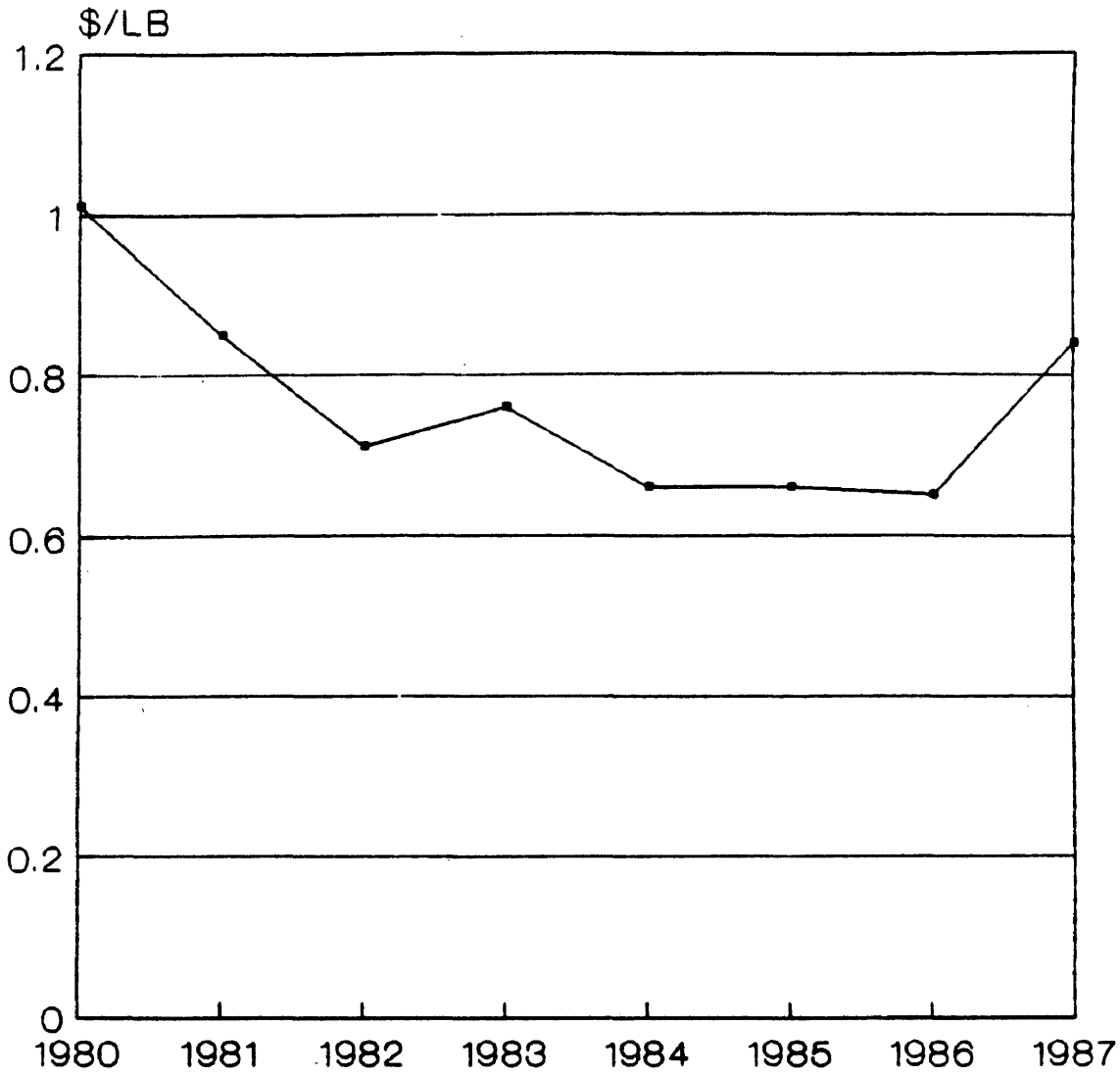

Figure 1.1 Annual Average Price of Copper

Source: Metals Week, January, 1980 to 1987

McGraw Hill

Cost reduction in western U.S. open-pit mines has been achieved primarily through improvements in material movement within the pit. Implementation of conveyors has reduced mine operating costs via savings in labor and fuel requirements. The introduction of larger trucks has lowered haul costs as much as 50% in some mines(1). Use of in-pit movable primary crushers has also reduced hauling requirements and costs.

Mill costs have been reduced by advancements in equipment design. Lining modifications in grinding media have cut maintenance costs and increased output by limiting downtime. The introduction of column flotation cell design has improved concentrate grade as much as 3%, reducing smelter treatment charges and transportation costs(2). The use of automated systems control in monitoring grinding and flotation circuits to optimize equipment and reagent usage has also helped to reduce the cost of producing copper concentrates.

Cost reductions in smelting were realized through technological process revisions. Conversion of existing reverberatory furnaces to "flash" furnaces cut fuel costs in half by utilizing this exothermic process. Theoretically, smelter output could be increased by more than 30% when utilizing flash furnace conversions(3).

Two labor contracts have been negotiated since the

decline of copper prices in 1980, each bringing change. In 1983, major copper producers negotiated for wage freezes and modifications in the Cost of Living Adjustment (COLA). Labor agreements were reached by ASARCO, Magma, Inspiration, and Kennecott by freezing wages and leaving the COLA unchanged. Phelps Dodge insisted that the COLA must be tied to the price of copper instead of to the consumer price index. This action prompted a strike(4). Phelps Dodge has now operated non-union for five years. Western U.S. copper producers and unions met again in June 1986 for negotiations with copper prices stabilized at $.66/lbs. Typical settlements included 20%-25% wage reductions and elimination of COLA. Substantial reductions in operating costs were realized by producers(5).

1.2 U.S. Producers

U.S. copper production decreased 40% from 1981 to 1984, from 1.7 st in 1981 to 1.2 million st in 1984. It rose to 1.4 million st by the end of 1987. As some companies reorganized to become competitive in world markets, others withdrew from the business. Pennzoil announced that Duval would stop production in 1984. Anaconda and Anamax followed suit. By 1986, Standard Oil decided to sell two major properties of Kennecott's: Chino Mines to Phelps Dodge and Ray Mines to ASARCO(6).

Kennecott retained the Utah operations where a $400 million modernization program was planned for 1988 production. As quickly as the oil companies of the 1970s purchased mineral firms with two decades of financial growth, they sold off and closed them down as profits declined in the 1980s. In 1981, U.S. leading copper producers consisted of Phelps Dodge, Anaconda, Anamax, and Duval. In 1987, Phelps Dodge remained the leading domestic producer of mined copper, followed by Magma, ASARCO, and Cyprus, as listed in Table 1.1. As the names of the biggest producers changed so did the way they planned business for the future.

1.3 Cost Reductions 1981-1986

Three events of the 1970s contributed to rising copper production costs. First, increases in energy costs starting in 1973 affected the copper business in much the same way they affected other U.S. industries. An attempt to measure the impact of increased energy prices on copper production indicates costs may have gone up 7%-10% by 1975(7). Second, labor cost increases tied to COLAs in a decade that realized double-digit inflation dramatically increased operating expenses above early 1970s values. Third, large capital expenditures to retrofit existing smelting capacity to meet federal and state environmental compliance increased both capital and operating costs(8).

Table 1.1
U.S. Copper Production by Company
Thousands of Short Tons

COMPANY	1980	1981	1982	1983	1984	1985	1986	1987
ANACONDA	92.7	149.2	164.3	43.2	14.9	-	-	-
ANAMAX	115.3	135.2	145.3	49.1	25.7	9.9	-	-
ASARCO	56.4	112.7	119.6	110.7	103.7	85.5	98.3	194.7
COMINCO	2.8	2.1	2.0	0.9	1.0	1.2	1.9	1.9
COPPER RANGE	35.8	43.4	22.6	26.6	24.7	-	31.3	53.1
CYPRUS	98.0	117.4	111.6	157.3	120.5	197.5	145.4	173.4
DUVAL	144.6	130.6	58.1	71.5	92.2	-	-	-
HECLA	0.5	1.6	1.2	1.3	0.7	0.7	0.3	0.3
INSPIRATION	40.8	64.7	54.7	40.7	44.1	40.1	32.1	35.6
KENNECOTT	33.6	372.2	285.7	318.0	303.0	235.0	190.0	60.0
MAGMA	99.3	165.6	132.4	99.7	120.3	108.6	112.5	197.0
MONTANA RESOURCES	-	-	-	-	-	-	8.9	30.8
NORANDA	-	13.0	22.8	18.8	7.7	6.8	3.6	-
PHELPS DODGE	267.8	315.7	150.1	263.1	331.2	410.1	405.4	468.9
PINTO VALLEY	52.8	92.3	56.8	10.3	56.5	-	-	-
TENESSEE CHEM	10.9	12.6	11.7	11.7	9.2	8.4	7.5	4.6

SOURCE: AMERICAN BUREAU OF METAL STATISTICS INC., 1985 AND 1988.
Non-Ferrous Metal Data 1984.
Non-Ferrous Metal Data 1987.

By the end of the 1970s increases in costs of production were rising faster than adaptive technology could reduce costs. The 1980s began with the price of copper sliding to its lowest real value in decades. The cost of copper production had to be reduced for U.S firms to stay in business. Areas where cost reduction was most significant included mine planning, material transportation, labor, corporate reorganizations, and new technology.

Mine plan changes included select high grading of ore to deliver the most contained copper per pound of ore to the mill(9). Pit walls were steepened at mines to reduce haul costs. Stripping ratios were reduced to minimize waste rock removal costs. Modernized equipment focused on more effective methods of material transfer. Installation of larger capacity loading and hauling equipment, started in the 1970s became integrated with automated production monitoring and dispatching techniques of the 1980s.

Labor costs constituted approximately 45% of U.S. total mine operating cost and 30% of U.S. total mill operating cost in 1984(9). Labor costs for smelting and refining were 41% and 53% of total operating cost, respectively(9). Phelps Dodge was the only U.S. copper firm able to reduce labor costs through a 1983 labor dispute resulting in a strike. In 1986 western U.S. copper producer's bargaining units agreed to more than 20%

reductions in wages and elimination of the cost of living allowance. Corporate reorganization included simplifications of organizational charts to streamline management. At ASARCO, Inc., North American salaried employees were reduced from 11,200 in 1981 to fewer than 7,400 in 1985(10). Companies sought to eliminate levels of management and to make more direct lines from president to production.

The trend toward retrofitting existing conventional smelting operations to "flash" smelting processes began in the early 1980s. Phelps Dodge's installation of an Outokumpu design furnace at Hidalgo, New Mexico, and ASARCO's Inco furnace at Hayden, Arizona, proved economically beneficial early after implementation. Cost savings from flash smelting as compared to conventional reverberatory furnaces are acquired through fuel savings and increased throughput. In the flash smelting process, copper concentrates from fluid bed dryers are introduced to the furnaces mixed with oxygen causing an instantaneous ignition, using the heat from the exothermic reaction to drive the process. Flash smelting yields a steady flow of gases with 6% to 10% SO_2 content, making an optimum feed for acid plants, resulting in better air emission control for environmental compliance.

Development of new technology in the 1980s revolved

around material transfer. Conventional open pit mining assumed the transportation of loose rock out of the pit to crushing-grinding and milling circuit by means of truck or rail. As pit sizes increased, the cost of production increased. A different means of material transport was necessary to lower cost. The use of in-pit portable gyratory crushers and belt conveyors as a substitute for hauling ore out of the pit to the crusher has reduced mining cost. Truck haulage is then limited to transporting ore from the working face of the pit to the nearest crusher. Although conveyors have physical limitations, proper design significantly reduces labor and fuel costs per unit of production. Initial high capital cost investment in a conveyor belt system realizes the rate-of-return expectations by incremental savings generated from lower operating and maintenance costs. Conveyors are capable of carrying material up grades as steep as 30%. Conveyors are used best when long, steep haulage routes are necessary. Trucks are used best when many benches must be worked in a short, level distance. Best mine economics are achieved when both material transport systems are used for each optimum performance(11).

Kennecott Utah Copper completed a $400 million modernization project at Bingham Copper in September 1988.

The four key components of this investment focused on cost reduction of material transfer. First, installation of a 60-by-190-inch Allis-Chalmer in-pit gyratory crusher is sized to process 10,000 tons of ore per hour. Second, a five-mile belt conveyor system consisting of six individual sections move crushed ore at a speed of 900-feet per minute to the mill. Third, conveyed ore is stockpiled to feed three new 34-foot semi-autogenous grinding mills that grind 1,188 tons of ore per hour. After ball mill processing, the finely ground ore enters the 3,000 cubic foot flotation cells which are presently the largest in the world. Fourth, a 17-mile 6-inch-diameter steel pipeline was constructed to transport concentrate from the mill to the Kennecott-owned Garfield smelter. Kennecott management believes that the savings in operating costs realized by this investment in modernization will make Kennecott Utah Copper competitive with all world copper producers(12).

Use of 170-ton haul trucks became an industry standard in the 1980s. Larger capacity trucks in conjunction with communication dispatching maximized the amount of ore carried from the mine face. The effects of these systems at Cyprus Bagdad in 1980 reduced transportation costs by 50% and doubled the tons hauled per shift per man hour. In 1986, Phelps Dodge replaced its 1941 rail transfer system at Morenci with new 170-ton trucks. Two in-pit gyratory

crushers were scheduled to be operable in 1988 to reduce truck travel(13).

Transportation costs from mill to smelter have been reduced by more efficient designs in flotation processes and de-watering of concentrates. At the Phelps Dodge mine in Morenci and at the Cyprus mine in Sierrita, column flotation cells have increased concentrate grade 2% to 3%(12,13). By making a 28% to 29% copper concentrate, treatment and transportation costs are reduced. Improved de-watering filters have lowered moisture contents 6% to 7%. At Morenci, bypass of concentrate dryers yields an annual fuel savings of $1.2 million(13).

Investment in new technology, including solvent extraction-electro winning (SX-EW) projects, has had a dramatic effect on the average cost per pound of copper. Although recovery of copper by means of hydrometallurgical techniques from low-grade oxide ores has been practiced since the early 1900s, none have been as economically beneficial as SX-EW. Investments in SX-EW facilities include Inspiration in 1978, Magma at San Manuel in 1985, Phelps Dodge at Tyrone in 1984 and doubled capacity in 1988, and ASARCO at Ray Mines in 1987. Phelps Dodge attributes much of its cost reduction success to investments in SX-EW. At Tyrone, 1986 production of 35,000 short tons (st) of SX-EW cathode copper was achieved at

costs reported to be lower than $.30/lb(13). Construction of a 50,000 st/year SX-EW plant at Phelps Dodge, Morenci, began in 1987 and similar designs are to be implemented at Phelps Dodge's Chino mines in 1988. A total of 175,000 st/year copper from SX-EW is forecast by Phelps Dodge in 1989(13).

In considering the effects of industry changes, the Bureau of Mines feels the U.S. copper industry will remain competitive through the year 2000 for the following reasons(15):

1. U.S. production is a significant part of world supply, 14% in 1987, and is forecast to increase to 17% by 2000.

2. U.S. reserves and ore grade are sufficient to sustain current production levels.

3. U.S. copper deposits have been adapted to new mining and milling techniques to increase productivity.

4. The average cost of U.S. production has lowered the U.S. position along the international supply curve.

The Bureau of Mines reports that U.S. producer copper production costs for mining through refining is located in the middle of the world cost curve but is the third lowest cost mine producer, behind Peru and Australia.

The cost of conventional U.S. mining applications would seem likely to increase moderately in the next few years primarily due to predicted labor cost increases and

revised mining plans. However, the efficiency of mine productivity should have a lasting influence on U.S. copper production.

> In the United States, copper mine productivity increased from 39.3 employee hours per metric ton produced in 1981 to 17.65 hours per metric ton in 1986. Increased productivity at U.S. mines more than offset advantages gained in other countries from mining deposits with higher ore grades. . . . Although the average ore grade at U.S. mines is not expected to decline much during the next 12 years, those of some other countries, such as Chile and Zambia, are expected to decline significantly; consequently, competitive production costs relating to this factor will move toward U.S. advantage. Costs for recovery of capital are high in the United States and lower in countries such as Chile, Zaire, and Australia(15).

New technology has been applied successfully to U.S. mines because of favorable mineralogy, lending deposits to bulk mining methods and SX-EW applications that will enhance U.S. mine competitiveness in the future.

The use of discounted cash flow analysis will be used in this paper to evaluate the economic decisions facing the U.S. copper industry. Hypothetical evaluations of service producing projects to calculate breakeven cost and investment calculation of breakeven price will be demonstrated.

> Alternative economic evaluation techniques are used in industry to properly analyze the economic potential of various investment projects. "Discounted Cash Flow" analysis is

> the phrase commonly used to describe these techniques. Whether you want to analyze projects in mineral, petroleum, real estate, refining, pipeline transportation, or any other industry, proper application of discounted cash flow analysis techniques enables you to fairly compare the economic potential of alternative projects as well or better than you can using any other project evaluation approaches(15).

The application of present worth cost, present worth cost per unit, and incremental rate of return analysis will be used in service alternative comparisons for material transfer within the open pit mine via conveyor or truck service. When comparing alternative ways of providing a service, it is common to have only costs and perhaps salvage values for the projects being evaluated. This means that the rate of return for each individual service-producing alternative is negative and does not give useful information for economic decision making.

> For rate of return, net value, or ratio analysis of alternatives that provide a service you must analyze the incremental differences between the alternative to determine if the incremental investments in the more costly initial investment alternatives are justified by incremental savings. If the rate of return on the incremental investment is greater than the minimum rate of return, or if NPV is greater than zero, then the incremental investment is satisfactory from an economic view point and selecting the larger investment alternative is economically justified(16).

The use of present worth cost per unit analysis which has not been illustrated in engineering economy literature

as a tool to calculate breakeven cost per unit will be demonstrated. The basis of present worth cost per unit analysis is the accounting for future production as an after-tax and discounted term in the present worth cost equation, as calculated by(16):

PW Cost = X(1-effective tax rate)(PW Production)

where X is the breakeven price per unit that gives the investor a specified DCFROR on invested capital.

Solving for X in this equation yields the breakeven price or cost per unit. This method of illustrating the best economic choice for service-producing alternatives has seldom been utilized for industrial applications, but it gives the investor a very clear indication of the impact on breakeven product price that different service-product equipment changes can make.

Discounted Cash Flow Rate of Return (DCFROR) and Net Present Value (NPV) analysis will be used to illustrate investment capital economic analysis of a hypothetical mine development evaluation. Then a variation of NPV analysis will be used to determine breakeven copper price that gives an investor a specified rate of return on invested capital. Sensitivity of copper price cycles will be evaluated to determine the risk of fluctuating income for project investment.

> Mining has always been sensitive to the fluctuating income of downstream customer industries. The industry is now becoming more vulnerable to booms and busts as economic pulsations increase and demand for mining products shows little or no long term growth. As the general economy has become more cyclical in the last decade, the capital-intensive primary industries have become more aware that timing as well as preparation of survival plans are vital in investment decisions(17).

Proper use of discounted cash flow analysis techniques gives investors a better chance of correctly analyzing the potential of alternative investments than can be achieved using any other evaluation technique.

Chapter 2

SERVICE INVESTMENT ANALYSIS

2.1 A Mining Service Analysis Illustration

During the 1980s western U.S. copper producers have had to evaluate their existing production methods to determine if better methods of operation would lower the costs of producing copper. In looking at alternative ways of providing mining, transportation, and processing services necessary in mining operations, several different discounted cash flow economic analysis approaches can be taken. Whether an analysis relates to economic comparison of different ways of providing service, such as moving material with trucks or a conveyor, classical analysis involves comparison of present, annual, or future costs to provide service for a common study period of time or an analysis of the incremental differences of these alternatives using rate of return, net present value, or ratio analysis.

In this chapter these approaches are illustrated with a present-worth cost analysis and an incremental rate-of-return analysis for moving ore from the mine by a capital-intensive conveyor system and by a less capital-intensive truck haulage system. Then, unlike any analysis found in the literature, the present- worth cost results

are converted to cost-per-unit of product produced which directly relates the service analysis results with the impact of the cost of producing a pound of copper product. Finally, risk considerations related to different downtime projections are evaluated to determine their impact on cost per unit of copper product produced.

Determination of the most economic alternative to provide the same service of transporting ore from the mine to a processing facility is illustrated here for a hypothetical analysis of conveyors versus haul trucks. Although the numbers in the analysis are hypothetical, they are very closely related to an actual open-pit copper mine analysis made several years ago. Capital cost of the new conveyor system is projected to be $10 million with annual operating costs of $1.8 million in year one which will increase by 5% per year. Major maintenance repairs are scheduled for the conveyor system in year five costing $3 million charged to operating expense. The service life of the conveyor system is estimated to be ten years with a salvage value in year ten of $5 million. Seven 170-ton haul trucks are necessary to transport equal tonnage of ore to the mill. Capital cost for the truck fleet would be $900,000 per truck, with operating costs of $400,000 per truck in year one, increasing by 5% per year. Salvage value at year five for the truck fleet is estimated to be

$450,000 per truck. Replacement cost of trucks at year five is expected to be $945,000 per truck. Operating costs of the new trucks will be $450,000 in year six and will increase by 5% per year. Salvage value for replacement trucks is expected to be $472,500 per truck in year ten. Assets for both alternatives are depreciated by the 7-year Modified Accelerated Cost Recovery System (MACRS). An effective state and federal tax rate of 38% is assumed.

Comparison of alternatives that provide a necessary service over equivalent lives is possible by present worth, annual worth, or future worth cost determination, or by incremental rate-of-return, or net present value analyses. Table 2.1 illustrates the incremental differences of cost for the conveyor vs. truck service comparison. Negative incremental operating costs are the same as positive savings for development of discounted cash flow analysis. Incremental savings are subject to tax consideration, as if it were earned incremental revenue. Table 2.2 illustrates the discounted cash flow proceeds of the conveyor vs. truck service comparison. Application of incremental rate of return analysis is used to determine the best method of ore transport for a specified minimum rate of return of $i^* = 15\%$. Tables 2.3 and 2.4 illustrate present worth cost analysis as a method of choosing the best economic alternative in the conveyor vs. truck fleet problem. Both

Table 2.1
Conveyor - Truck
Incremental Savings
(000's)

YEAR	CONVEYOR			TRUCK			CONVEYOR-TRUCK		
	CAP.COST	SALV.	O.C.	CAP.COST	SALV.	O.C.	CAP.COST	SALV.	O.C.
0	-10,000			-6,300			-3,700		
1			-1800			-2800			1000
2			-1890			-2940			1050
3			-1984			-3087			1137
4			-2084			-3241			1157
5			-2188	-6615	3150	-3403	6615	-3150	1215
6			-2297			-3150			853
7			-2412			-3308			896
8			-2533			-3473			940
9			-2659			-3646			987
10		5000	-2792		3308	-3829		1692	1037

Table 2.2
Incremental Cash Flow
Conveyor - Truck
(000's)

	0	1	2	3	4	5	6	7	8	9	10
SAVINGS		1000	1050	1137	1157	1215	853	896	940	987	1037
- DEPRECIATION*		-529	-906	-647	-462	-893	+53	+727	+710	+826	
- DEP. WRITE OFF						1968					2068
SALVAGE						-3150					1692
TAXABLE INCOME		471	144	490	695	-860	906	1623	1650	1813	4797
- TAX (38%)		-179	-55	-186	-264	+327	-344	-617	-627	-689	-1823
NET INCOME		292	89	304	431	-533	562	1006	1023	1124	2974
+ DEPRECIATION		529	906	647	462	893	-53	-727	-710	-826	
+ DEP WRITE OFF											-2068
- CAPITAL COST	-3700					6615					
CASH FLOW	-3700	821	995	951	893	6975	509	279	313	298	906

SOLVE FOR INCREMENTAL RATE OF RETURN BY TRIAL AND ERROR:

$$0 = 3700 + 821(P/F_{i,1}) + 995(P/F_{i,2}) + 951(P/F_{i,3}) + 893(P/F_{i,4}) + 6975(P/F_{i,5}) + 509(P/F_{i,6}) + 279(P/F_{i,7}) + 313(P/F_{i,8}) + 298(P/F_{i,9}) + 906(P/F_{i,10})$$

$$i = 33.4\%$$

i = Incremental Investment DCFROR = 33.4%

*Depreciation calculated by modified ACRS rates 7 year life

Table 2.3
Present Worth Cost of Conveyor
(10^6)

YEAR	0	1	2	3	4	5	6	7	8	9	10
REVENUE											5.0
- OPER. COST		-1.8	-1.9	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.7	-2.8
- DEPRECIATION		-0.7	-2.4	-1.7	-1.2	-1.0	-1.0	-1.0	-0.7	0	0
- DEP. WRITE OFF											
TAXABLE INCOME		-2.5	-4.3	-3.7	-3.3	-3.2	-3.3	-3.4	-3.2	-2.7	+2.2
- TAX (38%)		1.0	1.6	1.4	1.2	1.2	1.2	1.3	1.2	1.0	-0.8
NET INCOME		-1.5	-2.7	-2.3	-2.1	-2.0	-2.0	-2.1	-2.0	-1.7	+1.4
+ DEPRECIATION		0.7	2.4	1.7	1.2	1.0	1.0	1.0	0.7	0	0
+ DEP WRITE OFF											
- CAPITAL COST	-10.0										
CASH FLOW	-10.0	-0.8	-0.3	-0.5	-0.9	-1.0	-1.0	-1.1	-1.3	-1.7	+1.4

$$\text{PW COST (CONVEYOR)} = 10.0 + 0.8\,(P/F_{15,1}) + 0.3(P/F_{15,2}) + 0.5(P/F_{15,3}) + 0.9(P/F_{15,4}) + 1.0(P/F_{15,5}) + 1.0(P/F_{15,6}) + 1.1(P/F_{15,7}) + 1.3(P/F_{15,8}) + 1.7(P/F_{15,9}) - 1.4(P/F_{15,10})$$
$$= 13.5$$

Table 2.4
Present Worth Cost of Trucks
(10^6)

YEAR	0	1	2	3	4	5	6	7	8	9	10
REVENUE						3.2					3.3
- OPER. COST		-2.8	-2.9	-3.1	-3.2	-3.4	-3.2	-3.3	-3.5	-3.6	-3.8
- DEPRECIATION		-0.4	-1.5	-1.1	-0.8	0	-0.5	-1.6	-1.2	-0.8	0
- DEP WRITE OFF						-2.4					-2.5
TAXABLE INCOME		-3.2	-4.4	-4.2	-4.0	-2.6	-3.7	-4.9	-4.7	-4.4	-3.0
- TAX (38%)		1.2	1.7	1.6	1.5	1.0	1.4	1.9	1.8	1.7	1.1
NET INCOME		-2.0	-2.7	-2.6	-2.5	-1.6	-2.3	-3.0	-2.9	-2.7	-1.9
+ DEPRECIATION		0.4	1.5	1.1	0.8	2.4	0.5	1.6	1.2	0.8	
+ DEP. WRITE OFF											2.5
- CAPITAL COST	-6.3					-6.6					
CASH FLOW	-6.3	-1.6	-1.2	-1.5	-1.7	-5.8	-1.8	-1.4	-1.7	-1.9	+0.6

$$\text{PW COST (TRUCKS)} = 6.3 + 1.6(P/F_{15,1}) + 1.2(P/F_{15,2}) + 1.5(P/F_{15,3}) + 1.7(P/F_{15,4}) + 5.8(P/F_{15,5}) + 1.8(P/F_{15,6}) + 1.4(P/F_{15,7}) + 1.7(P/F_{15,8}) + 1.9(P/F_{15,9}) - 0.6(P/F_{15,10}) = 15.7$$

incremental rate of return analysis and present worth cost analysis will give the same economic results concerning the best economic alternative for the stated problem. The incremental conveyor investment DCFROR of 33.4% compared to a minimum discount rate of 15% indicates accept the conveyor investment and present worth cost analysis using the 15% minimum discount rate also indicates that capital investment in the proposed conveyor system is more economical than truck transport. Comparison of present worth cost calculations for a ten year evaluation life gives $15.7 X 10^6 for present worth cost using truck service compared to $13.5 X 10^6 for conveyor service. The conveyor service alternative with minimum present worth cost is the best economic choice, consistent with the incremental rate of return analysis conclusion. The present worth cost results are converted to breakeven cost per unit of copper produced in the next section.

2.2 Cost Per Unit of Service Analysis

In this evaluation the cost per unit of copper produced was calculated on an after-tax basis for economic decision-making purposes. This enables management to see the economic impact of the truck versus conveyor economic-investment decision on the cost-per- pound of copper produced. For this analysis an estimated tonnage

and grade of ore transported per year is needed to perform present-worth cost-per-unit of copper produced calculations. Assume that the seven 170-ton capacity trucks operate 16 hours per day, 350 days per year with a cycle time of 15 minutes per truck.

The quantity of copper ore transported per truck year is calculated by

$$\left[\frac{350 \text{ days}}{\text{yr}}\right]\left[\frac{16\text{-hour}}{\text{day}}\right]\left[\frac{4 \text{ cycles/truck}}{\text{hour}}\right]\left[7 \text{ trucks}\right]\left[\frac{170\text{-ton}}{\text{truck}}\right]$$

$$= 26.6 \times 10^6 \text{ tons ore per year}$$

It is assumed that the conveyor or truck will move equal tonnages per year for present-worth cost-per-unit analysis. Present-worth cost for the conveyor and trucks has been calculated in Tables 2.3 and 2.4. Breakeven cost per unit (X) represents the before-tax revenue per unit produced that is necessary to cover all costs and give the investor the specified after-tax DCFROR on invested capital. It is calculated by setting Present Worth Cost equal to after-tax Present Worth Production times "X" as follows:

PW Cost = X(1-effective tax rate)(PW Production)

Substituting values for truck haulage into the above equation, accounting for the time value of money at a 15% minimum DCFROR, and using an effective tax rate of 38% yields an annual breakeven cost per unit as calculated by:

$$\$15.7 \times 10^6 = X(1 - 0.38)(26.6 \times 10^6 \text{ ton})(P/A_{15,10})$$

$$X = \frac{\$15.7 \times 10^6}{82.5 \times 10^6 \text{ton}} = \$0.190 \text{ per ton}$$

Now solving the Present Worth cost per unit equation for the conveyor alternative:

$$\$13.5 \times 10^6 = X(1 - 0.38)(26.6 \times 10^6 \text{ton})(P/A_{15,10})$$

$$X = \frac{\$13.5 \times 10^6}{82.5 \times 10^6 \text{ton}} = \$0.164 \text{ per ton}$$

Analysis of the incremental difference in cost per ton transported, use of the conveyor system saves \$0.190 - \$0.164 or \$0.026 per ton of ore transported. This gives annual savings of 26.6×10^6 tons ore per year times \$0.026 savings per ton, which equals \$691,600.00 saved per year.

Conversion of cost per ton of ore to cost per pound of copper is possible by projecting an average ore grade and the metallurgical recovery of the process facility. Assuming an average copper content of 0.68% and recovery of 83.5%, the savings per pound of copper produced for this example is calculated by:

(2000 lb/ton)(0.0068)(0.835)=11.36 lb Cu/ton ore

Cost per pound of copper produced for truck service is calculated by:

(0.190 \$/ton ore) ÷ 11.36 lb Cu/ton ore = 0.017 \$/lb Cu

Cost per pound of copper produced for conveyor service is calculated by:

(0.164 $/ton ore) ÷ 11.36 lb Cu/ton ore = 0.014 $/lb Cu

The conveyor system provides cheaper cost per pound of copper produced through truck haulage, giving savings of $0.017-$0.014 or $0.003 per pound of copper produced.

2.3 Impact of Risk Considerations on Service Analysis

The effects of downtime for the conveyor must be compared to downtime of truck service to properly evaluate the risk differences in providing service with the conveyor system compared to trucks. When the conveyor is out of service, production will be stopped completely. Present Worth Cost per Unit of copper produced analysis provides the basis to illustrate the sensitivity of downtime on the alternatives.

Present worth cost per unit analysis provides an effective means of evaluating sensitivity of truck cycle time and its effects on cost per unit. The sensitivity of downtime can now be evaluated by deducting 76,000 tons of ore produced for each down day for the conveyor and one-seventh of this amount, 10,860 tons of ore, for downtime of one truck day. Comparisons at discount rates of 10%, 15%, 20%, and 25% have been constructed in Figures 2.1, 2.2, 2.3, and 2.4 to demonstrate the impact of the cost-per-unit of service with trucks or conveyor on changing the number of days downtime per year. The

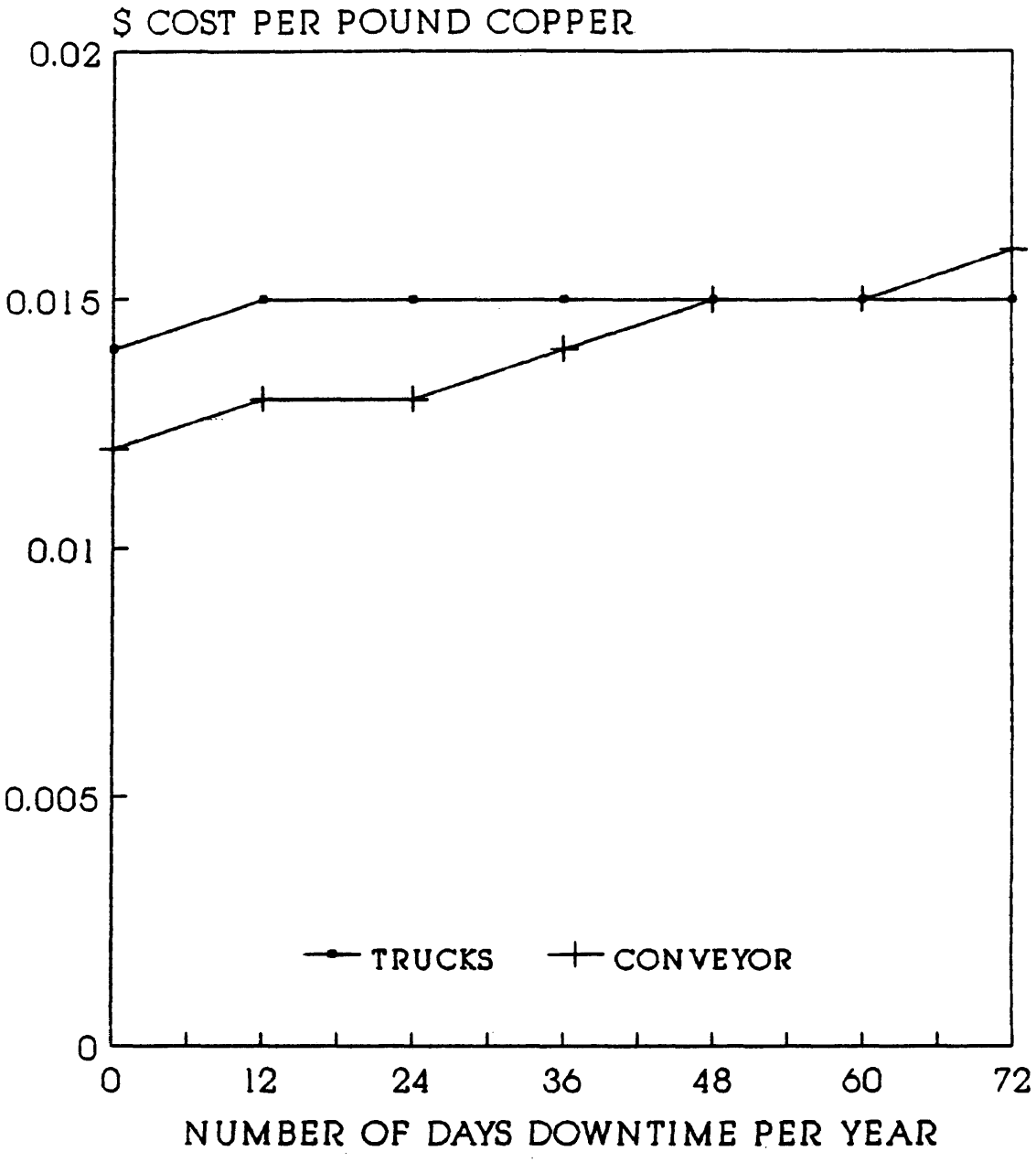

Figure 2.1: Risk Evaluation of Downtime for Conveyor versus Trucks at 10% Discount Rate

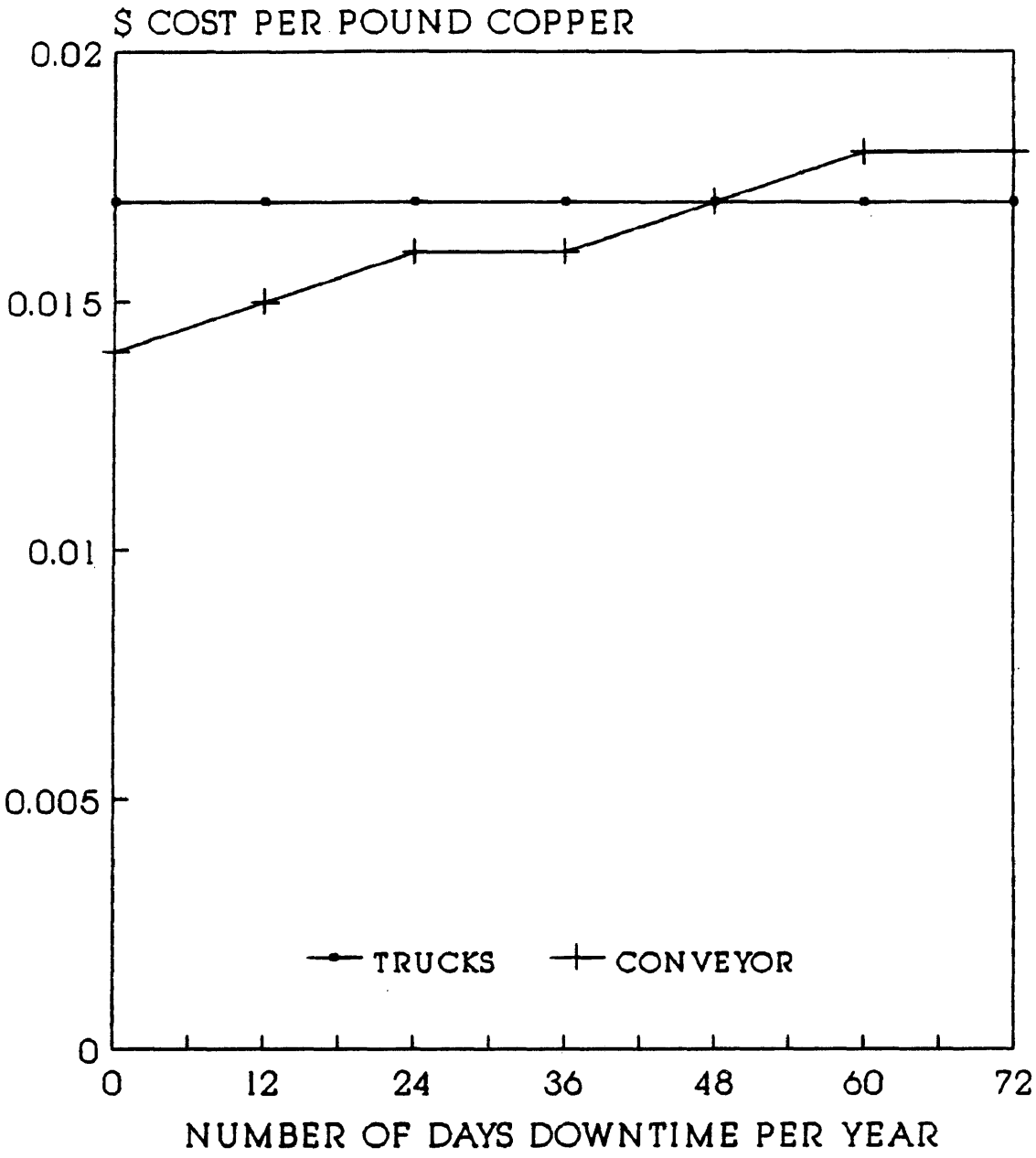

Figure 2.2: Risk Evaluation of Downtime for Conveyor versus Trucks at 15% Discount Rate

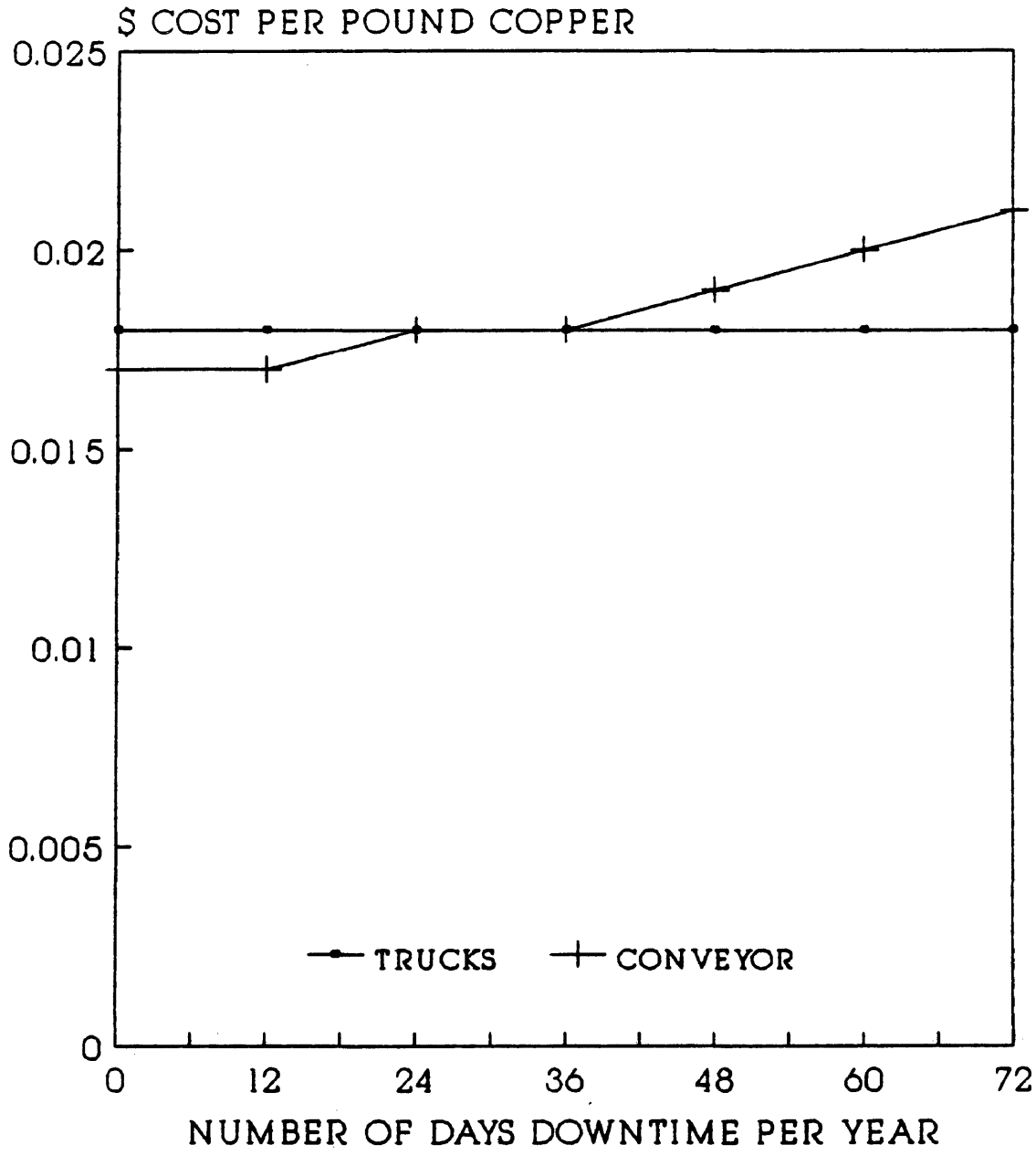

Figure 2.3: Risk Evaluation of Downtime for Conveyor versus Trucks at 20% Discount Rate

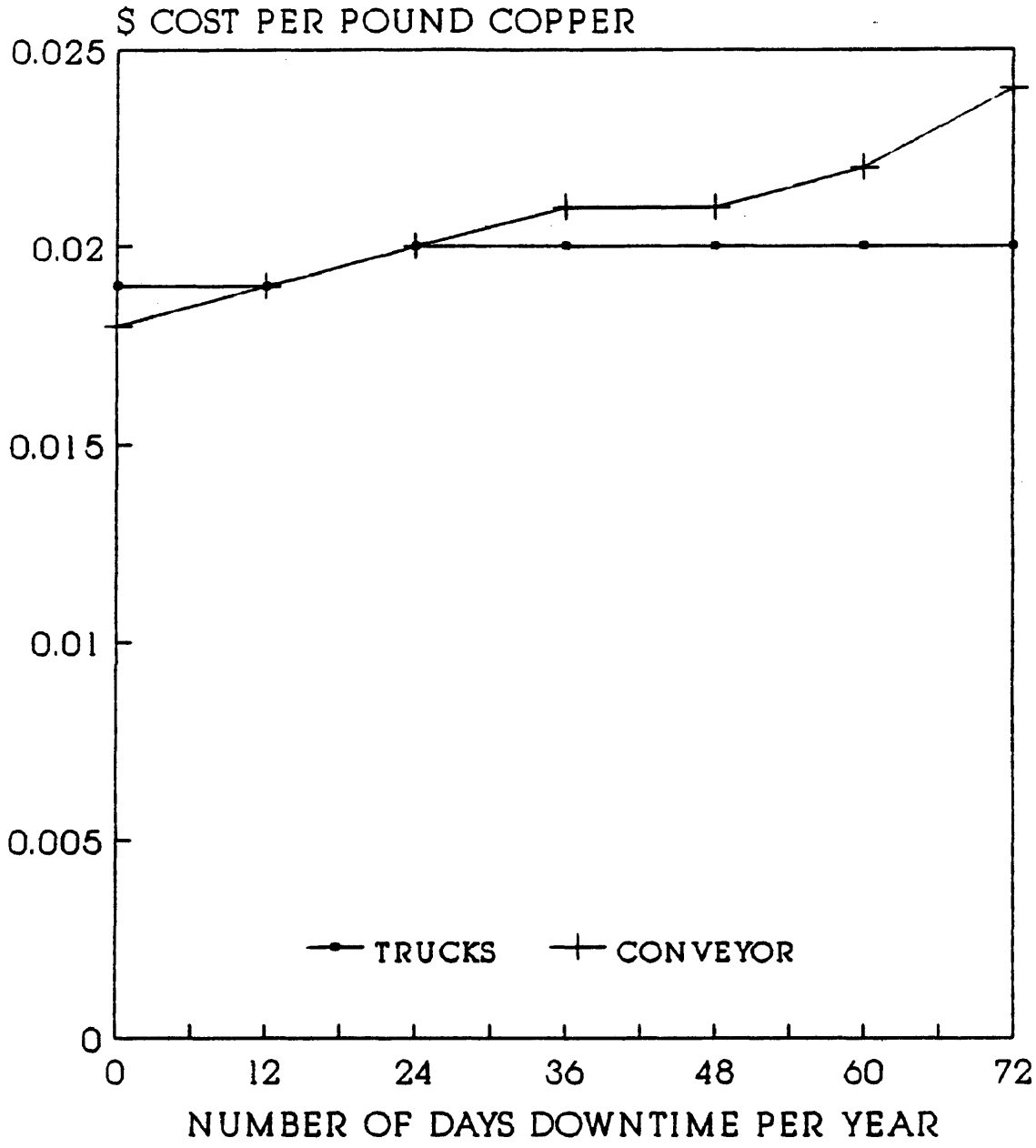

Figure 2.4: Risk Evaluation of Downtime for Conveyor versus Trucks at 25% Discount Rates

breakeven days of downtime per year make the present worth costs equal for the trucks and the conveyor. The breakeven downtime days are affected significantly by the discount rate. At a relatively high discount rate such as 25%, a range of twelve to twenty-four downtime days per year make the economics breakeven for providing service with either the trucks or conveyor system. For fewer than twelve downtime days per year the conveyor is economically preferable, and for more than twnety-four downtime days per year, the trucks are economically preferable. For a discount rate of 10%, the breakeven downtime days are higher in the forty-eight to sixty day range. Owning to the more capital intensive nature of the conveyor system, lowering the discount rate increases the days of downtime that still make the conveyor equivalent economically to trucks. Calculations supporting these graphs are listed in Appendix B.

2.4 Summary

The economic analyses illustrated in this section for moving material with trucks versus conveyors are indicative of how alternative ways of providing service of all types can be evaluated using discounted cash flow analysis. Further, presenting the cost analysis results on a cost per unit of product produced has illustrated an approach to

service analysis that expresses the economic results on a basis directly related to product unit price. If all mining and metallurgical processing costs for a mining operation are similarly expressed on a cost per unit of product produced basis, it would give the breakeven product price that would yield the investor the minimum DCFROR on invested dollars.

A different approach to looking at the overall breakeven of a mining operation is presented in Chapter 3. It is based on looking at the total capital costs and operating costs projected to be incurred over the mine life and analyzing the total mining operation at once instead of making many individual service alternative analyses and adding up the results to get the overall breakeven cost per unit of product produced.

Chapter 3

MINE DEVELOPMENT INVESTMENT ANALYSIS

3.1 Introduction

Cost reduction efforts by Western U.S. copper producers have succeeded in reducing average mining costs through the 1980s. To illustrate overall mine economic analysis the following evaluations based on discounted cash flow analysis provide insight related to the necessary selling price of copper to support investment in mine development for projected capital and operating costs for a typical mining operation. Instead of conventionally calculating DCFROR or NPV for specified copper product prices, determination of breakeven copper price will be calculated from projected mine production and costs by assuming a hypothetical smelter payment agreement used to market concentrates. The terms of the smelter payment calculation are developed in Appendix A. Current U.S. mineral tax is utilized in the analysis with 38% effective plus state tax rate. Other taxable income is assumed to exist against which to use deductions in any year.

3.2 Economic Evaluation of Breakeven Copper Price

A hypothetical proposed open-pit copper mine will

produce 18,000 stpd copper ore from a 2:1 stripping ratio. Scheduled operation is 350 days per year. The average ore grade for the life of the project is considered to be 0.68%Cu. Mill concentrate is expected to consist of 26% Cu, 4.4 opt Ag and 0.02 opt Au. Mine and mill operating costs (excluding capital recovery) are estimated to be $.39/lb. The concentrate will be sold FOB Smelter and delivered via gondola car. Mine-mill description and capital cost estimate are listed in Tables 3.1 and 3.2.

CASH FLOW DESCRIPTION:

Find Net Smelter Return, X, in $/lb of copper necessary to invest in a $140 million mine-mill project.

Revenue: $\left[\frac{200{,}000 \text{ ton conc}}{\text{yr}}\right]\left[\frac{2000 \text{ lb}}{\text{ton}}\right]\left[\frac{.26 \text{ Cu}}{\text{lb conc}}\right][X \$/\text{lb}]$

$= 104 \times 10^6 \$/\text{yr}$

Operating Cost: Mining = .23$/lb; Milling = .16$/lb

(200,000 ton conc./yr)(2000 lb/ton)(.26)(0.39$/lb)

$= 41 \times 10^6 \$/\text{yr}$

Escalation:

Escalation of revenues from copper price escalation is assumed to exactly offset evaluation of operating costs so the before tax profit margin remains the same each year.

Development Cost:

70% expensed in year where costs are incurred, remaining 30% amortized(16).

Table 3.1
Results of Capital Cost Estimate
for Open Pit Mine
($000's)

Equipment Description:

4 shovels, 11 cu. yard each
11 trucks, 117 tons each

		Evaluation Year
Site Preparation	$ 944	0
Preproduction Stripping		
Soil Overburden	1,625	0
Rock Overburden	10,290	0
Open Pit Equipment		
Shovel Fleet	10,757	0
Truck Fleet	11,516	0
Drilling Equipment	2,762	0
Maintenance Facilities	8,008	0
Feas., Eng., Planning	2,776	0
Sup., Man., Camp., Const.	4,230	0
Admin., Acct., Legal	2,644	0
Total Capital Cost	$55,552	

Source: Petrick, A. Cost Estimation in the Evaluation of Minerals and Energy Projects. Colorado School of Mines Publication (1984).

Table 3.2
Results of Capital Cost Estimate
for Process Plant
($000's)

Summary of Plant Data:
Flotation - Low Grade Cu Ores
500 Tons Concentrate Produced Daily
Powered by Utility Substation (11378 KW)
2433 GPM water supply rate (2 miles)
Reclaim Water - Pumped 4 miles (1069 GPM)
40 Miles of Access Roads

		Evaluation Year
Clearing & Excavation	$ 1,735	0
Foundation & Details	6,117	2
Crushing & Conveying	7,647	1
Mill Building	5,098	2
Grinding & Storage	11,980	1
Flotation & Processing	2,995	1
Thickening & Filtering	850	1
Concentrate Storage	1,172	1
Power & Lines		
Power	1,249	2
Lines	2,142	2
Tailing Pond	510	1
Water Supply		
Piping	1,550	1
Fresh Water Pumping	530	1
Reclaim Water Pumping	400	1
Plant Services	1,716	2
Access Roads		
Roads	24,372	0
Bridges	0	
Housing	0	
Feas., Eng., Planning	4,258	1
Sup., Man., Camp, Cons.	6,303	1
Admin., Acct., Legal	3,852	1
Total Capital Cost	$84,448	

SOURCE: Petrick, A. Cost Estimation in the Evaluation of Minerals and Energy Projects. Colorado School of Mines Publication (1984).

Depreciation:

1. Mine-Mill Equipment - 7 yr Modified Accelerated Cost Recovery System
2. Utilities - 20 yr, 150% Declining Balance switching to straight line
3. Building Structure - 31.5 yr., straight line(16).

Depletion:

Percentage depletion (15%) with 50% limit to depletion were used in calculating depletion allowance. Cost depletion was not considered in this evaluation because of its requirement of using the capital cost of the mineral reserve in question as an adjusted base for recovery of investment. The use of an assumed acquisition cost would add another variable to the determination of price, which is not necessary for this calculation(16).

Tax:

Effective tax rate is 38%, including state and local withholdings.

Table 3.3 shows the cash flow calculations that provide the basis for determining the breakeven copper selling price, X.

Table 3.3
Mine-Mill Investment
Cash Flow
(10^6 Dollars)

YEAR	0	1	2	3	4	5	6	7	8-21
REQUIRE CAPITAL									
Mineral Devlpmt.	47								
Mine/Mill Equip.	29	34							
Utility		10	10						
Bldg. Structure			10						
CASH FLOW CALC.									
Revenue				104X	104X	104X	104X	104X	104X
- Oper. Cost				-41	-41	-41	-41	-41	-41
- Development	-33								
- Depreciation		-9	-17	-13	-10	-9	-9	-10	-2
- Amortization	-3	-3	-3	-3	-3				
BEFORE DEPLTN.	-36	-12	-20	104X-57	104X-54	104X-50	104X-50	104X-51	104X-43
- 50% Limit				52X-29	52X-27	52X-25	52X-25	52X-25	52X-22
- 15% Deplin.				-(16X-09)	-(16X-09)	-(16X-08)	-(16X-08)	-(16X-08)	-(16X-06)
- Cost Deplin.									
TAXABLE INC.	-36	-12	-20	88X-48	88X-46	88X-43	88X-42	88X-42	88X-37
- Tax (38%)	14	5	8	-(34X-18)	-(34X-17)	-(34X-16)	-(34x-16)	-(34x-16)	-(34x-14)
NET INCOME	-22	-7	-12	54X-30	54X-29	54X-27	54X-26	54X-26	54X-23
+ Depreciation		9	17	13	10	9	9	10	2
+ Depletion				16X-9	16X-8	16X-8	16X-8	16X-8	16X-6
+ Amortization	3	3	5	3	3				
- Capital Costs	-43	-44	-20			-10			
CASH FLOW	-62	-39	-15	70X-23	70X-24	70X-36	70X-25	70X-24	70X-27

* Capital Cost includes $29 mine/mill equipment cost and 30% of $47 mineral development cost

Solve for X by Present Worth Equation @ i* = 15%

$$0 = -62 - 39(P/F)_{15,1} - 15(P/F)_{15,2} + (70X-20)(P/F)_{15,3} + (70X-24)(P/F)_{15,4} + (70X-26)(P/F)_{15,5} + (70X-24)(P/F)_{15,6} + (70X-24)(P/F)_{15,7} + (70X-27)(P/A)_{15,14}\,(P/F)_{15,7}$$

X = Net Smelter Return Price = 0.69$/lb Cu @ i* = 15%

Solving the equation for i* = 10% and 20%

X = Net Smelter Return Price = 0.59$/lb @ i* = 10%
X = Net Smelter Return Price = 0.79$/lb @ i* = 20%

The market price of copper necessary to support a Net Smelter Return illustrated in this example are as listed below if a .20$/lb copper smelting cost is assumed:

	i=10%	i=15%	i=20%
Net Smelter Return ($/lb)	0.59	0.69	0.77
Market Price Copper ($/lb)	0.79	0.90	1.01

Calculations to support the .20$/lb per lb smelting cost are demonstrated in Appendix A.

Effects of project life on DCFROR and NPV analysis results for 15-, 21-, and 30- year mine lives is seen through the calculations on the following page. Uniform and equal cash flow values are assumed beyond year 8. This assumes that required major maintenance repair and equipment replacement costs have been distributed equally over the mine life years to simplify the analysis.

15 year life Cash Flow:

Assume Net Smelter Return (X) = 0.69$/lb

YEAR	0	1	2	3	4	5	6	7	8-15
Cash Flow	-62	-39	-15	29	25	23	23	23	21

DCFROR Calculation:

$$0 = -62 - 39(P/F)_{i,1} - 15(P/F)_{i,2} + 29(P/F)_{i,3} + 25(P/F)_{i,4} + 23(P/A)_{i,3}(P/F)_{i,4} + 21(P/A)_{i,8}(P/F)_{i,7}$$

DCFROR = 14%
NPVi* = 10% = 26
NPVi* = 15% = -9
NPVi* = 20% = -30

21 year life Cash Flow:
Assume Net Smelter Return (X) = 0.69$/lb

YEAR	0	1	2	3	4	5	6	7	8-21
Cash Flow	-62	-39	-15	29	25	23	23	23	21

DCFROR = 15%
NPVi* = 10% = 48
NPVi* = 15% = 1
NPVi* = 20% = -25

30 year life Cash Flow:
Assume Net Smelter Return (X) = 0.69$/lb

YEAR	0	1	2	3	4	5	6	7	8-30
Cash Flow	-62	-39	-15	29	25	23	23	23	21

DCFROR = 16%
NPVi* = 10% = 65
NPVi* = 15% = 7
NPVi* = 20% = -23

The previous example of mine-mill investment feasibility assumed capital requirements were available from internal generation of cash. Partial financing of large investments is almost always necessary; however, it was excluded from this example to provide a simpler analysis for sensitivity of net smelter return and copper price. The effects of borrowed money and interest rates cannot be ignored in actual feasibility analysis, although care must be taken to compare project economics for different alternative investments analyzed using the same debt to equity ratio.

The preceding calculations present a comparison of ROR and NPV analyses for 15-, 21-, and 30-year cash flows. These calculations illustrate that changes in project life for a specified low minimum rate of return, i*, have a more sensitive effect on net present value results than occur with higher i* requirements. This implies that a project that appears marginal (10% ROR) for a short cash-flow generation life may prove economically attractive by extending project life. This analysis consideration may be appropriate for properties containing large reserves with long production lives, such as Kennecott's Bingham Canyon mine.

The reason that Net Present Value analysis at a minimum discount rate of i* = 10% yields better economic

results than for a 15% or 20% discount rate as project life is extended from 15 to 30 years is due to the mathematical form of the single payment compound amount factor. The future worth, F, of a present value, P, with a compounded interest rate of i% per period for "n" periods is calculated by

$$F = P(1+i)^n$$

Arranging the terms to solve for P yields

$$P = F[1/(1+i)^n]$$

The mathematical factor $1/(1+i)^n$ is universally called the "single payment present worth factor." It is evident in looking at the mathematical definition of this factor that increasing either or both "i" and "n" increases the denominator of this factor, making the factor get smaller. Table 3.4 consists of single payment present worth factors for values of "n" from five to thirty and values of "i" from ten to twenty percent demonstrates this effect.

3.3 Copper Price Cycle Sensitivity

Determination of Net Present Value for the mine and mill investment project have been calculated for specific copper prices for four different hypothetical copper price cycles at given discount rates from 5% to 25%. Project life has been varied for 15, 21, and 30 years to illustrate the effects of discount rates with project length. Copper

Table 3.4

Single Payment Present Worth Factor, $1/(1+i)^n$

n	i=10%	i=15%	i=20%
5	0.62092	0.49718	0.40188
10	0.38554	0.24718	0.16151
15	0.23939	0.12289	0.06491
20	0.14864	0.06110	0.02608
30	0.05731	0.01510	0.00421

Clearly, values further in the future contribute less to present value than values closer to time zero. However, smaller discount rates cause values in the future to have a greater impact on present value than are realized for larger discount rates.

price cycle sensitivity has been integrated into the mine evaluation Net Present Value calculations for the 5% to 25% range of discount rates to evaluate mine and mill project economics.

The non-ferrous mining industry has always been sensitive to the fluctuating demand of consumer industries.

> Upstream industries also tend to be whipsawed by inventory cycles. With high interest rates and good transportation, downstream fabricators can lighten their inventories during recessions. They know that upstream suppliers can deliver supplies and raw materials immediately, and with the advent of electronic accounting, the fabricator with timely inventory information can afford to hold fewer contingency stocks. Likewise, when recovery returns, inventories surge back through industry pipelines, accelerating demands on primary supplies(17).

As business cycles have appeared to be more pronounced since the early 1970s, the timing of an investment can significantly influence Net Present Value calculations. Table 3.5 lists four hypothetical cycles of copper prices to be used for sensitivity analysis for the mine and mill investment evaluation. Figure 3.1 illustrates the effects of the business cycles in Net Present Value calculations. Figure 3.1 illustrates the effects of discount rates of 5%, 10%, 15%, 20%, and 25% in calculating Net Present Value for the four business cycles developed in Table 3.5. Review of Figure 3.1 leads to several conclusions. First, the general evaluation premise the due to the time value of

Table 3.5
Copper Prices for Four Business Cycles
($/lb)

YEAR:	3	4	5	6	7	8	9	10	11	12	13	14	15
CYCLE 1	1.50	1.50	1.50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.50	1.50	1.50
CYCLE 2	0.60	0.60	0.60	1.50	1.50	1.50	1.50	1.50	1.50	1.50	0.60	0.60	0.60
CYCLE 3	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.50	1.50	1.50	1.50	1.50	1.50
CYCLE 4	1.50	1.50	1.50	1.50	1.50	1.50	1.50	0.60	0.60	0.60	0.60	0.60	0.60

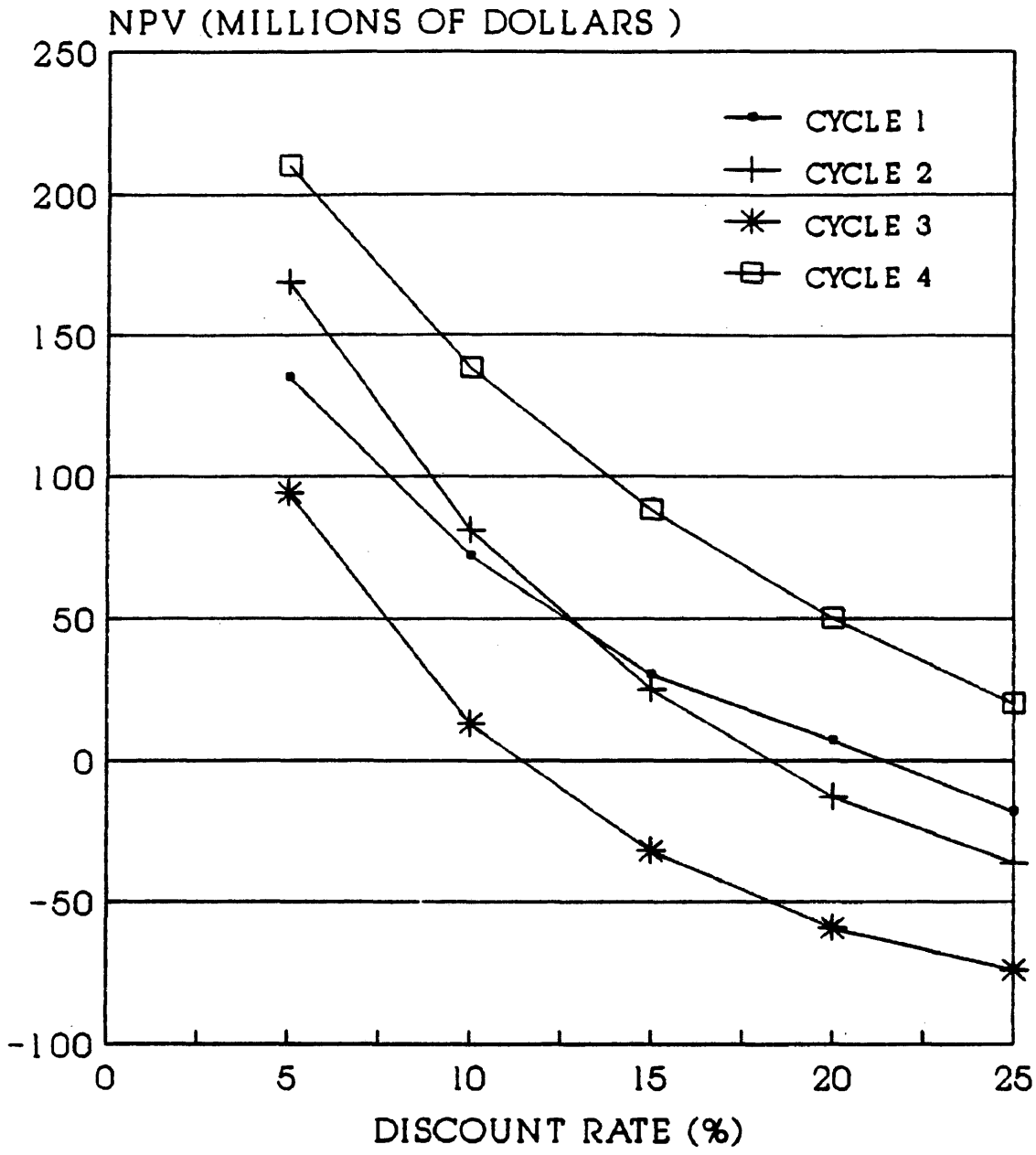

Figure 3.1: Sensitivity of NPV to Copper Price and Discount Rate Change

money, dollar values realized early in the life of a project are more significant than dollar values realized later is supported. The cycle 4 copper price scenario has the larger $1.50 per pound copper price in the first seven years of production and this gives the maximum NPV of any cycle for all discount rates. Second, both discount rate and copper price impact NPV significantly. At small discount rates, revenues further into the future contribute more to NPV than at larger discount rates. The cross-over in the NPV versus discount rate curves for cycles 1 and 2 supports this premise. At low discount rates of 5% and 10% the large copper prices beyond the third year of production (evaluation year 6 and beyond) cause the cycle 2 NPV to be higher than the cycle 1 NPV which has the higher copper price in the first three years of production. At higher discount rates of 20% and 25% the larger early year revenues associated with cycle 1 make its NPV larger than cycle 2 NPV. Third, low price and revenue in the early years of project life is disastrous to project economics as illustrated by cycle 3 with $.60/lb copper in the first seven production years having the lowest NPV for all discount rates.

Examination of price sequence within a business cycle can also illustrate for a projected product price cycle when project profit maximization should be focused on

maximizing revenue from increased production versus from savings through operating at lowest possible cost. Figure 3.2 illustrates that the out-of-pocket operating costs of production stated earlier in this chapter equal to $.39/lb are unaffected by discount rate. This suggests that when the price of copper is $.60/lb and is approaching the breakeven price for investment, strict cost control measures must be enforced to maintain profitability. However, if the business cycle shifts to a copper price of $1.50/lb, well above the breakeven price for investment, consideration of increasing production at the risk of increasing costs of production should be evaluated for profit maximization. An investor can afford to spend a lot of money in operating costs to produce low grade ores profitably when prices are high. When product prices are low, operating costs must be cut and production of higher grade ores emphasized to maximize NPV. However, the mine plan for the entire life of the mine must be taken into account, so it is important to emphasize that very general profit optimization principles are being discussed here. The idiosyncrasies of each detailed mine development plan must be considered in real world evaluations.

The Kennecott Utah Copper operation at Bingham Canyon exemplified this process in 1988. Kennecott invested $400

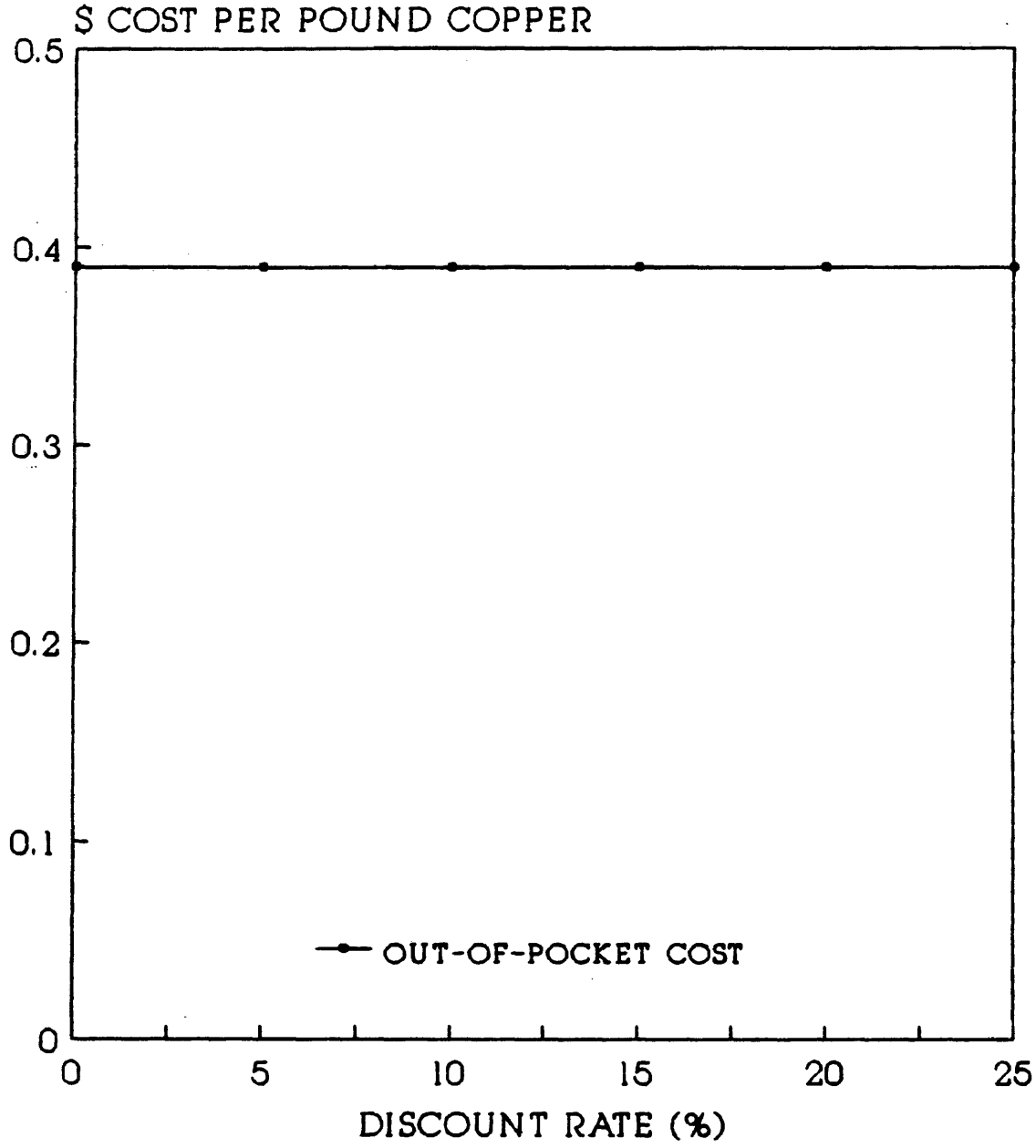

Figure 3.2: Mine and Mill Operating Cost Per Pound of Copper for Selected Discount Rates

million in modernization of material transfer systems to reduce operating costs. The project started in 1986 when copper prices were below $.70/lb. When the project was completed in 1988 the price of copper was approaching $1.50/lb. Kennecott plans to operate the new system and portions of the old facilities as long as higher copper prices continue(18).

3.4 After-tax Sensitivity of Exchange Rates

Although the effects of exchange rate fluctuations cannot be controlled by the United States or international copper industry, exchange rate fluctuations have a very significant impact on international copper mining economics and therefore on worldwide copper supplies. This impacts copper mining economics for U.S. as well as international mining organizations. This section of the report will illustrate the discounted cash flow results of international currency sensitivity to copper breakeven production costs when international copper production is sold in contracts around the world written in U.S. dollars. In spite of recent ups and downs in the U.S dollar relative to other foreign currencies, it still is the most common currency for international contracts. This makes changes in the relative value of the U.S. dollar to foreign currencies very important to mineral producers around the

world even though U.S. investors have nothing to do with a project.

The economic effects of exchange rate changes can be illustrated by returning to the developed mine and mill investment project discussed earlier in this chapter. Assume this project exists in a foreign country and all costs are incurred in the foreign currency of that country, which we will call "international currency." Also assume that revenues will be received from the sale of copper in contracts written in U.S. dollars. To convert the U.S. dollar sale revenues to foreign currency, an "international" exchange rate is used for simplicity. Particular foreign currencies would be used to demonstrate specific foreign trade economic relationships. The exchange rate of 1 U.S. dollar per 1 international dollar is considered to be the basis for the 15-year-life mine and mill cash-flow model developed earlier to give breakeven copper selling price in U.S. dollars for 10%, 15%, and 20% discount rates. The foreign country tax considerations will be assumed to be identical to U.S. tax considerations so that the effect of exchange rate changes alone can be evaluated. Now the impact on breakeven copper price for changes in the exchange rate to U.S. $1.00 per I $1.15 and U.S. $1.00 per I $0.85 will be evaluated.

In calculating breakeven copper price per pound of

copper produced for the sensitivity of exchange rates described above, costs remain unchanged. Only revenues will change by the factors of the given exchange rates. Table 3.6 lists the after-tax cash flows for the three different exchange rates. Using the after-tax cash flows of Table 3.6 and solving for the net smelter return (X) by using the Present Worth Cost Equation for discount rates of 10%, 15%, and 20% leads to the construction of Figure 3.3. Notice in Figure 3.3 that the strongest international currency situation of 0.085 international dollars per U.S. dollar, foreign mining project economics are the poorest (breakeven copper price is largest) and vice versa for the weak international currency situation of 1.15 international dollars per U.S. dollar. Investors in domestic projects anywhere in the world always have better looking economics with a weak domestic currency when exported products are being sold in another currency.

As the U.S. dollar weakens against foreign currencies, the foreign currencies become relatively stronger against the U.S. dollar, and foreign mining projects involving the sale of products in U.S. dollars become economically less desirable. These considerations can affect breakeven ore grades and worldwide production and supply of minerals over short term, intermediate term, or long term time periods.

Table 3.6
Cash Flow Data for Exchange Rate Sensitivity

YEAR:	0	1	2	3	4	5	6	7	8-15
EXCHANGE RATE									
1.15	-62	-39	-15	61X-23	61X-24	61X-36	61X-24	61X-25	61X-27
1.00	-62	-39	-15	70X-23	70X-24	70X-36	70X-24	70X-25	70X-27
0.85	-62	-39	-15	82X-23	82X-24	82X-36	82X-24	82X-25	82X-27

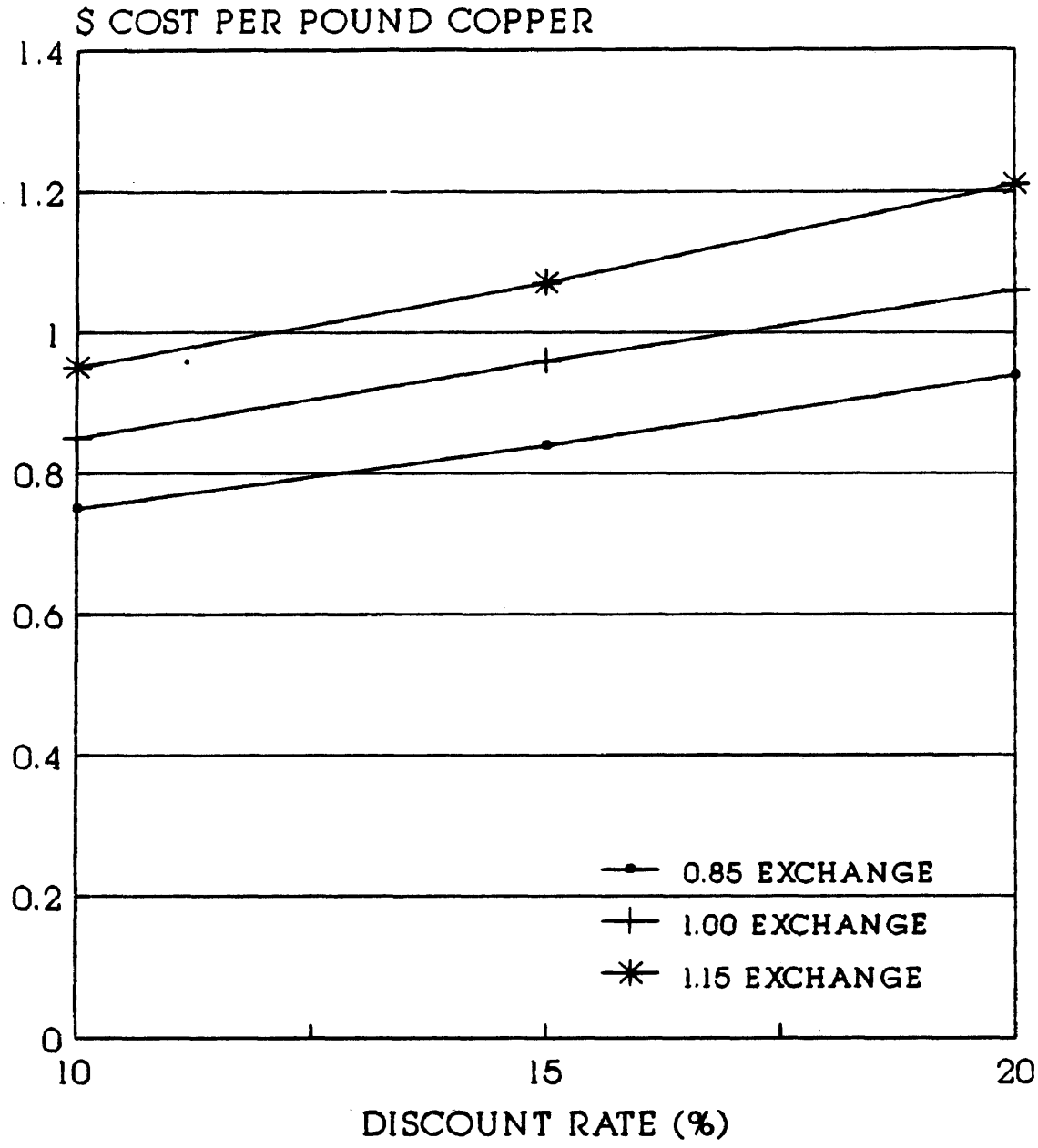

Figure 3.3: International Exchange Rate Sensitivity for Selected Discount Rates

Chapter 4

CONCLUSIONS

The objective of this thesis was to demonstrate how discounted cash flow analysis is applied to evaluate the economic effects of changes in the U.S. copper industry. Although the examples evaluated in this paper were hypothetical examples of service investment alternatives, income generating capital investment analyses, and foreign exchange sensitivity, the illustrated techniques of analysis could all be applied to a broad variety of specific industrial operations.

The economic evaluation of service-producing alternatives was illustrated by comparing mine ore transportation using truck service versus a conveyor system. Incremental rate-of-return analysis, present worth cost-analysis and present worth cost-per-unit analysis were all used to determine in this case that the conveyor system was the best economic choice of service for a specified minimum rate of return of 15% and zero days of lost production due to downtime of equipment. Further evaluations using present worth cost-per-unit analysis to compare effects of downtime to changes in the discount rate were calculated to determine breakeven cost per pound oc copper produced for service provided by the trucks and

conveyor system. As illustrated in Figures 2.1 through 2.4, a lower discount rate permits increasing the days of downtime that will make the conveyor system equivalent economically to the truck fleet. Relating the service analysis to cost per pound of copper produced enables the investor to see directly the economic effect of providing service with the different alternatives being evaluated. This type of cost per pound of copper produced service analysis has not been illustrated elsewhere in economic evaluation literature.

Economic evaluation to determine the breakeven copper price for investment of $140 million in a mining project was demonstrated at discount rates of 10%, 15%, and 20% using NPV analysis. Sensitivity of project life was included in breakeven price determination, illustrating that smaller discount rates cause values in the future to have a greater impact on present value than are realized for larger discount rates. Sensitivity to copper price cycles at various discount rates were evaluated to determine the effects on breakeven copper price. It was illustrated that dollar values realized early in a project life are more significant than dollars realized later in the evaluation. For this reason, of the four price cycles evaluated, the cycle with the highest price in the early stages of production proved to be the most economical by

generating the largest NPV. Conversely, the price cycle with the lowest price in the early stages of production produced the lowest NPV value of the four evaluation cycles. It was also shown that both the discount rate and copper price impact NPV. At a small discount rate of 5% or 10%, higher copper prices beyond the first few years of production contribute to NPV more than do evaluations with discount rates of 20% to 25%. This relationship was demonstrated through the mathematics of the single payment present worth factor, $1/(1+i)^n$.

Fluctuations in exchange rates can affect breakeven ore grades and worldwide production and supply of minerals over short and long periods of time. This directly affects copper price and copper mining project economics. This was illustrated by evaluating a hypothetical foreign copper producer's breakeven price for production when all costs are incurred in an international currency and revenue is assumed to be received from copper sales in U.S. dollars. Calculations demonstrated that as the U.S. dollar weakens against foreign currency, the foreign currency becomes relatively stronger, making the foreign mining project's breakeven price higher and therefore economically less desirable.

Discounted cash flow analysis economic evaluation techniques provided the basis for all of the quantitative

economic analyses presented in this thesis. Whether the effects of changes in foreign currency exchange rates are being analyzed or alternative methods of providing service or generating income are being evaluated, discounted cash flow techniques give investors a quantitative basis for analyzing economic differences in alternative projects. However, it is important to remember that the calculation results from using these techniques are only as good as the input data. With good data as the basis for economic analysis, discounted cash flow analysis provides the best basis known today for evaluating the economic potential of alternative investment scenarios. Illustrating this for U.S. copper industry applications in the 1980s has been a primary objective of this thesis.

REFERENCES CITED

1. Niemi, Les "Cyprus Bagdad: Successful Expansion Creates State-of-the-Art Copper-Molly Producer in Northwest Arizona." EM&J (August, 1980): 56-63

2. Suttill, Keith R. "Column Cells Raise Grade At Sierrita." EM&J (October, 1987): 54-55

3. Cormack, Kenneth "The Case for Oxygen Sprinkle." EM&J (June, 1985): 44-48

4. EM&J (October, 1983): 25. "Phelps Dodge Union Controversy Escalates Into the Courts."

5. EM&J (July, 1986): 14. "U.S. Copper Companies Seek Survival Through Wage Cuts."

6. EM&J (October, 1986): 19. "Standard Sells Off Two Kennecott Copper Operations."

7. Radetzki, Marian, "The Rising Costs of Base Materials - The Case of Copper." Mining Magazine, April 1979. 352-359.

8. Durham, Robert G. "U.S. Copper Industry Regaining Competitiveness." Pay Dirt March, 1988: 8-11.

9. U.S. Bureau of Mines, Bulletin 692 (1987). An Appraisal of Minerals Availability for 34 Commodities.: 81-93.

10. ASARCO Incorporated (1985). ASARCO Incorporated Annual Report 1984.

11. Peterson, Andrew N. "Using Conveyors to Cut Costs." Mining Engineer (June 1983): 589-591.

12. Walenga, Karen "Updated Plant Makes Bingham Low-Cost Producer." Pay Dirt, October, 1988: 4A-6A.

13. Ellingson, David "Phelps Dodge Has Something to Smile About." EM&J (August, 1987): 24-32

14. Jolly, Janice L.W. "Competitiveness of the U.S. Copper Mining Industry." Bureau of Mines, Washington, D.C. 1988.

15. Stermole, Franklin J. "Personal Skills: Economic Analysis of Mineral and Energy Investments." Mining Engineer, Feburary, 1984. 143-146.

16. Stermole, F.J. and Stermole, J.M. (1987) Economic Evaluation and Investment Decision Methods, 6th Ed., USA. p. 75

17. Kaufmann, Thomas D. "Business Cycles and Feasibility Tests in Mining Ventures." Mining Engineer, June, 1984. 610-612

18. Mining Engineering, "BP Minerals Completes $400 Million Modernization at Bingham Canyon." November, 1988. pgs 1017-1020.P

SELECTED BIBLIOGRAPHY

Almond, R. Mead "Overland Conveyers." EM&J, (August 1980): 92-96.

Bureau of Mines Information Circular 8930 (1983). "Copper Availability": 24-25.

EM&J (September, 1984). "U.S. Copper Can Stay Competitive: Osborne.": 24-25.

EM&J (August, 1986). "Unions and U.S. Copper Producers Avert Strike.": 24.

Jolly, Janice L.W. and Edelstein, Danile. "Copper". Minerals Yearbook 1986, Volume I. U.S. Government Printing Office, WAshington, D.C.: 1987.

Jolly, Janice L.W. "Copper". Minerals Yearbook 1985, Volume 1. Bureau of Mines: U.S. Government Printing Office, Washington, D.C.: 1987.

Korpi, P.A. and Dopson, G.W. "New Ball Mill Lining Cuts Cost." EM&J (February, 1981): 78-82.

Nilsson, Dan "Productivity in Mining." International Mining (October, 1987): 38-43.

Sassus, Michael P. "In-Pit Crushing and Conveying Systems." EM&J (April, 1984): 46-59.

Sassus, Michael P. "Copper Flash Smelting." EM&J (June, 1983): 76-81.

Timmers, J., Fountain, J., Houseweart, J., "New Hydromet Route Wins Lower Cost Copper." EM&J (October, 1983): 64-65.

Westergard, Alan F. "How Pressure Filtration Dewaters Butte Concentrates." EM&J (June 1983) 60-73.

Appendix A

SMELTER PAYMENT CALCULATION

Smelter Payment Calculation

The smelter payment calculation is a negotiated contract to pay for a given percentage of contained copper in the concentrate less deductions for treatment charges and freight. Credit is also given to the mine for specified percentages of contained by products.

EXAMPLE DESCRIPTION OF SMELTER PAYMENT:

Assumed Concentrate: Cu=26%, Ag=4.40 opt; Au=0.02 opt

Payment for Cu:
(0.26 - 0.01)(2000)(.975) = 487.5(PRICE)

Where: 0.26 is the percent contained Cu in the concentrate
0.01 is a smelter deduction
2000 converts calculation to pounds
0.975 is the percentage of payable Cu
Price is the market price of Cu $/lb quoted to the mine in the month of delivery to the smelter

Payment for Ag:
(4.40 - 1.0)(.95) = 3.23 (PRICE)

Where: 4.40 opt is the contained Ag in concentrate
1.0 is a smelter deduction
0.95 is the percentage of payable Ag

Payment for Au:
(0.02 - 0.02)(.95) = 0(PRICE)

Where: 0.02 opt is the contained Au in concentrate
0.02 is a smelter deduction
0.95 is the percentage of payable Au

EXAMPLE SMELTER PAYMENT:

Assumed Prices: Cu = 0.66$/lb
Ag = 6.50$/oz.
Au = 430.00$/oz.

Gross Payment Calculation:

Cu: (0.26-0.01)(2000)(.975)=487.5(0.66)=321.75$/ton

*Ag: (4.40-1.0)(.95)=3.23(6.50)=21.00$/ton

*Au: (0.02-0.02)(.95)=0(430)=0

Gross Smelter Payment	= 342.75$/ton
Base Smelter T.C.	= (60.00)
Less Freight	= (20.00)
Net Smelter Payment	= 262.75$/ton

*By product credit consists of only 6% of gross smelter payment and for this reason is not included in the cash flow analysis for determining mine investment.

EXAMPLE CALCULATION OF DETERMINING NET SMELTER RETURN PER POUND COPPER FROM A GIVEN PRICE OF COPPER:

Payment for Cu:

(0.26 - 0.01)(2000)(0.975) = 487.5(price)

Smelter deductions:

60 $/ton Base Smelter Treatment Charge
20 $/ton Freight Charge

Total contained copper:

(2000)(0.26) = 520 lb Cu

Given a copper price of 1.50$/lb, Net Smelter return per pound copper is calculated by:

$$\left[\frac{487.5 \text{ lb payable Cu}}{\text{ton}}\right]\left[\frac{1.50\$}{\text{lb Cu}}\right] = 731.25 \frac{\$}{\text{ton}}$$

less 80$/ton treatment and freight charges:

(651.25$/ton) ÷ (520 lb Cu/ton) = 1.25$/lb Cu

This equation can be used to find price given net smelter return.

Appendix B

PRESENT WORTH COST PER POUND CALCULATIONS

PRESENT WORTH PRODUCTION OF CONVEYOR SERVICE

Calculation of Present Worth Cost from Table 2.3

Discount Rate	Present Worth Cost
10%	14.5
15%	13.5
20%	13.0
25%	12.5

Calculation of Present Worth Production

Downtime	Production per year After Tax	$P/A_{10,10}$	$P/A_{15,10}$	$P/A_{20,10}$	$P/A_{25,10}$
0	26.6(1-.38)	100.6	82.5	69.3	59.4
12	25.7(1-.38)	97.2	79.7	66.9	57.4
24	24.8(1-.38)	93.8	76.9	64.6	55.4
36	23.9(1-.38)	90.4	74.1	62.2	53.3
48	23.0(1-.38)	87.0	71.3	59.9	51.3
60	22.0(1-.38)	83.2	68.2	57.3	49.1
72	21.1(1-.38)	79.8	65.4	54.9	47.1

PRESENT WORTH PRODUCTION OF TRUCK SERVICE

Calculation of Present Worth Cost from Table 2.4

Discount Rate	Present Worth Cost
10%	16.6
15%	15.7
20%	14.1
25%	13.0

Calculation of Present Worth Production

Downtime	Production per year After Tax	$P/A_{10,10}$	$P/A_{15,10}$	$P/A_{20,10}$	$P/A_{25,10}$
0	26.6(1-.38)	100.6	82.5	69.3	59.4
12	26.5(1-.38)	100.2	82.2	69.0	59.2
24	26.3(1-.38)	99.5	81.5	68.4	58.7
36	26.2(1-.38)	99.1	81.2	68.2	58.5
48	26.1(1-.38)	98.7	80.9	68.0	58.3
60	26.0(1-.38)	98.3	80.6	67.7	58.0
72	25.8(1-.38)	97.6	80.0	67.2	57.6

PRESENT WORTH COST PER POUND OF CONVEYOR SERVICE VS. PRESENT WORTH COST PER POUND TRUCK SERVICE

CONVEYOR:

	$P/A_{10,10}$		$P/A_{15,10}$		$P/A_{20,10}$		$P/A_{25,10}$	
Down	$/ton	$/lbCu	$/ton	$/lbCu	$/ton	$/lbCu	$/ton	$/lbCu
0	0.144	0.012	0.164	0.014	0.188	0.017	0.210	0.018
12	0.149	0.013	0.169	0.015	0.194	0.017	0.218	0.079
24	0.154	0.013	0.176	0.016	0.201	0.018	0.226	0.020
36	0.160	0.014	0.182	0.016	0.209	0.018	0.234	0.020
48	0.166	0.015	0.189	0.017	0.217	0.019	0.244	0.021
60	0.174	0.015	0.198	0.018	0.227	0.020	0.254	0.022
72	0.182	0.016	0.206	0.018	0.237	0.021	0.265	0.024

TRUCKS:

	$P/A_{10,10}$		$P/A_{15,10}$		$P/A_{20,10}$		$P/A_{25,10}$	
Down	$/ton	$/lbCu	$/ton	$/lbCu	$/ton	$/lbCu	$/ton	$/lbCu
0	0.165	0.014	0.190	0.017	0.203	0.018	0.219	0.019
12	0.166	0.015	0.191	0.017	0.204	0.018	0.220	0.019
24	0.167	0.015	0.193	0.017	0.206	0.018	0.221	0.020
36	0.168	0.015	0.193	0.017	0.207	0.018	0.222	0.020
48	0.168	0.015	0.194	0.017	0.207	0.018	0.223	0.020
60	0.169	0.015	0.195	0.017	0.208	0.018	0.224	0.020
72	0.170	0.015	0.196	0.017	0.210	0.018	0.226	0.020

Appendix C

BUSINESS CYCLE CASH FLOW CALCULATIONS

BUSINESS CYCLE CASH FLOW CALCULATIONS

YEAR	Cycle 1 (Price Cu $/lb)	5%	10%	15%	20%	25%
0	-	-62	-62	-62	-62	-62
1	-	-37	-35	-34	-32	-31
2	-	-14	-12	-11	-10	-10
3	1.50	58	51	45	40	34
4	1.50	52	43	36	30	26
5	1.50	40	32	26	21	17
6	0.60	4	5	3	2	1
7	0.60	2	3	2	2	1
8	0.60	1	2	1	1	0
9	0.60	1	2	1	1	0
10	0.60	-8	-13	-5	-3	-1
11	0.60	2	3	1	1	0
12	0.60	2	4	1	1	0
13	1.50	33	18	10	6	3
14	1.50	31	16	9	5	2
15	1.50	30	15	7	4	2
NPV		135	72	30	7	-18

YEAR	Cycle 2 (Price Cu $/lb)	5%	10%	15%	20%	25%
0	-	-62	-62	-62	-62	-62
1	-	-37	-35	-34	-32	-31
2	-	-14	-12	-11	-10	-10
3	0.60	8	7	6	5	5
4	0.60	8	7	6	5	5
5	0.60	-6	-4	-4	-3	-2
6	1.50	48	36	27	21	16
7	1.50	44	32	24	18	13
8	1.50	41	28	20	14	10
9	1.50	39	25	17	12	8
10	1.50	28	18	12	7	5
11	1.50	36	22	14	8	6
12	1.50	35	20	12	7	4
13	0.60	2	1	1	0	0
14	0.60	2	1	0	0	0
15	0.60	1	1	0	0	0
NPV		169	81	25	-13	-36

BUSINESS CYCLE CASH FLOW CALCULATIONS

YEAR	Cycle 3 (Price Cu $/lb)	5%	10%	15%	20%	25%
0	-	-62	-62	-62	-62	-62
1	-	-37	-35	-34	-32	-31
2	-	-14	-12	-11	-10	-10
3	0.60	8	7	6	5	5
4	0.60	4	3	3	2	2
5	0.60	-6	-4	-4	-3	-2
6	0.60	4	3	2	2	1
7	0.60	2	2	2	1	1
8	0.60	1	1	1	1	0
9	0.60	1	1	1	0	0
10	1.50	28	18	12	7	5
11	1.50	36	22	14	8	6
12	1.50	35	20	12	7	4
13	1.50	33	18	10	6	3
14	1.50	31	16	9	5	2
15	1.50	30	15	7	4	2
NPV		94	13	-32	-59	-74

YEAR	Cycle 4 (Price Cu $/lb)	5%	10%	15%	20%	25%
0	-	-62	-62	-62	-62	-62
1	-	-37	-35	-34	-32	-31
2	-	-14	-12	-11	-10	-10
3	1.50	58	51	45	40	34
4	1.50	52	43	36	30	26
5	1.50	40	32	26	21	17
6	1.50	48	36	27	21	16
7	1.50	44	32	24	18	13
8	1.50	41	28	20	14	10
9	1.50	39	25	17	12	8
10	0.60	-8	-5	-3	-2	-1
11	0.60	2	1	1	0	0
12	0.60	2	1	1	0	0
13	0.60	2	1	1	0	0
14	0.60	2	1	0	0	0
15	0.60	1	1	0	0	0
NPV		210	138	88	50	20