THE INTERACTION OF THE STEEL MINI-MILL WITH ITS MARKETS

by

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Their contributions in this quest for clarity and worthiness must be recognized here at the commencement of this work.

ABSTRACT

The purpose of this thesis is to discover the effect of market structure on the development of the steel-making mini-mill. Because the mini-mill sector of the domestic steel industry enjoys relative decentralization, the question is asked if this state is the result of the market environment in which the mini-mill exists.

To investigate this query, the mini-mill is described in terms of its position in the steel industry, its similarities and differences with integrated mills, and, most important, its economic peculiarities. A model mini-mill is then constructed and its interaction with its markets is suggested by a sensitivity analysis of several criteria.

The question of market interaction with the mini-mill is dealt with by evoking a measure of market suitability. The basis of this measure is commodity mobility which demonstrates how freely a commodity can travel in a geographic region. It is suggested that immobile commodities are particularly well suited to decentralized industrial structures such as the mini-mill.

The model of market suitability fails to fully explain the available data; however, the results uncover several interesting aspects of the mini-mill's markets.

By investigating this area of market interaction with the mini-mill structure, the basis is established for further work dealing with the future of the mini-mill.

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CHAPTER I. INTRODUCTION

Objectives

Just as the old cliche reminds us that no man is an island, so too it is a fact that no enterprise is isolated from its environment. Any producer must purchase a multitude of inputs from the resource markets, operate on those inputs and add value to them, and then, sell the resultant goods in their respective product markets.

How the producer actually pursues this process is often times the result of the structure of the markets he must deal in. The object of this paper is to explore the importance of the market structures, or the environment that confronts the steel-making mini-mill, and why this environment is particularly well suited to the mini-mill.

The mini-mill is a relatively recent competitor in the domestic steel industry (it has flourished only since World War II). Its growth is not so much the result of technical innovation because all of its processes are the result of research and development work carried out and experience gained, for the large part, by the giant steel companies, foreign and domestic. Rather, the advent and development of this type of steel producer is more the result of its economic peculiarities. The mini-mill has forfeited the enormous economies of scale enjoyed by the huge steel mills in favor of lower investment, reduced overhead costs, contracted and limited markets, and increased flexibility; this trade-off has been profitable for the mini-mill and a detriment to its competitors (Industry Week, 1971; Annual Report, Nucor Corp., 1972).

In order to analyze the environment in which the mini-mill produces, and to observe the suitability of this environment to the mini-mill, it is first necessary to define the mini-mill and to put it into perspective. Once this definitive action has been accomplished, the mini-mill can be explored in more detail; the costs and cash inflows for a model mini-mill will be laid out and an economic evaluation performed. At this point, it will be possible to actually measure how variations in the resource and product markets affect the profitability of this operation.

Having established the importance of the environment to the mini-mill, it will be possible to center attention on these markets and discover if, and why, they are particularly well suited to the mini-mill.

Yet, this presentation is objective in nature and it does not intend to predict future events. It does, however, set a basis for such extrapolations, if one is intent on pursuing future trends.

Scope

It is intended to limit the scope of this analysis to an evaluation within the U.S. economy, since this will avert over-generalization and simplification to some degree. Furthermore, any implication of future effects must be confined to a time frame of ten years or less because of the dynamic nature of the steel industry and the economy. More specific restrictions are mentioned throughout the paper as they are assumed.

Although the model of a mini-mill (as described in Chapter 3) is a simulation, the applicability of the conclusions presented here is in no way denigrated. The model is simply used to find those criteria that must be investigated further, and these observations are very real.

Previous Studies

There have been a multitude of studies conducted on the components of the mini-mill industry. Many articles are referred to in the bibliography that have specifically attacked the problems of the scrap market, while an almost equal number have offered viable alternatives to facing these scrap problems and these articles are also referenced in the text. However, this set of articles was written from the general steel (and scrap) industry point of view and not specifically with the mini-mill in mind.

A wealth of information was available from the annual Electric Furnace Proceedings of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME). These contributions were directed toward the technical aspects of the various processes involved in making steel in the mini-mill; but, in addition, there were several studies from this source that projected the future directions for some of these processes.

There were very few studies that were largely directed toward mini-mills and an analysis thereof. One such study by R. J. Kuhl (1972) produced the cash flows that were used in Chapter 3 of this work to conduct the economic evaluation of the mini-mill and the ensuing sensitivity analysis.

In addition, there were several articles that described the operations of mini-mills and these were helpful in formulating the definitive sections of Chapter 2.

Unfortunately, no studies were found that brought together all the economic considerations that must be appraised in planning a mini-mill. This present work is designed to partially fill this void by analyzing two of the most important criteria--the resource market and the product market.

Methods of Analysis

The only techniques used in this paper and not defined in the text are the quantitative tools applied in Chapter 3. Discounted-cash-flow-rate-of-return (DCFROR) is a method of calculating an interest rate on the cash inflows that will provide an exact balance with the cash outflows over the project life. The technique is widely used in economic evaluations and reference to an engineering economic text (such as Stermole, 1971) will provide the basis for its use. Sensitivity analysis simply demonstrates the change resulting in the DCFROR when one of the variables used to calculate DCFROR is changed; such a tool permits insight into the relative importance of the variables.

The analyses conducted in Chapter 4 are quantitative and all techniques used there are fully explained within the text.

Part of the data used in this thesis is somewhat outdated. However, since it is felt that these data could denote trends and directions without detailed implications, the data were used. The cost information upon which Chapter 3 is based has not been brought up to date because it seems that the qualitative conclusions drawn from this chapter would not be affected by such action.

CHAPTER II. THE MINI-MILL IN PERSPECTIVE

The Mini-Mill in the Steel Industry

In 1971, Kotsch (1971) described some forty mini-mills in the U.S. that accounted for a combined raw steel capacity in excess of 6,000,000 tons per year. Although this figure is not very impressive compared to the singular outputs of some of the larger integrated steel mills, the fact remains that this output is concentrated in the reinforcing bar (rebar) and merchant bar markets and accounted for about 20 percent of these combined markets in 1970 (Miller, 1970). Furthermore, mini-mills' share of this market is expected to increase, considering some of their advantages:

> "During 1972, the (mini)mill used less than 5 man-hours per ton of steel produced. This compares with an average of over 8 man-hours for the domestic steel industry and 6 man-hours in the Japanese steel industry... The (mini) mill was built at a capital cost of about $70 per ton, while for the domestic steel industry as a whole, capital cost averages $200 per ton." (Nucor Corporation Annual Report, 1972)

A natural implication to be drawn from such a statement, as well as other descriptions, is the eventual transfer of investment and capacity from large integrated mills to mini-mills. Such a conclusion is not valid in light of the reasons why mini-mills are so attractive, and this will be discussed later.

The advent of this entity is largely the result of both backward and forward vertical integration. Although many of the mini-mills are now independent steel producrs, some of them resulted when building contractors became desperate for rebar supplies during periods of steel shortage, or when scrap dealers suffered lost business when steel demand was low or new hot metal (i.e. blast furnace) capacity was brought on stream. Because the investment and technological barriers for entry into mini-mill steel production are relatively easily overcome, these dissatisfied consumers and suppliers of the steel industry were able to merge their interests independently and integrate. (Industry Week, 1971 and Hogan, 1971).

<u>Similarities with Integrated Mills</u>: Structurally, mini-mills and integrated mills differ with regards to the principle processes, the size of the operation (and investment required), the resource and product markets, and

the economies of scale; these differences will be discussed in the next section. It is sufficient to note here that mini-mills are not miniature integrated mills.

The principal processes of the mini-mill are the electric furnace, casting facilities, and rolling capabilities. Integrated operations also utilize casting and rolling capacities (of a much larger scale) to process their steel, but the major portion of their raw steel production is by a process entirely different from the electric furnace.

Both the resource and product markets of mini-mill operations are encompassed by the respective markets of integrated mills. The major feed material for mini-mills is purchased scrap, whereas this input accounts for some 20 percent of the metallics for the integrated mills. The product market for mini-mills consists largely of hot-rolled merchant bar and rebar to supply the construction industry and others, while hot-rolled bar production accounts for only about 15 percent of the total output of the the entire domestic industry (Annual Statistic Report, American Iron and Steel Institute, 1972).

Although these two types of steel producers share markets and technology, it is the difference between them that accounts for the mini-mills' growth.

Differences with Integrated Mills: The most significant difference between these two operations is scale. While an integrated plant producing 4 million net tons of steel per year might require $2,000 million in the first stage of capital expenditure (Merklin, 1974), a 60,000 ton per year mini-mill was built in 1968-69 for $7.5 million and an additional $1 million a year later doubled its capacity (Nucor Annual Report, 1972). Scale is very much reflected in lcoational economics as noted in Figure 1 and Table 1 below. Large integrated mills are usually located near water and/or rail transportation, so that economies of ore and product transport can be fully exploited. For example, the right-hand side of Table 2 displays the predominant use of rail to transport finished steel as opposed to the use of motor carrier in the larger steel-making division. In addition, the third largest steel-making sector (i.e. districts V, VI, and VIII--the Southeast and Southcentral part of the country) makes excellent use of water transport. This is not the case with mini-mills which may maintain a market area of about 250 miles radius (Industry Week, 1971) and depend a great deal on truck transportation.

Furthermore, due to the extensive investment in large integrated steel works, there must be substantial assurances of guaranteed inputs and product markets. The latter are

TABLE 1

Geographic Distribution of Mini-mill Raw Steel Capacity in 1971

Geographic Division of Origin (see fig. 1)	No. of mills	Thousands of tons	% of total mini-mill tons
I	1	120	1.9
II	5	655	10.4
III	4	640	10.1
IV	1	300	4.8
V	9	1278	20.2
VI	6	745	11.8
VII	6	810	12.8
VIII	1	180	2.8
IX	9	1587	25.1
Total	42	6315	100

Source: Kotsch, 1971

IX includes Alaska and Hawaii

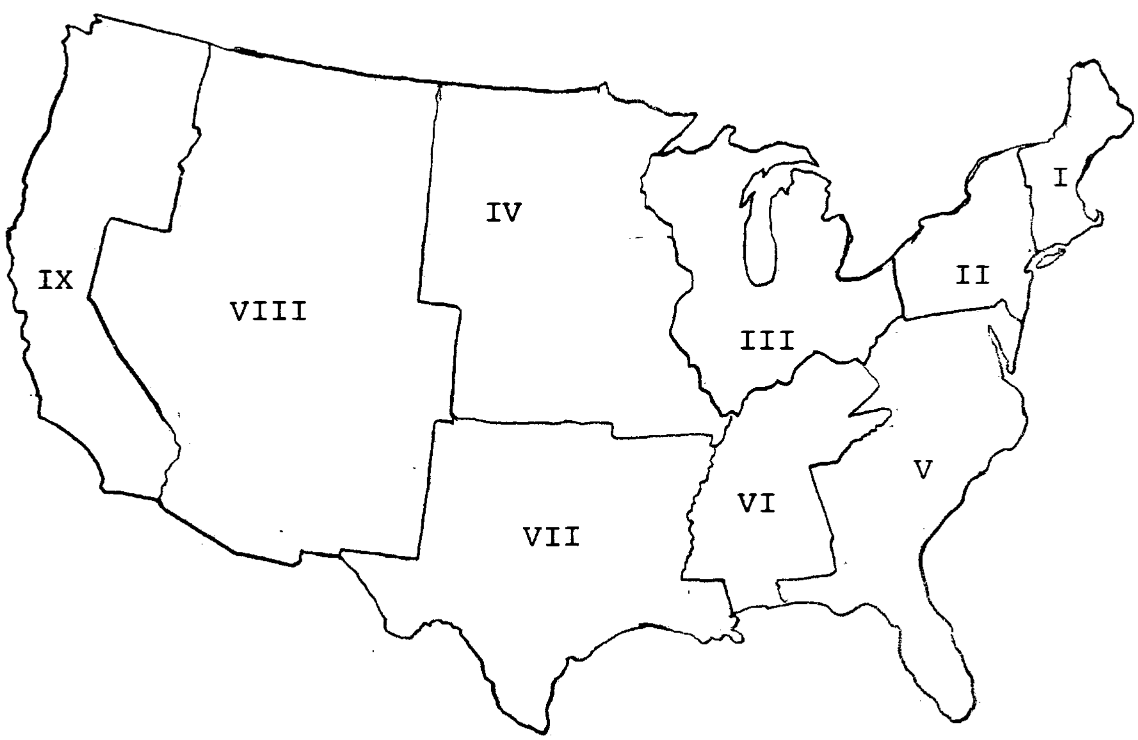


Figure 1: Geographic Divisions

TABLE 2

Geographic Distribution of Total Steel Shipments in the U.S. in 1963

Geographic Division of Origin (see Fig. 1)	% of tons shipped	Percent distribution of ton-miles (in each division) by means of transport				
		Rail	Motor Carrier	Private Truck	Water	Other
I	.88	30.1	45.7	15.1	8.4	.7
II	33.8	65.4	25.7	.8	7.3	.8
III	44.0	57.6	30.1	2.3	9.5	.6
IV	1.22	61.7	36.7	1.3	.9	-
V, VI, VII	14.8	53.6	16.5	4.1	25.7	.1
VIII, IX	5.3	85.5	12.7	1.7		

Source: 1963 Census of Transportation v. 111 - Dept. of Commerce assured by forming subsidiaries such as construction companies and steel service centers (distributors), while the former are guaranteed by ownership of iron ore and coking coal reserves, as well as long-term contracts. Such assurances are readily observed by the market preference of integrated mills to depend upon their own reliable sources of hot metal and self-generated scrap than risk the uncertainties of the uncontrolled scrap market. Integrated mills can afford this degree of assurance because their steel is produced from iron generated in their own blast furnaces and scrap recycled from within the plant. Mini-mills, on the other hand, do not enjoy the same degree of captiveness. Long-term contracts are not realistic for the resource market of mini-mills because of intense fluctuations in prices and the product market is geographically limited because freight savings and rapid deliveries appear to be among the major advantages enjoyed by these operations.

The difference in scale is manifested in other aspects. For example, Cartwright (1972) demonstrates the flexibility of mini-mills in expanding; since the processes utilized in mini-mills are of low capacity, additional units can be brought on line without inundating the product market as much as an expansion in an integrated mill. In addition, mini-mills have usually limited their expansion to less than half of the resource and product markets in a 250-mile radius area, so that cyclical variations in these markets are not so damaging (Industry Week, 1971). Of course, integrated mills must operate as close to full capacity as is possible in order to offset high fixed costs and may even sacrifice as much as their average variable cost in order to achieve this end. Thus, softening in usual product markets often forces high-capital cost mills to search the world over for consumers of their products.

Furthermore, flexibility is enhanced by size because small-sized orders can be readily accomodated and, along with a smaller time delay, this establishes excellent rapport between the mini-mill and consumers.

Technical Definition

The mini-mill is a non-integrated steel mill defined by the range of 40,000 to 300,000 annual ton capacity of carbon steel. Data published in late 1971 (Industry Week) describe some 40 mills in the U.S. in this category at that time. Increasing the range to 400,000 tons annually brings another five mills into consideration.

A quick comparison with an integrated mill of the inputs required to make a ton of hot rolled bar product is available through a single column summary of the input-output work conducted by Tsao and Day (1971):

Inputs Required Per Ton of Hot Rolled Bar

(for an integrated mill with byproduct coke ovens using bituminous coal, blast furnace using pellets, and a basic oxygen furnace using 70 percent hot metal and 30 percent scrap).

Note: negative number denotes output

		Quantity used or produced
Hot rolled bars and light shapes	Preliminary	-1.00 net tons(N.T.)
Labor	shaping and	4.82 man hrs.
Home scrap	final finishing	- .076 N.T.
Ingot steel	sector	1.38 N.T.
Ingot steel		-1.38 N.T.
Electric power		32 Kwh
Fluorspar	Steel pro-	17.93 lbs
Burnt lime	ducing	.09 N.T.
Heavy melting scrap	sector	.47 N.T.
Hot metal		1.09 N.T.
Oxygen		$2.29 \times 10^3 ft^3$
Labor		.83 man hrs.
Hot metal		-1.09 N.T.
Coke	Blast	.60 N.T.
Pellets	furnace	1.27 N.T.
Limestone	sector	.24 N.T.
Light scrap		.02 N.T.
Fuel consumption		16.83 MBTU
Recoverable waste heat		-6.94 MBTU
Labor		.69 man hrs
Oxygen		$.11 \times 10^3 ft^3$
Coke		- .60 N.T.
Bituminous coal	Coke	.86 N.T.
Fuel consumption	sector	1.94 MBTU
Recoverable byproduct fuel or waste heat		-7.78 MBTU
Labor		.27 man hrs

Because this enterprise uses iron and steel scrap rather than the typical iron ore-coal feed of an integrated steel mill, its flow sheet can be relatively simpler. An additional simplifying factor is the rather limited product schedule that these mills offer.

A mini-mill configuration assumed by Kuhl (1971) is two 40-ton 16,000 KVA electric furnaces for melting and refining the scrap to carbon steel; one 2-strand billet continuous caster for transforming the refined steel to its initial solid state; a billet reheat furnace for preparing the solid billets for hot rolling; and a continuous rolling mill for achieving the desired shapes from the billets. The flow diagram in Fig. 2, taken from Kuhl's article, displays this configuration along with a material balance for a 150,000 ton mini-mill. Commonly the final products of these units are reinforcing bar, angles, rounds, and other merchant bars.

This configuration, however, cannot be construed as typical. Because the mini-mill operation offers quite a bargain in terms of investment, some companies have further exercised this advantage by purchasing their electric furnaces and rolling equipment used. Unfortunately, the rather recent (early 1960's) adoption of continuous casting has not made this facility readily available under second-hand

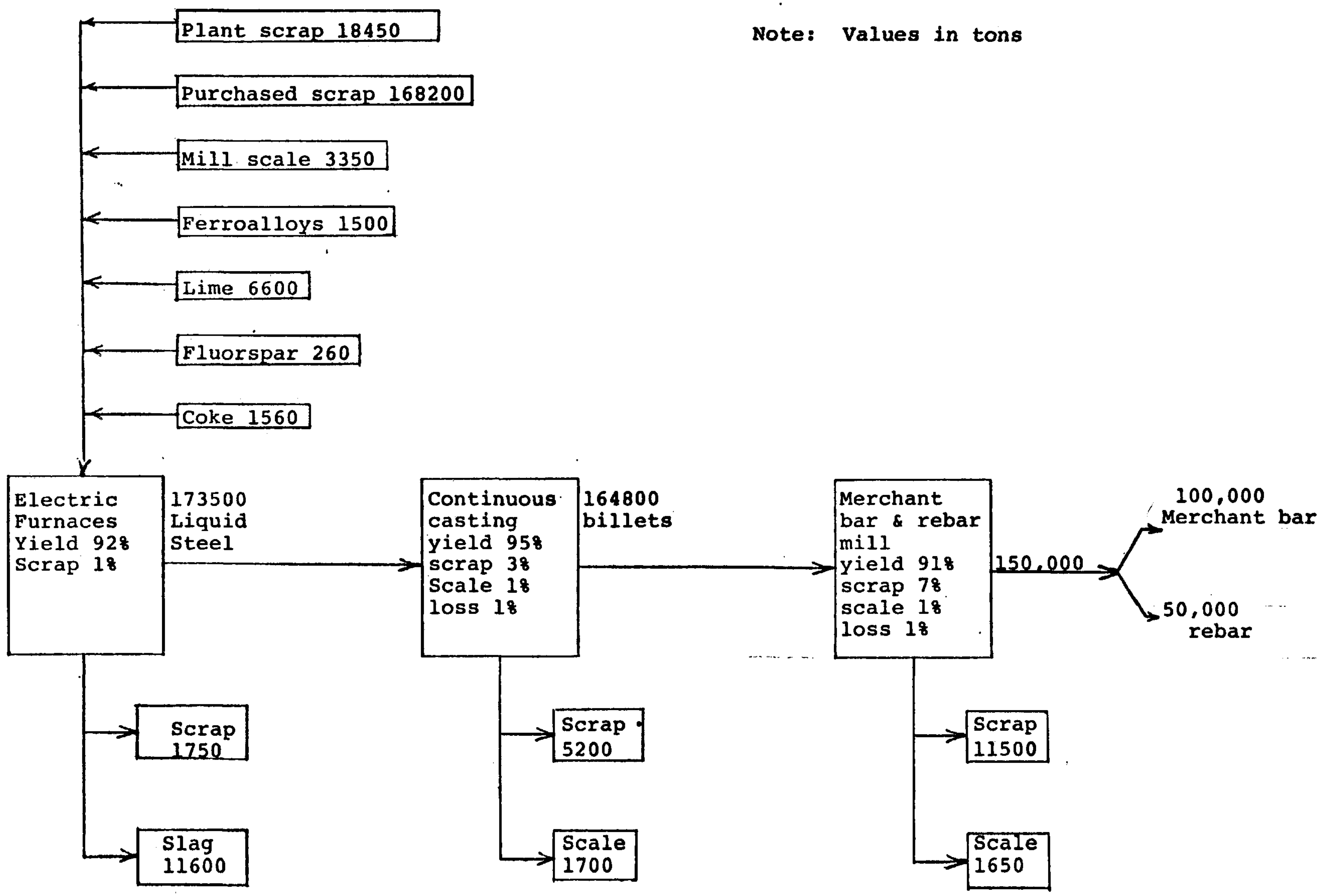


Fig. 2 A Model of a Mini-Mill
Source: Kuhl, 1972

terms. Of the mini-mill raw steel annual capacity of 6.315 million tons in 1971, Kotsch (1971) has surveyed only about 3.527 million annual tons of continuous casting capability for these mills. However, with the prospects of lower operating costs than the conventional ingot-producing method, the increased yield, the enhanced uniformity and quality of the product, and the overall suitability of the process to the mini-mill structure, the continuous caster will make further inroads into this industry.

Other than variations in casting procedure, the equipment of the present mini-mills is generally well represented by the assumed model. Of course, the size and number of the electric furnaces and rolling facilities vary from mill to mill along with the annual output. However, in the majority of cases, rolling capacity appears to be the bottleneck in the mill.

In addition, some mills have forging capabilities and wire drawing equipment; at least one mill (Allison Steel Manufacturing Co., Arizona) has a scrap shredder, indicating some backward integration into its resource market.

Another exception to this general representation is the use of small (50 tons and 160 tons) basic open hearth furnaces by two mini-mill companies (Harrisburg and Pacific States). However, these types of furnaces are losing favor in the steel industry and will probably not enjoy further technological advances; besides, they suffer diseconomies on this small scale when compared to electric furnace steelmaking.

A very important variation from the model is the replacement of direct reduced pellets for scrap as the major feed material. At present, such procedure is practiced by two mills (Georgetown Steel Corp. and Oregon Steel Mills, Inc.), but future expansion in this area is predicted (Miller, 1970; Kuhl, 1969; Sibakin et al, 1967) because it obviates the uncertainty of fluctuating scrap prices.

Some important technical aspects of the mini-mill are not involved with its operation, but result from construction considerations. It has already been mentioned that these projects often enjoy reduced investment due to the purchase of used equipment. Another facet of construction is the rather rapid rate at which mini-mills can be put into operation. For example, Florida Steel Corporation reported in its 1971 Annual Report the completion of its Indiantown plant some 13 months after construction began; this factor is especially brought into prospect when considering the time value of future cash flows. A third construction consideration has been touched upon previously; the technology utilized in the mini-mill is not new, and further, future developments in this technology will probably become available through the efforts of the larger steel companies who are concerned with much larger-scale equipment but of the same function as that used by the mini-mills. This is the benefit of technological fallout.

The mini-mill, then, is a non-integrated operation in the capacity range of 40,000 to 300,000 annual tons that consumes iron and steel scrap to produce carbon steel in the form of rebar and merchant bars.

Economic Pecularities

The purpose of this chapter is to acquaint the reader with the mini-mill by comparing it to its competitor (i.e. the integrated mill) in steel production and by describing an overview of its technical structure. Because the economics of a process is often the criterion that dictates a project's viability even in the face of adverse technical considerations (e.g. the maintenance of open hearth steelmaking despite the technical superiority of the basic oxygen furnace [BOF]), it is important that the economic aspects of the mini-mill now be listed in review:

1) The mini-mill has sacrificed lower production costs for lower investment costs to achieve a relatively higher rate of return at low production levels. This return is very sensitive to scrap prices (Cartwright, 1972). In addition, because of a rapid construction period, these mills

offer an early return on capital.

2) Low production levels do not permit the mini-mill to take advantage of economies of scale in transporting resources or products .

3) Further, the low-value nature of scrap and merchant bar products does not permit economic transport of small quantities over long distances.

4) Therefore, the market area of these mills is relatively limited.

5) However, because both of these markets are naturally decentralized, the mill can be profitable, since a large operation might not survive under such limiting conditions.

6) Although some mini-mills initially were conceived as extensions to a scrap or construction firm, many have gone beyond being captive operations to serve the open market.

7) The processes employed in mini-mills permit a high degree of flexibility in expansion and also in contraction due to the relative mobility of the component equipment and its resale value.

There are several noneconomic advantages pursuant to mini-mill operation such as less-difficult pollution problems, removal of accumulated scrap in an area, stimulation of construction in the vicinity, a source of employment in a depressed area, etc.

Of the economic pecularities listed above, it is item five that this thesis will investigate in some depth in chapter 4.

The difference between the environments in which the steel industry in general and the mini-mill in particular operate is illustrated in Figure 3. The top portion of Figure 3 portrays the markets that are faced by integrated mills. The resource markets for coal and iron are relatively concentrated geographically, as shown in Figures 4a and 4b. Therefore, the centralized integrated mill can enjoy economies of scale in transporting large quantities of raw materials from few sources to the mill; furthermore, the integrated mill can and does practice economies of scale in processing. In addition, the product markets for integrated mills can also be geographically concentrated, as exemplified by the high percentage of steel shipments (over 40%) going to the automotive industry and steel service centers.

The environment in which the mini-mill exists is quite different. The lower portion of Figure 3 indicates that the mini-mill faces decentralization in both its markets. Figure 4c demonstrates the relatively greater dispersion of scrap supply as compared to iron ore and coking coal sources, and the product market for the mini-mill is essentially rebar

Figure 3 Market-Process Relationships

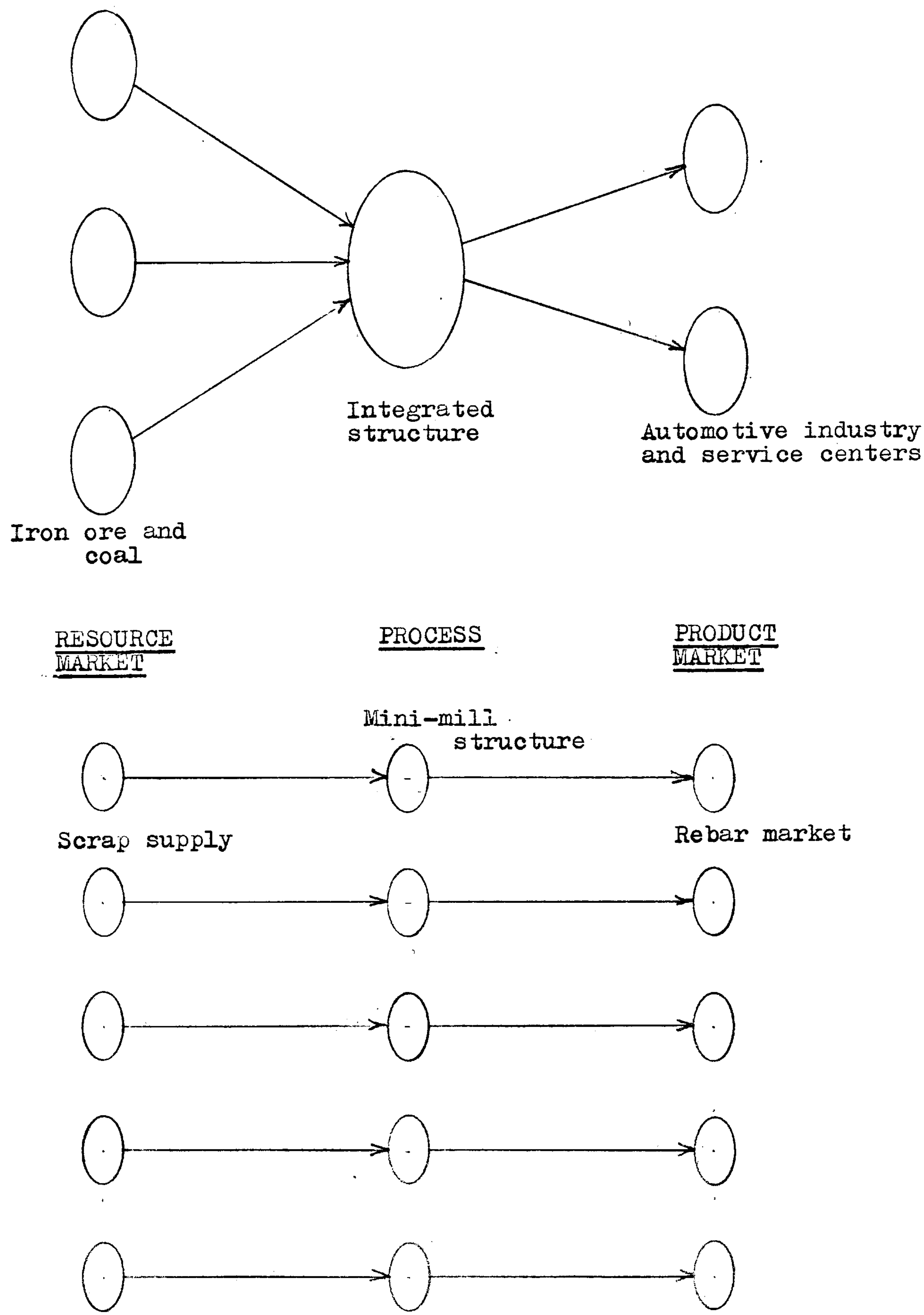


Figure 4a

Coking Coal Source Geographical Distribution

Total quantity produced in 1971:
79397 thousand short tons = 100%

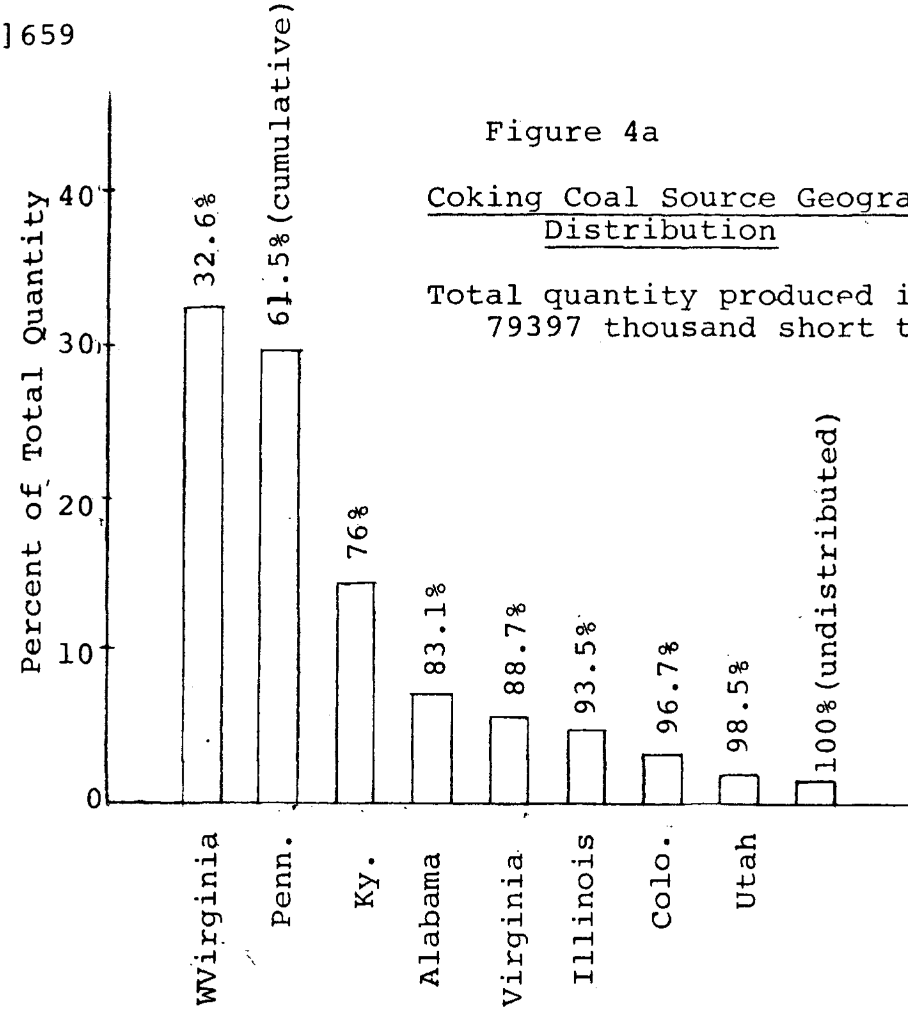


Figure 4b

Ore Source Geographic Distribution

Total quantity shipped (domestic&imported)
in 1971:
117230 thousand long tons = 100%

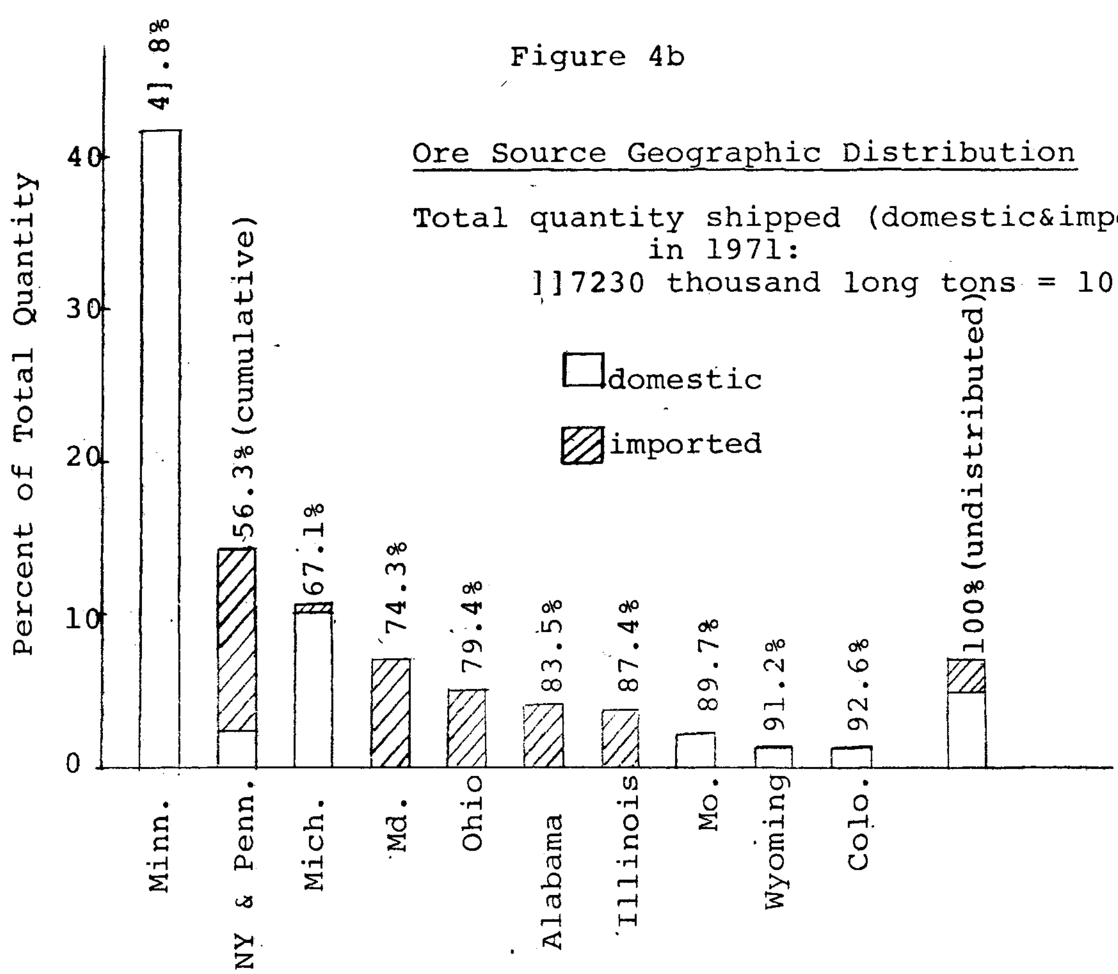
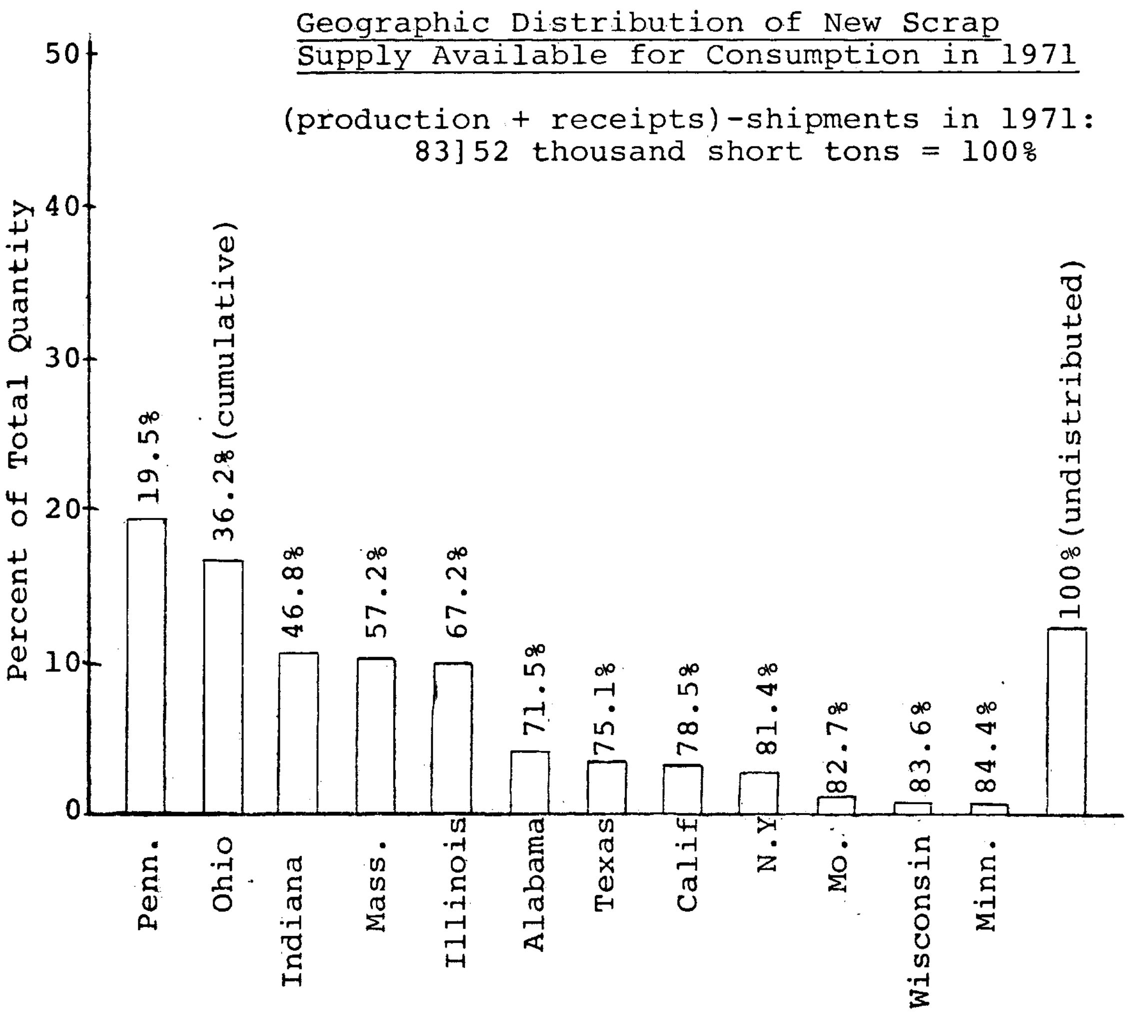


Figure 4c



Source: U.S. Bureau of Mines Minerals' Yearbook,1971 used in concrete construction--also a disseminated market. Rather than entailing the benefits of economies of scale in processing by sacrificing high transportation costs for bringing resources together and distributing products, the mini-mill has conformed to the decentralized nature of its markets.

The effect of such events as centralized scrap processing operations (e.g. shredders) will be adverse to the suitability of the scrap market to the mini-mill.

The philosophy of market suitability will be further studied in Chapter 4.

In Chapter 3 an economic evaluation of a model of a mini-mill will be conducted, and the most important criteria that warrant further study will be determined.

CHAPTER III. THE MINI-MILL IN DETAIL

The purpose of the present chapter is to present a quantitative evaluation of the profit sensitivity of the mini-mill to variations in the resource and product markets. This analysis will specifically list those criteria in the order in which they most affect the economics of the mini-mill.

An order-of-magnitude capital cost estimation and production cost evaluation have already been conducted by Kuhl (1972) for the mill configuration illustrated in Fig. 2, and this chapter will utilize this information because it is somewhat in agreement with another production cost evaluation prepared by Miller (1970). In addition, Kuhl's cash flow calculations are incorporated in this chapter. With this basis, a sensitivity analyses will be conducted on the following parameters to determine their effect on the Discounted-Cash-Flow-Rate-Of-Return (DCFROR).

I. Resource market

1) Scrap costs
2) Electric power costs

II. Product market

Product price

III. Variation in start-up time

The effect of this last factor is studied because the closer positive cash flows can be brought to the initial investment in terms of time the greater the DCFROR will be.

The capital and production costs, as prepared by Kuhl, are presented in Table 3. The cash flow calculations are presented in Table 4 and they will provide the base case for the sensitivity analysis. Each of the parameters listed above was varied 10 percent above its base value (one at a time) and the resulting DCFROR for the project was calculated. A variation in the start up time was simulated by increased output for the first two years of production rather than moving production into the previous year since start-up time can only be practically decreased by a few months. The results of this sensitivity exercise are illustrated in Table 5.

The assumptions made by Kuhl are:

1) Delivered price of $140 per ton for merchant bar and $110 per ton for reinforcing bar; these prices have been determined such that all of the output of the mill will be sold.

2) The cost assumptions of various inputs are available from Table 3.

TABLE 3a

Construction Cost Estimate for a 150,000 ton per Year Mini-Mill

	Thousand dollars (1969)
Material handling facilities	500
Electric furnace plant	3,500
Continuous costing	3,300
Bar and rebar mill	8,000
General plant	500
Total direct costs	15,800
Contractor's field overhead, plant and profit	1,200
Subtotal	17,000
Engineering, supervision and procurement	1,700
Subtotal	18,700
Contingency	1,300
Total design and construction	20,000
Escalation	2,400
Subtotal	22,400
Spare parts	200
Owner's costs	1,400
Total project	24,000

Source: Kuhl, 1972

TABLE 3b

Production Cost Calculations

Electric Furnace Plant

Steelmaking	Material NT per year	Product NP per year	$ per NT Material	$ per NT liquid steel
Plant scrap	18,450		31.00	3.30
Purchased scrap	168,200		31.00	30.05
Mill scale	3,350		8.00	.15
Ferro alloys	1,500		210.00	1.82
Total metallics				35.32
Lime	6,600		16.00	.61
Fluorspar	260		48.00	.07
Coke	1,560		25.00	.22
Total other materials				.90
Total materials				36.22
Labor - Supervision & Production		Cost Above		4.10
Repair and Maintenance				.90
Electrodes				3.20
Power-process				4.00
-other				.20
Fuel				.15
Water				.10
Oxygen				.20
Maintenance materials				.90
Furnace rebuild-Contract labor				.60
Furnace refractories				.90
Ladle refractories				.80
Slag disposal				.20
Misc. supplies & services				.75
Total cost above				17.00
Total cost Credit Scrap		1,750	28.00	- .28
Net cost of liquid steel		173,500		52.94

Table 3b continued

Electric Furnace Plant Continuous Casting	Material NP per year	Product NP per year	Costs $ per NT material	$ per NT billet
Liquid steel	173,500		52.94	55.73
Cost above				6.80
Total cost		164,800		62.53
Credit scrap		5,200	28.00	- .88
Credit scale		1,700	4.00	- .04
Net cost of billets		164,800		61.61

Merchant Bar and Rebar Mill				$ per NT final product
Billets	164,800		61.61	67.69
Cost above-merchant bar				15.00
-rebar				11.00
Total cost-merchant bar		100,000		82.69
-rebar		50,000		78.69
Credit scrap		11,500	28.00	- 2.15
Credit scale		1,650	4.00	- .04
Net cost of merchant bar		100,000		80.50
Net cost of rebar		50,000		76.50
Plant administration expense, warehouse and shipping				6.00
Total production cost				
Merchant bar		100,000		86.50
Rebar		50,000		76.50

Source: Kuhl, 1972

TABLE 4

Cash Flow Calculation

	1969	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88
Sales revenue	-	-	3300	15600	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500	19500
Production costs	-	-	2295	9980	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475	12475
Start-up costs	-	-	550	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gross manufacturing profit	-	-	455	4620	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025	7025
Selling and admin. expenses	-	-	330	1560	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950
Property taxes	-	-	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Insurance	-	-	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Depreciation	-	-	2274	2148	2021	1895	1769	1641	1517	1388	1264	1136	1011	884	758	633	505	378	253	125
Net earnings before taxes	-	-	-2698	362	2504	2630	2756	2884	3008	3137	3261	3389	3424	3641	3767	3892	4020	4147	4272	4400
Federal and State taxes (@ 50%)	-	-	0	0	84	1315	1378	1442	1504	1568	1631	1694	1712	1820	1884	1946	2010	2073	2136	2200
Net earnings after taxes	-	-	-2699	362	2420	1315	1378	1442	1504	1568	1631	1694	1712	1820	1884	1946	2010	2073	2136	2200
+ Depreciation	-	-	2274	2148	2021	1895	1769	1641	1517	1388	1264	1136	1011	884	758	633	505	378	253	125
Cash flow from operations	-	-	- 425	2510	4441	3210	3147	3083	3021	2956	2895	2830	2723	2704	2642	2579	2515	2451	2389	2325
Investment assets	-600	-14100	-6900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Working capital	0	0	- 900	-3000	-1100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+5000
New cash flow	-600	-14100	-8225	- 490	+3341	+3210	+3147	+3083	+3021	+2956	+2895	+2830	+2723	+2704	+2642	+2579	+2515	+2451	+2389	+7325

Source: Kuhl, 1972,

DCFROR (Base case) = 8.26%

TABLE 5

Sensitivity Analysis

	DCFROR	Difference
Base case (Table 4)	8.26%	--
Parameter		
Scrap cost + 10%	6.72%	-1.54%
Electric power cost (incl. electrode) + 10%	7.98%	- .28%
Product price + 10%	12.54%	+4.28%
Start up time increase first year output to 30% increase second year output to 90%	8.83%	+ .57%

3) Engineering will begin in mid 1969; initial field work will start in that year and the plant will start operations in mid 1971.

4) During 1971, only 20 percent of annual plant capacity will be produced--all in the form of rebar; 1972 will experience 80 percent production and 1973 will be the first year of full production.

5) Depreciation was assumed on an 18-year sum-of-the-years-digits basis.

6) There will be no salvage value at the end of the project life.

The results of the sensitivity model demonstrate that, of the criteria varied, the profitability of this model mill is most sensitive to product price. Scrap cost, the second most critical factor, has only two thirds of the effect of the product price on the DCFROR. Start up time appears to be third in importance, and the possibilities of varying this parameter are good, considering the 12-month construction period required for Florida Steel's Indiantown plant (Florida Steel Annual Report, 1971), as compared to the longer period assumed in the model. Of the four criteria varied, profitability of this mill is least affected by variations in the cost of electricity and electrodes.

It is important to realize the limitation of the conclusions derived from this analysis, First, nothing can be discerned about what variation these parameters will actually experience, although this area will be discussed in the succeeding chapter for scrap costs and product prices; the sensitivity work in this chapter has not utilized that qualitative discussion. Second, it has been assumed in the present sensitivity evaluation that one criterion at a time could be varied while the other parameters were held constant. This procedure is unrealistic because, in fact, cost increases in the resource market are often offset by price increases in the product market, or by more efficient-less costly operating methods. Third, the costs and prices of the base case are maintained throughout the project life and this is perhaps the most objectionable assumption. In a more complex evaluation, using a Monte Carlo simulation, an expected range of values for the important parameters over the project life can be introduced in the place of a single over-all value for each parameter. This more involved scheme may permit more realistic results to be generated; however, it is still dependent upon the subjective opinions of the planner who has suggested these ranges of values.

In conclusion then, this sensitivity study has pointed out the relative importance of the various parameters that affect the profitability of the mini-mill. The results allow the planner to specifically direct his efforts in these areas to evolve greater certainty of what these most sensitive parameters will be in the future, for it is these values that will affect his planning the most.

CHAPTER IV. THE ENVIRONMENT OF THE MINI-MILL

Measure of Market Suitability

In the introductory chapter of this thesis, the importance of resource and product markets was pointed out. Chapter 2 provided an overview of some of the pecularities of the markets of the mini-mill; some of these were disaggregation of both input and product markets, relatively small market areas lacking economies of transportation as well as other external economies, and a limited schedule of products. In Chapter 3, a model was employed to demonstrate the importance of various criteria to the profitability of the mini-mill and thus stimulated further scrutiny of the resource and product markets.

The purpose of this chapter is to explore the suitability of these markets to the mini-mill structure. Since the mini-mill sector of the steel industry is relatively decentralized and lacking in economies of scale, it may enjoy competitiveness through market situations that are more favorable to its structure than to that of its competitors. This suitability of a market to an industry structure can be measured by the mobility of the commodity being traded in the market place. Mobility is the ease with which supply can move to meet demand for either a resource or product. It is measured here by the variance of the commodity price sampled throughout the country. Highly mobile goods induce a very uniform price at all locations.

It is suggested here that large centralized (integrated) steel producers utilize relatively mobile resources, such as iron and coal ore, that are shipped from half way around the world (e.g. Liberia, Australia), and similarly produce goods that are also highly mobile (as exemplified by the intensity of world trade in steel commodities). But this phenomenon of mobility of resources and products is not just the result of a firm's size and economies of transportation it can practice. For example, another sector of the industry, specialty and exotic steel production, does not entail large scale, and yet it also enjoys mobility of resources and products as exemplified by the geographical size of its markets.

Thus, a mobility factor might be an indicator of how far that resource will move to a point where it will be consumed. If the resource is relatively immobile (e.g. sand and gravel) it will be utilized by nearby consumers and if the resource is also very dispersed and lacks high concentration, then these consumers will operate at a relatively small scale.

However, should the resource be highly mobile, then the consumer can centralize his operation and enjoy economies of scale and import the resource from remote sources.

Mobility factors can be equally well applied to a product. If the good is highly mobile then the decentralized producer who lacks economies of scale will find his market being invaded by centralized competitors who are geographically distant. But, if the product is relatively immobile his market area will be insulated from outside competition.

Mobility then is a measure of how supply will distribute itself to meet demand. Supply can be mobile and readily prevent demand-pull price increases on limited supplies, or supply can be geographically "sticky" and cause diverse prices throughout an economy. Mobility for a particular commodity (whether resource or product) is the resultant of many influences and criteria. Perhaps the first aspect to come to mind is the distance between the source and the consumer and as this distance increases, mobility decreases. However, this factor is often subjugated by the expense of shipping being influenced more by capital costs and/or loading costs than by the variable cost of the distance involved. This occurs in the case of very large ocean-going orecarriers or crude oil tankers. These transports require large capital investments and the marginal cost of transporting a raw material an additional distance is relatively unimportant. Another consideration that will also diminish the distance-mobility relationship is the increased mobility for any commodities that can be backhauled by an empty transport returning after a delivery; this effect occurs as well on other means of transportation (e.g. truck carriers, railroads).

Another aspect that is involved in defining the mobility of an item is the value of the commodity and how it compares with the cost of transportation. If the cost of transportation is only a small fraction of the value (as is the case for consumer and capital goods), then mobility will be high and the producer may centralize.

Still, many other factors influence mobility. Among them are level of transportation development, options of different means of transportation, the transportability of the good, etc. These and other criteria are investigated in some depth by Hoover (1948, 1971) and Manners (1971).

Fortunately, the resultant mobility of a resource or a product can be measured by a mobility factor without a thorough analysis of all of the considerations regarded above.

It is proposed here that geographical variations in the price of a commodity are exclusively the result of supply being hindered in its move to fulfill demand. This barrier may be artifical, in part, and also the result of those aspects already mentioned; but, nonetheless, this variation in prices is an indication of mobility. Although it is beyond the scope of this thesis to fully investigate this phenomenon, it is apparent that a higher price for an item at some location will attract sellers to this area, and the only friction to such a movement will be the cost of transferring to this lucrative market. Ideally, supply would be highly mobile and any deviations in prices would be quickly cancelled out by the movement of this supply. Perhaps an approach to such a state is exemplified by the value of currency in various international money markets and the function of arbitrage in maintaining an equivalent value in all of these markets by transferring currency among them.

In order to investigate the suitability of its resource and product markets to the mini-mill's structure, the mobility of these commodities must be measured. It is assumed that high mobility is advantageous to centralized organizations with large markets (such as integrated mills), whereas low mobility favors decentralized, contracted-market structures.

The mobility of two grades of scrap will be determined to represent the resource market for the mini-mill, and the general category of merchant bar will represent the product market.

In order to compare these mobilities with those of other steel industry products, similar values will be calculated for cold rolled and hot rolled sheets, which together accounted for about one-third of the net shipments of steel in the country in 1972 (American Iron and Steel Institute, 1972). Unfortunately, coke and iron ore f.o.b. prices were not available due to the long-term contract and captive nature of these markets; in 1971, about 60% of the coking coal produced came from captive operations (1971 Minerals Yearbook).

The prices that were used in finding the variances were those of the marketplace (c.i.f.) and not those at either the mill or the point of scrap generation (f.o.b.). The reason for this approach is to avoid such adverse effects as freight absorption that may cloud the mobility factor. Steel service center prices were used to represent the market place, although these prices do not represent the major portion of the product that is consumed and, in fact, the truly representative marketplace is contract oriented. Therefore, mobility is being measured here between service centers and not for the whole product market overall.

Mobility Calculation

Mobility is measured by determining how widely prices vary over a geographical area. This is accomplished by finding the statistical variance of a set of prices that have been collected from around the region.

At first it was felt that each price should have a tonnage associated with it so that its relative importance (in comparison to the other prices) could be recognized. However, this was not done for two reasons: first, there were no data available that provided the amount of commodity transacted at each price at a point in time; second, because the variances are being compared with each other, and the prices were taken from the same locations, any adverse effects (such as a low-quantity level market or inaccessability of the market) are experienced by all of the variances. In addition, it should be recognized that any market, without regard to size, should attract sellers or buyers if the price is high or low, respectively. The only barrier to this migration, which will equalize prices, is a lack of mobility.

The mean prices and variances of these steel products at various times are presented in Table 6. A similar presentation for types of scrap is provided in Table 7. The price data are raw, without seasonal or geographical weighting, nor has the price been adjusted in any way. It was felt that such a lack of adjustment was valid because

TABLE 6

A Comparison of the Mobility of Selected Steel Products

Data based on steel service center prices in 24 cities throughout the U.S. - Information Source - Iron Age (dates listed below) Dollars/100 lbs.

	Sheet				Merchant Bar	
	Hot rolled		Cold rolled		Hot rolled	
Week of:	Mean Price	Variance	Mean Price	Variance	Mean Price	Variance
1/7/74	13.21	1.82	14.93	2.89	14.04	.41
5/24/63	13.13	1.69	14.90	2.79	14.01	.76
1/11/73	13.23	2.04	14.87	2.96	13.01	1.17
5/25/72	12.65	2.72	13.91	3.28	13.36	1.02
5/27/71	12.205	2.16	13.39	2.04	12.85	.83
4/30/70	11.80	1.51	12.84	1.19	12.15	.69
2/12/70	11.58	1.61	12.60	1.06	12.07	.66

TABLE 7

A Comparison of the Mobility of Two Types of Scrap

Data based on marketplace prices in 17 cities - Information source-Iron Age (dates listed below).

	No. 1 Heavy Melting		No. 2 Bundles	
Week of	Mean Price	Variance	Mean Price	Variance
1/7/74	67.50	67.24	45.44	53.00
5/24/73	47.21	44.09	34.79	52.70
1/11/73	41.00	35.05	29.50	30.03
5/25/72	29.00	16.97	19.47	15.84
1/6/72	26.76	23.81	16.94	24.80
5/27/71	29.21	19.01	19.09	21.90
4/30/70	39.13	33.87	27.60	39.82
2/12/70	41.43	34.69	31.34	45.29

variances of various commodities were being compared across the table at specific dates and would thus be equally affected by prevailing conditions.

The variance is inversely proportional to mobility, so that on a given date, a commodity with a relatively high variance has a relatively low mobility when compared to the other commodities transacted on that date.

Another possible independent approach to delineate mobility is illustrated in Figure 5. The data for this graph were taken from the 1963 Census of Transportation (U.S. Department of Commerce) and it is a representation of the distance that various commodity groups travelled in that year. However, because it does represent groups, an analysis of specific commodities cannot be undertaken from these data.

Conclusions

The purpose of this presentation was to demonstrate the relatively higher immobilities of mini-mill markets in comparison to those of integrated mills. This result would then be used to account for the growth of mini-mills because of market suitability.

Although it was shown that the mobility of scrap is much less than that of products, the results failed to show that merchant bar products were less mobile than sheet products. In fact, the variance (i.e. the inverse of the

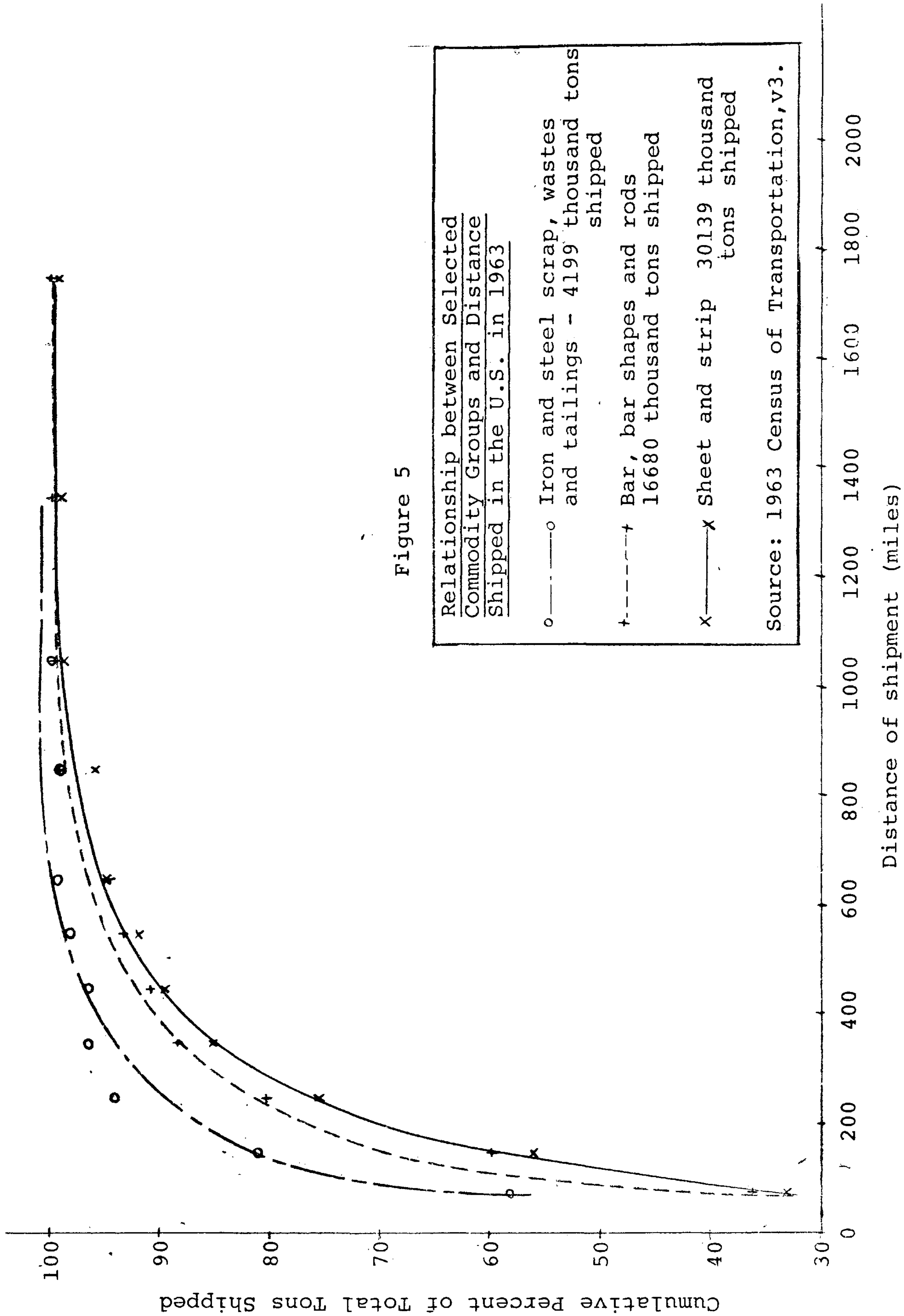

Relationship between Selected Commodity Groups and Distance Shipped in the U.S. in 1963
o———o Iron and steel scrap, wastes and tailings - 4199 thousand tons shipped
+- - - -+ Bar, bar shapes and rods 16680 thousand tons shipped
x———x Sheet and strip 30139 thousand tons shipped
Source: 1963 Census of Transportation, v3.
Cumulative Percent of Total Tons Shipped
100
90
80
70
60
50
40
30
Distance of shipment (miles)
0
200
400
600
800
1000
1200
1400
1600
1800
2000

Figure 5

mobility factor) for merchant bar was almost consistently below the variances for the other products.

It is believed that this inconsistency with the proposed model is due to the locational concentration of buyers of sheet products as compared to the dispersement of merchant bar consumers. For example, the 1963 Census of Manufacturers (Consumption of Selected Metal-Mill Shapes and Forms) reveals that over 65 percent of the value of steel sheet and strip was consumed in the mid-west central states (i.e. Ohio, Indiana, Illinois, Michigan, and Wisconsin), with nearly 25 percent of the total being used in Michigan alone. With such a preponderance of consumption in one area (and a probable high mobility into this area) it is unrealistic to treat all prices with equal regard, as was done. Although a number of market places may be important to the level of consumption of merchant bar, only a very few market places need be considered in the case of sheet.

Therefore, the assumption that an area is considered in the same light by each product is not valid in this case, because the consumers of different products are distributed and concentrated to different degrees throughout the country.

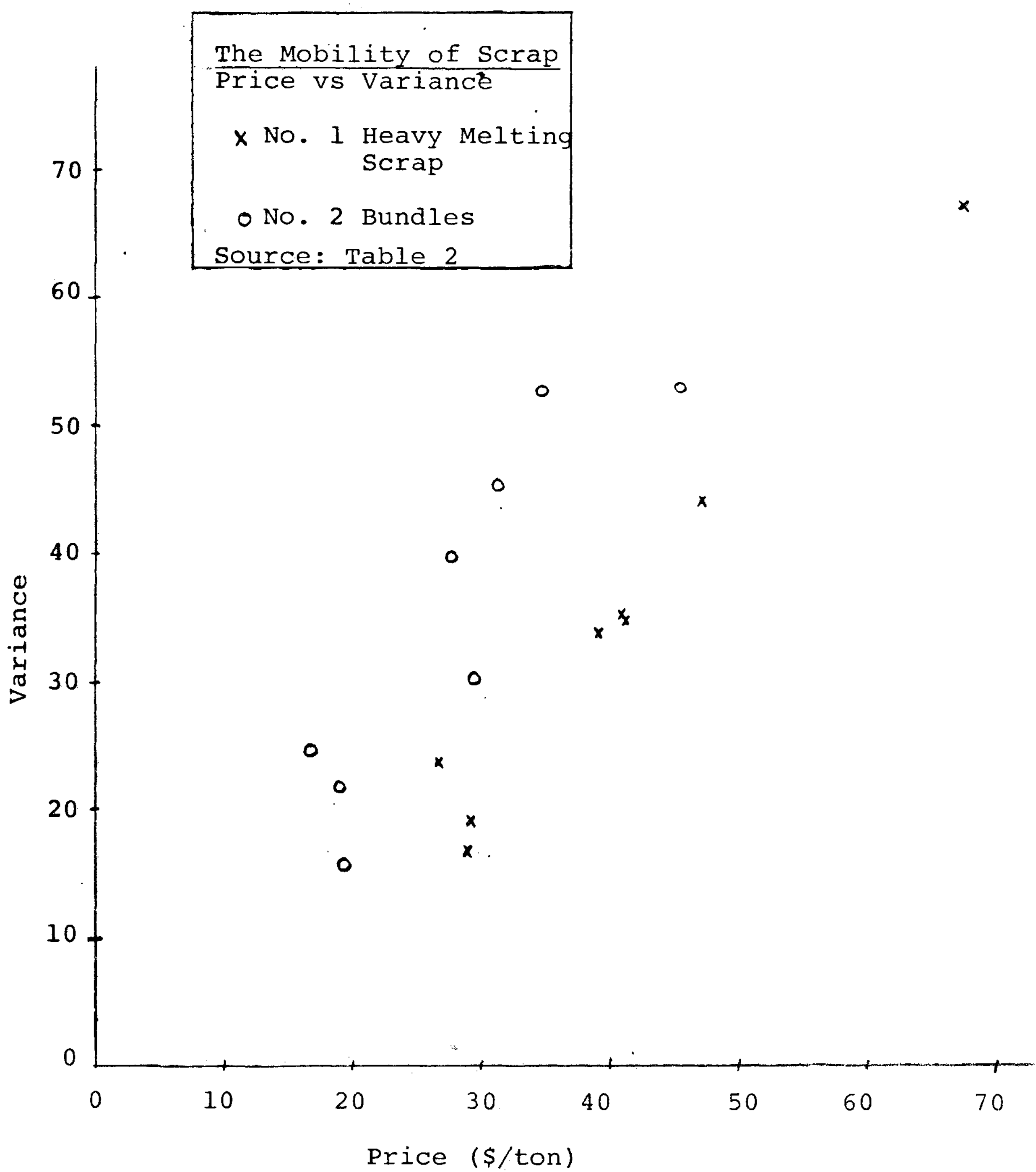
We cannot conclude then that sheet products would be better suited to the mini-mill than the integrated mill because of the invalidity of this assumption.

Another factor that may have disturbed these results is the price differential between rebar (the major product of mini-mills) and the general category of merchant bar. The value of the former is some 20 percent less than the value of merchant bar. And, the hypothesis suggests higher value commodity should enjoy greater mobility and less variance in prices.

In terms of the resource market the data illustrate the greater fluctuation of scrap prices as compared to product prices and this leads to the conclusion that this is a relatively immobile commodity. This conclusions is supported by the presentation in Fig. 5. Because of its lack of mobility, this resource is particularly well suited to the decentralized nature of the mini-mill.

An unexpected trend was detected from the data, and this is presented in Fig. 6. The variance appears to definitely increase with the price of scrap; that is scrap seems to become less mobile when its value increases, and this is in contrast to the proposed model. This characteristic is of benefit to a mini-mill located in an area where scrap prices have not increased as much as in other areas because that mill can now compete with mills located in higher-price scrap areas.

Figure 6


The Mobility of Scrap
Price vs Variance
x No. 1 Heavy Melting Scrap
o No. 2 Bundles
Source: Table 2
Variance
0
10
20
30
40
50
60
70
Price ($/ton)

It is not fully recognized why the scrap market has this characteristic, but it is felt that the intense demand for scrap is especially magnified during short-run high-steel demand periods. This demand for scrap fluctuates tremendously (the variation in the mean prices of scrap is much greater than that for product prices as well as pig iron prices - see 1969 Institute of Iron & Steel Year-book) and it is believed that the price instability that ensues is reflected by locational price differences. Perhaps these differences cannot be equalized before the high demand subsides or hot metal production increases to satisfy demand.

The technique presented here was for determining mobility factors and gaining appreciation of the suitability of the markets to a particular processing structure. Though the evaluation did not fulfill its objectives wholly because of simplifying assumptions and lack of data, it has verified the suitability of the scrap market to decentralized processing. In addition, the technique has brought to light the decreasing mobility of scrap with increasing prices. This effect may result in greater quantities of scrap being directed toward mini-mills in an environment of rising prices despite the sensitivity of such a mill to scrap prices (see Chapter 3).

CHAPTER V. SUMMARY

Conclusions

The purpose of this work has been to investigate the steel-making mini-mill's interaction with its surrounding market environments. After defining the mini-mill in terms of its position in the steel industry and the importance of the markets to its profitability, the suitability of the environment to the mini-mill's structure has been discussed.

The importance of market suitability cannot be stressed enough because of its effect on the viability of the mini-mill. Both the present resource market and product market are decentralized geographically, thus providing a fertile environment for the decentralized mini-mill. Should these markets change in nature--such as achieving centralization--this will have adverse effects on the development of mini-mills.

In addition to the degree of market centralization, the suitability of the environment must include a measure of how freely the commodity can travel between geographic marketplaces. It was argued that a high degree of immobility was an asset for the mini-mill's resource or product because such a state prevents market penetration by large integrated companies that enjoy economies of scale in processing.

Mobility was measured by the degree of variation of prices for a commodity around the country. Mobility for various commodities were compared to demonstrate their suitabilities to centralized or decentralized processing structures.

However, because of a lack of sufficiently detailed data and a simplifying assumption--the degree of price variation was calculated with each price having an equal importance--verification of the model was not achieved in full. Nevertheless, scrap was shown to be a highly immobile commodity in comparison to the products surveyed, and is thus well suited to the decentralized nature of the mini-mill.

Mobility of various products and scrap were also compared by another method which did verify the lower mobility levels of merchant bar and scrap.

Recommendations

Since the suitability of the environment is as important to an enterprise as its technical competence, it is important to measure this aspect in relation to the process.

Although this thesis attempted such an evaluation and was partially unsuccessful, a very interesting trend was detected that warrants further examination.

The apparent increase in the degree of price variation for scrap as its price increased was noted. This suggests that this commodity may become less mobile as its value increases. Although the increase in the price of scrap was shown to be detrimental to the profitability of the mini-mill (as was shown in Chapter 3), the decreasing mobility may make the mini-mill even more competitive during times of rising prices for scrap. The effect of these two opposing forces should be further studied.

The failure of price variance to show the expected difference in mobility for several products was believed to be due to a lack of weighting of prices by their relative importance. This assumption should be rejected and new data accumulated to demonstrate the proposed mobility effect. These new data should be in the form of the tonnage of the commodity that was exchanged at the different prices at different locations on a given date.

This thesis provides the basis for extrapolating into the future for mini-mill growth. The facets of this organization have been disassembled and studied. By subjecting the components of mobility (described on pp. 39-40) to their respective expected trends, the direction of the mini-mill in the future can also be predicted.

BIBLIOGRAPHY

American Iron and Steel Institute, 1972, Annual statistical report: Amer. Iron and Steel Inst., Washington, 82 p.

Cartwright, W. F., 1972, The place of mini-steelworks in the world: J. of the Iron and Steel Inst., v. 210, pt. 4, p. 221-228.

Florida Steel Corporation, 1972, 1971 annual report: Florida Steel Corp., Tampa, Fla.

Hogan, W. T., 1971, Economic history of the iron and steel industry in the United States, v. 4 and v. 5: Lexington, Mass., Lexington Books.

__________, 1972, The 1970's-critical years for steel: Lexington, Mass., Lexington Books, 132 p.

Hoover, E. M., 1948, The location of economic activity: Washington, McGraw-Hill.

__________, 1971, An introduction to regional economics: New York, Alfred A. Knopf, 395 p.

Industry Week, 1971, No more mini-mills?: Industry Week, v. 171, no. 1, p. 46-49.

Kotsch, J. A., 1971, A look at the mini-plants: Iron and Steel Eng., v. 48, no. 8, p. 61-78.

Kuhl, R. J., 1969, Metallics for electric furnace steel-making: Proc. of the 27th Annual Electric Furnace Conf., TWS-AIME, v. 27, p. 116-121.

__________, 1972, Maxi or mini?: Technical Economics for Metallurgists and Miners, TWS-AIME, p. 24-31.

Leary, R. J. and Larwood, G. M., 1973, Effects of direct reduction upon mineral supply requirements for iron and steel production: U.S. Bur. Mines Inf. Circ. 8583, 94 p.

Manners, Gerald, 1971, The changing world market for iron ore 1950-1980--an economic geography: Baltimore, Resources for the Future, 384 p.

Merklin, K. E., 1974, Iron and steel--economy and energy will play key roles in future industry growth: Eng. Mining Jour., v. 173, no. 3, p. 78-81.

Miller, J. R., 1970, Scrap, prereduced iron ore and electric furnace steelmaking in the 1970 decade: Facts, 31st ed., Inst. of Scrap Iron and Steel, p. 84-93.

Nucor Corporation, 1973, 1972 annual report: Nucor Corp., Charlotte, N. C., 19 p.

Sibakin, J. G., and others, 1967, Utilization of SL/RN reduced pellets in electric arc furnaces: Proc. of the 27th Annual Electric Furnace Conf., TMS-AIME, v. 25, p. 169-175.

Stermole, F. J., 1971, Engineering economy and investment decision methods: Golden, Colo., 331 p.

Tsao, C. S., and Day, R. H., 1971, A process analysis model of the U.S. steel industry: Mgt. Sci., v. 17, no. 10, p. B-588-B-608.

Uhlig, F. J., 1969, GM efforts in junk car processing: Facts 30th ed., Inst. of Scrap Iron and Steel, p. 10-19.

U.S. Bureau of the Census, 1966, 1963 Census of transportation, v. III, commodity transportation survey, pts. 1-4: Washington, U.S. Govt. Printing Office, pts. 1-2, p. 177-187, pts. 3-4, p. 66-67, 86-87.

__________, 1968, Consumption of selected metal mill shapes and forms: 1963 Census of Manufacturers, Washington, U.S. Govt. Printing Office, 219 p.

U.S. Bureau of Mines, staff, 1967, Automobile disposal, a national problem: Washington, U.S. Govt. Printing Office, 569 p.

U.S. Bureau of Mines, 1971, Bureau of Mines minerals yearbook: Washington, U.S. Govt. Printing Office.

U.S. Department of Commerce, 1966, Iron and steel scrap-consumption problems: Washington, U.S. Govt. Printing Office, 52 p.

(U.S.) National Commission on Materials Policy, 1973, Material needs and the environment today and tomorrow: Washington, U.S. Govt. Printing Office.