T-1615

INPUT-OUTPUT ANALYSIS OF THE ECONOMIC IMPACT OF A NON-FERROUS CHEMICAL SMELTER ON THE COLORADO ECONOMY

by

Frank Louis Natta

This Thesis is submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science, Mineral Economics.

Signed: Frank Louis
Frank Louis Natta

Golden, Colorado

Date: June 27, 1974

Approved: John A. Cleveson
Thesis Advisor

Jean Paul Mattey
Head of Department

Golden, Colorado

Date: June 27, 1974

ABSTRACT

The mining and processing of base and precious metals has been of great interest in Colorado throughout its entire history. Higher prices for these metals and the corresponding resurge in interest, as well as the current lack of any indigenous smelter to treat base and precious metal ores, provided the stimulus to quantify the potential impact of a non-ferrous smelter on the Colorado economy. An input-output model, describing the interrelationships of the various industrial activities in the Colorado economy, was utilized to measure the smelter's impact on the household income and total output of each process industry included in the input-output analysis. This analysis is expressed in the form of a transaction matrix which is mathematically manipulated to yield various multipliers which can be used to measure the economic impact of any independent change in the economy such as the introduction of a new industry like a non-ferrous chemical smelter. By including a thorough description of each stage of the model's development and the methodology of its use for calculating economic impact, this Thesis not

only measures the impact, but also introduces the means by which any analyst can conduct a regional, economic impact analysis.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I am very grateful to the many individuals who aided me with this Thesis. In particular, I would like to acknowledge those persons who were especially helpful. They include Bruce Schiller who aided me in writing the computer programs that were utilized to facilitate the many calculations in this Thesis; Karen Schiller who was a gracious hostess during my visits to Denver; and George DaBai who checked data for accuracy. I would also like to thank the members of my Thesis committee and in particular Dr. John A. Pederson whose aid, encouragement, and patience made this Thesis possible. In addition, I would like to acknowledge the U.S. Bureau of Mines and Mr. Harold Ballard of the Mining Industrial Board for providing the incentive and the means by which I could implement this study.

CHAPTER 1: INTRODUCTION

The United States is currently in a period in which the formulation of an effective mineral policy is of paramount importance. The need for providing a suitable environment which will insure a viable, domestic mineral industry has never been more apparent than during the last year. The Arab oil embargo and the threat of other cartel situations in commodities like copper and aluminum clarify the danger of relying on foreign sources for essential raw materials.

Unfortunately, the expansion of our domestic mineral industry to meet the incremental demand for mineral commodities also involves the degradation of our natural environment. Whether a potential project involves the actual severance of the mineral from the ground or its processing, the realization of any mineral project will consume some portion of that abstract commodity which is known as the "quality of life". Within the past few years, many have begun to question the value of economic growth against the value of our environment (i.e., the quality of life). Others have foreseen the need to develop additional mineral production, but have accepted the "not in my backyard" philosophy, fearing the social and environmental problems associated with mineral development.

In addition to the concern for the environment, the most beneficial use of two other essential raw materials, land and water, must be considered in the evaluation of any mineral project. These two resources are limited and the demands placed upon them for human consumption and agricultural uses present severe restrictions to mineral producers in certain areas of the United States.

The preservation of our environment, the most beneficial use of our natural resources, and the need for economic growth are the criteria for the evaluation of any mineral project. The development of a means by which these criteria can be measured and compared is essential to effective mineral resource management. The purpose of this Thesis is to quantify one of these criteria, economic growth. This author has concerned himself with measuring the potential economic impact of a mineral project on a regional economy. The problem of quantifying other social and environmental criteria is left to others who have more expertise in those fields.

Since the greatest impact of industrial development is on the area of close proximity to the project, this study encompasses a relatively small area, an individual state. The study region chosen was the State of Colorado because the mineral industry is an important entity in its economy, because Colorado abounds in natural beauty which could be damaged by increased mineral production, and because the State faces serious water-availability and land-use problems which are associated with its urban sprawl and high population growth rate. It provides an ideal setting in which to begin to study the potential impact of mineral development.

The means by which the economic impact is calculated involves input-output analysis. Such an analysis provides a quantitative measurement of the impact of independent changes on a regional economy. It also shows the interrelationships that exist between various mineral industries and between the mineral industries and other economic activities in an economy. There is considerable precedent for applying an input-output model for economic impact-analysis of mineral development. 1.1/, 1.2/, 1.3/, 1.4/.

In addition to applying an input-output model to the Colorado economy and utilizing this model to measure the impact of a specific mineral project, the development of a non-ferrous chemical smelter, a discussion of the problems associated with the formulation and use of the model has been included where appropriate.

The choice of subject matter for this Thesis was to some degree affected by the completion of a recent study of the mineral industry in Colorado on which this author also worked. 1.5/ This study provided reasonably accurate, up-to-date data for the mineral industry which eliminated many of the data-availability problems that plague most input-output studies. Supporting this situation is the large, rapid price increase of base and precious metals and the corresponding interest to reestablish a smelting operation in Colorado.

The economic impact analysis which follows can be split into three areas: 1) definition of the study region, 2) presentation of the impact sector, and 3) calculation of economic impact. The definition of the study region includes Chapters 2, 3, and 4. A brief description of Colorado's geographic and economic characteristics as well as a discussion of the problems associated with defining the study region are presented in Chapter 2. Chapter 3 describes the conventions of input-output analysis and Chapter 4 encompasses a discussion of the methodology of formulating an economic model of the Colorado economy. Chapter 4 also includes the model and its associated input-output calculations.

The impact sector, the non-ferrous chemical smelter, is presented in Chapter 5. The physical and economic characteristics of the plant are described. The methodology of estimating the plant's capital and operating costs and the incorporation of these estimates into the input-output model is also discussed.

The economic impact of the chemical smelter on the Colorado economy is calculated in Chapter 6. The presentation is divided to show both the impact of capital expenditures and the impact of operating expenditures. The operating expenditures are divided further according to the impact resulting from the smelter's employment and the impact resulting from the purchase of goods and services from other industries in the regional economy. Particular emphasis is placed on the smelter's potential impact on base and precious metal mining and the subsequent impact on the entire economy.

The final chapter is devoted to a general discussion of economic modeling and to a discussion of the limitations of the model presented in this Thesis. Here, however, this author would like to note that the following economic model and impact calculation provide only a simple, crude approximation of the real-world situation. Although every attempt has been made to achieve an accurate representation, differences will no doubt occur between the real-world impact and the impact estimated from the input-output model.

Lastly, it should be noted that the following economic analysis is based on 1972 data. In other words, the input-output model represents the structure of the Colorado economy during 1972. Similarly, the estimates of the smelter's capital and operating costs have also been expressed in 1972 dollars.

CHAPTER 2: REGION OF ANALYSIS

The formulation and subsequent utilization of any model for economic impact analysis is contingent upon first defining the region of analysis. The purpose of this chapter is to describe the geographical setting of this Thesis, the State of Colorado. A brief review of the State's geographical and economic characteristics will bring the spatial aspects of this economic impact analysis into perspective for the reader. In addition, a description of Colorado's mineral industry is included since this Thesis deals with one aspect of the mineral industry, a chemical smelter.

Geographic and Economic Characteristics

Before the characteristics of the study region are discussed, however, the problem of data availability should be mentioned. In determining the geographical limitations of the study region, the analyst must take into account the problem of data availability. Economic data may be obtained from secondary and primary sources. Secondary sources refer to published information, while primary sources refer to actual contact with individuals and firms in the field such as personal interviews or surveys. Although primary data sources allow the analyst greater freedom in defining the study region, effort to secure it is greater than with secondary sources.

Colorado is a high-altitude state with an average elevation of 6,800 feet. It's climate is classified as semiarid with an average precipitation of about 17 inches. Due to the pronounced differences in Colorado's topography, however, elevation and climatic conditions vary greatly across the State.

Colorado's geography is made up of three topographic zones: 1) mountain, 2) plains, and 3) plateaus. The mountain zone runs north and south through the middle of the state and consists of a complex system of ranges: the Front range, Park range, Sawatch range, Elk mountains, and San Juan mountains. The mountains are Colorado's most dominant characteristic and they abound in natural beauty and mineral wealth. The plains zone is a semiarid, treeless region stretching eastward from the base of the Rocky Mountains. The plateau zone lies in the western part of the state and consists of a series of mesas or plateaus that gradually decline towards the State's western border.

Colorado is sparsely populated in relation to the whole United States. The population per square mile in 1973 was 23.8 as compared with 58.0 for the U.S. Most of the population is urban and is concentrated along the base of the

Front range in the three metropolitan areas of Colorado Springs, Pueblo, and Denver (see Figure 2-1). Almost 75 percent of the State's population is located in these three metropolitan areas. The population of Colorado has been increasing at almost three times the national average. For the past decade, the national population growth rate has averaged about 1.2 percent, while Colorado's growth rate since 1967 has averaged near 4.0 percent (see Table 2-1). The high rate of growth is due to immigration to Colorado. It appears that Colorado's favorable climate, natural beauty, and economic strength have drawn many people to move to the state.

Colorado's growing population and overall economic health have lead the way for significant increases in employment. Nonagricultural wage and salary employment increased by 4.4 percent during 1973. This increase is matched by Colorado's unemployment rate which has been below the national average for several years. During 1973, Colorado's rate was about 3.1 percent while the National average was 4.8 percent. A breakdown of Colorado's labor force is shown in Table 2-2.

As one may gather from Table 2-2, Colorado's economy is very broad-based. The agricultural industry encompasses the production of fruit, grains, and vegetables and the raising of livestock which include cattle, poultry, sheep, and hogs.

FIGURE 2-1

Geographical Setting of Colorado

TABLE 2-1

Total Population, Colorado and United States 2.1/

(As of July 1, of each year)

1940 - 1973

Base Year = 1960

Year	Index	Colorado Population	Index	United States Population
1940	64	1,123,296	73	132,594,000
1950	75	1,325,089	84	152,271,000
1960	100	1,768,000	100	180,667,000
1961	104	1,836,000	102	183,672,000
1962	107	1,886,000	103	186,504,000
1963	108	1,916,000	105	189,197,000
1964	110	1,944,000	106	191,833,000
1965	110	1,953,000	108	194,237,000
1966	111	1,969,000	109	196,485,000
1967	114	2,008,000	110	198,629,000
1968	117	2,067,000	111	200,619,000
1969	120	2,130,000	112	202,599,000
1970	125	2,216,393	113	204,800,000
1971	129	2,277,000	115	207,006,000
1972	134	2,376,000*	116	209,181,000*
1973	140	2,476,000*	117	211,530,000*

* Estimated

TABLE 2-2

Colorado Labor Force Summary 1969-1973 2.2/
(in thousands)

	1969	1970	1971	1972*	1973*
Total Labor Force	882.2	919.6	950.7	989.3	1,028.0
Unemp. & Labor Dis.	26.4	31.0	32.0	31.3	31.9
Unemployment Rate	3.0	3.3	3.3	3.1	3.1
Labor Force Part. Rate	41.4	41.5	41.8	41.6	41.5
Total Employment	855.8	888.6	918.7	958.0	996.1
Agriculture	52.9	54.1	49.9	48.0	47.5
Nonagricultural	802.9	834.5	868.8	910.0	948.6
All other	89.7	91.8	96.3	99.0	101.8
Wage & Salaried	713.2	742.7	772.5	811.0	846.8
Mining	13.5	14.0	13.4	14.0	14.1
Construction	38.1	41.1	45.0	48.8	48.5
Manufacturing	114.6	117.5	117.7	121.7	126.5
Transp. & P.U.	50.8	51.3	52.5	53.3	55.1
Trade	168.8	173.4	180.8	190.0	198.8
Fin.Ins. & R.E.	37.8	39.6	41.4	43.0	45.0
Services	124.3	130.3	134.7	140.0	145.2
Government	165.3	175.5	187.0	200.1	213.6

*Estimated

The major trade and industrial groups are wholesale and retail trade, services, manufacturing, transportation, communication and public utilities, and construction. The principal manufacturing industries include nonelectrical machinery, food and kindred products, primary metal products, and electrical machinery. The service industries are extremely varied, encompassing many educational, medical, financial, and technical fields. One service industry, tourism, is the State's major economic activity. The government also has a significant impact on the economy. In terms of employment the government is the most important sector in the State. The mineral industry is another important segment of Colorado's economy. It will be discussed in greater detail later in this chapter.

Colorado's economy is very complex. It encompasses a wide variety of economic and governmental activities. Its geographical setting and metropolitan centers have drawn many firms and government agencies into the State. Many firms have located central or district offices in the greater Denver metropolitan area. The federal government has located many research, administrative, and armed services agencies in the State. The Denver area is also a center for major road, rail, and air transportation systems. In a sense, Colorado is a "mini-country" which encompasses almost the entire spectrum of economic and governmental activities, and thus serves as an excellent example for regional economic impact analysis.

Colorado's Mineral Industry

A more detailed description of Colorado's mineral industry is warranted here since the primary emphasis of this Thesis concerns the economic importance of the mineral industry on the region's economy. In this Thesis, the term "mineral industry" encompasses a wider range of activities than has been traditionally included in the Standard Industrial Classification Manual 2.3/, (S.I.C.) which defines the mineral industry as:

> ...establishments primarily engaged in mining. Mining is here used in the broad sense to include the extraction of minerals occuring naturally: solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. The term "mining" is also used in the broad sense to include quarrying, well operation, milling (crushing, screening, washing, flotation, etc.), and other preparation needed to render the material marketable. Exploration and development of mineral properties are included. Services performed on a contract, fee, or other basis in the development or operation of mineral properties are classified separately but within this division.

The concept of the mineral industry utilized in this thesis is based on the broader view developed by Kung-Lee Wang 2.4/, who defined the mineral industry as follows:

> ..."mineral industries" include all mining industries and basic mineral processing industries. "Mining industries" includes all the 2-digit Standard Industrial Classifications for all mining activities--metal mining, coal mining, oil and gas extraction, and non-metal mining. "Basic mineral processing industries" includes all the basic mineral processing industries (1) that use the output of the SIC-defined mining industries as their primary raw material for value-added, and (2) whose outputs are generally used by the other producing industries as their respective essential raw material.

This broader view of the mineral industry was developed further in a recent study conducted at the Colorado School of Mines 2.5/. The definition developed in this study and utilized in this Thesis is shown in block-diagram form in Figure 2-2. This diagram also shows the general flow of commodities between the nine mineral industry sectors and the rest of the economy. The mineral industry in Colorado encompasses every sector shown in Figure 2-2.

From the early gold and silver days of the 1880's, Colorado's inherent mineral wealth has insured a viable mineral industry. Total output from the industry approaches 1.25 billion dollars and encompasses nearly every county in the State. Mining activities include the production of iron; the ferrous alloys-molybdenum, vanadium, and tungsten, the precious metals-gold and silver: the base metals-zinc, lead, copper, and cadmium, other metals such as tin, and beryllium,

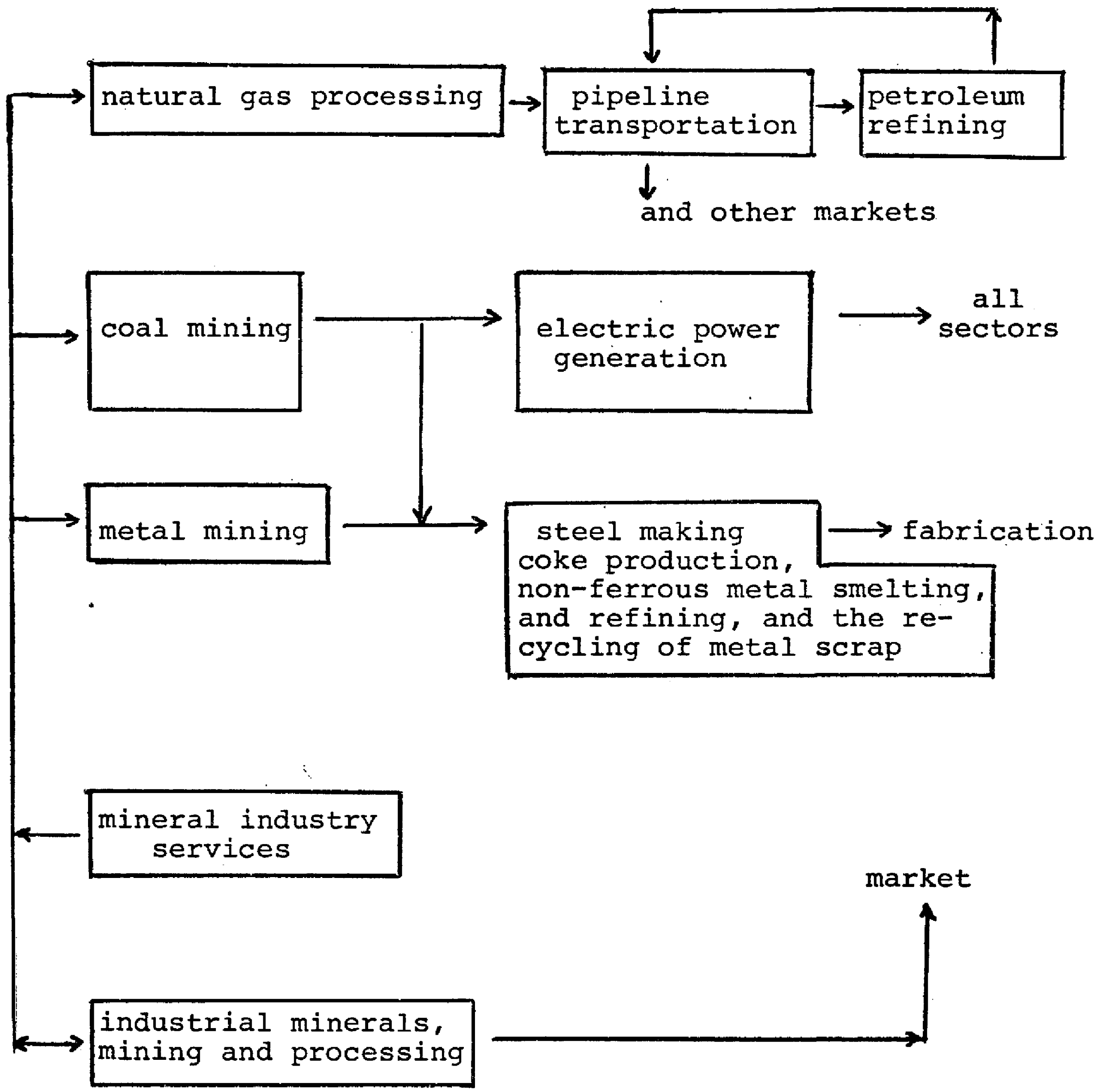

FIGURE 2-2

Mineral Industry Groups

the nonmetallics-sand, gravel, limestone, fluorspar, stone, clay, dolomite, volcanic scoria, gypsum, peat, perlite, feldspar, mica, and silica; and the mineral fuels-crude oil, natural gas, and coal. Processing activities include electric power generation; uranium and vanadium processing; iron, steel, and coke production; recycling of ferrous and non-ferrous metals; petroleum refining and natural gas processing; cement production; and the processing of various rare metals. In addition, there are a wide variety of firms providing technological and engineering services to exploration, mining, and processing operations.

No attempt will be made here to fully describe Colorado's mineral industry since other, more comprehensive studies exist 2.6/. Rather, this author will concern himself with the base and precious metals production within the State.

The development of a viable base and precious metals smelter within Colorado is dependent on both the quality and quantity of available raw materials. Any potential smelter must be able to treat complex metal sulfide ores or concentrates. Most of the concentrates produced in Colorado are of a very complex nature, often consisting of lead, zinc, copper, gold, and silver. A typical metal concentrate may assay 23 percent lead, 5 percent copper, 33 percent zinc, 13 oz silver per ton, and .16 oz gold per ton. Some mines are small volume operations and do not upgrade their ore to a concentrate. A smelter should thus include a processing mill, probably a sulfide flotation mill.

The main base and precious metals producing areas of Colorado are shown in Figure 2-3. The collective production from the four areas amounts to about 35,000 tons of zinc, 25,000 tons of lead, 5,000 tons of copper, 1.4 million oz. of silver, and 17,000 oz. of gold per year. Collective resources of lead, zinc, and copper are estimated by the U.S. Bureau of Mines to be 3,040,617 tons 2.7/. Almost 54 percent of these resources are located in area #4. Here resources refer to all measured, indicated or inferred ore that is or may be profitable to mine. Current mine production is more than adequate to provide the necessary feed for a smelter. In addition, reserves appear to be adequate to insure continued mine production for 30 years at the current production rate. It may be that a smelter would stimulate increased production and exploration, since under existing conditions all of the ore and concentrate produced must be exported from the State. The high transportation costs render many small operations uneconomic.

A more thorough analysis of the Colorado economy is provided in Chapter 4 of this Thesis. The input-output model developed in that chapter will show the interrelationships of various industrial activities within the State and the role of the mineral industry in the entire economy.

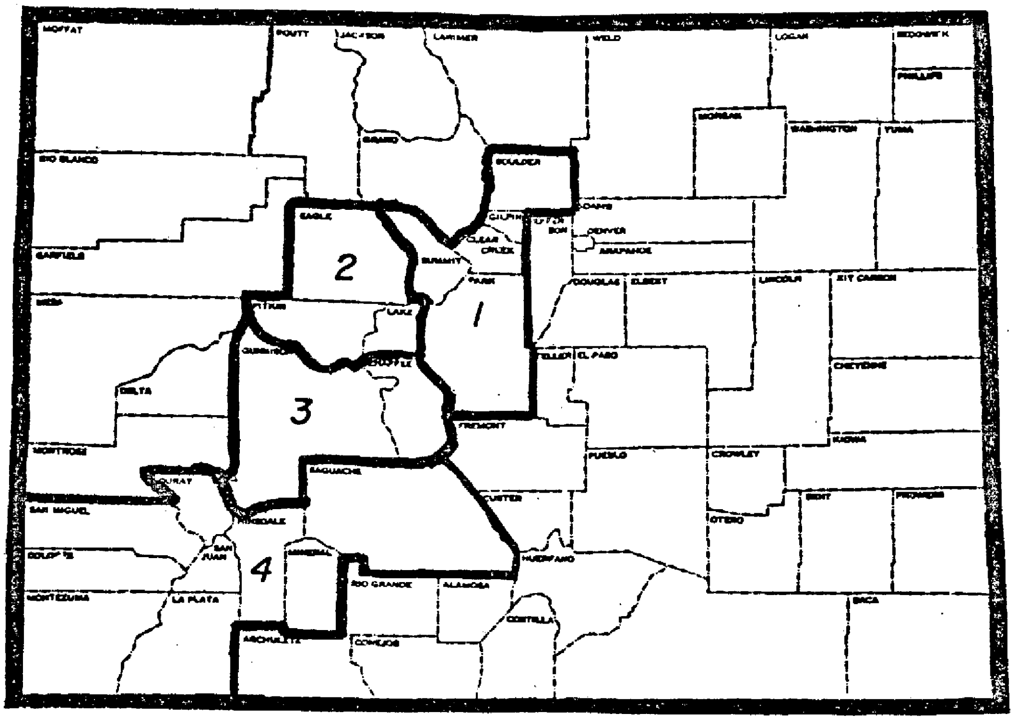

FIGURE 2-3

Major Producing Areas of Base and Precious Metal in Colorado

CHAPTER 3: ELEMENTS OF INPUT-OUTPUT ANALYSIS

Every region's economy is made up of many separate industrial activities or sectors which engage in commercial transactions both in and out of the region. An input-output model attempts to describe both the interdependence of the sectors within the region (intra-regional transactions) and the flow of goods in and out of the region (imports and exports). It is a balanced, static model which shows the flow of goods and services at a given point in time.

The interdependence of sectors within a regional economy has been a subject of considerable interest for many years. The first efforts were made by Francois Quesnay in 1758. 3.1 / In his Tableau Economique, Quesnay developed a crude input-output model which described the flow of goods among three economic classes. Other pioneers included Leon Walras, Gustav Cassel, and Vilfrado Pareto. 3.2/

More than any other individual, however, it is Wassily Leontief who is responsible for the input-output model as we know it today. His work climaxed in 1941 with the publication of the input-output models for 1919 and 1929 for the United States. 3.3/

Having discussed the study region previously, this chapter will describe the elements of the input-output model. In other words, this chapter will show how this model is developed and utilized to describe the economy of a region.

Input-Output Accounting System

In any economy, an industry may sell some of the product to itself through intra-industry sales, to other industries through inter-industry sales, and to the final consuming sectors which include households, government, capital formulation, and regional exports. In order to produce its product, the industry must purchase intermediate inputs from other industries and primary inputs from households, government, capital accumulation, and regional imports (i.e. land products, labor, capital, and management).

The pattern of sales and purchases of a given number of industries in a regional economy is described in the transaction table. A generalized transaction table is provided in Figure 3-1 for a four-industry regional economy. In Figure 3-1, "I" represents the intermediate purchases and sales between the four industries. "F" represents sales to the final consuming sectors (final demand) and "H" represents purchases of the primary inputs (value added). The table is balanced so that the sum of each row (total production) equals the

Producing Industry \ Purchasing Industry	1	2	3	4	5	Final Demand	Row Σ Total Production
1	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	F_1	X_1
2	I_{21}	I_{22}	I_{23}	I_{24}	I_{25}	F_2	X_2
3	I_{31}	I_{32}	I_{33}	I_{34}	I_{35}	F_3	X_3
4	I_{41}	I_{42}	I_{43}	I_{44}	I_{45}	F_4	X_4
5	I_{51}	I_{52}	I_{53}	I_{54}	I_{55}	F_5	X_5
Wages, Salaries, Interest, Taxes, Dep'n Profits	H_1	H_2	H_3	H_4	H_5	Σ Row or Column GNP	
Column Σ Total Outlays	X_1	X_2	X_3	X_4	X_5		

FIGURE 3-1

Input-Output Accounting System

sum of each column (total purchases or outlays). For example, the sum of the final demand column, "F", is equal to the primary input or value added row, "H", which is also equal to the gross regional product, GRP. The transaction table may be expressed by the equation below:

$$X_i = \sum_{j=1}^{n} I_{ij} + F_i$$

where X_i = total gross output,

I_{ij} = intermediate purchases or sales by a sector,

n = number of industries,

and F_i = final demand.

Considering a more specific example, a transaction table for a three industry economy is given in Figure 3-2. Applying the general equation given above to the farming sector, total production (1200) is equal to final demand (600 = 100 + 500) plus all intermediate sales (600 = 100 + 200 + 300). Similarly, total purchases or outlays (1200) are equal to the purchase of primary inputs (700 = 600 + 100) plus the purchase of all intermediate inputs (500 = 150 + 250 + 100). In other words, each entry of the transaction table represents a sales by the row sector to the column sector and a purchase by the column sector from the row sector. For example, the farming sectors sells 200 units

I = Processing Sector | II = Final Demand

	Outputs or sale / Inputs or purchases	Farming	Manufacturing	Trade	Total Intermediate Sales	Households	Other Payments	Total Final Demand	Total Production
Intermediate Inputs	Farming	100	200	300	600	100	500	600	1200
	Manufacturing	250	500	100	850	100	550	650	1400
	Trade	150	200	300	650	250	500	750	1500
	Total Intermediate Purchases	500	900	700	2100	450	1550	2000	4100
Primary Inputs	Households	100	250	100	450	50	150	200	650
	Other Payments	600	350	600	1550	150	25	175	1725
	Total Value Added	700	600	700	2000	200	175	375	2375
	Total gross outlays or purchases	1200	1500	1400	4100	650	1725	2375	6475

III = Intermediate Uses | IV = Final Uses

Figure 3-2

Hypothetical Transaction Table

of its output to the manufacturing sector. Similarly, the manufacturing sector purchases 200 of the farming sector's output.

To clarify this transacation table in Figure 3-2, it should be noted that the column labeled, "other payments" includes the following final consuming sectors: gross inventory accumulation, exports, government purchases, and gross private capital formation. The row labeled, "other payments" includes the following primary input or value added sectors: gross inventory depletion, imports, payments to government (taxes), and depreciation allowances.

Actually, the transaction table, also known as the input-output table or I-O matrix, may be divided into four quadrants, as also shown in Figure 3-2. 3.4/ Quadrant I shows the intermediate purchases and sales of goods and services among the producing or processing sectors. Quadrant II shows the sales by the producing sectors to the final consuming sectors. Thus, Quadrants I and II together describe the allocation of the output of every sector in the regional economy. Quadrant III shows the purchase of primary inputs or value added of each sector. Quandrants I and III show the distribution of inputs required for production by each sector. Quadrant IV shows important accounting totals such as gross regional products, GRP.

Utilization of the I-O Matrix

Once the I-O matrix has been formulated, it can be used to calculate several groups of numerical values which describe the interdependence of the sectors in the regional economy. The calculation of these values is a prerequisite to measuring economic impact. The calculation and use of the three groups of numerical values will be discussed below under the following headings: (1) technical coefficients, (2) output multipliers, and (3) income multipliers.

Technical Coefficients. Quadrant I is the most important aspect of the I-O matrix since it shows all intermediate purchases and sales. It may be expressed in a more simplified form, however, by calculating the technical coefficients. In order to calculate these coefficients, one must assume that the consumption of inputs is a linear function of total output for each consuming industry. The constancy of the technical coefficients depends upon the rate of technological change in the production process. Since technological change is always present, the use of the coefficients is questionable. Yet, it is a constraint of input-output analysis that the analyst must live with.

The technical coefficient may be calculated by dividing each column element of the I-O matrix by the column's respective total gross output as shown below:

$$a_{ij} = I_{ij}/X_j$$

where a_{ij} = technical coefficient of intermediate sales,
I_{ij} = intermediate purchase or sale by a sector,
X_j = total gross output,
and n = total number of sectors.

Using the above equation and the previous specific example, Table 3-1 and Table 3-2 were formulated. The technical coefficients for the original group of processing sectors, Quadrant I of Figure 3-2, are included in Table 3-1, while the technical coefficients for an expanded processing quadrant which includes the households sector are included in Table 3-2. These technical coefficients show the dollar purchases required by each column industry from each row industry to produce one dollar worth of the column industry's output. In this respect, the technical coefficients table is often referred to as the direct requirements table since it shows the dollar value of purchased inputs required to produce one dollar of product. For example, the farming sector must purchase \$0.0833 from itself, \$0.2083 from the manufacturing sector, \$0.1250 from the trade sector and \$0.5834 from the primary input sectors to produce one dollar of final output.

TABLE 3-1

Technical Coefficients or Direct Requirements Table

for Processing Sectors

	Farming	Manufacturing	Trade
Farming	0.0833	0.1333	0.2143
Manufacturing	0.2083	0.3333	0.0714
Trade	0.1250	0.1333	0.2143

TABLE 3-2

Technical Coefficients or Direct Requirements Table

for Processing Sectors, with Households Included

	Farming	Manufacturing	Trade	Households
Farming	0.0833	0.1333	0.2143	0.1538
Manufacturing	0.2083	0.3333	0.0714	0.1538
Trade	0.1250	0.1333	0.2143	0.3846
Households	0.0873	0.1667	0.0714	0.0769

If the purchases of the primary inputs are included in the direct requirements table, the resulting technical coefficients of each column sum to unity and thus define a sort of unit production function as shown below:

$$1 = \sum_{j=1}^{n} a_{ij} + a_{iHH} + a_{iop}$$

where n = total number of sectors,

a_{ij} = technical coefficients of intermediate sales,

a_{iHH} = household technical coefficient,

and a_{iop} = technical coefficient of other primary inputs.

Output Multipliers. The technical coefficients can be used to measure the direct impact on the level of purchases that results from a one dollar change in the output of any one industry. This is of limited use, however, since the total effect on the economy includes many indirect effects. When the output of one industry increases by one dollar, its purchases increase by the corresponding amounts as given by the industry's technical coefficients. This sets in motion a series of interactions and reactions throughout the whole I-O matrix since an additional purchase by one industry is an additional sale (increase in output) by another industry. A complicated process, utilizating matrix algebra, can be used to calculate the total direct and indirect impact of this change. In other words, the impact is actually measured across two static or equilibrium points, i.e. before and after the one dollar change.

The series of equations below demonstrates the method of calculating the total direct and indirect impact. In these equations the notation M^{-1}, where M is some matrix, signifies the inverse of matrix M and the notation, M^T, signifies the transposition of matrix M (i.e. exchanging corresponding rows and columns).

$$I - A = L,$$

$$(I - A)^{-1} = L^{-1},$$

$$\text{and } [(I - A)^{-1}]^T = (L^{-1})^T$$

where I = identity matrix,

A = matrix of technical coefficients of original processing sector

and L = Leontief matrix (input requirements matrix)

Using the above equations and the previous example, Table 3-3 was constructed.

TABLE 3-3

Direct and Indirect Requirements per Dollar of Final Demand

	Farming	Manufacturing	Trade	Total
Farming	1.211	0.406	0.262	1.879
Manufacturing	0.314	1.633	0.327	2.274
Trade	0.359	0.259	1.374	1.992

Each row entry of Table 3-3, signified by the notation E_{ij}, represents the total dollar production directly and indirectly required by the row industry from the column industry in order that the row industry can deliver one dollar of its output to final demand. The sum of a row $\sum_{j=1}^{n} E_{ij}$, is known as an output multiplier and represents the total increase in the output of all industries directly and indirectly required by the row industry to deliver one more dollar to final demand. For example, if the farming sector delivers one more dollar to final demand, the manufacturing sector will increase the output by \$0.406 and the trade sector will increase its output by \$0.262. The farming sector will increase its output by \$1.211; \$1.00 is delivered to final demand and \$0.211 is accounted for by direct and indirect effects. The farming sector's output multiplier shows that if the sector delivers one more dollar of its output to final demand, the output by all industries will increase by \$1.879.

Income Multipliers. The income multipliers are calculated in a manner similar to the output multipliers. First, however, the processing sector, Quadrant I, must be expanded to include the household sector. That is, we must include one additional row and one additional column. The technical coefficient table is then calculated as was done in Table 3-2. Using the same matrix algebra as described earlier, the direct, indirect, and induced requirements table is calculated as shown in Table 3-4.

TABLE 3-4

Direct, Indirect, and Induced Requirements per Dollar of Final Demand

	Farming	Manufac-turing	Trade	Households
Farming	1.301	0.506	0.411	0.241
Manufacturing	0.468	1.804	0.583	0.413
Trade	0.441	0.350	1.510	0.220
Households	0.478	0.531	0.795	1.284

Each row entry of Table 3-4 represents the total dollar increase in the column industry's production when the row industry delivers an additional dollar to final demand. This table measures the impact on production which results from increased spending by the household sector.

This table can be used with other requirements tables previously calculated to determine two types of multipliers 3.5/. In order to calculate the income multipliers, the direct, indirect, and induced income effects must be separated. The direct income effect is given by the household row of Table 3-3, the direct requirements table with the households sector included in the processing sectors. The total direct and indirect income effect is equal to the sum of the products of each row entry of Table 3-3, the direct and indirect requirements table, times the household coefficient of the corresponding column in Table 3-2. The Type I income multiplier is equal to the sum of the direct and indirect income effects divided by the direct income effect. The multiplier represents the direct and indirect impact on income that results when a sector delivers an additional dollar of its output to final demand. It is known as the interindustry income multiplier.

TABLE 3-5

Type I Income Multiplier

Industry	Direct Income Effect	Direct and Indirect Income Effect	Type I Income Multiplier
	(1)	(2)	(3)=(2)/(1)
Farming	0.08	0.19	2.25
Manufacturing	0.17	0.32	1.93
Trade	0.07	0.17	2.40

The second type of income multiplier, Type II is known as the total income multiplier and is equal to the sum of the direct, indirect, and induced income effects divided by the direct income effect. The direct, indirect, and induced income effect is given by the household column of Table 3-4. This income multiplier shows "the chain reaction of interindustry reactions in income, output, and once more on consumer expenditures" 3.6/. The calculation of the Type II income multiplier is shown in Table 3-6.

TABLE 3-6

Type II Income Multiplier

Industry	Direct Income Effect	Direct, Indirect and Induced Income Effect	Type II Income Multiplier
	(1)	(2)	(3)=(2)/(1)
Farming	0.08	0.24	2.89
Manufacturing	0.17	0.41	2.48
Trade	0.07	0.22	3.08

There are several other types of multipliers which one may calculate such as the employment multipliers described by Miernyk and others 3.7/, 3.8/, 3.9/, and the consumption multiplier described by Wang. 3.10/ No attempt has been made in this Thesis, however, to calculate these additional multipliers and this author refers the reader to the above noted works for additional information.

The above description of input-output analysis is a summary of many individuals work. This author refers the reader to works of Miernyk 3.11/, Geehan 3.12/, Yan 3.13/, and Chenery and Clark 3.14/ for further information. In particular, the work of Geehan includes a very clear and concise description of input-output analysis.

CHAPTER 4: ECONOMIC MODEL OF THE STATE OF COLORADO

Having discussed the elements of input-output analysis, the Colorado economy can now be incorporated into the input-output model. The purpose of this chapter is two-fold: 1) to describe how the model was formulated and 2) to present the raw data which will be used later in this Thesis to measure economic impact.

Methodology

The methodology of developing an economic model consists of disaggregating the economy into separate industrial activities or sectors, defining a set of conventions upon which the data is collected and compiled, and obtaining the necessary data to formulate the model.

Disaggregation of the Colorado Economy. The first step towards developing an economic model involves the organization of the economy into discrete sectors. Each sector represents a group of firms or industries which have certain similarities. The organization of a regional economy into various sectors can be based on several criteria: type of product, kind of market, or level of production. In practice, however, no one criteria can be used to formulate the entire model. Some industries may service the same kind of market, but produce a variety of products. Other firms may deal with the same commodity, but be engaged in different levels of production. In this Thesis, all three criteria were considered when defining the individual sectors.

Another factor which must be considered when disaggregating the economy is industrial emphasis. This refers to the degree of disaggregation or importance placed on one type of industry such as mining, agriculture, or manufacturing. In a study of the Kansas economy 4.1/, for example, the agricultural industry was disaggregated into 12 separate sectors. In this study all agriculture has been aggregated into one sector. Similarly, in the Kansas study the mineral industry included 5 sectors, while in this study the mineral industry has been split into 9 sectors out of a total of 20 processing sectors. Clearly, this study emphasizes the importance and impact of the mineral industry on the Colorado economy.

The Colorado economy was disaggregated into 20 processing sectors, as shown in Figure 4-1. A definition of each sector is included in the appendix. The 20-sector model is highly

Colorado Economy

Mineral Industry	Non-Mineral Industry
1) Petroleum production and natural gas processing	1) Agriculture
2) Coal mining	2) Food and kindred products
3) Metal mining	3) Fabricated metal
4) Industrial minerals (mining and processing)	4) Chemical industries
5) Industrial services	5) Printing and publishing
6) Pipeline transportation	6) All other manufacturing
7) Petroleum refining	7) Retail and wholesale trade
8) Electric power generation	8) Construction
9) Metal processing	9) All other transportation
	10) Communications and public utilities
	11) Insurance, finance, real estate, and general services

FIGURE 4-1

Processing Sectors in Colorado Economy

aggregated in comparison to other studies. The Kansas model was made up of 69 processing sectors, while the 1963 Input-Output Structure of the U.S. Economy utilized 370 sectors. As such, the model does not fully describe the complex nature of the interrelationships between individual industrial activities in the economy. It does, however, show the relationships between individual industrial activities in the economy. In addition, the model is adequate for measuring aggregated economic impact on broad areas of the regional economy. These are the two major points of emphasis of this study. Although it is very favorable to obtain a high degree of disaggregation, it was not of primary importance in this study.

Accounting Conventions. Before the data are presented, the various accounting conventions utilized in collecting and compiling the data should be explained in order to clarify the interpretation of the overall model.

First, the commodity flows given in the transaction matrix are expressed in terms of 1972 dollars and represent, for each sector in the State, purchases from and sales to other sectors.

Second, the dollar values of interindustry transactions are based on producer prices rather than purchaser or consumer prices. The difference between these two price systems is that the latter includes marketing costs such as transportation and retail and wholesale trade. These marketing costs have been expressed as a direct purchase from the transportation, and retail and wholesale trade sectors, rather than as part of the cost of the commodity purchased from one of the other processing sectors.

Third, the transactions of the retail and wholesale sector with other processing sectors are expressed on a gross margin basis of operating costs and net revenue which is approximately equal to gross sales minus the cost of goods sold. In effect, the retail and wholesale trade sector does not purchase any commodities for resale. Instead, these commodities are shown as direct purchases by the consuming sector. Although this procedure is incongruous with the real world, the flow of commodities between producing and consuming sectors is more clearly represented than if all commodities flowed to the trade sector and then to the final consumers.

Fourth, the commodity flows expressed by the transaction matrix include only materials used in the productive process and exclude capital expenditures. Capital that is consumed is expressed as depreciation under "other payments" in the value added sectors. Sales of capital goods or capital investment is shown under "other payments" in the final demand sectors.

Fifth, the output of secondary products was included in the output of the sector's primary output. The treatment of secondary products presented no problem in this study since the economy is highly aggregated into only 20 sectors.

Sixth, it was assumed that inventory draw-down and build-up was in balance for each sector. No attempt was made to show changes in inventory since this type of data was not available on a sector-by-sector basis.

The six conventions described above are standard practice for input-output studies. These conventions were used in the government study of the U.S. economy 4.3/, the Kansas study 4.4/, and by others who have studied the mineral industry by input-output analysis. 4.5/

Data Collection and Compilation. All of the data collected to formulate the transaction matrix were obtained from secondary sources of information. Both the sources of information and the manner in which they were used fall into two categories: the data for the mineral industry sectors and the data for the non-mineral industry sectors.

All of the necessary data for the mineral industry sectors were obtained directly from a recent study of the mineral industry in Colorado 4.6/. This study, which was conducted at the Colorado School of Mines, was based primarily on direct industry information and provided data for total output, interindustry purchases and sales, elements of value added, and sales to the final demand sectors. The data were easily implemented into the model with very little adjustment.

The collection and compilation of data for the non-mineral industry sectors, however, were more difficult. First, the regional industry or sector total gross outputs were either obtained or estimated from a survey of the Colorado economy 4.7/. Next, an aggregated technical coefficients table was calculated from an input-output analysis of the Kansas economy 4.8/. The Kansas study was made up of 69 industry sectors; thus, this author aggregated the sectors so that the Kansas model was in the same form as the model developed in this Thesis. A comparison of the Kansas model and the input-output model developed here is provided in the appendix.

Each element of an industry column included in the technical coefficient table was multiplied times the corresponding industry's total gross output. This procedure yielded the imports, interindustry purchases, and elements of value added for each column sector (i.e. all processing sectors). By repeating this procedure for each column sector, quadrants I and III of the transaction table were formulated. Here it should be noted that the use of the Kansas study is based on the assumption that Colorado's input patterns are identical to Kansas input patterns. In addition, it assumes that the technical coefficients or level of technology has not changed over time. Both of these assumptions introduce a great amount of error into the model and because of this, they will be discussed at greater length in the concluding chapter of this Thesis.

The process of calculating the column elements can be expressed mathematically as shown below:

$$I_i = I_{ik} (TO_i)$$

where I_i = imports of goods by Colorado industry's,

I_{ik} = imports coefficient for Kansas study (i.e. value of imports divided to total output),

and TO_i = total output of Colorado industry i;

$$X_{il} = A_{ilk} (TO_l),$$

where X_{il} = intermediate purchase by Colorado sector l from Colorado sector i,

A_{ilk} = technical coefficient of sector l of Kansas study (i.e. purchase by sector l from sector l, divided by total output of sector l),

and TO_l= total output of Colorado sector l; and

$$VA_{il} = VA_{ilk} (TO_l),$$

where VA_{il} = value added element i of Colorado sector l,

VA_{ilk} = value added coefficient of sector l of Kansas study (i.e. value added element i of sector l, divided by total gross output of sector l),

and TO_l = total output of Colorado sector l.

Next, the second quadrant of the transaction matrix was formulated by calculating the element of final demand (sales to households, government, exports, and "other payments") by multiplying the total gross output of each row industry by a final demand coefficient calculated for the corresponding industry in the Kansas study. This procedure is expressed mathematically as shown below:

$$FD_{il} = fd_{ilk}\ (TO_l),$$

where FD_{il} = final demand element i of Colorado sector l,

fd_{ilk} = final demand coefficient of sector l of Kansas study (i.e. final demand of sector l divided by total output of sector l),

and TO_l = total gross output of Colorado sector l.

The final step of development concerns the balancing of the rows and columns of the transaction table. It is the most critical step in formulating an accurate input-output study. The balancing of row and column elements so that they add up to total gross output involves the adjustments of import and export values.

The elements of each row in the transaction table may be expressed as follows:

$$X_{11} + X_{12} + \ldots + X_{1i} + H_1 + G_1 + O_1 + E_1 = TO_1, \tag{3-1}$$

where,

H_1 = sales to households by sector 1,

G_1 = sales to government by sector 1,

O_1 = sales to other payments (i.e. capital formation and inventory build-up) by sector 1,

E_1 = exports from region by sector 1,

and TO_1 = total gross output of sector 1.

The left hand side of equation (3-1) should equal the right-hand side of the equation, the total gross output. However, since the intermediate purchases and sales were calculated independently from final demand, inequalities invariably occurred. When the left-hand side of the equation was less than the total gross output, it was assumed that the sector had more exports than had been originally calculated. The value for exports was then adjusted so that equation (3-1) balanced. When the left-hand side of the equation was greater than total gross output, a more complex approach was needed to balance equation (3-1).

For the import-case, when the left-hand side of equation (3-1) was greater than total gross output, either the original value calculated for exports was too large or the interindustry sales originally calculated were too large and thus included additional imports. The method used to determine which case applied was developed by Schaffer and Chu 4.9/ and was also used in a similar input-output study of the mineral industry 4.10/. This method, which has been found to be very accurate, involves the use of location quotients which can be defined as:

$$LQ_i = \frac{TO_{Ri}/GRO}{TO_{Ni}/GNO},$$

where LQ_i = location quotient of sector i,

TO_{Ri} = total regional output of sector i,

GRO = total gross output of all regional sectors,

TO_{Ni} = total national output of sector i,

and GNO = total gross output of all national sectors which exist in the region.

When the location quotient calculated as shown above was greater than or equal to one, the value of exports originally calculated was reduced so that equation (3-1) was in balance (i.e. that the sum of all row elements equaled total gross output of sector i). When the location quotient was less than one, each row element was multiplied by the quotient, thereby reducing it accordingly. The value of imports originally calculated was then increased by an amount equal to the sum of the multiplication of each row entry of sector i times the quantity of one minus the location coefficient.

With quadrants I, II, and III completed, the fourth and final quadrant showing pertinent accounting totals could be formulated. The values were derived by calculating coefficients similar to those already discussed from the Kansas study. The household row and column was balanced first, followed by government, exports and imports, and lastly the "other payments" row and column. It should be mentioned that some of these entries are not that meaningful and only represent accounting totals so that all rows and columns balance.

The description above may have left the reader with a simplistic view of the methodology of developing an input-output model. In practice, the formulation of the transaction matrix is a tedious, subjective, trial and error procedure. It at best yields only a crude approximation of the complex real world. A more thorough discussion of the problems involved in developing an input-output model will be included in the last chapter of this Thesis.

Transaction Matrix

The methods described above resulted in the transaction matrix shown in Table 4-1. Quadrant IV of this table shows important accounting totals which describe the overall Colorado economy. The total output from the household sector, $10.4 billion, represents total personal income. The intersection of the "import row" with the "export column", $243 million, represents net exports, i.e. the value of exports minus imports. The intersection of the "other payments" row and column, $2.5 billion, represents the total value of

TABLE 4-1

Transaction Matrix of Colorado Economy*
Quadrant I: Processing Sectors

Output / Input	Pet. Prod. & NG Prc.	Coal Mining	Metal Mining	Indust. Mineral	Indust. Services	Pipeline Trans.	Petrol. Refining
Pet. Prod. & NG Prc.	14,554	0	0	0	0	129,985	0
Coal Mining	0	0	0	0	0	0	0
Metal Mining	0	0	0	0	0	0	0
Indust. Minerals	0	975	1,362	0	415	0	0
Indust. Services	35,435	1,276	20,701	216	0	0	0
Pipeline Trans.	0	0	0	0	0	0	60,011
Petrol. Refining	0	0	0	0	0	0	0
Elec. Pow. Generat.	0	0	0	0	0	0	0
Metal Proces.	0	0	0	0	0	0	0
Agric.	0	0	0	0	0	0	0
Food & Kin. Prod.	0	0	0	0	0	0	0
Fab. Metal	6,771	3,401	5,991	6,160	2,360	3,210	2,350
Chemical etc.	2,455	1,698	8,033	2,194	336	650	458
Printing & Pub.	633	50	272	333	45	85	30
All other Manufac.	316	518	8,576	7,156	6,767	4,111	4,048
Retail & Misc. Tr.	633	249	4,188	10,839	4,851	3,818	1,552
Construction	0	1,000	4,814	5,375	0	0	0
All other Trans.	3,291	3,374	5,994	26,785	2,167	380	100
Comm. & Pub. Util.	6,581	1,399	11,441	2,711	151	765	31
In., F., R.E., GS	2,685	190	401	786	4,163	1,037	20
Households	18,935	15,577	59,655	37,718	110,566	11,377	3,380
Government	14,580	3,401	8,038	5,807	5,500	5,474	443
Imports	0	7,477	17,032	0	0	112,519	109,423
Other	37,697	12,233	31,785	22,964	5,862	51,570	5,794
Total Output	144,539	52,818	188,283	129,044	143,183	324,981	187,640

* All values in $1,000

TABLE 4-1 (Cont.)

Transaction Matrix of Colorado Economy
Quadrant I: Processing Sectors

Elec. Power Generat.	Metal Proc-cessing	Agri-culture	Food & Kindred Prod.	Fabri-cated Metal	Chemical Industries	Printing & Publish.	All Other Manufac.	Retail & Wholesale Trade
0	0	0	0	0	0	0	0	0
19,840	10,644	0	0	2,300	40	0	1,000	0
0	17,957	0	0	0	0	0	0	0
0	1,726	0	0	0	3,000	0	0	2,522
0	0	0	0	0	0	0	0	0
17,107	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	187,640
0	0	0	0	0	0	0	0	0
0	21,746	0	0	32,397	0	0	0	0
0	0	592,994	873,418	0	336	0	8,059	1,175
0	0	89,155	69,300	0	2,315	0	0	289,996
4,889	13,850	10,578	47	50,470	1,015	628	4,192	283,340
0	1,995	46,508	745	2,668	9,495	1,313	1,920	160,348
150	90	3,694	22,728	8,094	27,356	8,563	9,578	55,271
6,505	6,871	168	1,084	1,340	1,006	0	1,167	176,249
5,184	6,421	88,315	52,945	251,649	80,284	48,105	22,336	181,662
3,211	5,600	8,221	3,959	8,742	1,155	4,289	16,000	209,671
0	345	5,541	17,019	19,396	8,906	5,052	5,661	191,712
0	5,029	12,257	9,574	28,105	5,860	4,510	4,062	186,043
350	393	24,010	13,957	14,646	5,454	3,168	3,155	348,225
12,448	51,599	385,170	200,977	368,554	82,861	84,514	362,000	1,320,672
29,648	9,188	27,536	96,777	128,025	23,081	18,980	22,289	651,317
0	0	280,560	471,865	553,671	203,419	92,534	195,704	1,931,048
51,685	10,616	384,853	32,605	83,243	57,517	23,634	25,477	714,334
151,017	164,070	1,959,560	1,867,000	1,553,300	513,100	295,200	682,600	6,892,025

TABLE 4-1 (Cont.)

Transaction Matrix of Colorado Economy
Quadrant I.: Processing Sectors

Construction	All Other Transportation	Commun. & Public Utilities	In., Fin., R.E. & Gen. Svs.	Households	Government	Exports	Other	Total Output
0	0	0	0	0	0	0	0	144,539
2,000	0	0	0	500	0	15,994	500	52,818
0	0	0	0	0	0	170,326	0	188,283
100,267	0	0	0	0	10,000	8,777	0	129,044
0	0	0	0	0	0	85,555	0	143,183
0	0	103,529	0	0	0	144,334	0	324,981
0	0	0	0	0	0	0	0	187,640
0	0	151,017	0	0	0	0	0	151,017
0	0	0	0	0	0	109,927	0	164,070
0	0	0	0	16,681	73,000	393,897	0	1,959,560
0	0	0	34,325	290,598	75,374	1,014,492	1,445	1,867,000
42,020	5,542	6,927	41,761	18,802	228,746	567,893	242,357	1,553,300
27,340	1,412	1,020	3,453	57,675	6,138	175,011	235	513,100
825	7,104	7,564	1,992	11,275	4,413	122,652	2,403	295,200
7,423	303	648	6,007	8,524	256,200	173,472	4,141	682,600
348,040	89,840	16,580	98,555	3,785,660	546,020	1,198,509	45,880	6,892,025
389,508	6,173	26,360	61,788	65,817	172,574	351,603	714,811	2,060,671
13,169	33,272	63,086	5,750	69,602	53,705	344,576	0	878,883
7,451	5,172	37,256	76,615	301,083	113,519	67,726	0	883,231
41,374	20,648	18,580	116,618	926,037	431,032	333,357	0	2,310,259
405,382	303,677	228,070	1,271,633	1,625,553	1,885,000	0	1,554,682	10,400,000
107,564	105,987	35,843	164,686	1,555,853	645,448	0	1,003,342	4,668,806
513,357	210,048	16,828	314,445	0	145,066	243,171	0	5,418,167
54,861	89,705	169,924	112,631	1,666,340	22,571	(98,105)	(2,508,104)	1,061,692
2,060,671	878,883	883,231	2,310,259	10,400,000	4,668,806	5,418,167	1,061,692	42,932,069

transfer payments. Transfer payments include payments made by one sector to another for which no services are performed and government debt. Private transfer payments include payments for old products (resale) and gifts. The value of transfer payments in Colorado was estimated from national data 4.12/.

Another value which can be calculated from the transaction table is gross regional product, GRP. The sum of the total outputs of the household, government, and "other payments" sectors less transfer payments is equal to the gross regional product. The calculation of the gross Colorado Product (GCP) is as follows:

$$GCP = TO_H + TO_G + TO_O - TRP,$$

where GCP = gross Colorado product ($13,622,394,000),

TO_H = total output of households sector ($10,400,000,000),

TO_O = total output of "other payments" sector ($1,061,692,000),

and TRP = transfer payments ($2,508,104,000).

The above method for calculting GRP is the same as that used in the Kansas study. The resulting GCP value compares favorably with other estimates which are calculated by factoring GCP out of total U.S. GNP on the basis of population or personal income 4.13/. Such estimates vary between $12.8 and $13.1 billion.

The gross regional product is also related to value added which is equal to the value of total output minus the cost of goods and services consumed in the productive process. The value added by each processing sector has been estimated in Table 4-2 by summing the household, government, and "other payments" column entries for each processing sector. On the basis of value added, retail and wholesale trade and services are the two largest sectors in Colorado. Colorado's economy is basicly a service economy in which labor is the most important commodity. Wages and salaries represent the largest portion of value added and both of the above sectors are labor intensive. The value added of all of the mineral industry sectors amounts to only $633.54 million or 7.2 percent of the value added of all processing sectors. On the average, value added represents 53.7 percent of the total value of production from each processing sector in Colorado.

If one adds the value added from all processing sectors ($8.78 billion) to the value added by government ($1,885 billion) and households ($.485 billion), GCP can be estimated. Value added by government includes only wages and salaries for government employees. It is interesting to note the importance of government employment in Colorado which is valued at almost $1.9 billion and represents 18.1 percent of total personal income. The value added by

TABLE 4-2

Comparison of Value Added for Each Sector of Colorado Economy

Sector	Total Output Less Imports (1000 dollars)	Value Added (1000 dollars)	Value Added as a Percent of Total Output
Retail & Wholesale Trade	4,960,977	2,686,323	54.1
In., Fin., R.E., & Gen. Svs.	1,995,814	1,548,950	77.6
Agriculture	1,679,000	797,559	47.5
Fabricated Metal	999,629	579,822	58.0
Construction	1,547,314	567,807	36.7
All Other Transportation	668,785	499,369	74.7
Comm. & Public Utilities	866,403	433,836	50.1
All Other Manufacturing	486,896	409,766	84.2
Food & Kindred Products	1,395,135	330,359	23.7
Chemical Industries	309,681	163,459	52.8
Printing & Publishing	202,666	127,128	62.7
Industrial Services	143,183	121,928	85.2
Metal Mining	171,251	99,478	58.1
Electric Power Generation	151,017	93,781	62.1
Metal Processing	164,070	71,403	43.5
Pet. Prod. & N.G. Process.	144,539	71,212	49.3
Pipeline Transportation	212,462	68,421	32.2
Industrial Minerals	129,044	66,489	51.5
Coal Mining	45,341	31,211	68.8
Petroleum Refining	78,217	9,617	12.3
Total	16,351,424	8,777,918	53.7

households includes only the compensation of servants and other household employees. It was estimated from national data to be $485 million. The resulting value of GCP is $11.15 billion and is somewhat low in comparison with other estimates. This author felt, however, that all estimates of GCP were within reasonable limits, considering the error involved in developing the input-output model.

Multiplier Analysis

Following the outline described in Chapter 3, the various I-O matrices were calculated. By dividing each column entry by the column sector's total output, the direct requirements or technical coefficient table was calculated. The direct requirements for each processing sector and the household sector is shown in Table 4-3. Each column entry of this table represents the direct requirements by the column sector from the row sector per dollar of final demand.

By subtracting the processing sectors' direct requirement matrix from an identity matrix to form the Leontief matrix and then transposing the inverse of the Leontief matrix, the direct and indirect requirements matrix was developed as shown in Table 4-4. Each column entry of this table represents the total direct and indirect requirements by the row industry from the column industry per dollar of

TABLE 4-3

Technical Coefficients Per Dollar of Total Output or Direct Requirements

Sector	1	2	3	4	5	6	7
Pet. Prod. & N.G. Process.	0.100692	0	0	0	0	0.399977	0
Coal Mining	0	0	0	0	0	0	0
Metal Mining	0	0	0	0	0	0	0
Industrial Minerals	0	0.018459	0.007234	0	0.002898	0	0
Industrial Services	0.245158	0.024158	0.109946	0.001674	0	0	0
Pipeline Transportation	0	0	0	0	0	0	.319819
Petroleum Refining	0	0	0	0	0	0	0
Electric Power Generation	0	0	0	0	0	0	0
Metal Processing	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0
Food & Kindred Products	0	0	0	0	0	0	0
Fabricated Metal	0.046845	0.064391	0.031819	0.047736	0.016482	0.009878	0.012524
Chemical Industries	0.016985	0.032148	0.042664	0.017002	0.002347	0.002000	0.002441
Printing & Publishing	0.004379	0.000947	0.001445	0.002581	0.000314	0.000262	0.000160
All Other Manufacturing	0.002186	0.009807	0.045548	0.055454	0.047261	0.012650	0.021573
Retail & Wholesale Trade	0.004379	0.004714	0.022243	0.083995	0.033880	0.011748	0.008271
Construction	0	0.018935	0.025568	0.041652	0	0	0
All Other Transportation	0.022769	0.063880	0.031835	0.207564	0.015134	0.001169	0.000533
Communications & Public Utilities	0.045531	0.026487	0.060765	0.021008	0.001054	0.002354	0.000165
In., Fin., R.E., Gen. Services	0.018390	0.003597	0.002130	0.006091	0.032218	0.003191	0.000106
Households	0.131002	0.294918	0.316836	0.292287	0.772200	0.235008	0.018013

TABLE 4-3 (Cont.)

Technical Coefficients Per Dollar of Total Output or Direct Requirements

8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0
0.131375	0.064875	0	0	0.001407	0.000078	0	0.001465	0	0.000971
0	0.109447	0	0	0	0	0	0	0	0
0	0.010520	0	0	0	0.005847	0	0	0.000366	0.048657
C	0	0	0	0	0	0	0	0	0
0.113278	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0.027226	0
0	0	0	0	0	0	0	0	0	0
0	0.132540	0	0	0.020857	0	0	0	0	0
0	0	0.302615	0.467818	0	0.000655	0	0.011806	0.000170	0
0	0	0.045497	0.037118	0	0.004512	0	0	0.042077	0
0.032374	0.084415	0.005398	0.000025	0.032492	0.001978	0.002127	0.006141	0.041111	0.020391
0	0.012159	0.023734	0.000399	0.001718	0.018505	0.004448	0.002813	0.023266	0.013267
0.000993	0.000548	0.001885	0.012174	0.005211	0.053315	0.029007	0.014032	0.008020	0.000400
0.043075	0.041878	0.000086	0.000581	0.000863	0.001961	0	0.001710	0.025573	0.003602
0.034327	0.039136	0.045069	0.028358	0.162009	0.156468	0.162652	0.032722	0.026358	0.168896
0.021262	0.034132	0.004195	0.002121	0.005628	0.002251	0.014529	0.023440	0.030422	0.189019
0	0.002103	0.002828	0.009116	0.012487	0.017357	0.017114	0.008293	0.027816	0.006391
0	0.030652	0.006255	0.005128	0.018094	0.011421	0.015278	0.005951	0.027110	0.003659
0.002318	0.002395	0.012253	0.007476	0.009429	0.010630	0.010732	0.004622	0.050526	0.020078
0.082428	0.314493	0.196559	0.107647	0.237271	0.161490	0.286294	0.530325	0.191623	0.196723

TABLE 4-3 (Cont.)

Technical Coefficients Per Dollar of Total Output of Direct Requirements

18	19	20	Households
0	0	0	0
0	0	0	0.000048
0	0	0	0
0	0	0	0
0	0	0	0
0	0.117216	0	0
0	0	0	0
0	0.170982	0	0
0	0	0	0
0	0	0	0.001604
0	0	0.014858	0.027942
0.006306	0.007843	0.018076	0.001809
0.001606	0.001155	0.001495	0.005546
0.008083	0.008564	0.000862	0.001084
0.000345	0.000734	0.002600	0.000820
0.102220	0.018772	0.042660	0.364005
0.007024	0.029845	0.026745	0.006328
0.037857	0.071426	0.002489	0.006692
0.005885	0.042181	0.033163	0.028950
0.023493	0.021036	0.050478	0.089042
0.345526	0.258222	0.550428	0.063900

TABLE 4-4

Direct and Indirect Requirements Per Dollar of Final Demand*

Sector	1	2	3	4	5	6	7	8
Pet. Prod. & N.G. Proc.	1.115610	0.001523	0.000165	0.001305	0.273557	0.008237	0.001064	0.009886
Coal Mining	0.002131	1.000960	0.000190	0.020226	0.024759	0.004791	0.001121	0.005548
Metal Mining	0.004393	0.001786	1.000090	0.009848	0.111089	0.009877	0.001619	0.011717
Industrial Minerals	0.002405	0.001022	0.000158	1.003280	0.002311	0.005408	0.003833	0.005236
Industrial Services	0.000468	0.000247	0.000054	0.003110	1.000100	0.001053	0.001254	0.000816
Pipeline Transportation	0.446495	0.000742	0.000096	0.000617	0.109486	1.003880	0.000856	0.004546
Petroleum Refining	0.142909	0.000337	0.000067	0.000291	0.035051	0.321322	1.000590	0.001636
Electric Power Generation	0.051230	0.131859	0.000133	0.004242	0.015766	0.115184	0.001604	1.001740
Metal Processing	0.003673	0.076522	0.126476	0.017867	0.016685	0.008259	0.002592	0.009302
Agriculture	0.001209	0.000385	0.000035	0.000904	0.000311	0.002719	0.002327	0.002472
Food and Kindred Products	0.001178	0.000368	0.000023	0.000718	0.000301	0.002648	0.002116	0.002468
Fabricated Metal	0.002396	0.003829	0.002752	0.001348	0.000985	0.005388	0.005061	0.004719
Chemical Industries	0.001940	0.000593	0.000032	0.006728	0.000505	0.004362	0.005040	0.003443
Printing & Publishing	0.002149	0.000601	0.000032	0.001500	0.000547	0.004832	0.005075	0.004016
All Other Manufacturing	0.000722	0.001731	0.000026	0.001647	0.000224	0.001623	0.001291	0.001515
Retail & wholesale Trade	0.006249	0.001030	0.000130	0.002806	0.001576	0.014051	0.028911	0.006015
Construction	0.001909	0.001723	0.000109	0.061026	0.000624	0.004292	0.006545	0.002753
All Other Transportation	0.001172	0.000324	0.000035	0.000844	0.000300	0.002636	0.003255	0.001996
Communications & Public Utilities	0.064156	0.023788	0.000068	0.002930	0.016315	0.144245	0.001535	0.179961
In., Fin., R. E. & Gen Svs.	0.002649	0.001011	0.000064	0.002003	0.000684	0.005957	0.001691	0.006780
Sum of Column	1.855043	1.250381	1.130735	1.143240	1.611176	1.670764	1.077380	1.266565

*requirements matrix is not transposed

TABLE 4-4 (Cont.)

Direct and Indirect Requirements Per Dollar of Final Demand

9	10	11	12	13	14	15	16	17	18
0.001510	0.001977	0.002465	0.062794	0.021526	0.008130	0.017380	0.039081	0.006719	0.038194
0.001733	0.001772	0.002226	0.072082	0.035064	0.004889	0.013914	0.041186	0.029520	0.076906
0.000989	0.003109	0.003183	0.041168	0.046545	0.006701	0.054072	0.059455	0.040171	0.046309
0.001444	0.005695	0.006883	0.060082	0.022596	0.008576	0.060398	0.140790	0.063304	0.225384
0.000495	0.002681	0.002739	0.020605	0.003984	0.002030	0.048962	0.046053	0.005152	0.019103
0.000874	0.001564	0.001796	0.036334	0.011154	0.004111	0.020129	0.031432	0.004103	0.017597
0.000610	0.001297	0.001199	0.025386	0.006504	0.002171	0.028443	0.022748	0.002667	0.007117
0.001214	0.002796	0.002902	0.050517	0.007806	0.003609	0.048810	0.058925	0.034546	0.015313
1.155600	0.004226	0.004708	0.118611	0.026525	0.005550	0.060270	0.095202	0.064621	0.025957
0.000319	1.483920	0.074432	0.013270	0.038320	0.006988	0.002853	0.085473	0.013090	0.010038
0.000208	0.722241	1.076490	0.008645	0.020142	0.017041	0.003101	0.077713	0.011548	0.016800
0.025144	0.006078	0.008791	1.045750	0.007441	0.008288	0.007564	0.185903	0.018048	0.022393
0.000288	0.010359	0.013748	0.012001	1.024250	0.058612	0.007643	0.185127	0.013471	0.028456
0.000293	0.006083	0.008848	0.012182	0.009883	1.032680	0.005478	0.186410	0.027911	0.026668
0.000237	0.019110	0.003142	0.009876	0.005138	0.015513	1.003310	0.047425	0.032156	0.011992
0.001192	0.033695	0.049071	0.049576	0.027360	0.012382	0.029066	1.061890	0.045636	0.036832
0.000995	0.008144	0.011648	0.041384	0.024238	0.005045	0.014687	0.240387	1.248550	0.031220
0.000319	0.004094	0.005954	0.013304	0.005067	0.010322	0.003872	0.119542	0.015617	1.044650
0.000624	0.002334	0.003110	0.025948	0.005909	0.011758	0.013510	0.056394	0.048941	0.085147
0.000588	0.013326	0.019707	0.024435	0.004224	0.002633	0.005159	0.062109	0.039627	0.009037
1.194676	2.334501	1.303042	1.743950	1.353676	1.227029	1.448621	2.843245	1.765398	1.795113

TABLE 4-4 (Cont.)

Direct and Indirect Requirements per Dollar of Final Demand

19	20	Sum of Row	Household
0.057820	0.036492	1.705435	.131002
0.032451	0.011547	1.383016	.294919
0.068527	0.014243	1.534891	.316836
0.030621	0.023054	1.672480	.292287
0.004773	0.037676	1.201355	.772200
0.026588	0.019204	1.741604	.035008
0.009569	0.007327	1.617241	.018013
0.010215	0.010288	1.568699	.082428
0.054403	0.014494	1.891543	.314493
0.014459	0.025839	1.779363	.196559
0.014431	0.023484	2.001664	.107647
0.027597	0.022388	1.411863	.237271
0.020138	0.023937	1.420673	.161490
0.023490	0.023867	1.382545	.286294
0.008861	0.009231	1.174770	.530325
0.035178	0.061328	1.503974	.191623
0.016099	0.041810	1.763188	.196723
0.011676	0.033276	1.278255	.345526
1.052520	0.032868	1.772061	.258222
0.039653	1.059210	1.300547	.550428
1.559069	1.531563	31.105167	5.319293

final demand. The sum of each row of Table 4-4 is the output multiplier and represents the cumulative effect on the output of all sectors if the column sector delivers an additional dollar to final demand.

A comparison of the output multipliers of all processing sectors is provided in Table 4-5. This multiplier provides a good indication of the dependence of one sector on all other sectors. In general, the greater the value of the output multiplier, the greater the dependency of one sector on itself and all other sectors for its inputs to the productive process. Conversely, a low output multiplier indicates that that sector purchases a relatively small portion of its production inputs from other sectors in the region. The output multiplier minus one represents the purchase of inputs from other regional sectors. Referring to Table 4-5, it is interesting to note that many of the base industries, which include some of the mineral industry sectors, food and agricultural sectors, and the construction sector, have relatively large output multipliers. On the other hand, the labor intensive sectors such as mineral industry services, general services, and the trade sector have relatively small output multipliers.

By including the household sector in the direct requirements matrix and utilizing the matrix algebra described above, the direct, indirect and induced requirements matrix

TABLE 4-5

Comparison of Output Multipliers for Each Sector of Colorado Economy

Sector	Output Multiplier
11. Food & Kindred Prod.	2.001664
9. Metal Processing	1.891543
10. Agriculture	1.779363
19. Communications & Public Utilities	1.772061
17. Construction	1.763188
6. Pipeline Transportation	1.741604
1. Pet. Prod. & NG Process.	1.705435
4. Industrial Minerals	1.672480
7. Petroleum Refining	1.617241
8. Electric Power Generation	1.568699
3. Metal Mining	1.534891
16. Retail & Wholesale Trade	1.503974
13. Chemical Industries	1.420673
12. Fabricated Metal	1.411863
2. Coal Mining	1.383016
14. Printing & Publishing	1.382545
20. Ins., Fin., R.E., & Gen. Svs.	1.300547
18. All Other Transportation	1.278255
5. Industrial Services	1.201355
15. All Other Manufacturing	1.174770

can be developed as shown in Table 4-6. Each column entry of this table represents the total direct, indirect, and induced requirements by the row industry from the column industry if the row industry delivers one additional dollar to final demand. This matrix represents the total potential impact on all sectors. The matrix includes the induced impact which is due to the increased spending by the household sector. This matrix can be used in its present form to calculate two types of income multipliers as well as show the various income effects. A comparison of income multipliers and the various income effects for all of the processing sectors is provided in Table 4-7.

The income multipliers shown in Table 4-7 show the different amounts of income that are generated when the region's processing sectors increase their output by one dollar. The Type-I multiplier reveals only the direct and indirect impact on income from a change in output, while the Type-II multiplier shows the total interrelationship between income, output, and consumer spending. The greater the degree of interdependence of sectors within the economy or conversely the smaller the dependence on imports, the greater the direct income effect. The labor intensive sectors will yield a larger direct income effect than a capital intensive sector. The situation is often reversed,

TABLE 4-6

Direct, Indirect, and Induced Requirements Per Dollar of Final Demand *

Sector	1	2	3	4	5	6	7	8
Pet. Prod. & NG Process.	1.118310	0.002278	0.000203	0.002367	0.274244	0.014324	0.007702	0.014849
Coal Mining	0.004605	1.001640	0.000224	0.021196	0.025383	0.010353	0.007187	0.010083
Metal Mining	0.007527	0.002660	1.000130	0.011077	0.111885	0.016923	0.009302	0.017461
Industrial Minerals	0.005364	0.001847	0.000199	1.004440	0.003063	0.012060	0.011087	0.010659
Industrial Services	0,005581	0.001672	0.000126	0.005205	1.001390	0.012548	0.013789	0.010187
Pipeline Transportation	0.447901	0.001134	0.000115	0.001169	0.109843	1.007040	0.004303	0.007124
Petroleum Refining	0.143590	0.000527	0.000076	0.000558	0.035224	0.322853	1.002260	0.002885
Electric Power Generation	0.052554	0.132228	0.000151	0.004761	0.016103	0.118160	0.004850	1.004160
Metal Processing	0.007153	0.077294	0.126524	0.019231	0.017596	0.016082	0.011122	0.015679
Agriculture	0.003852	0.000982	0.000065	0.001744	0.000856	0.007537	0.007581	0.006399
Food & Kindred Products	0.003056	0.000891	0.000049	0.001455	0.000778	0.006870	0.008720	0.005910
Fabricated Metal	0.004431	0.004396	0.002780	0.002146	0.001502	0.009962	0.010050	0.008448
Chemical Industries	0.003528	0.001035	0.000054	0.007350	0.000908	0.007931	0.008932	0.006353
Printing & Publishing	0.004429	0.001236	0.000064	0.002394	0.001127	0.009958	0.010665	0.008196
All Other Manufacturing	0.004184	0.002696	0.000074	0.003005	0.001104	0.009408	0.009781	0.007862
Retail & Wholesale Trade	0.008186	0.001569	0.000158	0.003566	0.002068	0.018406	0.033660	0.009565
Construction	0.004180	0.002356	0.000141	0.061917	0.001201	0.009398	0.012113	0.006916
All Other Transportation	0.003712	0.001032	0.000070	0.001840	0.000946	0.008347	0.009483	0.006652
Communications & Public Utilities	0.066619	0.024475	0.000103	0.003896	0.016941	0.149783	0.007575	0.184476
Ins., Fin., R.E., & Gen. Services	0.006482	0.002080	0.000118	0.003506	0.001658	0.014575	0.011089	0.013806
Households	0.006050	0.001687	0.000084	0.002373	0.001537	0.013604	0.014834	0.011090

*requirements matix is not transposed

TABLE 4-6 (Cont.)

Direct, Indirect, and Induced Requirements Per Dollar of Final Demand

9	10	11	12	13	14	15	16	17	18
0.001855	0.024077	0.033023	0.077162	0.031907	0.012484	0.025016	0.282898	0.025052	0.053186
0.002049	0.021967	0.030151	0.085212	0.044551	0.008869	0.020892	0.263995	0.046274	0.090606
0.001390	0.028689	0.038554	0.057799	0.058561	0.011742	0.062911	0.341679	0.061392	0.063662
0.001822	0.029846	0.040278	0.075784	0.033941	0.013335	0.068743	0.407239	0.083339	0.241767
0.001148	0.044413	0.060444	0.047737	0.023587	0.010253	0.063381	0.506470	0.039771	0.047413
0.001053	0.013041	0.017667	0.043797	0.016546	0.006372	0.024095	0.158062	0.013624	0.025383
0.000697	0.006858	0.008838	0.029001	0.009116	0.003267	0.030364	0.084102	0.007281	0.010890
0.001384	0.013604	0.017846	0.057543	0.012883	0.005738	0.052633	0.178156	0.043511	0.022645
1.156040	0.032626	0.043978	0.137075	0.039866	0.011146	0.070083	0.408530	0.088181	0.045223
0.000592	1.501410	0.098618	0.024642	0.046536	0.010435	0.008897	0.278444	0.027599	0.021903
0.000447	0.737571	1.097680	0.018612	0.027343	0.020062	0.008398	0.246846	0.024265	0.027199
0.025404	0.022685	0.031755	1.056540	0.015242	0.011561	0.013302	0.369128	0.031825	0.033660
0.000491	0.023316	0.031664	0.020425	1.030330	0.061165	0.012120	0.328076	0.024220	0.037246
0.000584	0.024694	0.034553	0.024282	0.018625	1.036340	0.011908	0.391742	0.043350	0.039293
0.000679	0.047373	0.042223	0.028252	0.018415	0.021082	1.013070	0.359250	0.055605	0.031166
0.001439	0.049506	0.070934	0.059855	0.034787	0.015498	0.034529	1.236330	0.058753	0.047558
0.001285	0.026683	0.03728	0.053437	0.032947	0.008698	0.021093	0.444925	1.263920	0.043797
0.000644	0.024829	0.034626	0.026785	0.014807	0.014408	0.011036	0.348310	0.032818	1.058710
0.000938	0.022443	0.030915	0.039022	0.015355	0.015721	0.020458	0.278253	0.065622	0.098789
0.001077	0.044616	0.062973	0.044778	0.018922	0.008798	0.015970	0.407320	0.065584	0.030264
0.000772	0.049388	0.068292	0.032110	0.023200	0.009732	0.017065	0.544888	0.040971	0.033505

TABLE 4-6 (Cont.)

Direct, Indirect, and Induced Requirements Per Dollar of Final Demand

19	20	Households
0.086844	0.109026	0.609647
0.098974	0.077832	0.557117
0.102122	0.098203	0.705679
0.062339	0.102320	0.666236
0.059581	0.174647	1.151230
0.041662	0.056876	0.316627
0.016872	0.025580	0.153411
0.024408	0.045758	0.298128
0.091701	0.107707	0.783453
0.037431	0.083248	0.482511
0.034565	0.073800	0.422907
0.049408	0.076897	0.458140
0.037154	0.066464	0.357434
0.047933	0.084952	0.513418
0.045981	0.101997	0.779697
0.055944	0.113224	0.436191
0.040448	0.102660	0.511433
0.038908	0.101332	0.572017
1.078930	0.098870	0554740
0.080747	1.161900	0.863175
0.064863	0.162101	1.362440

TABLE 4-7

Income Multipliers

Sector	Direct Income Change (1)	Direct and Indirect Income Change (2)	Indirect Income Change (3)	Type I Multi-plier (4)	Direct, Indirect, &Induced Income Change (5)	Induced Income Change (6)	Indirect &Induced Income Change (7)	Type II Multi-plier (8)
Pet. Prod. & N.G. Process	0.131002	0.434979	0.303977	3.320397	0.609647	0.174668	0.478645	4.653723
Coal Mining	0.294918	0.398724	0.103806	1.351982	0.557117	0.158393	0.262199	1.889057
Metal Mining	0.316836	0.502225	0.185389	1.585126	0.705679	0.203454	0.388843	2.227269
Industrial Minerals	0.292287	0.462172	0.169885	1.581228	0.666236	0.204064	0.373949	2.279390
Industrial Services	0.772200	0.823117	0.050917	1.065938	1.151230	0.328113	0.379030	1.490844
Pipeline Transportation	0.035008	0.277170	0.242162	7.917339	0.316627	0.039457	0.281619	9.044418
Petroleum Refining	0.018013	0.121323	0.103310	6.735302	0.153411	0.032088	0.135398	8.516682
Electric Power Generation	0.082428	0.212702	0.130274	2.580458	0.298128	0.085426	0.215280	3.616829
Metal Processing	0.314493	0.555079	0.240586	1.764997	0.783453	0.228374	0.468960	2.491162
Agriculture	0.196559	0.371334	0.174775	1.889175	0.482511	0.111177	0.285952	2.454790
Food & Kindred Products	0.107647	0.314384	0.206737	2.920510	0.422907	0.108523	0.315260	3.928646
Fabricated Metal	0.237271	0.332710	0.095439	1.402238	0.458140	0.125430	0.220867	1.930872
Chemical Industries	0.161490	0.259177	0.097687	1.604910	0.357434	0.098257	0.195944	2.213351
Printing & Publishing	0.286294	0.348438	0.062144	1.217062	0.513418	0.164980	0.227124	1.793324
All Other Manufacturing	0.530325	0.575297	0.044972	1.084801	0.779697	0.204400	0.249372	1.470225
Retail & Wholesale Trade	0.191623	0.322791	0.131168	1.684511	0.436191	0.113400	0.244568	2.276298
Construction	0.196723	0.432663	0.235940	2.199350	0.511433	0.078770	0.314710	2.599762
All Otner Transportation	0.345526	0.414164	0.068638	1.198648	0.572017	0.157853	0.226491	1.655496
Communications & Public Utilities	0.25822	0.496490	0.238268	1.922726	0.554740	0.058250	0.296518	2.148306
Ins., Fin., R. E., Gen. Services	0.550428	0.643592	0.093164	1.169258	0.863175	0.219583	0.312747	1.568189
			1-2	3/1	.	5-2	3+6	5/1

however, when one considers the indirect income effects. The indirect income effect and thus the Type-I multiplier is often larger for a capital intensive industry than for a labor intensive industry. The reasons for this has been adequately described by Miernyk 4.14/:

> An industry which uses a great deal of labor but not many other inputs will probably have fewer interactions with other industries than one which utilizes a considerable amount of capital equipment. When an industry which uses a great deal of capital expands its output the "chain reaction" this sets off will spread throughout many sectors of the economy.

The situation described above held true for this input-output model of the Colorado economy. The labor intensive mineral industry services sector yielded the largest direct income effect while the largest indirect income effect was experienced by the capital intensive petroleum production and natural gas processing sector. Two other capital intensive sectors, pipeline transportation and petroleum refining, had the largest Type-I multipliers.

The various I-O matrices and multipliers discussed above provided a complete description of the Colorado economy. These matrices and multipliers will be used later in this Thesis to calculate the economic impact of a new industry, a non-ferrous chemical smelter, which will be described in the next chapter.

CHAPTER 5: DESCRIPTION OF IMPACT SECTOR

The possibility of constructing a non-ferrous smelting or refining plant in the State of Colorado has been a subject of great interest for several years. The adaptability of the Imperial Smelter to Colorado ores was studied by the Colorado School of Mines Research Foundation in 1963. 5.1/ The Imperial Smelter was found infeasible, however, due to inadequate reserves of lead and zinc ores within the State. In 1964, a paper titled, "Why Not a Chemical Smelter", was presented to the Colorado Mining Association. 5.2/ This paper presented the possibility of constructing a chemical refinery consisting of a combination of hydrometallurgical and electrolytic operations. A chemical refinery, treating base and precious metal ores, was investigated further by O. W. Walvoord, Inc. for the Colorado Mining Industrial Development Board in 1964. 5.3/ The results of the Walvoord study were very encouraging, and other investigations were undertaken. 5.4/

In this author's opinion, the rapid rise in the value of nearly all base and precious metals within the last year and the apparent lack of adequate smelter capacity provides sufficient incentive to once again investigate the possibility of constructing a chemical refinery within Colorado. As stated previously, this Thesis will not deal with the technical apsects of the chemical refinery, but will emphasize the potential economic impact on the Colorado economy.

The plant flowsheet and economic estimates which follow have been based on the Walvoord study. The implementation of the basic economic data into the input-output model was achieved by applying the purchase distributions (technical coefficients) of similar chemical refinery and hydrometallurgical operations.

Plant Processes

The proposed chemical refinery would process 125 tons-per-day of concentrate, i.e. 900 tons-per-day of ore, for a period of 15 years. The plant is designed to process both high and low grade ores and metal concentrates. In order to bring the plant into proper perspective for the reader, an artist's view of the refinery and the plant flowsheet are provided in Figures 5-1 and 5-2.

As shown in Figure 5-2, there are seven basic circuits in the refinery. A verbal description of each circuit of the plant is provided below.

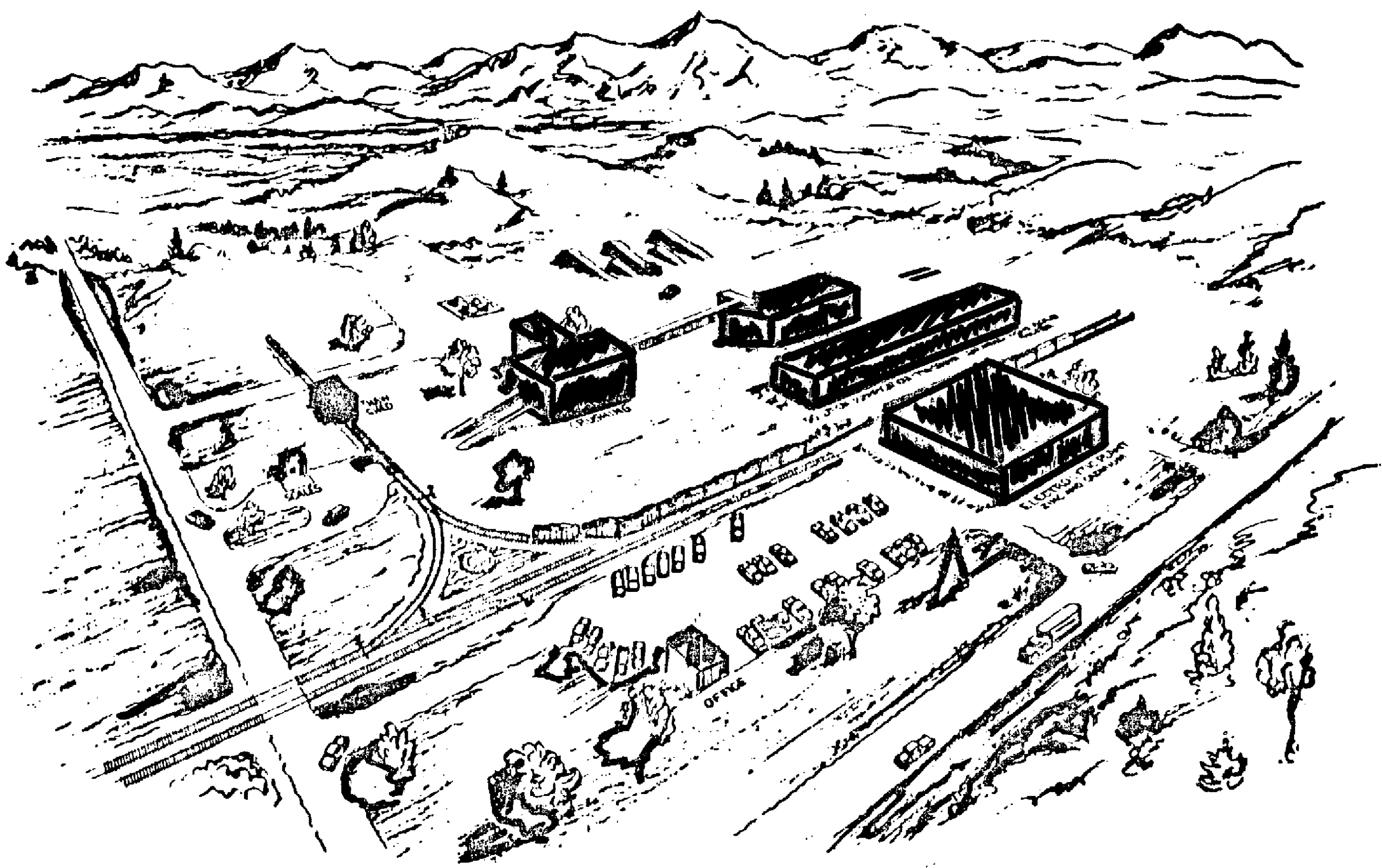

FIGURE 5-1

Artist's Interpretation of Chemical Smelter-Refinery

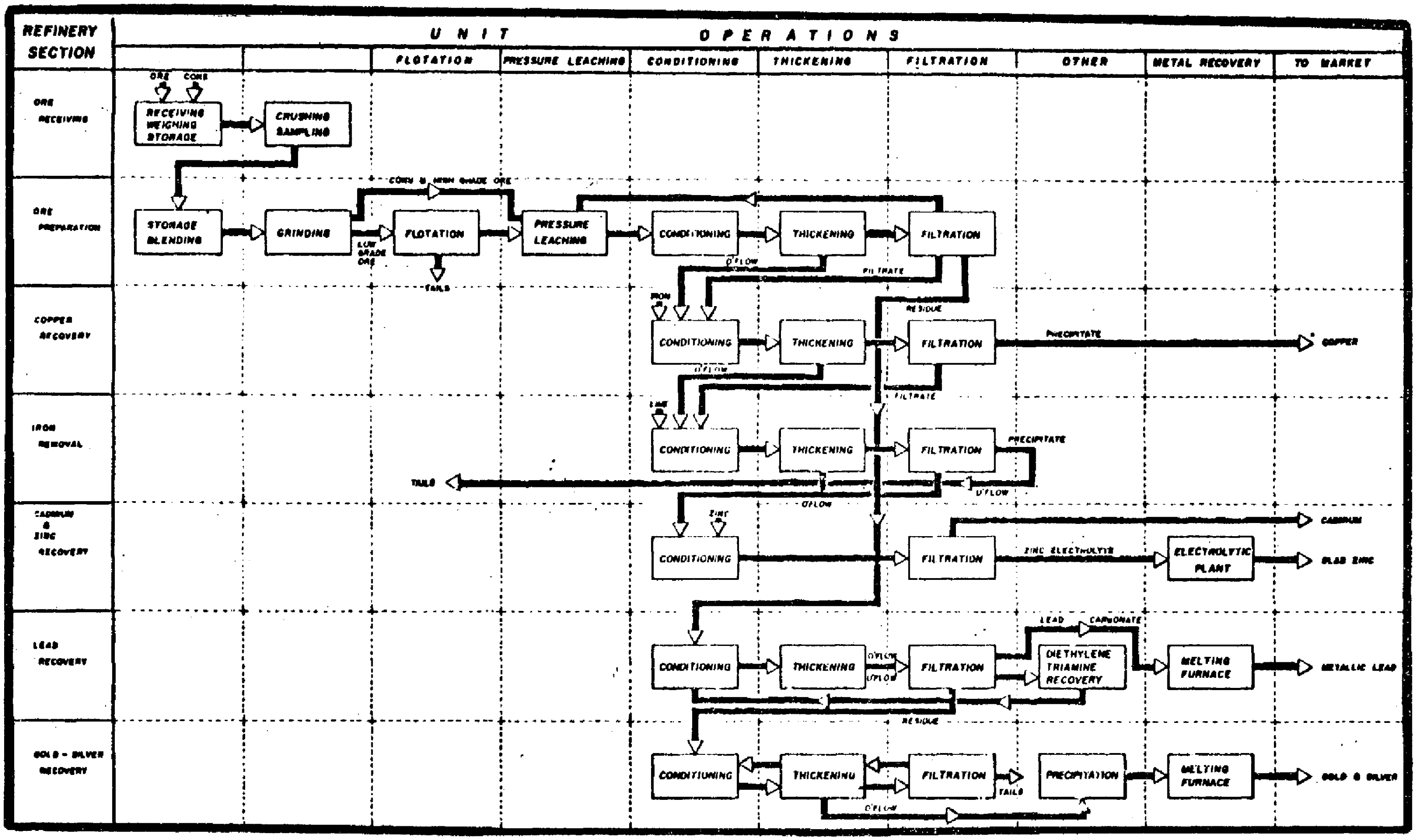

FIGURE 5-2

Process Flowsheet for Chemical Smelter-Refinery

1) Ore Receiving. This section involves the facilities for acceptance of raw material by rail and truck and the subsequent weighing, marking, sampling, and eventual assignment to a storage area.

2) Ore Preparation: This section involves crushing and grinding circuits with a throughput of 150 tons-per-day, producing a minus 65 mesh product suitable for flotation. The resulting bulk concentrate is subsequently thickened, filtered, and blended with purchased concentrates for feeding to a fine grinding mill which produces a minus 200 mesh product. The fine pulp is then blended with neutralized anolyte liquor or water to achieve the required pulp density for continuous pumping to a leaching autoclave where the metal sulfides are oxidized to sulfates, using high pressure air. This high-temperature, high-pressure oxidation of metal sulfides to the sulfate can be described by the general reaction shown below:

$$MeS + 2O_2 \rightleftarrows MeSO_4,$$

where Me represents any metal.

The leached pulp is then flashed to atmospheric pressure and conditioned with limestone before being thickened and filtered. The recovered residue, containing lead ($PbSO_4$), gold, silver, arsenic, and iron is washed and sent to the lead recovery circuit. The pregnant liquor recovered as thickener overflow and filtrate is sent to various circuits for recovery of the dissolved metal values.

3) Copper Recovery. The pregnant liquor is sent to a cementation circuit for copper recovery. The copper in solution as Cu^{++} ions reacts with iron (Fe) as shown below:

$$Cu^{++} + Fe \rightleftarrows Fe^{++} + Cu.$$

The precipitated copper cement is collected by hydrocyclones and settling chambers and washed for marketing to the smelters.

4) Iron Removal. The solution obtained from the copper recovery circuit is purified in the iron removal circuit. The iron present in the solution from the leaching and cementation circuits is removed by oxidation of the ferrous iron to the ferric with air and the subsequent hydrolysis of the ferric iron as hydrated iron oxide. This reaction is described by the following two chemical equations:

$$4Fe\,SO_4 + O_2 + 2H_2\,SO_4 \rightarrow Fe_2(SO_4)_3 + 2H_2O$$

$$Fe_2(SO_4)_3 + 3H_2O \rightarrow 3H_2SO_4 + Fe_2O_3$$

The slurry, containing the iron precipitate (Fe_2O_3) plus small amounts of arsenic, antimony, and germanium, is thickened and filtered so the iron residue can be discarded.

5) Cadmium and Zinc Recovery. Zinc is added to the liquor recovered from the iron recovery circuit to precipitate any residual copper and any cadmium present. Cobalt may also be removed at this stage by the addition of nitroso-b-naphthol. The purified solution is then sent to the electrolytic circuit for zinc recovery.

6) Lead Recovery. The lead sulfate is leached with an amine to form a soluble lead amine sulfate solution, which is then carbonated to precipitate a high-purity basic lead carbonate. The carbonate is further reduced to metallic lead in a small melting furnace. This circuit is described by the following six chemical equations:

Amine Leach:

$$PbSO_4 + 2\,EDA \rightarrow [Pb(EDA)_2]\,SO_4 \qquad (1)$$

$$PbO + EDA + EDAH_2SO_4 \rightarrow [Pb(EDA)_2]\,SO_4 + H_2 \qquad (2)$$

Carbonation:

$$2\ Pb(EDA)_2SO_4 + 3CO_2 + 5H_2O \rightarrow$$

$$PbCO_2.Pb(CH)_2 + EDAH_2CO_3 + 2EDAH_2SO_4 \quad (3)$$

Regeneration:

$$EDAH_2SO_4 + Ca(CH)_2 \rightarrow CaSO_4.2H_2O + EDA \quad (4)$$

Reduction:

$$C + PbCO_2.Pb(CH)_2 800°C \rightarrow 2Pb = CO_2 + H_2O \quad (5)$$

7) Gold and Silver Recovery. The residue obtained from the lead recovery circuit is treated in a cyanide circuit for gold and silver. The cyanide pulp is washed in a series of counter-current thickeners and finally filtered. The iron residue is discarded, while the gold and silver is precipitated from the filtrate by fine dust. The gold and silver precipitate is fluxed, melted, and cast into dore bullion bars.

Plant Economics

The economics of the chemical refinery involve two separate areas: 1) capital investment and 2) operating expenditures. The Walvoord study included estimates of capital requirements and operating expenditures, but these estimates were outdated and of insufficient detail to implement them into the input-output model. The methods utilized to update the Walvoord estimates and to break them down into greater detail, if required, will be fully described below.

Capital Investment. The original capital cost estimate was broken down by each plant section. By applying an engineering plant construction cost index, the present cost was obtained. 5.5/ The resulting capital cost estimate is shown in Table 5-1.

The capital expenditures involved in constructing a chemical refinery can be included in the input-output model under one sector, the construction industry. These expenditures would occur only once and thus its impact on the Colorado economy would be felt only once, but probably spread over a one to two year period. A more complete treatment of the impact of the capital expenditures will be given in Chapter 6.

Operating Expenditures. The estimates of operating costs involve the following cost items: 1) labor, 2) feed (raw ore and concentrates purchased from surrounding mines), 3) operating supplies, 4) freight on products, and 5) value added items (depreciation, taxes, profit, etc.).

Walvoord estimated the labor requirements of the chemical refinery to be 130 semi-skilled and skilled men. The annual cost of this labor ($1,557,000) was estimated to be the total employment times the average annual income for men employed in Colorado's mineral industry in 1972.

TABLE 5-1

Capital Cost Estimate (1972 dollars)

Plant Section	Capital Cost
1. Receiving, sampling and plant services	$165,300
2. Flotation mill	359,100
3. Regrind mill	152,200
4. Leaching section	1,524,700
5. Solution purification	813,600
6. Zinc electrolytic plant	1,269,900
7. Zinc casting plant	601,900
8. Cadmium recovery	166,200
9. Lead recovery	839,100
10. Gold-silver recovery	228,400
Total	$6,120,400

The cost of ores and concentrates to the mill was calculated in the same manner as the Walvoord study. In so doing, it was assumed that 80 percent of the feed would be made up of metal concentrates and 20 percent would be obtained from custom flotation mills. The total value of metal per ton of concentrate was calculated using the weighted assay of typical lead, zinc and copper concentrates produced in Colorado and the average 1972 prices of the respective metals. It was assumed that the chemical refinery would pay for the concentrates at 55 percent of this calculated value. A summary of this calculation is provided in Table 5-2.

The total annual cost of feed to the chemical refinery as purchased from the mining sector is shown below.

Feed	Ore	Concentrate	
Concentrate	--	33,000 tons @ $146.84	= $4,845,651
Ore	57,570	8,250 tons @ $73.79	= 608,767
		Total cost	= $5,454,418

The cost of miscellaneous supplies and services was estimated to be $1,407,000 or about 15 percent of the total operating cost. This compares with 19 percent for an aluminum smelter using the Bayer process 5.6/, 11.4 percent for a flotation plant treating metal sulfides 5.7/, 18 percent

TABLE 5-2

Cost of Feed to Chemical Refinery

Metal	Average Weight Per Ton of Concentrate	1972 Average Unit Price of Metal	Value of Metal Per Ton of Concentrate
Lead-Pb	459.4 lbs	$0.1534/lb	$70.472
Gold-Au	.1596 oz.	42.22/oz	6.738
Silver-Ag	13.230 oz.	1.6845/oz	22.286
Copper-Cu	97.0 lbs	0.5144/lb	49.897
Zinc-Zn	663.2 lbs	0.1773/lb	117.585
Total			$266.978
Payment to Mines (55%)			$146.838

for a mercury leaching plant 5.8/, and 25 percent for a copper smelter 5.9/. Utilizing the detailed cost data of the above processes as guidelines and other cost estimation methods 5.10/, the cost breakdown provided in Table 5-3 was determined. Although one may consider these estimates crude approximation, it was felt by this author that they were within the accuracy of the rest of the study.

Freight costs on products was estimated to be $500,000 or roughly Walvoord's estimate plus 10 percent to allow for inflation. Depreciation costs amounted to $408,000 and was calculated by applying the straight line depreciation method to the original capital investment ($6,120,400/15 years = $408,000 per year).

In order to calculate the tax cost, the total revenue was first estimated by utilizing the production volumes given in the Walvoord study and the average 1972 metal prices. As shown in Table 5-4, total revenue was $11,010,214. Taxable income is equal to total sales ($11,010,214) minus total operating costs ($9,326,418) or $1,683,796.

Assuming local, state, and federal taxes yield an effective rate of 50 percent, the tax cost and operating profit are equal to $841,898.

A summary of the above cost data, as well as the manner in which these estimates can be implemented into the input-

TABLE 5-3

Cost of Supplies and Services

	Dollar Amount	Percent
Finance, Insurance Real Estate and General Services	$11,000	.78
Printing & Publishing	5,000	.35
Utilities	350,000	24.87
Industrial Minerals	25,000	1.79
Chemical Industries	586,000	41.65
Fabricated Metal	200,000	14.21
Retail & Wholesale Trade	230,000	16.35
Total	$1,407,000	100%

TABLE 5-4

Annual Income

Metal	Production	Volume	1972 Average Unit Value of Metal	Total Metal Value
Lead	(9474 tons)	(2000 lbs)	($.1534/lb)	$2,906,623
Gold	(6,600 oz)		($42.2063/oz)	278,562
Silver	(544,500 oz)		($1.6845/oz)	917,210
Copper	(2,000 tons)	(2000 lbs)	($.5144/lb)	2,057,600
Zinc	(13,678 tons)	(2000 lbs)	($.1773/lb)	4,850,219
			Total	$11,010,214

Source: Engineering and Mining Journal

output model, is shown in Table 5-5. This distribution represents an additional column in the existing input-output matrix. In formulating the corresponding row, it was assumed that the chemical refinery would sell about 10 percent of its output or $1,195,772 to metal processing firms within Colorado and export the balance of its output or $9,814,442.

TABLE 5-5

Purchase Distribution of Chemical Refinery

3. Metal Mining	$5,454,418
4. Industrial Minerals	25,000
12. Fabricated Metal	200,000
13. Chemical Industries	586,000
14. Printing & Publishing	5,000
16. Retail & Wholesale Trade	230,000
18. All Other Transportation	500,000
19. Communications & Public Utilities	350,000
20. Insurance, Finance, Real Estate, General Service	11,000
Households	1,557,000
Government	841,898
Imports	0
Other	1,249,898
Total output	$ 11,010,214

CHAPTER 6: ECONOMIC IMPACT OF A NON-FERROUS CHEMICAL SMELTER ON COLORADO ECONOMY

Having developed an input-output model of the Colorado economy and having presented the new sector, the economic impact can now be calculated. The purpose of this chapter is to describe the methodology of calculating economic impact and to present the economic results that were obtained.

Economic Impact Concepts

Before proceeding, however, economic impact should be defined here. The economic impact referred to in this Thesis is defined as 6.1/

> ...the direct effect plus the cumulative indirect effects on all industries in a specific regional economy (i.e. local sales and purchases) of some autonomous or outside change in the demand for an industry's or firm's output.

An example of an autonomous change would be the expansion of existing facilities or the opening of new plants to meet increased demand. An example of an independent outside change would be an increase in the payments to the region's industries from the sale of commodities and services outside the region's economy. The analysis of the output and income effects on a region's economy that results from such changes makes up an economic impact study.

Analysis techniques usually involve the use of static tools while assuming that the structure of the region's economy has not changed over the study period. The principal tools being multiplier and interindustry analysis, associated with economic-base type or input-output type studies.

Multiplier analysis involves the measurement of the interactions of the individual sectors or industry groups within a regional economy over a given time period, usually one year. These interactions, originating from a change in one sector, spread throughout all the sectors of the economy. These direct and indirect interactions lead to a series of cumulative effects in each and every sector. The multiplier obtained is a numerical coefficient expressing the multiplying interactions and cumulative effects on income and employment that result from a change in autonomous spending (payments within or into the region) due to changes in capital investment, domestic purchases, and export demand. Multiplier coefficients can be calculated from economic-base or input-output type studies. Interindustry analysis refers to the calculation of submultipliers which reveal the interrelationships between the individual sectors of the local economy and is usually associated only with input-output type studies.

Economic-Base Type Studies. Economic-base type studies separate the individual economic activities of a local economy into two general categories: 1) basic or autonomous and 2) nonbasic or dependent. Basic economic activities include those activities which exogenously (exporting) generate regional income. Nonbasic economic activities are those activities which endogenously generate regional income, that is, they serve only the local economy. In other words, basic activities purchase goods and services from non-basic activities and also generate further regional income by exporting their goods and services outside the region. It is generally felt that such an analysis provides only gross measurements of economic impact because of the highly aggregated nature of the data and the difficulty in classifying the firms. The limitations of this type of study have been adequately described by Wang: 6.2/

> The export base approach does not take into account the complexity of interrelationships and interaction that explains the growth in an economy. The model offers only skeleton answers in terms of total level of income and employment. There is no indication of the linkage between sectors in its economy. The gross aggregation of sectors, particularly of the manufacturing and mining sectors, tell us nothing about the types of industry on which the region depends. At best, this type of analysis must be restricted to the macro aggregated industry-level type of regional analysis.

Input-Output Type Studies. An input-output study is the most powerful tool for regional economic impact analysis. It is usually utilized in a static form for a given period of time, usually one year. The regional input-output analysis yields three types of sector and subsector level multipliers: 1) output, 2) income, and 3) employment. In this way, one may estimate the effect of a change in one sector on the rest of the local economy. These effects include the direct impact from changes in final demand of a producing sector, the indirect input requirements, the indirect autonomous income effect resulting from the purchase of goods from local industries, and the induced income effect resulting from local household consumption expenditures.

In this Thesis, the change is an autonomous change in which a new industry, a non-ferrous chemical smelter, is introduced into the Colorado economy. The resulting impact on the output and income of all other sectors in Colorado has been analyzed by the use of an input-output model.

Measurement of Economic Impact

The first step in measuring economic impact is to formulate the purchase distribution of the impact sector. In other words, the analyst must determine the purchases made by the impact sector from all of the processing sectors and the household sector. These purchases represent an increase in the output of the various sectors in the input-output model. For the purposes of this study, the purchase data can be presented in the form of a one by twenty matrix. Henceforth, this matrix will be referred to as the "purchase matrix". Since in this Thesis the calculation of impact was segregated into three areas (capital expenditures, purchases from processing sectors, and employment), three purchase matrices were utilized. These matrices will be presented later in this chapter when each impact area is discussed.

Once the purchase matrix has been formulated, the economic impact can be calculated in three stages: 1) direct impact, 2) direct and indirect impact, and 3) the direct, indirect, and induced impact. The calculation involves multiplying the requirements matrix by the purchase matrix to obtain the impact matrix. The mathematical representation of these calculations is as follows:

$$\text{Direct Impact Matrix} = \text{Direct Requirements or Technical Coefficient Matrix} \times \text{Purchase Matrix} \quad ;$$

$$
\begin{matrix} DR_1 \\ DR_2 \\ DR_3 \\ \vdots \\ DR_i \\ \vdots \\ DR_{20} \end{matrix}
=
\begin{matrix} A_{1,1}, A_{2,1}, A_{3,1}, \ldots, A_{20,1} \\ A_{1,2}, A_{2,2}, A_{3,2}, \ldots, A_{20,2} \\ A_{1,3}, A_{2,3}, A_{3,3}, \ldots, A_{20,3} \\ \vdots \\ A_{1,20}, A_{2,20}, A_{3,30}, \ldots, A_{i,j} \\ \\ \\ \end{matrix}
\quad x \quad
\begin{matrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_i \\ \vdots \\ X_{20} \end{matrix} \quad ;
$$

where i = column sector number,

j = row sector number,

DR_i = direct impact on sector i (row sector),

$A_{i,j}$ = direct requirement of sector i (column sector) from sector j (row sector),

and X_i = purchase of impact sector from sector i (column sector).

The calculation of the direct and indirect impact is the same as that shown above, except the direct and indirect requirements matrix is substituted for the direct requirements matrix. Similarly, the direct, indirect, and induced impact is calculated by substituting the direct, indirect, and induced requirements matrix for the direct requirements matrix. These requirement matrices were presented in Chapter 4 of this Thesis (pages 53 - 64).

Arithmetically, the matrix algebra presented above amounts to multiplying every column entry in the requirements matrix by the respective purchase made by the impact sector and then summing all the new elements of each row to determine the impact of all purchases on the row sector. When the number of sectors is large, matrix algebra and a high-speed computer must be used to facilitate the calculations. In this Thesis, however, the number of sectors was small and thus the arithmetic approach was used. The preceeding impact matrices show the intermediate steps. It was felt by this author that such a presentation would clarify the calculation of economic impact for the reader.

The method used in this Thesis for calculating economic impact is a standard method which has been used by others. In a study of the Kansas economy 6.3/, the impact resulting from an increase in the demand for meat products and the impact resulting from a cut in federal government purchases of airplanes were calculated. In another study, Leontief measured the impact that resulted from an arms cut. 6.4/

Another study, with which this author is familiar, utilized the multiplier-comparison approach in which the output and income multipliers are calculated over a period of time and then compared. 6.5/ The multiplier-comparison approach can also be applied to this type of analysis by calculating the multipliers before and after some economic "change" and then comparing the two sets of results. This method is very difficult to implement, however, since one must balance the input-output table twice instead of only once as was done in this Thesis. In addition, this author felt that the multiplier-comparison approach does not provide the detail which the method used in this Thesis achieves.

One final concept must be discussed before the impact data is presented. When considering the purchases by the non-ferrous chemical smelter from the other sectors, it was assumed that these purchases represented an increase in the total output of each corresponding sector. This output is made up of domestic production and imports. It was assumed that the same split between domestic production and imports which exists in the original transaction table be applied to the incremental increase in output due to the purchases by the smelter. It was assumed that the value of exports would remain the same. In other words, the increased domestic purchases would not draw upon the export market or conversely, it would stimulate increased production and imports. This method allowed the use of the requirement matrices developed in Chapter 4. The treatment of the metal mining sector was an exception to the above convention. The smelter purchase from this sector was treated in two ways.

First, the purchase was drawn from the export market. This procedure yielded no new production and thus no impact on the economy. This is a reasonable approach since under current conditions, mines must ship their material out of the State. If a smelter is built within Colorado, mines would probably elect to sell to the smelter and thus save on transportation costs. This condition would bring about a decrease in the output of the transportation sector. No attempt was made, however, to measure this impact since the smelter was not placed in a specific location and thus the difference in transportation costs could not be calculated. It is felt by this author, however, that the decrease would be very small in comparison with the total pruchases made by the smelter.

Second, it was assumed that the smelter purchase from the metal mining sector would result in new production. In this case, the treatment of the purchase was the same as all other purchases. This two-stage treatment of the metal mining purchase represents an "all or nothing" approach. In reality, a new smelter would probably stimulate some new production as well as draw from the export market. It is impossible, however, to determine what the split would be. This author has chosen to bracket the range by providing both the smallest and largest impact cases.

Economic Impact of Smelter on Colorado Economy

The economic impact of the chemical smelter on the Colorado economy was calculated in three stages: 1) capital expenditures, 2) process industry purchases, and 3) employment impact. The impact data for each stage will be presented and discussed in turn as well as summarized at the end of this chapter.

Capital Expenditures. When the chemical smelter is built, a one-time impact is experienced by the economy. The capital expenditures was estimated to be $6,120,400 and represents a purchase from the construction sector only. The direct impact was calculated by multiplying the value for capital expenditures by every column entry in the direct requirement column for the construction sector. The direct and indirect impact was calculated by using the direct and indirect requirements column and similarly, the direct, indirect, and induced impact was calculated by using the direct, indirect, and induced requirements column. If one were to use matrix algebra, a one by twenty matrix would be formulated in which the first 16 values would be zero, value number 17 would be $6,120,400, and values 18 through 20 would be zero. These impact calculations are summarized in Table 6-1.

TABLE 6-1

Impact of Capital Expenditures on Colorado Economy

Sector	Direct	Direct & Indirect	Direct, Indirect, & Induced
1. Pet. Prod. & NG Process.	0	11,683	25,583
2. Coal Mining	5,943	10,543	14,420
3. Metal Mining	0	667	863
4. Industrial Minerals	297,800	373,503	378,957
5. Industrial Services	0	3,819	7,351
6. Pipeline Transportation	0	26,269	57,520
7. Petroleum Refining	0	40,058	74,136
8. Electric Power Generation	0	16,849	42,329
9. Metal Processing	0	6,090	7,865
10. Agriculture	0	49,844	163,311
11. Food & Kindred Prod.	0	71,290	228,187
12. Fabricated Metal	124,801	253,287	327,056
13. Chemical Industries	81,199	148,346	201,649
14. Printing & Publishing	2,448	30,877	53,235
15. All Other Manufacturing	22,046	89,890	129,098
16. Retail & Wholesale Trade	1,033,711	1,471,264	2,723,119
17. Construction	1,156,872	7,641,625	7,735,696
18. All Other Transportation	39,115	191,079	268,055
19. Communications & Public Utilities	22,394	98,539	247,558
20. Ins., Fin, R.E. & Gen. Svs.	122,885	255,893	628,320
Households	1,204,025	--	3,130,174
Government	319,476	--	--
Imports	1,524,721	--	--
Other	162,964	--	--
Total	6,120,400	10,791,415	16,444,482

Referring to Table 6-1, if one divides the total direct and indirect impact by the direct impact, one obtains the output multiplier for the construction industry. In other words,

$$\text{output multiplier} = \frac{\text{direct + indirect impact}}{\text{direct impact}} = \frac{\$10{,}791{,}415}{\$6{,}120{,}400} = 1.7632.$$

Similarly, the direct income impact ($1,204,025) times the construction sector's Type-II income multiplier (2.5998) equals the total direct, indirect, and induced income impact ($3,130,174). The capital expenditures of $6,120,400 result in imports of $1,524,721 (imported construction services) and $4,595,679 in increased output by all processing sectors. The indirect effect of these purchases equals $4,671,015 and the induced effect equals $5,653,067. The total impact totals $16,444,482 or 2.687 times the original values of the capital expenditures.

Although this impact is only a one-time situation, it represents a significant portion of the total impact of the chemical smelter on the Colorado economy. In particular, it would have a large impact on the immediate area around the plant location. It may even stimulate economic activities such as hotels, apartments, and trade stores which would continue on after the plant is constructed. If it is a remote area, the development of adjoining infrastructure could be significant. If such were the case, the above estimate of economic impact would be very conservative. The point of importance is that any new construction may start in motion changes in the basic pattern of an economy. Input-output analysis cannot measure the changes in the structure of an economy and thus its potential social and economic impact.

Processing Sector Purchases. The direct; direct and indirect; and direct, indirect, and induced impacts were calculated by multiplying each smelter purchase by each entry in the corresponding column in the proper requirement matrix and then summing across the rows. If one were to use matrix algebra, the matrices would be as shown in Table 6-2. There are two matrices, one with a metal mining purchase and one without a metal mining purchase. The calculation of each type of impact, both with and without the metal mining purchase, is shown in Tables 6-3, 6-4, and 6-5. Economic impact summaries are shown for both metal mining cases in tables 6-6 and 6-7. The intermediate impact tables have been included in this Thesis to clarify the calculations for the reader. Tables 6-6 and 6-7 represent the total impact on all processing sectors and households that results from the purchase of goods and supplies by the chemical smelter. It is interesting to note that although the chemical smelter makes direct purchases from only nine of the processing sectors

TABLE 6-2

Purchase Matrices

Without Mining Sector		With Mining Sector
0	Pet. Prod. & NG Process.	0
0	Coal Mining	0
0	Metal Mining	5,454,418
25,000	Industrial Minerals	25,000
0	Industrial Services	0
0	Pipeline Transportation	0
0	Petroleum Refining	0
0	Electric Power Generation	0
0	Metal Processing	0
0	Agriculture	0
0	Food & Kindred Prod.	0
200,000	Fabricated Metal	200,000
586,000	Chemical Industries	586,000
5,000	Printing & Publishing	5,000
0	All Other Manufacturing	0
230,000	Retail & Wholesale Trade	230,000
0	Construction	0
500,000	All Other Transportation	500,000
350,000	Communications & Public Utilities	350,000
11,000	Ins., Fin., R.E., & Gen. Svs.	11,000

TABLE 6-3

Direct Impact of Chemical Smelter on Colorado Economy

	Indus-trial Minerals	Fabri-cated Metal	Chemical Indus-tries	Printing & Pub-lishing	Retail & Whole-sale Trade	All Other Trans-portation	Communi-cations & Public Utilities	Ins., Fin. R.E. & Gen. Svs.	Total	Metal Mining	Total
Pet. Prod. & NG Process.	0	0	0	0	0	0	0	0	0	0	0
Coal Mining	0	281	46	0	0	0	0	0	327	0	327
Metal Mining	0	0	0	0	0	0	0	0	0	0	0
Industrial Minerals	0	0	3,426	0	84	0	0	0	3,510	39,457	42,967
Industrial Services	42	0	0	0	0	0	0	0	42	599,691	599,733
Pipeline Transportation	0	0	0	0	0	0	41,026	0	41,026	0	41,026
Petroleum Refining	0	0	0	0	6,262	0	0	0	6,262	0	6,262
Electric Power Generation	0	0	0	0	0	0	59,844	0	59,844	0	59,844
Metal Processing	0	4,171	0	0	0	0	0	0	4,171	0	4,171
Agriculture	0	0	384	0	39	0	0	0	423	0	423
Food & Kindred Prod.	0	0	2,644	0	9,678	0	0	163	12,485	0	12,485
Fabricated Metal	1,193	6,498	1,159	11	9,456	3,153	2,745	199	24,414	173,554	197,968
Chemical Industries	425	344	10,844	22	5,351	803	404	16	18,209	232,707	250,916
Printing & Publishing	64	1,042	31,242	145	1,845	4,042	2,997	9	41,386	7,882	49,268
All Other Manufacturing	1,386	173	1,149	0	5,881	172	257	29	9,047	248,438	257,485
Retail and Wholesale Trade	2,100	32,402	91,690	813	6,062	51,110	6,570	469	191,216	121,326	312,542
Construction	1,041	1,126	1,319	73	6,997	3,512	10,446	294	24,808	139,458	164,266
All Other Transportation	5,189	2,497	10,171	86	6,398	18,928	24,999	27	68,295	173,644	241,939
Communications & Public Utilities	525	3,619	6,693	76	6,235	2,942	14,763	365	35,218	331,438	366,656
Ins., Fin., R.E. & GS	152	1,886	6,229	54	11,621	11,746	7,363	555	39,606	11,618	51,224
Households	7,309	47,464	94,633	1,432	44,073	172,763	90,378	6,055	464,107	1,728,158	2,192,265
Government	1,125	16,489	26,360	321	21,736	60,298	14,204	784	141,317	232,854	374,171
Imports	0	71,290	232,322	1,567	64,443	119,497	6,668	1,499	497,286	493,404	990,690
Other	4,449	10,718	65,689	400	23,839	51,034	67,336	536	224,001	920,789	1,144,790
Total	25,000	200,000	586,000	5,000	230,000	500,000	350,000	11,000	1,907,000	5,454,418	7,361,418

TABLE 6-4

Direct and Indirect Impact of Chemical Smelter on Colorado Economy

	Industrial Minerals	Fabricated Metal	Chemical Industries	Printing & Publishing	Retail & Wholesale Trade	All Other Transportation	Communications & Public Utilities	Ins., Fin. R.E. & Gen. Svs.	Total	Metal Mining	Total
Pet. Prod. & NG Process.	60	479	1,137	11	1,437	586	22,455	29	26,194	23,961	50,155
Coal Mining	26	768	347	3	237	162	8,326	11	9,880	9,742	19,622
Metal Mining	4	550	19	--	30	18	24	1	646	5,454,909	5,455,555
Industrial Minerals	25,082	270	3,943	8	645	422	1,026	22	31,418	53,715	85,133
Industrial Services	58	197	296	3	362	150	5,710	8	6,784	605,926	612,710
Pipeline Transport.	135	1,078	2,556	24	3,232	1,318	50,486	66	58,895	53,873	112,768
Pet. Refining	96	1,010	2,953	25	6,650	1,628	537	19	12,918	8,831	21,749
Electric Power Gen.	131	944	2,018	20	1,383	998	6,298	74	68,554	63,909	132,463
Metal Processing	36	5,029	169	1	284	160	218	6	5,903	5,394	11,297
Agriculture	142	1,216	6,070	30	7,750	2,047	820	146	18,221	16,958	35,179
Food & Kindred Prod.	172	1,758	8,056	44	11,286	2,977	1,088	217	25,598	17,361	42,959
Fabricated Metal	1,502	209,150	7,032	61	11,402	6,652	9,082	269	245,150	224,547	469,697
Chemical Industries	565	1,488	600,211	49	6,293	2,534	2,068	46	613,254	253,876	867,130
Printing & Publishing	214	1,658	34,347	5,165	2,849	5,161	4,115	29	53,538	36,550	90,088
All Other Manuf.	1,510	1,513	4,479	27	6,685	1,936	4,728	57	20,935	294,932	315,867
Retail & Wholesale Trade	3,520	37,180	108,484	933	244,275	59,770	19,738	683	474,583	324,292	798,875
Construction	1,583	3,610	7,894	140	10,496	7,808	17,128	436	49,095	219,109	268,204
All Other Trans.	5,635	4,479	16,675	133	8,481	522,325	29,800	99	587,627	252,589	840,216
Communications & Public Utilities	766	5,518	11,801	117	8,092	5,838	368,382	436	400,950	373,776	774,726
Ins., Fin., R.E. & GS	576	4,478	14,027	119	14,045	16,638	11,504	11,652	73,039	77,687	150,726
Total	41,813	282,373	832,514	6,913	345,914	639,128	563,533	14,306	2,783,182	8,371,937	11,155,119

TABLE 6-5

Direct, Indirect, and Induced Impact of Chemical Smelter on Colorado Economy

	Industrial Minerals	Fabricated Metal	Chemical Industries	Printing & Publishing	Retail & Wholesale Trade	All Other Transportation	Communication & Public Utilities	Ins., Fin., R.E. & Gen. Svs.	Total	Metal Mining	Total
Pet. Prod. & NG Process.	134	886	2,067	22	1,883	1,856	23,317	71	30,236	41,055	71,291
Coal Mining	46	879	606	6	361	516	8,566	23	11,003	14,509	25,512
Metal Mining	5	556	32	-	36	35	36	1	701	5,455,127	5,455,828
Industrial Minerals	25,111	429	4,307	12	820	920	1,364	38	33,001	60,418	93,419
Industrial Services	76	300	532	6	476	473	5,929	18	7,810	610,268	618,078
Pipeline Transport.	302	1,992	4,648	50	4,233	4,174	52,424	160	67,983	92,305	160,288
Pet. Refining	277	2,010	5,234	53	7,742	4,742	2,651	122	22,831	50,737	73,568
Electric Power Gen.	266	1,690	3,723	41	2,200	3,326	64,567	152	75,965	95,240	171,205
Metal Process.	45	5,081	288	3	331	13,322	328	12	6,410	7,582	13,992
Agriculture	746	4,537	13,663	123	11,386	12,414	7,855	491	51,215	156,482	207,697
Food & Kindred Prod.	1,007	6,351	18,555	173	16,315	17,313	10,820	693	71,227	210,290	281,517
Fabricated Metal	1,895	211,308	11,969	121	13,767	13,392	13,658	492	266,602	315,260	581,862
Chemical Industries	848	3,048	603,773	243	8,001	7,404	5,374	208	628,899	319,416	948,315
Printing & Pub.	333	2,312	35,843	5,182	3,564	7,204	5,502	97	60,037	64,046	124,083
All Other Manuf.	1,718	2,660	7,102	60	7,942	5,518	7,160	176	32,336	343,143	375,479
Retail & Wholesale Trade	10,181	73,826	192,252	1,959	284,356	174,155	97,388	4,481	838,598	1,863,660	2,702,258
Construction	2,083	6,365	14,193	217	13,513	16,409	22,968	721	76,469	334,858	411,327
All Other Trans.	6,044	6,732	21,826	196	10,938	529,355	34,576	333	610,000	347,239	957,239
Communication & Public Utilities	1,558	9,882	21,772	240	12,867	19,454	377,626	888	444,287	557,016	1,001,303
Ins., Fin., R.E. & Gen. Svs.	2,558	15,379	38,948	425	26,042	50,666	34,604	12,781	181,403	535,640	717,043
Households	16,657	91,628	209,456	2,567	100,324	286,008	194,159	9,495	910,294	3,849,068	4,759,362
Total	71,890	447,851	1,210,789	11,699	527,097	1,155,656	970,872	31,453	4,427,307	15,323,359	19,750,666

TABLE 6-6

Economic Impact Summary Without Metal Mining Sector

Sector	Direct Impact	Direct and Indirect Impact	Direct, Indirect, and Induced Impact
Pet. Prod. & NG Process.	0	26,194	30,236
Coal Mining	327	9,880	11,003
Metal Mining	0	646	701
Industrial Minerals	3,510	31,418	33,001
Industrial Services	42	6,784	7,810
Pipeline Transportation	41,026	58,895	67,983
Petroleum Refining	6,262	12,918	22,831
Elec. Power Generation	59,844	68,554	75,965
Metal Processing	4,171	5,903	6,410
Agriculture	423	18,221	51,215
Food & Kindred Prod.	12,485	25,598	71,227
Fabricated Metal	24,414	245,150	266,602
Chemical Industries	18,209	613,254	628,899
Printing & Publishing	41,386	53,538	60,037
All Other Manufacturing	9,047	20,935	32,336
Retail & Wholesale Trade	191,216	474,583	838,598
Construction	24,808	49,095	76,469
All Other Transportation	68,295	587,627	610,000
Communications & Public Utilities	35,218	400,950	444,287
Ins., Fin., R.E. & Gen. Svs.	39,606	73,039	181,403
Households	464,107	0	910,294
Government	141,317	0	0
Imports	497,286	0	0
Other	224,001	0	0
Total	1,907,000	2,783,182	4,427,307

TABLE 6-7

Economic Impact Summary with Metal Mining Sector

Sector	Direct Impact	Direct and Indirect Impact	Direct, Indirect, and Induced Impact
Pet. Prod. & NG Proc.	0	50,155	71,291
Coal Mining	327	19,622	25,512
Metal Mining	0	5,455,555	5,455,828
Industrial Minerals	42,967	85,133	93,419
Industrial Services	599,733	612,710	618,078
Pipeline Transpor.	41,026	112,768	160,288
Petroleum Refining	6,262	21,749	73,568
Electric Power Generation	59,844	132,463	171,205
Metal Processing	4,171	11,297	13,992
Agriculture	423	35,179	207,697
Food & Kindred Prod.	12,485	42,959	281,517
Fabricated Metal	197,968	469,697	581,862
Chemical Industries	250,916	867,130	948,315
Printing & Publishing	49,268	90,088	124,083
All Other Manufact.	257,485	315,867	375,479
Retail & Wholesale Trade	312,542	798,875	2,702,258
Construction	164,266	268,204	411,327
All Other Transp.	241,939	840,216	957,239
Communications & Public Util.	366,656	774,726	1,001,303
Ins., Fin., R.E., & Gen Svs.	51,224	150,726	717,043
Households	2,192,265	0	4,759,362
Government	374,171	0	0
Imports	990,690	0	0
Other	1,144,790	0	0
Total	7,361,418	11,155,119	19,750,666

(including metal mining sector), all of the processing sectors experience an increase in output or correspondingly an increase in the demand for their product. This situation is a result of Colorado's inherently broad-based economy. If the economy were dominated by a few number of large industries or if the State were very dependent on imports, both the extent and the value of the impact would be greatly reduced.

The interdependency of the individual sectors in the Colorado economy is made clearer by including the purchases from the metal mining sector in the impact calculation. If these purchases originate from new mine production, the impact on the economy is significantly greater than would otherwise be the case. The impact of the metal mining sector is shown in Table 6-8.

Since the metal mining sector is capital intensive, its impact on the economy is relatively greater than the impact of labor intensive sectors. The indirect and induced impact of an increase in mine output is proportionately greater than the average for all sectors. This situation is shown by the various factors provided in Table 6-8. These factors are multipliers which represent only the impact of process industry purchases. They are not to be confused with the "multipliers" previously referred to in

TABLE 6-8

Impact Comparison of Metal Mining Purchase

	Without an Increase in Metal Mining Output	With an Increase in Metal Mining Output	Impact of Metal Mining Sector
Direct Impact on Purchases	$1,907,000	$7,361,418	$5,454,418
Direct and Indirect Impact	$2,783,182	$11,155,119	$8,371,937
Aggregate Output Factor	1.46	1.51	1.53
Direct Impact on Household Income	$464,107	$2,192,265	$1,728,158
Total Impact on Household Income	$910,294	$4,759,362	$3,849,068
Aggregate Type-II Income Factor	1.96	2.17	2.23
Total Impact on Economy	$4,427,307	$19,750,666	$15,323,359
Aggregate Total Impact Factor	2.32	2.68	2.81

this Thesis. As can be seen from Table 6-8, an increase in the output of the metal mining sector results in a 10.7 percent increase in the income factor and a 15.5 percent increase in the total impact factor. In other words, the metal mining sector has a proportionately greater impact on the economy than the average impact of the other sectors from which the chemical smelter purchases its goods and services.

Employment. In addition to the impact that results from process industry purchases, the chemical smelter purchases labor from the household sector. This employment and subsequent household income will have an impact on the economy. For the purpose of calculating the employment impact, it was assumed that these individuals would dispose of their income in the same manner as shown in the original transaction matrix of the Colorado economy. The income distribution of the smelter's employment is shown in the first column of Table 6-9. If one was to utilize a purchase matrix to calculate the economic impact as previously mentioned, one need only fill in zeros for the sectors not shown in Table 6-9.

The data shown in Table 6-9 represent only aggregated impact values. These values represent the impact on all sectors that result when the household sector makes a direct

TABLE 6-9

Impact of Chemical Smelter Employment
(dollars)

	Direct Requirements from Processing Sectors	Direct & Indirect Requirements from Processing Sectors	Direct, Indirect & Induced Requirements from Processing Sectors Including Households
Coal Mining	$ 75	$ 104	$ 179
Agriculture	2,497	4,443	6,619
Food & Kindred Products	43,506	87,084	120,312
Fabricated Metal	2,817	3,977	6,308
Chemical Industries	8,635	12,268	17,842
Printing & Publishing	1,688	2,334	5,567
All Other Manufacturing	1,277	1,500	3,298
Retail & Wholesale Trade	566,756	852,386	1,298,849
Construction	9,853	17,373	26,844
All Other Transportation	10,419	13,318	24,082
Communications & P.U.	45,075	79,876	125,034
In., Fin., R.E., GS	138,638	180,305	396,416
Total	$831,236	$1,254,968	$2,031,350

purchase from one of the sectors shown on the left side of the table. The total for the first column represents the direct impact. The total for the second column represents the direct and indirect impact and the total for the third column represents the total impact (direct, indirect, and induced). Referring to Table 5-5, the value of the smelter's employment, $1,557,000, results in household purchases from the processing sectors of $831,236 as shown on Table 6-9. The direct and indirect impact amounted to $1,255 thousand and the total impact including increased household spending was $2,031 thousand. As the output of each sector shown on Table 6-9 increases, the payments made by each processing sector to the household sector will also increase. The direct impact on household income was $210,511 and the total impact on household income was $428,772.

Although the impact data shown in Table 6-9 is somewhat aggregated, it was felt by this author that the calculation of economic impact need not be duplicated in the same detail as that shown for the process industry purchases.

<u>Total Economic Impact</u>. By adding the impact due to the smelters employment and the process industry purchases, the total annual impact on the Colorado economy can be calculated, as shown in Table 6-10. The impact which results from the employment in the chemical smelter and the direct purchases of goods and services from the processing sectors

TABLE 6-10

Total Economic Impact of Chemical Smelter on Colorado Economy

	Minimum: No Increase in Metal Mining Output	Maximum: Increase in Metal Mining Output
Direct Impact	$2,738,236*	$8,192,654*
Direct and Indirect Impact	$4,038,150	$12,410,087
Output Multiplier for Chemical Smelter	1.475	1.515
Direct Impact on Household Income	$674,618	$2,402,776
Total Impact on Household Income	$1,339,066	$5,188,164
Type-I Income Multiplier for Chemical Smelter	1.985	2.159
Total Impact on Economy	$6,461,657	$21,785,016
Total Impact Multiplier for Chemical Smelter	2.360	2.659

* Direct impact of employment includes only direct, household purchases from the processing sectors $831,236.

is shown for two cases, with and without an increase in metal mining output. As previously noted, these two cases bracket the potential impact of a chemical smelter on the Colorado economy.

For the first case in which there is no increase in metal mining output, the direct impact and the direct and indirect impact are $2.74 and $4.04 million, respectively. From these two values, the output multiplier for the chemical smelter can be calculated. This multiplier shows that for every one dollar increase in the smelter's output, the total output from all processing sectors will increase by $1.47. This increased economic activity will result in additional income to households of $1.34 million or 1.98 times the direct payments to households as wages and salaries. Including the induced effect due to increased consumer spending, the total impact on the economy is $6.46 million or 2.36 times the original value of the smelter's purchases.

For the second case in which there is an increase in metal mining output, the calculated impact far exceeds that of the first case. This situation is due mainly to the fact that the purchase of ore and concentrate from the metal mining sector is the largest purchase made by the chemical smelter. The absolute value of the impact calculated for the second case is not directly comparable to that of the first case since the two cases represent entirely different situations. It is interesting to note, however, that the multipliers calculated for the second case are larger than those for the first case. One would expect this result since the metal mining sector is capital intensive.

CHAPTER 7: CONCLUSIONS

Economic models, including input-output models, are mathematical approximations of real-world situations at either one instant in time or over a specified time period. A model is an empirical relationship which is based on data that are collected and compiled over a given time period. In effect, economic models reduce complex, real-world data into a manageable form which can be utilized by the analyst. This reduction step is accomplished by manipulating the data acccording to a given set of simplifying assumptions. These assumptions, however, invariably introduce error into the model. The amount of error depends upon the skill and subjective judgement of the analyst.

Models vary over a broad spectrum according to methodology of formulation, purpose, detail, and complexity; yet all models have one characteristic in common which is at their very foundation - the "time-environment anachronism". This characteristic refers to the assumption that the environment (social, political, or economic) either does not change at all or that if it does change, it does so according to some predetermined pattern. In other words, the element of change is either eliminated or at least constrained. The inability of a model to cope with change is its major limitation and results in most of the error involved in utilizing an economic model.

Although an old cliche states that the more things change, the more they remain the same, a more reasonable interpretation would be that the only thing that is constant is change. When an analyst uses a model, he in effect projects the environment which existed at the time of model-formulation into a future time period. The results which the analyst obtains will not be an accurate representation of the future situation because of change and in general, the greater the change, the greater the error of the estimates. It should be mentioned, however, that models provide a quantitative measure of probable future situations, and that although inaccurate, they are better than no estimates at all. In other words, every analyst realizes the limitations of economic models, yet in the absence of crystal balls, economic models provide an essential service by giving us probable future events on a "could be" basis. Such information provides invaluable guidelines for decision-making.

Another factor which contributes to the time-environment anachronism is the time-lag between data collection and compilation and model development. In many cases, the time-lag is so long that by the time the model is developed, it is no longer applicable. This situation is particularly true for input-output models which have very stringent data requirements. Data-availability problems always plague input-output studies and thus data collection is usually a lengthy, time-consuming procedure unless, however, one resorts to the use of secondary sources of information or other input-output studies.

The use of other input-output studies may solve many of the data-availability problems, but it also introduces another type of error into the model - the "economy-location anachorism". By using another regional input-output study, the analyst assumes that the economic structure of his study region is the same as the other region. He is transferring another region's economy into his study region. The choice of existing input-output studies is of paramount importance if one is to minimize the error due to the economy-location anachorism.

In the Thesis, the input-output model was based on another input-output study. By applying the input-output model of the Kansas economy, this author assumed that the structure of the Colorado economy was very similar to the Kansas economy. In addition, since the Kansas study was somewhat outdated, this author also assumed that there were no technological structural changes in the Kansas economy. Thus, this author has introduced both error due to the time-environment anachronism and error due to the economy-location anachorism. Due to the limitation of time and financial resources, however, no other course of action was feasible.

Although the use of primary sources of information and a further disaggregation of the economy would have provided a much more accurate and complete representation of the Colorado economy, it is doubtful that the use of the model for projection purposes or impact analysis would be any more valid. The dynamic nature of the Colorado economy will probably render any input-output model obsolete in a very short time. The importation of large amounts of steam coal from Wyoming, the development of a new large underground molybdenum mine, the conversion from open-hearth steelmaking to electric furnace steelmaking at CF&I, Climax's switch from underground to open pit mining, and the development of a new steam coal mine are just a few examples of recent structural changes in the Colorado economy which have not been accounted for in this input-output model.

In any event, the U.S. and the world are entering a new era of uncertainty and change. The energy events which have transpired in the last year have had a large, lasting effect on the government, the public, and industry. Declining supplies of energy fuels and their sharply higher prices have increased the relative importance of energy in comparison to other productive inputs. If the current situation persists, real changes in life styles and industry patterns could result. In a given region, some industries may stagnate or die-out, while others begin operation, resulting in a shift of manpower and capital, both within and without the region.

In regard to the energy situation, Colorado ranks high in terms of potential significant changes in the structure of its economy. The development of oil shale is only one example of projects which could have a tremendous, long-term impact on the economy.

Thus, given the current energy situation and the dynamic nature of Colorado's economy, no analyst can expect to formulate an economic model which could describe future events with any degree of accuracy. The economy is changing too fast and is subject to too many variables.

APPENDIX A: COMPUTER PROGRAMS

Program #1: Calculation of Output Multiplier

```
10 LIM AS(21.21),BS(20,20),CS(20,20)
20 J=0
30 J=J+1
40 IF J=22 THEN 110
50 READ X
60 FOR I=1 TO 21
70 READY
80 A(I,J)=(Y/X)
90 NEXT I
100 GO TO 30
110 FOR I=1 TO 20
120 FOR J=1 TO 20
130 B(I,J)=A(I,J)
140 NEXT J
150 NEXT I
160 REDIM R(20,20)
170 MAT A=B
180 PRINT "   ***********DIRECT REQUIREMENT TABLE*******
190 PRINT
200 MAT PRINT A
210 PRINT
220 PRINT
230 J=0
```

Program #1: Calculation of Output Multiplier (Cont.)

```
240 Z=O
250 J=J+1
260 IF J=21 THEN 320
270 FOR I=1 TO 20
280 Z=A(I,J)+Z
290 NEXT I
300 PRINT "THE TOTAL FOR COLUMN";J;"IS";Z
310 GO TO 240
320 MAT B=IDN(20,20)
330 MAT C=B-A
340 MAT A=INV(C)
350 MAT B=TRN(A)
360 PRINT
370 PRINT
380 PRINT
390 PRINT "*******DIRECT, INDIRECT, AND INDUCED REQUIREMENT"
400 PRINT
410 MAT PRINT B
420 PRINT
430 PRINT
440 J=0
450 Z=0
460 J=J+1
```

Program #1: Calculation of Output Multiplier (Cont.)

```
470 IF J=21 THEN 840
480 FOR I-1 TO 20
490 Z=B(I,J)+Z
500 NEXT I
510 PRINT "THE TOTAL FOR COLUMN";J;"IS";Z
520 GO TO 450
```

Program #2: Calculation of Income Multiplier

```
10 DIM AS(21,21),BS(21,21),CS(21,21)
20 J=0
30 J=J+1
40 IF J=22 THEN 110
50 READ X
60 FOR I=1 TO 21
70 READ Y
80 A(I,J)=(Y/X)
90 NEXT I
100 GO TO 30
110 PRINT  "*******DIRECT REQUIREMENT TABLE *******"
120 PRINT
130 MAT PRINT A
140 PRINT
150 PRINT
160 J=0
170 Z=0
180 J=J+1
190 IF J=22 THEN 250
200 FOR I=1 TO 21
210 Z=A(I,J)+Z
220 NEXT I
230 PRINT "THE TOTAL FOR COLUMN";J;"IS";Z
```

```
240 GO TO 170
250 MAT B=IDN(21,21)
260 MAT C=B-A
270 MAT A=INV(C)
280 MAT B=TRN(A)
290 PRINT
300 PRINT
310 PRINT
320 PRINT "******DIRECT, INDIRECT, AND INDUCED REQUIREMENT"
330 PRINT
340 MAT PRINT B
350 PRINT
360 PRINT
370 J=0
380 Z=0
390 J=J+1
400 IF J=22 THEN 790
410 FOR I=1 TO 21
420 Z=B(I,J)+Z
430 NEXT I
460 PRINT "THE TOTAL FOR COLUMN";J;"IS";Z
470 GO TO 380
```

APPENDIX B: DESCRIPTION OF INDUSTRY SECTORS

Comparison of Colorado Interindustry Model
and Kansas Input-Output Model

Colorado Interindustry Model	Kansas Input-Output Study
1. Petroleum Production and Natural Gas Processing	13. Crude Oil and Natural Gas
2. Coal Mining	16. Other Mining
3. Metal Mining	
4. Industrial Minerals	15. Nonmetallic Mining 33. Cement and Concrete 34. Other Stone and Clay
5. Industrial Services	14. Oil and Gas Service
6. Pipeline Transportation	50. Other Transportation
7. Petroleum Refining	31. Petroleum and Coal Products
8. Electric Power Generation	
9. Metal Processing	35. Primary Metals
10. Agriculture	1. Corn 2. Sorghum 3. Wheat 4. Other grains 5. Soybeans 6. Hay 7. Dairying 8. Poultry & poultry products 9. Cattle 10. Hogs 11. Other agricultural products 12. Agricultural services

11. Food & kindred products	21. Meat products 22. Dairy products 23. Grain mill products 24. Other food & kindred products
12. Fabricated metal	36. Fabricated metals 37. Other fabricated metal products 38. Farm machinery 39. Construction machinery 40. Food products machinery 41. Electric machinery 42. Other machinery 43. Motor vehicles 45. Trailer coaches 46. Other transportation equipment
13. Chemical industries	28. Industrial chemicals 29. Agricultural chemicals 30. Other chemicals 32. Rubber & plastics
14. Printing & publishing	27. Printing & publishing
15. All other manufacturing	26. Paper and allied products 25. Apparel 44. Aerospace 47. Other manufacturing
16. Retail & wholesale trade	53. Groceries 54. Farm products 55. Machinery & equipment 56. Other wholesale trade 57. Farm equipment dealers 58. Gasoline service stations 59. Eating & drinking 60. Other retail trade
17. Construction	17. Maintenance and repair 18. Building construction 19. Heavy construction 20. Special trade construction

18. All other transportation	48. Railroad transportation 49. Motor freight
19. Communications and public utilities	51. Communications 52. Electric, gas and sanitary services
20. Insurance, Finance, Real Estate and General Services	61. Banking 62. Other finance 63. Insurance and real estate 64. Lodging services 65. Personal services 66. Business services 67. Medical and health services 68. Other services 69. Education
Households	70. Households
Government	71. Federal government 72. State government 73. Local government
Imports	75. Imports
Other	76. Gross savings/ gross private investment/ change in finished goods inventory

Definition of Sectors in Interindustry Model

1. Petroleum Production and Natural Gas Processing: This sector includes all establishments engaged in the production of crude oil and natural gas and in the operation of natural gas processing plants.

2. Coal Mining: This sector includes all establishments engaged in the severance of coal from the earth and any subsequent coal processing (crushing, screening, washing, flotation, etc.) required to render the coal marketable.

3. Metal Mining: This sector includes all establishments engaged in the severance of all ferrous and non-ferrous metal ores from the earth and the subsequent ore processing (crushing, screening, washing, flotation, etc.) involved in the production of metal concentrates.

4. Industrial Minerals: This sector includes all establishments engaged in the quarrying or mining of all non-fuel and non-metallic materials (rock, clay, peat, etc.). It also includes the processing of industrial minerals such as cement and brick production, and stone, glass, and clay processing.

5. Industrial Services: This sector includes all establishments engaged in providing services to mineral industry sectors (mining, petroleum and natural gas processing, coal mining, and industrial minerals) on a contract, fee, or other basis. Such services include well logging, exploration drilling, mine or petroleum field operation, and engineering or economic consulting.

6. Pipeline Transportation: This sector includes all establishments engaged in the transportation by pipeline of crude oil, natural gas, natural gas liquids, and petroleum refinery products.

7. Petroleum Refining: This sector includes all sectors engaged in the processing of crude oil for the production of gasoline, tar, fuel oil, jet fuel, and any other petroleum-based material produced from a petroleum refinery.

8. Electric Power Generation: This sector includes all sectors engaged in the operation of power plants for the production of electricity and the subsequent transportation of electricity to consuming metropolitan areas.

9. Metal Processing: This sector includes all establishments engaged in the smelting and refining of both ferrous and non-ferrous ores or concentrates and the subsequent

casting, rolling, drawing, and alloying of ferrous and non-ferrous metals for the production of ingots, blooms or billots. This sector also includes the production of coke.

10. Agriculture: This sector includes all establishments engaged in farming, the production of all grains, vegetables, animal feed, and animals. The sector also includes all establishments engaged in performing agricultural, animal husbandry, and horticultural services on a fee or contract basis.

11. Food and Kindred Products: This sector includes all establishments engaged in the processing of dairy, meat, grain, and vegetable products such as meat packing plants, flour and other grain mill products, the manufacture of dairy products, and cereal preparation plants.

12. Fabricated Metal: This sector includes all establishments engaged in the production of ferrous and non-ferrous metal products, electrical equipment, machinery, and transportation equipment.

13. Chemical Industries: This sector includes all establishments engaged in the production of agricultural and industrial chemicals, rubber, plastics, explosives, etc.

14. Printing and Publishing: This sector includes all establishments engaged in printing and publishing and associated services such as binding and engraving on a contract or fee basis.

15. All Other Manufacturing: This sector includes all establishments not included in other sectors such as aerospace, tobacco, sporting goods, paper and allied products, lumber and wood products, furniture, toys, pencils, etc.

16. Retail and Wholesale Trade: This sector includes all establishments primarily engaged in selling merchandise to industrial, commercial, professional, and institutional consumers, and to private individuals.

17. Construction: This sector includes all establishments engaged in the maintenance and repair of buildings and structures and the contract construction of buildings and structures such as highways, dams, and bridges.

18. All Other Transportation: This sector includes all establishments engaged in the transportation of liquid and solid materials by railroad, truck, air, or any other means available except pipelines.

19. Communications and Public Utilities: This sector includes all establishments engaged in providing sanitary and

and telephone service or in the sale and distribution of gas and electricity to industry, commercial, and private consumers.

20. Insurance, Finance, Real Estate, General Services: This sector includes all establishments engaged in the fields of insurance, finance, and real estate. Finance includes banks, credit agencies, holding companies, and investment companies. Insurance covers all types of insurance and insurance brokers and agents. Real estate includes owners, lessors, lessees, buyers, sellers, agents, and developers of real estate. This sector also includes establishments providing services not included in other sectors such as education, eating and lodging services, medical and health services, legal, and other engineering services.

21. Base and Precious Metal Refinery: This sector includes all establishments engaged in the chemical processing (leaching, solvent refining precipitation, etc.) of base and precious metal ores and concentrates for the production of a semi-refined or refined non-ferrous metal ingot or super concentrate.

Households: A purchase from households includes all salaries, and wages, which are paid by a firm to the individual. Expenditure by households includes all revenues to the firm not attained by the sale of goods and services to other firms or government or from exports.

Government: This sector includes all local, state, and federal government activities.

Imports: Imports include any material or service which is brought into the state of Colorado from the surrounding states by any industrial, commercial, or private consumer or government agency.

Exports: Exports include any material or service which is transported out of the state of Colorado by any government agency or industrial, commercial, or private consumer.

Other Payments: This sector includes all royalties, rents, payments, dividends, depreciation, profits, and inventory change which may be paid or received by any industrial or commercial establishment, private individual, or government agency.

APPENDIX C: TRANSACTION MATRIX

Transaction Matrix of Colorado Economy*

Quadrant I: Processing Sectors / Quadrant II: Final Demand

Inputs \ Outputs	1 Petrol. Prod. & NG Prc.	2 Coal Mining	3 Metal Mining	4 Indust. Mineral	5 Indust. Service	6 Pipel. Trans.	7 Petrol. Refin.	8 Elect. Power Generat	9 Metal Processing	10 Agriculture	11 Food & Kindred Products	12 Fabricated Metal	13 Chemicals etc.	14 Printing & Publish.	15 All Other Manufac.	16 Retail & Wholesale Trade	17 Construction	18 Other Transportation	19 Commun. & Public Utilities	20 In., Fin., R.E., & Gen. Ser.	Households	Government	Exports	Other	Total Output
1:Pet. Pro. & NG Prc.	14,554	0	0	0	0	129,985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144,539
2:Coal Mining	0	0	0	0	0	0	0	19,840	10,844	0	0	2,100	40	0	1,500	0	2,000	0	0	0	500	0	35,994	500	52,818
3:Metal Mining	0	0	0	0	0	0	0	0	17,957	0	0	0	0	0	0	0	0	0	0	0	0	0	170,326	0	188,283
4:Indust. Minerals	0	975	1,362	0	415	0	0	0	1,726	0	0	0	3,000	0	0	2,522	100,267	0	0	0	0	10,000	8,777	0	129,044
5:Indust. Services	35,435	1,276	20,701	215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85,555	0	143,183
6:Pipeline Trans.	0	0	0	0	0	0	60,011	17,107	0	0	0	0	0	0	0	0	0	0	103,529	0	0	0	144,334	0	324,981
7:Petrol. Refining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	187,640	0	0	0	0	0	0	0	0	187,640
8:Elec. Pwr Generat.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	151,017	0	0	0	0	0	151,017
9:Metal Proces.	0	0	0	0	0	0	0	0	21,746	0	0	32,397	0	0	0	0	0	0	0	0	0	0	109,927	0	164,070
10:Agric.	0	0	0	0	0	0	0	0	0	592,994	673,418	0	336	0	2,059	1,175	0	0	0	0	16,681	73,000	393,997	0	1,959,560
11:Food & Kin. Pd.	0	0	0	0	0	0	0	0	0	89,155	69,300	0	2,315	0	0	229,996	0	0	0	34,325	290,598	75,374	1,014,492	1,445	1,861,000
12:Fab. Metal	6,771	3,401	5,991	6,160	2,360	3,210	2,350	4,589	13,850	10,578	47	50,470	1,015	628	4,192	283,340	42,020	5,543	6,917	41,761	18,802	223,746	567,593	242,357	1,553,100
13:Chemical etc.	2,455	1,698	8,033	2,194	336	650	458	0	1,995	46,508	745	2,668	9,495	7,313	1,920	160,348	22,340	1,412	1,020	3,453	57,675	6,138	175,011	235	513,100
14:Printing & Pub.	633	50	272	333	45	85	30	150	90	3,694	22,728	8,094	27,356	8,563	9,573	55,271	825	7,104	7,564	1,992	11,275	4,413	122,652	2,403	255,100
15:Other Manufact.	316	518	8,576	7,156	6,767	4,111	4,048	6,505	6,871	168	1,084	1,340	1,006	0	1,767	176,249	7,433	303	648	6,007	8,524	256,200	173,472	4,141	681,600
16:Retail & Whs. Tr.	633	249	4,188	10,839	4,851	3,818	7,552	5,184	6,427	88,315	52,945	251,649	80,284	48,105	22,336	181,662	348,040	8,984	16,580	98,555	3,785,660	546,020	1,298,505	45,850	6,592,025
17:Construction	0	1,000	4,814	5,375	0	0	0	3,211	5,600	6,221	3,959	8,742	1,155	4,289	16,000	209,671	389,508	6,173	26,360	61,758	65,817	172,574	351,603	714,511	2,050,677
18:Other Trans.	3,291	3,374	5,994	26,285	2,167	360	100	0	345	5,541	17,019	19,396	8,906	5,052	5,661	191,712	13,169	33,272	63,096	5,750	69,602	53,705	344,576	0	878,883
19:Comm. & Pub. Ut.	6,587	1,399	11,441	2,711	351	765	31	0	5,029	12,257	3,574	25,105	5,860	4,510	4,062	185,043	7,451	5,172	31,256	76,615	304,063	113,515	67,776	0	883,131
20:In., F., R.E., GS	2,685	190	401	786	4,613	1,037	20	350	393	24,010	13,957	14,646	5,454	3,168	3,155	348,225	41,374	28,648	18,586	775,618	926,037	431,033	333,357	0	2,310,259
Households	18,935	15,577	59,655	37,718	110,566	11,317	3,350	12,448	51,559	385,170	200,977	368,554	82,861	84,514	352,060	1,320,672	405,382	333,677	228,070	1,273,633	1,625,553	1,685,000	0	1,554,682	10,469,000
Government	14,580	3,401	6,038	5,807	5,500	5,474	443	19,648	5,788	27,536	96,777	128,025	23,081	18,980	22,289	657,317	107,564	105,987	35,842	164,686	1,555,855	645,448	0	1,003,342	4,663,806
Imports	0	7,477	17,032	0	0	112,519	109,423	0	0	280,560	471,565	553,571	203,419	92,534	195,704	1,931,048	573,357	210,048	16,828	314,445	0	145,066	243,171	0	5,418,167
Other	37,697	12,233	31,785	22,964	5,562	51,570	5,794	51,685	10,616	384,853	32,605	83,243	57,517	13,634	15,477	714,334	54,861	89,705	169,924	112,631	1,666,341	22,371	(98,105)	(2,508,104)	1,061,692
Total Output	144,539	52,818	188,283	129,044	143,183	324,981	187,640	151,017	164,070	1,959,560	1,861,000	1,553,100	513,100	255,100	682,600	6,592,025	2,050,677	878,883	883,131	2,310,259	10,469,000	4,666,806	5,418,167	1,061,692	42983069

Quadrant III: Primary Inputs or Value Added / Quadrant IV: Accounting Totals

*all values in $1000

LITERATURE CITED

1.1 Rudawsky, Oded, The role of cement production in promoting regional growth - the experiences of Israel and Mexico: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 175 - 204 (February 1970).

1.2 Faucett, Jack G., Implications of input-output analysis for the mineral industries: Washington, D.C., American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 308 - 320 (February 1969).

1.3 Wang, Kung-Lee, Regional impact analysis techniques for the mineral industries: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 153 - 174 (February 1970).

1.4 Geehan, Patrick H., Input-output analysis of the economic impact of petroleum exploration in four southeastern Colorado counties: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, Thesis No. T-1565 (1973).

1.5 Pederson, John A., and Rudawsky, Oded, The role of minerals and energy in the Colorado economy: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, 347 p. (1974).

2.1 University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, Colorado business and economic outlook forum, 1973: Boulder, Colorado, University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, p. 3 (1973).

2.2 University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, Colorado business and economic outlook forum, 1973: Boulder, Colorado, University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, p. 4 (1973).

2.3 Office of Management and Budget, Statistical Policy Division, Standard industrial classification mannual, 1972: Washington, D.C., U.S. Government Printing Office, p. 31 (1972).

2.4 Wang, Kung-Lee, Regional impact analysis techniques for the mineral industries: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 153 (February 1970).

2.5 Pederson, John A., and Rudawsky, Oded, The role of minerals and energy in the Colorado economy: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, 347 p. (1974).

2.6 Pederson, John A., and Rudawsky, Oded, The role of minerals in the Colorado economy: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, p. 114 - 134 (1974).

2.7 O. W. Walvoord, Inc., Chemical refining study of base and precious metal ore in Colorado: Denver, Colorado, O. W. Walvoord, Inc., p. 14.2 - 14.3 (June 1965).

3.1 Kendrik, John W., Economic accounts and their uses: New York, McGraw Hill Book Company, p. 56 (1972).

3.2 Kendrik, John W., Economic accounts and their uses: New York, McGraw Hill Book Company, p. 56 - 57 (1972).

3.3 Leontief, Wassily, The structure of the American economy, 1919 - 1939: New York, Oxford University Press, (1951).

3.4 Kendrik, John W., Economic accounts and their uses; New York, McGraw Hill Book Company, p. 59 - 60 (1972).

3.5 Miernyk, William H., The elements of input-output analysis: New York, Random House, p. 45 - 48 (1965).

3.6 Hirsch, Werner Z., "Interindustry relations of a metropolitan area," The review of economics and statistics: XLI, p. 360 - 369 (November 1959).

3.7 Miernyk, William H., The elements of input-output analysis: New York, Random House, p. 53 (1965).

3.8 Moore, F. T., and Peterson, J. W., "Regional analysis: an interindustry model of Utah," The review of economics and statistics: XXXVII, p. 368 - 383 (November 1955).

3.9 Isard, Walter, and Kuenne, R. E., "The impact of steel upon the greater New York - Philadelphia industrial region," The review of economics and statistics: P. 289 - 301 (November 1953).

3.10 Wang, Kung-Lee, Regional impact analysis techniques for the mineral industries: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 165 (February 1970).

3.11 Miernyk, William H., The elements of Input-output analysis: New York, Random House (1965).

3.12 Geehan, Patrick H., Input-output analysis of the economic impact of petroleum exploration in four southeastern Colorado counties: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, Thesis No. T-1565 (1973).

3.13 Yan, Chiou-Shuang, Introduction to input-output economics: New York, Holt, Rinehart and Winston, Inc. (1969).

3.14 Chenery, Hollis B., and Clark, Paul G., Interindustry economics: New York, John Wiley and Sons, Inc. (1959).

4.1 Emerson, M. J., The interindustry structure of the Kanas economy: Office of Economic Analysis and Kanas Department of Economic Development Planning Division (1969).

4.2 U.S. Department of Commerce, Input-output structure of the U.S. economy: 1963 Volume 2 - direct requirements, U.S. Government Printing Office (1969).

4.3 U.S. Department of Commerce, Input-output structure of the U.S. economy: 1963 Volume 2 - direct requirements, U.S. Government Printing Office (1969).

4.4 Emerson, M. J., The interindustry structure of the Kanas economy: Office of Economic Analysis and Kanas Department of Economic Development Planning Division, p. 28 - 29 (1969).

4.5 Geehan, Patrick H., Input-ouput analysis of the economic impact of petroleum exploration in four southeastern Colorado counties: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, Thesis No. T-1516, p. 50 - 51 (1973).

4.6 Pederson, John A., and Rudawsky, Oded, The role of minerals and energy in the Colorado economy: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, p. 250 - 273 (1974).

4.7 University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, Colorado business and economic outlook forum, 1973: Boulder, Colorado, University of Colorado, Graduate School of Business Administration and Colorado Division of Commerce and Development, 30 p. (1973).

4.8 Emerson, M. J., The interindustry structure of the Kanas economy: Office of Economic Analysis and Kanas Department of Economic Development Planning Division, Transaction Matrix (1969).

4.9 Schaffer, William A., and Chu, Kong, Simulating regional interindustry models for western states: Atlanta, Georgia, Georgia Institute of Technology, unpublished paper for Pacific Regional Science Conference, discussion paper 14, p. 8 - 9 (August 1969).

4.10 Geehan, Patrick H., Input-ouput analysis of the economic impact of petroleum exploration in four southeastern Colorado counties: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, Thesis No. T-1565, p. 34 - 36 (1973).

4.11 Leftwich, Richard H., An introduction to economic thinking: New York, Holt, Rinehart and Winston, Inc., p. 520 - 521 (1968).

4.12 U.S. Department of Commerce, Office of Business Economics, Survey of current business: V. 53, no. 3, p. 13 - 16 (March 1974).

4.13 Pederson, John A., and Rudawsky, Oded, The role of minerals and energy in the Colorado economy: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, p. 226 - 239 (1974).

4.14 Miernyk, William H., The elements of input-output analysis: New York, Random House, p. 49 (1965).

5.1 Colorado School of Mines Research Foundation, Inc., A preliminary analysis of the metallurgical and economic feasibility of an Imperial smelting plant in Colorado: Golden, Colorado, Colorado School of Mines Research Foundation, Inc., Project No. 221010, 71 p. (May 1964).

5.2 Hazen, H. L., Lang, E., and Ellerman, R., Why not a chemical smelter: Denver, Colorado, Colorado Mining Association (February 1964).

5.3 O. W. Walvoord, Inc., Chemical refining study of base and precious metal ore in Colorado: Denver, Colorado, O. W. Walvoord, Inc. (1965).

5.4 Turck, F. B. and Company, Inc., A study of non-ferrous metal refining opportunities in the Four Corners states: Truck, F. B. and Company, Inc. (November 1964).

5.5 Peters, Max S., Plant design and economics for chemical engineers: New York, McGraw Hill Book Company, Inc., p. 100 (1968).

5.6 Peters, Frank A., Johnson, Paul W., and Kirby, Ralph C., A cost estimate of the Bayer process for producing alumina: Washington, D. C., U.S. Department of Interior, Bureau of Mines, RI 6730, p. 11 (1966).

5.7 Wang, Kung-Lee, and Kokat, Robert G., The interindustry structure of the U.S. mining industries, 1958: Washington, D.C., U.S. Department of Interior, Bureau of Mines, IC 8338, p. 34 - 35 (1967).

5.8 Town, J. W., and Stickney, W. A., Cost estimates and optimum conditions for continuous-circuit leaching of mercury: Washington, D.C., U.S. Department of Interior, Bureau of Mines, RI 6459, p. 21 - 23 (1964).

5.9 Bennett, Harold, Moore, Lyman, and others, An economic appraisal of the supply of copper from primary domestic sources: Washington, D.C., U.S. Department of Interior, Bureau of Mines, IC 8598, p. 146 (1973).

5.10 Peters, Max S., Plant design and economics for chemical engineers: New York, McGraw Hill Book Company, p. 141 (1968).

6.1 Wang, Kung-Lee, Regional imapct analysis techniques for the mineral indsutries: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 156 (February 1970).

6.2 Wang, Kung-Lee, Regional impact analysis techniques for the mineral industries: Denver, Colorado, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Proceedings of the Council of Economics, p. 158 (February 1970).

6.3 Emerson, M. J., The interindustry structure of the Kanas economy: Office of Economic Analysis and Kanas Deparment of Economic Development Planning Division, p. 143 - 150 (1969).

6.4 Leontief, Wassily, Input-ouput economics: New York, Oxford University Press, p. 184 - 223 (1966).

6.5 Geehan, Patrick H., Input-output analysis of the economic impact of petroleum exploration in four southeastern Colorado counties: Golden, Colorado, Colorado School of Mines, Department of Mineral Economics, Thesis No. T-1565 (1973).