MINIMILLS AND FLAT-ROLLED STEEL PRODUCTS

by

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Submitted to the Alfred P. Sloan School of Management on May 6, 1996,
in partial fulfillment of the requirements for the Degree of
Master of Science in Management

ABSTRACT

Minimills -- steelmakers that operate only with electric furnaces and not
with blast furnaces/basic oxygen furnace -- are rushing to enter the flat-rolled
steel segment that has always been the exclusive domain of integrated
steelmakers in the past. By 1997, minimills' capacity for flat-rolled products
will have increased by 13 million tons from 1994 levels (including planned
expansion).

This expansion will have great impact on the market of approximately 70
million tons of flat-rolled products in the U.S. The additional capacity
will have to be absorbed by improving the trade balance. Also it will work
to lower the price of steel products. On the other hand, this expansion
will also have great impact on raw materials for minimills. Since the
supply of prime grade steel scrap (which is required to produce flat-rolled steel)
is not expected to increase, the supply of substitute materials such as direct reduced
iron will have to increase to support the greater demand. The supply of raw
materials is anticipated to be less than adequate for the time being and,
consequently, price increases are expected.

Under such circumstances, the minimills' profitability in the flat-rolled
products segment is not as optimistic for the short-term. However, due to their
cost advantage over the integrated steelmakers, this expansion will likely be
realized, at least for those whose decisions have been made. This phenomenon
will be part of the ongoing transition in the steelmaking process in the U.S.,
namely from the blast furnace/basic oxygen process to the scrap and/or
substitute material/electric furnace process.

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Environmental Policy Research
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Hiroyuki Kato
April 1996
Wellesley, Massachusetts
CHAPTER 1
INTRODUCTION

1.1 Purpose of the Thesis

Until the early 1960s, the U.S. steel industry was dominated by integrated steelmakers. Since its emergence, minimills -- steelmakers who operate only with electric furnaces and not with blast furnaces/basic oxygen furnace -- have continued to grow and have now wrested a significant share of many steel products, such as bars and structural shapes, away from integrated steelmakers. By the early 1990s, their production share had reached 40 percent in the U.S., and these mills are now advancing into the flat-rolled products segment, which is generally considered to be the last domain of the integrated steelmakers.

The purpose of this thesis is to analyze the current and future status of minimills in the flat-rolled product segment. I will examine whether minimills can continue to grow in this segment. The main subjects I will address include:

- the past and current status of minimills;
- reasons why minimills entered the flat-rolled segment;
- whether supplies of steel scrap and/or its substitutes, as the main raw material for minimills, will be able to support their increased production in this particular segment; and
- the possible effect of minimill expansion within the segment.

It is generally accepted that the U.S. steel industry's spectacular leading role in the industry ended some time ago. Some even say that the U.S. steel industry is no longer competitive. However, I believe that the U.S. steel industry is in a radical transition period
from a mature state to a revitalizing state. I think that the strengthening power of minimills is one symbol of this transition.

1.2 Overview of U.S. Steel Industry

In 1973, when the U.S. steel industry achieved a record 111.5 million tons\(^1\) of shipments, apparent consumption\(^2\) of total steel products reached 123.1 million tons. Since then, apparent consumption has decreased, reaching a record low of 75.3 million tons in 1982. Although by the early 1990s it had recovered to a level of 90 to 95 million tons.

Only a few years ago, many industry observers predicted that the U.S. steel industry and manufacturing base were doomed to steady decline as demand moved offshore and the U.S. became primarily a service economy. However, to many observers' surprise, apparent consumption of total steel products picked up dramatically in 1994, reaching 113.4 million tons. These figures are not as high as 1973, but were almost equal to 1978 and 1979 levels. This figure represents a 14 percent rise from 1993 levels.

For the first time since the early 1970s, the steel industry, as part of the U.S. economy, appeared to be on the rise, particularly in the sheet products market. Increases in steel demand, above and beyond the cyclical increases of the economic cycle, are evident across a number of end markets, most significantly in automotive, where steel demand jumped 17 percent in 1994 even though light vehicle sales rose only 8 percent. Capital goods manufacturers continue to become more internationally competitive, helped by the decline of the U.S. dollar and by major industry restructuring and modernization. It is no coincidence that U.S. merchandise exports doubled in the past six years and that the U.S. construction equipment industry is expected to be a net exporter this year for the first time since 1985.

\(^1\) The tonnage figures in this thesis refer to short ton unless otherwise specified.

\(^2\) Apparent consumption figures refer to product shipments, minus export, plus import. When apparent consumption of total steel products is discussed, it is common practice that imports of semi-finished products are deducted from the total import. Semi-finished products such as slabs and billets are processed into finished products domestically.
There have been several notable changes in the structure of the U.S. steel industry since 1973, and these changes bear directly on the theme of this thesis. Those key changes are explained briefly as follows.

1.2.1 Process Changes

There was a fundamental change in the steelmaking process during the postwar period. Until 1960, the open hearth furnace (OH) was the dominant process, accounting for as much as 87-90 percent of the raw steel produced. Between 1965 and 1970, OH output fell sharply to 36.5 percent of the total, while the basic-oxygen furnace (BOF) process maintained its dominance with around 59 percent by 1970. During this same period, the electric arc furnace (EAF) achieved a strong position, and in 1973 it accounted for 15.3 percent, or some 20 million tons. By 1994, its contribution was over 39 percent. These changes are shown in Exhibit 1-1.

Exhibit 1-1
U.S. Steel Industry Overview:
BOF vs. OH vs. EAF

Source: American Iron and Steel Institute
1.2.2 Raw Steel Capacity, Production, and Finished Product Shipments

The capacity for raw steel production has decreased dramatically, from 155.4 million tons in 1973 to 119.6 million tons in 1994.\(^3\) This tendency was especially noticeable after the early 1980s. In 1995, effective capacity was equal to about 86 percent of gross capacity.\(^4\)

The production of raw steel has also decreased drastically from 150.8 million tons in 1973 to 74.4 million tons in 1982. However, since then it has gradually increased, reaching 99.9 million tons in 1994.

The fluctuations of finished product shipments were almost parallel to raw steel production. One notable phenomenon during this period was the reduction of the gap between raw steel production capacity, raw steel production, and finished product shipments. This occurred because of past improvements in production efficiency which will be explained later. These fluctuations are shown in Exhibit 1-2.

\(^3\) Those capacities published by the American Institute of Iron and Steel (AISI) are understood to be gross capacity instead of effective capacity.

Exhibit 1.2
U.S. Steel Industry Overview:
Raw Steel Capacity vs. Raw Steel Production vs. Finished Steel Production

![Graph showing steel capacity, production, and finished steel production from 1973 to 1993.]

Source: American Iron and Steel Institute

1.2.3 Changes in Apparent Consumption

The apparent consumption of all steel products reached 113.4 million tons in 1994, almost equivalent to 1978 and 1979 levels. However, by 1994, the composition of that apparent consumption is completely different from those earlier years. Exhibit 1-3 shows this change clearly.
### Exhibit 1-3
Composition of Apparent Consumption

<table>
<thead>
<tr>
<th></th>
<th>1973</th>
<th>1979</th>
<th>1994</th>
<th>Comparison with 1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>111.5</td>
<td>100.3</td>
<td>95.1</td>
<td>-5.2</td>
</tr>
<tr>
<td>Export</td>
<td>4.0</td>
<td>2.8</td>
<td>3.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Import</td>
<td>15.9</td>
<td>18.7</td>
<td>30.0</td>
<td>11.3</td>
</tr>
<tr>
<td>Less Import of Semi-Finished</td>
<td>0.2</td>
<td>0.3</td>
<td>7.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>123.2</td>
<td>115.9</td>
<td>113.4</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

Source: American Iron and Steel Institute

While product shipments in 1994 were 5.2 million tons lower than 1979, the quantity of imported finished products in 1994 was 11.3 million tons larger than 1979. This indicates that the dependence on imports has increased dramatically during the last two decades.

Another obvious change is the significant increase of semi-finished products. Since semi-finished products are processed into final products, this amount is deducted from the value of total imports. The increase in semi-finished products indicates that there is a growing gap between raw steel production capacity and processing capacity in the U.S. It is clear that importing semi-finished products has buffered the change in steel demand in the U.S. Naturally, when steel demand is booming, import of semi-finished products increases and, when demand drops, it decreases.

As a result, the difference in apparent consumption between 1979 and 1994 becomes only 2.5 million tons. Exhibit 1-4 shows this historical movement since 1973.
Exhibit 1-4

U.S. Steel Industry Overview:
Composition of Apparent Consumption

Source: American Iron and Steel Institute
CHAPTER 2
MINIMILLS AND FLAT-ROLLED PRODUCTS

In this chapter, I will review the overall status of minimills and compare their features with those of integrated mills. Then I will discuss the expansion of minimill production over the past decades and reasons for this expansion. Finally will discuss the minimills' entry into the flat-rolled products segment.

2.1 Definition and Comparison of Minimills versus Integrated Mills

The term "minimill" is generally used for steelmakers who operate smaller steel-making mills using only the EAF process and not the blast furnace/BOF process. On the other hand, integrated mills are very large operations, with the capability of producing every kind of steel using the blast furnace/BOF process.

There are other fundamental differences between minimills and integrated mills beyond the process used to produce steel. The original concept of the minimill has changed considerably since the early 1960s when it was first developed. At the same time, the integrated mill has also undergone some basic changes. A comparison of these two sectors of the steel industry requires an analysis of each in order to make a proper evaluation.

2.1.1 The Minimill

The minimill, as originally conceived, had several basic characteristics: in terms of size, it generally had a raw-steel capacity of 100,000 tons or less. Its equipment consisted of an electric furnace, wholly dependent on scrap; a breakdown mill to reduce small ingots to
billet size, or a continuous caster which casts billets directly from molten steel; and a bar mill. The product output was usually restricted to concrete reinforcing bars, merchant bars and, in some instances, light structural shapes, such as small angles and channels. The mills were scattered over most of the U.S. and the markets they served were usually within a 200 to 300 miles radius of each mill.

The operating procedure for minimills is relatively simple. The raw material needed for production is scrap. It is unloaded in scrap yards, put in EAF, and then charged. When the scrap has been melted and refined into steel, it is poured into a ladle which then discharges into a continuous caster. Presently, almost all minimills cast billets. These are then poured into a reheat furnace and when they have reached a temperature suitable for rolling, are converted into final products in the bar mill. The final product is finished hot, allowed to cool, and then prepared for shipment. Thus, the process of producing steel and rolling it into a finished product is relatively straightforward and incorporates a limited number of operations that produce relatively few products. Most of the minimills' output is a hot-rolled product.

Since that original concept, however, a number of minimills have changed drastically, although some have remained basically true to it. In almost every case, the size of the plants (in terms of raw steel production) has grown significantly. Some of the original minimills that had less than 100,000 tons of capacity in 1960 are now producing over 200,000 tons. For example, in 1960, Florida Steel Corporation's Tampa plant had one furnace with a capacity of 51,000 tons. Today the plant has a rated capacity of 280,000 tons. When founded in 1975, the Chaparral plant at Midlothian, Texas had 400,000 tons; in 1987, as a result of adding a second furnace, it had a capacity of 1.5 million tons. Some of the newest plants began operations with large capacity. Nucor’s Crawfordsville plant for flat-rolled products started operation with 1 million tons of capacity in 1989. Now it operates with 1.8 million tons of capacity after subsequent expansion.
In terms of technology, most minimills operate essentially the same type of equipment as they did at their inception, with expansion and/or enlargement. However, many electric furnaces have been replaced by larger units and have been improved through the addition of sidewall cooling panels and, in a number of cases, larger electric transformers. Virtually all of the mills now have continuous casters, as contrasted with less than half in 1968. Some of them have updated earlier versions. In terms of bar mills, improvements have been made through modifications of old units and the installation of some new ones. Additional stands have been added; new and improved cooling beds as well as new heating furnaces have been installed.

The most notable technological innovation was the commercialization of the thin slab technology at Nucor’s Crawfordsville plant in 1989 which revolutionized flat-rolled production. This will be described in detail later. In addition to flat-rolled products, North Star completed a seamless-pipe mill at its Youngstown facility. Chaparral produces wide-flange beams of up to 12 inches and is gearing up to produce larger sizes. Further, most minimills with improved bar mills are producing small quantities of special-quality bars. Those products were formerly the exclusive province of the integrated mills.

As a result of their entrance into other fields, as well as the increase in their size, most minimills have found it necessary and desirable to expand their market area beyond the traditional 200-300 mile radius. Rod producers, for example, now supply half the country.

With these changes, the original concept of the minimill has become somewhat blurred as plants grow larger and move into different product areas. The tendency toward concentration, whereby one company owns several mills, has also changed radically from the original concept wherein each company owned a single minimill.
2.1.2 The Integrated Mill

An integrated mill is a large complex of facilities and differs from the minimill in many ways. It starts with basic raw materials, such as coal and iron ore, which have to be processed before they can be charged in the blast furnace. Coal is converted to coke and raw iron ore is transformed into pellets or sinter. Integrated mills are huge in comparison to minimills. Some integrated facilities produce as much as 6 to 7 million tons of raw steel, although others produce as little as 1 to 2 million tons. The facilities include coke ovens, sinter plants, blast furnaces, basic-oxygen steelmaking converters, electric furnaces, continuous casting, and a variety of rolling mills. Some of these, such as modern hot-strip mills, are capable of producing up to 5 million tons of hot-rolled coils a year. Other finishing facilities include plate mills, pipe mills, structural mills, cold-reduction mills, galvanizing lines, and electrolytic tinning lines.

The quality of the integrated mill product differs from that of the minimill. Chemical and physical specifications are more demanding. This is particularly true of sheet products that are to be formed into various parts of automobiles under the pressure of huge presses. Surface quality has become increasingly critical as has uniform width and gauge. These requirements have put considerable pressure on the mills to constantly upgrade their production processes.

The market covered by an integrated mill often includes a large area of the U.S. Integrated mills tend to be located in a few areas where the needed raw materials are present. The principal area is the Great Lakes, although there are other mills located on the East Coast, in the Midwest, and the South.

The iron and steelmaking processes in an integrated mill involve large tonnages and, consequently, large facilities. The prepared ore and coke are charged along with limestone in a blast furnace which, depending on its size, can produce from 3,000 to 10,000 tons of pig iron per day. The pig iron is then processed into steel in a BOF, after which the steel is either
continuously cast into semifinished shapes or poured into ingot molds where it is allowed to solidify.

The semifinished steel is further processed into a wide variety of products, including sheets, plates, pipes, heavy structural shapes, bars, tinplates, and galvanized steel. The production of these items from the semifinished state to the final product requires a number of steps. These differ markedly from the steps required by the minimill. Most of the minimill output is limited to hot-rolled products in a bar mill which are cooled and shipped. Further, the minimill does not require iron ore preparation, coke ovens, or blast furnaces. Thus, the integrated mill includes a number of steps that must be taken before reaching the steel furnace and many more after hot rolling.

An integrated mill’s primary product is sheet product, which requires a huge complex of equipment and an investment of $250 to $300 million. The hot-rolled sheet is the least processed sheet steel. Hot-rolled sheet is further reduced in thickness at room temperature by a cold-reduction mill, requiring an additional investment of at least $150 million. Some of this steel is sold as cold-rolled sheet, some is plated with tin to form tin-plate, and some is covered with zinc to form galvanized steel. Other products made by the integrated mill require many operations as they move from the semifinished state to the finished form. The basic production flow is shown in Exhibit 2-1.

In the past, integrated mills have undergone a number of basic changes. First, in the steel process, the OH has virtually been replaced by the BOF. Continuous casting has been installed in almost every large integrated mill in the U.S. so that the ingot process has been drastically reduced. EAFs have been installed in some plants to supplement the BOF steel process. The number of integrated plants operating blast furnaces, which feed molten iron into the BOFs, dropped significantly. Bethlehem at one time operated six integrated plants, but by 1995, this number was reduced to three. U.S. Steel previously operated ten integrated plants, but the number has now been reduced to four.
Exhibit 2-1
Basic Production Flow of an Integrated Mill

Source: Minimills and Integrated Mills
Another change in integrated plants has been the trend to simplification, i.e., producing fewer products at one location. Indeed, Inland Steel’s single plant, at Indiana Harbor, produces all of Inland’s product line. The trend toward simplification is also manifest at U.S. Steel: bar production was transferred from the Gary plant to the mill at Lorain, Ohio, which is being operated under a joint venture with Kobe Steel. Gary now produces only plates and sheets. Finally, in a number of instances, integrated mills have reduced their production capacity. For example, the National Steel mill at Ecorse, Michigan, has reduced its capacity to less than 4 million tons from its previous high of 6 million tons.

2.2 Historical Changes of Production Share Among Steelmaking Processes

As explained earlier, there has been a sharp decline in production using the OH process and a sharp increase in production using the BOF and EAF processes. This situation is shown in Exhibits 2-2 and 2-3.

<table>
<thead>
<tr>
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<th>BOF</th>
<th>OH</th>
<th>EAF</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>1973</td>
<td>83.7</td>
<td>55.5%</td>
<td>39.8</td>
<td>26.4%</td>
</tr>
<tr>
<td>1974</td>
<td>81.6</td>
<td>56.0%</td>
<td>35.5</td>
<td>24.4%</td>
</tr>
<tr>
<td>1975</td>
<td>71.8</td>
<td>61.5%</td>
<td>22.2</td>
<td>19.0%</td>
</tr>
<tr>
<td>1976</td>
<td>80.0</td>
<td>62.5%</td>
<td>23.5</td>
<td>18.3%</td>
</tr>
<tr>
<td>1977</td>
<td>77.7</td>
<td>62.0%</td>
<td>20.2</td>
<td>16.1%</td>
</tr>
<tr>
<td>1978</td>
<td>83.4</td>
<td>61.0%</td>
<td>21.3</td>
<td>15.5%</td>
</tr>
<tr>
<td>1979</td>
<td>83.7</td>
<td>61.4%</td>
<td>19.2</td>
<td>14.1%</td>
</tr>
<tr>
<td>1980</td>
<td>68.3</td>
<td>61.1%</td>
<td>13.0</td>
<td>11.6%</td>
</tr>
<tr>
<td>1981</td>
<td>74.1</td>
<td>61.4%</td>
<td>13.4</td>
<td>11.1%</td>
</tr>
<tr>
<td>1982</td>
<td>46.3</td>
<td>62.2%</td>
<td>6.1</td>
<td>8.1%</td>
</tr>
<tr>
<td>1983</td>
<td>52.4</td>
<td>61.8%</td>
<td>6.0</td>
<td>7.0%</td>
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<tr>
<td>1984</td>
<td>52.9</td>
<td>57.1%</td>
<td>8.4</td>
<td>9.0%</td>
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<td>1985</td>
<td>51.9</td>
<td>58.9%</td>
<td>6.4</td>
<td>7.3%</td>
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<tr>
<td>1986</td>
<td>47.8</td>
<td>58.6%</td>
<td>3.3</td>
<td>4.1%</td>
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<tr>
<td>1987</td>
<td>52.5</td>
<td>58.9%</td>
<td>2.6</td>
<td>3.0%</td>
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<td>1988</td>
<td>58.0</td>
<td>58.1%</td>
<td>5.1</td>
<td>5.1%</td>
</tr>
<tr>
<td>1989</td>
<td>58.3</td>
<td>59.6%</td>
<td>4.4</td>
<td>4.5%</td>
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<tr>
<td>1990</td>
<td>58.4</td>
<td>59.1%</td>
<td>3.5</td>
<td>3.6%</td>
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<tr>
<td>1991</td>
<td>52.7</td>
<td>60.0%</td>
<td>1.4</td>
<td>1.6%</td>
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<tr>
<td>1992</td>
<td>57.7</td>
<td>62.0%</td>
<td>-</td>
<td>0.0%</td>
</tr>
<tr>
<td>1993</td>
<td>59.3</td>
<td>60.7%</td>
<td>-</td>
<td>0.0%</td>
</tr>
<tr>
<td>1994</td>
<td>61.0</td>
<td>61.0%</td>
<td>-</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

(unit: million short tons)

Source: American Iron and Steel Institute
Exhibit 2-3
Raw Steel Production by Furnace Type

Source: American Iron and Steel Institute

As it moved from 17 percent of production in 1965 to an average of 60 percent in the 1980s and early 1990s, much publicity was given to the rise of the BOF process. Less attention was paid to the dramatic increase in EAF capacity and production over the same period. In 1975, EAF production was around 20 percent, and by 1986, over 37 percent. Since 1986, it has remained stable at a level of 36 to 39 percent.

This has had a number of repercussions. First, since the EAF does not require expensive accompanying equipment such as blast furnaces and coke ovens, that made it possible to enter the steel business with a relatively low capital investment. Anyone who installed an EAF could select a size, ranging from 100,000 to 2,000,000 tons of capacity. Second, EAFs operate on scrap as the main raw material, thus generating a heavy demand for scrap, which was in tight supply during the boom of the mid-1970s. However, since total raw steel output dropped in the 1980s, the scrap supply was adequate until the mid-1990s. Finally, EAFs also brought the minimill into prominence as a significant part of the steel industry.
The rising importance of the minimill evolved over a twenty-year period, from the 1960s to the 1980s. During the latter part of that period, a number of minimills were built, and at the same time there was a significant decline in the number of integrated steel mills. Considerable additions were made to minimill capacity by such companies as Nucor, Florida Steel, and Atlantic, while new companies were established, including Raritan River, Chaparral, Bayou, and Auburn. Capacity was also increased, in a number of instances, by the replacement of small EAFs with larger ones.

2.3 The Growth of Minimills

There are several reasons why minimills were able to expand their production and market share.

2.3.1 The Weakening Position of Integrated Steelmakers

Until the early 1970s, integrated steelmakers had dominated markets, and markets served by the U.S. steel industry had enjoyed healthy growth. Therefore, they were able to maximize the use of scale economies based on full-capacity operations. Also, in an oligopolistic market, they could add cost increases to their product prices without making any particular effort to rationalize their operation.

However, in the mid-1970s, their situation became far less favorable. First, the demand from U.S. markets such as automobiles, oil and gas, and machine industries declined dramatically. The automobile industry is a typical example. In the 1970s, the automobile industry purchased an average of more than 20 million tons of domestic steel each year, reaching a high point of 23 million tons in 1973. But by 1982, shipments to the automobile industry had fallen as low as 9.3 million. Such a decline occurred not only because of the depressed automobile industry itself, but also because the size of cars was being reduced, and
other materials than steel were being substituted, augmented by the sourcing of parts from abroad. In addition to the shrinkage in steel markets, direct steel imports in the 1980s gained a much larger share of the market with their competitive prices. Also a sizeable tonnage of steel entered in the form of products made of steel, such as automobiles and machinery. These are classified as indirect steel imports, which added to the shrinkage of steel markets.

Under these circumstances, integrated steelmakers were less able to utilize scale economies as a strength and instead were forced to deal with severe competition from other integrated steelmakers, minimills, and imported steel. In contrast, minimills, with their cost competitiveness based on full utilization of compact facilities with simpler management style, quickly expanded their production and market share.

The contraction of market size and price reductions due to competition with imported steel worsened the financial condition of integrated steelmakers. They began to institute restructuring program to cut costs, although many of the cost cuts were neutralized by the price cuts in order to remain competitive. In the process of restructuring, integrated steelmakers reduced their steelmaking capacity, thereby creating room for minimills to expand capacity. Particularly during the early 1980s, integrated steelmakers deliberately reduced capacity in order to cope with depressed steel demand. However, as a result, they were unable to fulfill orders when domestic demand recovered in the late 1980s, and they were forced to limit the number of customers. Consequently, users who could not secure steel from integrated steelmakers shifted their purchasing to minimills.

Integrated mills are concentrated primarily in locations in the northern and eastern part of the U.S., based on convenient access to raw materials and the markets for their products. The largest iron ore mines are located in Minnesota and Michigan, and automotive makers who are the primary users of their products, are concentrated in the lower Great Lakes regions. However, as industry bases spread to the south and west, the advantage of being located in a traditionally large steel consumption area has weakened. Given the shift of industry bases
and increased construction of infrastructure, minimills have been able to fulfill or supplement demand in local areas near the minimills.

2.3.2 Smaller Capital Requirement

The range of products produced by minimills was originally limited to products that did not require a high quality finish, such as light structural shapes and bars for the construction industry. In general, the production process is widely established and quality requirements are not as strict compared with other products. Therefore minimills could be able to produce these items easily using steel scrap as the main raw material. Since the capital requirement for rolling equipment for those items is relatively small, most of the small to medium-size minimills could enter this segment. As the business expanded, minimills used accumulated capital to aggressively invest in new products such as wide flange beam, seamless pipe, and plate.

2.3.3 Adequate Supply of Steel Scrap

When considering the profitability of minimills, the price difference between product price and raw material price is the most important factor. Therefore, the price of steel scrap as the main raw material greatly influences cost competitiveness. In the U.S., the supply of steel scrap has been adequate, supported by a huge scrap reservoir\(^1\), and the surplus has been exported overseas. In particular, the supply of ordinary grade steel scrap, which is required for production of minimills’ traditional products, has been more than adequate. It is clear, therefore, that an adequate supply of steel scrap has supported the expansion of minimill business.

\(^1\) It is estimated that the scrap reservoir in the U.S. was around 4 billion tons in 1994, which was the largest volume in the world. Scrap reserves in Japan are less than 1 billion tons.
2.4 Overview of Flat-Rolled Products

Flat-rolled products consist of various kinds of products such as plate products, tin mill products and sheet products.

The main users of flat-rolled products are automotive manufacturers, appliances manufacturers, construction companies, tube makers and intermediate steel processors. The flat-rolled products market represents approximately 60 percent of domestic deliveries although this percentage varies from year to year.

Using traditional processes, flat-rolled products requires sophisticated steel-making technology as well as huge capital expenditure. Except for plate products, flat-rolled products have been the exclusive domain of the integrated mill until Nucor began to produce hot-rolled and cold-rolled sheets at its Crawfordsville plant in 1989.

In 1973, the apparent consumption of flat-rolled products reached 72.1 million tons. Since then, it decreased steadily, reaching a low of 42.2 million tons in 1982. After 1983, it recovered to 55-60 million tons into the early 1990s. In 1994, it reached 72.4 million tons, breaking the previous 1973 record. These movements in relation to total steel products are shown in Exhibit 2-4.
The composition of apparent consumption is shown in Exhibit 2-5. When compared with 1973, product shipments were 6.5 million tons lower which was offset by increased imports. Exports was slightly lower and, consequently, the apparent consumption in 1994 was slightly higher than 1973.
Exhibit 2-5
Apparent Consumption of Flat-Rolled Products

(unit: million short tons)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>66.3</td>
<td>36.4</td>
<td>59.8</td>
<td>-6.5</td>
</tr>
<tr>
<td>Export</td>
<td>2.0</td>
<td>0.6</td>
<td>1.7</td>
<td>-0.3</td>
</tr>
<tr>
<td>Import</td>
<td>7.8</td>
<td>6.4</td>
<td>14.3</td>
<td>+6.5</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>72.1</td>
<td>42.2</td>
<td>72.4</td>
<td>+0.3</td>
</tr>
</tbody>
</table>

Source: American Iron and Steel Institute

While Exhibit 2-5 shows the extreme years of 1973, 1982, and 1994, Exhibit 2-6 shows figures for the continuous years from 1990-1995.

Exhibit 2-6
Apparent Consumption of Flat-Rolled Products in Recent 6 Years

(unit: million short tons)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>51.8</td>
<td>47.6</td>
<td>50.8</td>
<td>55.8</td>
<td>59.8</td>
<td>60.7</td>
</tr>
<tr>
<td>Export</td>
<td>2.4</td>
<td>3.6</td>
<td>2.2</td>
<td>1.7</td>
<td>1.7</td>
<td>3.9</td>
</tr>
<tr>
<td>Import</td>
<td>8.6</td>
<td>7.9</td>
<td>9.7</td>
<td>8.3</td>
<td>14.3</td>
<td>12.2</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>58.0</td>
<td>51.9</td>
<td>58.3</td>
<td>62.4</td>
<td>72.4</td>
<td>69.0</td>
</tr>
</tbody>
</table>

* For 1995, actual monthly figures were available only through September. The quantity for the period from January to September is annualized by multiplying by 12/9 for purposes of comparison with 1994.

Source: American Iron and Steel Institute
Apparent consumption in each category of flat-rolled products from 1990 to 1995 is shown in Exhibit 2-7.

**Exhibit 2-7**

**Apparent Consumption of Each Product Category**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-Rolled Sheet</td>
<td>15.7</td>
<td>14.3</td>
<td>16.2</td>
<td>17.7</td>
<td>20.6</td>
<td>18.6</td>
</tr>
<tr>
<td>Cold-Rolled Sheet</td>
<td>15.7</td>
<td>13.8</td>
<td>15.4</td>
<td>15.5</td>
<td>17.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Galvanized Sheet</td>
<td>11.3</td>
<td>10.2</td>
<td>12.3</td>
<td>14.2</td>
<td>16.3</td>
<td>16.4</td>
</tr>
<tr>
<td>Other Coated Sheet</td>
<td>1.9</td>
<td>1.7</td>
<td>2.0</td>
<td>2.1</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Plate Products</td>
<td>9.1</td>
<td>7.5</td>
<td>8.3</td>
<td>8.6</td>
<td>10.7</td>
<td>10.9</td>
</tr>
<tr>
<td>Tin Mill Products</td>
<td>4.4</td>
<td>4.4</td>
<td>4.2</td>
<td>4.3</td>
<td>4.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Total Flat-Rolled Products</td>
<td>58.1</td>
<td>51.8</td>
<td>58.4</td>
<td>62.4</td>
<td>72.3</td>
<td>69.0</td>
</tr>
</tbody>
</table>

(1 unit: million short tons)

Source: American Iron and Steel Institute

As briefly explained earlier, hot-rolled sheet processed by a hot-strip mill is the basic sheet material. As it is processed into value-added sheet products like cold-rolled sheet, galvanized sheet, coated sheet, etc, additional downstream processes are required.

2.4.1 **Segmentation of Flat-Rolled Products by Quality Requirements**

For reasons of service and quality, three different segments of flat-rolled products have evolved, namely high-end, mid-scale, and low-end segments. The characteristic features of each segment is discussed briefly below.²

² Much of the discussion of these characteristic features was found in “Steel's Thin-Slab/Flat-Rolling Revolution: Provoking Change,” Core Report 22, World Steel Dynamics, January 1996.
(1) High-End Segment - Tier 1
This segment is the highest level of product quality, including unique attributes such as smooth surface quality, internal cleanliness, and formability. This segment is very customer-specific and requires services by the steelmaker such as inventory programs and just-in-time delivery systems. In many of these markets, the cost of the steel is a relatively small percentage of the total cost of the steel buyers’ finished product.

2) Mid-Scale Segment - Tier 2
This segment is less demanding than the high-end segment. Requirements for physical specifications, such as width and thickness, are more strict than for the low-end segment. While customers are still sensitive to quality and service, price has a proportionately greater importance in the perception of value.

3) Low-End Segment - Tier 3
This segment is the least demanding for both steelmakers and steel buyers. There are fewer extremes when it comes to quality characteristics of the steel and the steelmakers’ service requirements. The buyers’ definition of supplier value is dominated by the price of the steel. This is due to the relatively high percentage that the steel represents of the total cost of the customers’ finished products.

The quantity of flat-rolled products in each segment based on apparent consumption in 1994 is shown in Exhibit 2-8.
Exhibit 2-8
Estimated Quantity of Each Segment in Flat-Rolled Products

<table>
<thead>
<tr>
<th></th>
<th>High-End Segment</th>
<th>Mid-Scale Segment</th>
<th>Low-End Segment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-Rolled Sheet</td>
<td>3.5</td>
<td>3.8</td>
<td>12.0</td>
<td>19.3</td>
</tr>
<tr>
<td>Cold-Rolled Sheet</td>
<td>6.0</td>
<td>6.1</td>
<td>6.0</td>
<td>18.1</td>
</tr>
<tr>
<td>Galvanized &amp; Coated Sheet</td>
<td>4.3</td>
<td>4.5</td>
<td>5.5</td>
<td>14.3</td>
</tr>
<tr>
<td>Electric Galvanized Sheet</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
<td>4.0</td>
</tr>
<tr>
<td>Tinmill Products</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td>Plates</td>
<td>1.3</td>
<td>3.1</td>
<td>6.4</td>
<td>10.8</td>
</tr>
<tr>
<td>Total</td>
<td>23.6</td>
<td>17.5</td>
<td>29.9</td>
<td>71.0</td>
</tr>
</tbody>
</table>

Source: *World Steel Dynamics*

2.4.2 The Success of Nucor’s Flat-Rolling Plant

Nucor’s flat-rolling plant at Crawfordsville, Indiana started up in the summer of 1989 following a two-year construction period. It used the new thin-slab casting technology (see Chapter 3) provided by SMS Schloemann-Siemag AG of Dusseldorf, Germany (SMS). After about $65 million of start-up costs, the plant broke into the black in the summer of 1990. Since then, production costs have continued to decline. Nucor provides a good example of revolutionary features that have been incorporated into the flat-rolled segment in addition to technical achievements.

(1) The land and facilities at the plant cost about $300 million. Given the one million ton steelmaking capacity of the plant (its original size before expansion), this is a capital cost of approximately $300 per ton. A traditional integrated mill with similar product capabilities and a capacity of 3.0 million tons per year would cost over $1,000 per ton. This significantly lower entry cost enabled minimills to expand into the flat-rolled product segment.
(2) With its highly efficient operation based on the SMS technology, Nucor’s production cost for flat-rolled products is considered to be amazingly lower than most of the integrated steelmakers based on a specific steel scrap price. Consequently, Nucor is able to shift its price in accord with demand in a more flexible manner.

(3) Nucor’s efficient operation derives from its management style and several corporate policies, including: keep overhead costs extremely low; give full responsibility to the general manager of the plants; remain non-union; develop strong incentive programs for the workers; operate plants at 100 percent of capacity; employ workers on a permanent basis; take technological risks; do not make acquisitions and build plants yourself.³

(4) The steel is offered on a unique basis in the domestic and international market, i.e., the f.o.b. price at the steel plant is same for all users. They do not equalize delivered price to users under any condition.

(5) Given its relatively small size, the owners of a thin-slab/flat-rolling plant can seek out the optimum economy with respect to proximity to customers, transportation costs, scrap costs, power rates, skilled reliable workers, and other factors.

In 1986, when Nucor decided to enter the flat-rolled segment, their annual production was 2.1 million tons. Although it is positioned as the second-largest minimill in the U.S., they were regarded as one of the small to medium-size steelmakers. In 1994, their production reached 7.2 million tons, making them the fourth-largest steelmaker in the U.S. Flat-rolled products account for 37 percent of their total production which has supported the company’s rapid advance. "For a decade, it has been the high-flying Wal-Mart of the steel industry, keeping costs down on basic products and passing the savings on to customers."⁴ Exhibit 2-9 shows the production growth of Nucor.

³ "Steel’s Thin-Slab/Flat-Rolling Revolution: Provoking Change," World Steel Dynamics, January 1996.

Exhibit 2-9
Nucor Historical Production Quantity

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Items</td>
<td>2,201</td>
<td>2,688</td>
<td>3,074</td>
<td>3,022</td>
<td>3,287</td>
<td>3,755</td>
<td>4,557</td>
</tr>
<tr>
<td>Flat Products</td>
<td>-</td>
<td>35</td>
<td>475</td>
<td>760</td>
<td>945</td>
<td>1,970</td>
<td>2,660</td>
</tr>
<tr>
<td>Percentage</td>
<td>0.0%</td>
<td>1.3%</td>
<td>13.4%</td>
<td>20.1%</td>
<td>22.3%</td>
<td>34.4%</td>
<td>36.9%</td>
</tr>
<tr>
<td>Total</td>
<td>2,201</td>
<td>2,723</td>
<td>3,549</td>
<td>3,782</td>
<td>4,232</td>
<td>5,725</td>
<td>7,217</td>
</tr>
</tbody>
</table>

Source: *World Steel Dynamics*

2.4.3 Addition and Expansion of Minimills for Flat-Rolled Products

The success in making hot-rolled sheets by EAF using the thin-slab casting process was a milestone for further minimill development. After resolving the problems experienced by Nucor in its first stage of operation, mini-strip production has now proved its advantage by producing low to medium-grade sheets less expensively than most integrated mills. Such success has motivated several other minimills to follow suit.

In 1992, Nucor build a second plant for thin slab flat-rolled products with a production capacity of 1.2 million tons at Hickman, Arkansas, followed by further expansion of both plants in 1994. After Nucor's success, many minimills are entering the flat-rolled product segment. Some of them have completed construction and begun production in 1995. Some have decided to build and have ordered equipment, while others are still in the decision-making stage. This additional new capacity is compiled in Exhibit 2-10. By the end of this century, the capacity for EAF-based flat-rolled products will reach 23 million tons. Even excluding undecided plans, capacity will reach 16 million tons. This means that by 1997, capacity will have increased by 13 million tons from 1994 levels.
It must be noted that part of this new capacity will be replacement of the existing imported slab-flat rolled process production. Therefore, when the impact on the products market is considered, 1.45 million tons\(^5\) must be deducted.

\(^5\) This figure represents 0.8 million tons of Tuscaloosa’s existing rolling capacity and 0.65 million tons of Beta Steel’s existing rolling capacity. These mills product flat-rolled products by processing imported slabs.
## Exhibit 2-10  EAF / Flat-Rolled Capacity - Newly Constructed and Planned in U.S.

(unit: 1,000 short tons)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucor</td>
<td>Crawfordville, IND</td>
<td>Sheet</td>
<td>1,000 C</td>
<td></td>
<td>800 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,800</td>
</tr>
<tr>
<td></td>
<td>Hickman, AK</td>
<td>Sheet</td>
<td>1,200 C</td>
<td></td>
<td>800 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>Gallatin Steel</td>
<td>Ghost, KY</td>
<td>Sheet</td>
<td>1,000 C</td>
<td></td>
<td></td>
<td>1,000 D</td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>AK Steel</td>
<td>Mansfield, OH</td>
<td>Sheet</td>
<td>800 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>Beta Steel</td>
<td>Portage, IND</td>
<td>Sheet</td>
<td>1,000 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000 P</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>Caparo Steel</td>
<td>Sharon, PA</td>
<td>Sheet</td>
<td>800 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>400 P</td>
<td>800 P</td>
<td></td>
</tr>
<tr>
<td>Steel Dynamics</td>
<td>Butler, IND</td>
<td>Sheet</td>
<td>1,200 C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>NSS-BHP</td>
<td>Delta, OH</td>
<td>Sheet</td>
<td>1,500 D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,500</td>
</tr>
<tr>
<td>IPSCO</td>
<td>Muscatine, IA</td>
<td>Plate</td>
<td>1,250 D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,250</td>
</tr>
<tr>
<td>Trico Steel</td>
<td>AL / MS</td>
<td>Sheet</td>
<td>2,200 D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,200</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>Tuscaloosa, AL</td>
<td>Plate</td>
<td>800 D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>Nucor</td>
<td>Barkley, SC</td>
<td>Sheet</td>
<td>1,000 D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>Nuco-Oregon</td>
<td>WA / OR</td>
<td>Sheet</td>
<td>1,200 P</td>
<td></td>
<td></td>
<td></td>
<td>1,000 P</td>
<td></td>
<td></td>
<td>2,200</td>
</tr>
<tr>
<td>World Class Steel</td>
<td>Pittsburgh, PA</td>
<td>Sheet</td>
<td>750 P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>750</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,000</td>
<td>1,200</td>
<td>1,600</td>
<td>4,800</td>
<td>2,750</td>
<td>7,350</td>
<td>3,800</td>
<td>22,500</td>
</tr>
</tbody>
</table>

### EAF Capacity

- **- Constructed**
  - 1,000 | 1,200 | 1,600 | 4,800 | - | - | - | - | 8,600
- **- Under Construction**
  - - | - | - | - | - | - | - | - | -
- **- Decided to Go Ahead**
  - - | - | - | - | 2,750 | 5,000 | - | - | 7,750
- **- Sub Total**
  - 1,000 | 1,200 | 1,600 | 4,800 | 2,750 | 5,000 | - | - | 16,350
- **- Planned / Possible**
  - - | - | - | - | 2,350 | 3,800 | - | - | 6,150
- **- Total**
  - 1,000 | 1,200 | 1,600 | 4,800 | 2,750 | 7,350 | 3,800 | - | 22,500

### Products Capacity

- **- Constructed**
  - 1,000 | 1,200 | 1,600 | 4,800 | - | - | - | - | 8,600
- **- Under Construction**
  - - | - | - | - | - | - | - | - | -
- **- Decided to Go Ahead**
  - - | - | - | - | 2,750 | 5,000 | - | - | 7,750
- **- Less Replacement**
  - - | - | - | - | (650) | (800) | - | - | (1,450)
- **- Sub Total**
  - 1,000 | 1,200 | 1,600 | 4,150 | 2,750 | 4,200 | - | - | 14,900
- **- Planned / Possible**
  - - | - | - | - | 2,350 | 3,800 | - | - | 6,150
- **- Total**
  - 1,000 | 1,200 | 1,600 | 4,150 | 2,750 | 6,550 | 3,800 | - | 21,050

Source: Various Publications Compiled by Mitsui & Co., Ltd.
CHAPTER 3

THE ENTRY OF MINIMILLS INTO THE FLAT-ROLLED PRODUCTS SEGMENT

It is clear that the success of Nucor was a turning point for other minimills to follow. However, there was clearly some fundamental motivation for Nucor and then others to enter the flat-rolled segment. Some of these reasons were:

- new technological innovations;
- saturation of traditional markets; and
- capacity contraction among integrated mills.

In this chapter, I will discuss these reasons for this move by the minimills into the flat-rolled segment.

3.1. Technological Innovation

The idea of casting molten steel directly into a thin, continuous ribbon can be traced back to Sir Henry Bessemer, who built and patented a machine for that purpose in 1857. But when Bessemer attempted to operate his machine, it was troubled by "breakouts" -- partially solidified strands of steel would rupture sending molten metal at nearly 3,000° F gushing through the machinery, creating fires and after cooling, welding the entire piece of machinery into a solid mass of steel. Breakouts were particularly likely to afflict attempts to cast steel in thin shapes because such shapes had a higher ratio of surface area to volume, thereby increasing friction between the casting mold and the steel poured through it. As a result, for another century, molten steel continued to be batch-cast into ingots, typically about two feet thick, that were cooled and stored before being reheated and rolled into thinner shapes.¹

¹ Most of this historical material was taken from "Nucor at a Crossroads," Harvard Business School Case, No. 9-793-039, May 5, 1993.
Continuous casting, which began to be commercialized in the late 1950s, marked an important step toward Bessemer's goal because it permitted molten steel to be cast into slabs that were only eight to ten inches thick. In the 1980s, the American steel industry poured billions of dollars into thick-slab continuous casters to catch up with European and Japanese competitors. The efficiency of this process continued to be constrained, however, by the need to reheat slabs, the multiple rolling stands required to crush them into flat sheet one-tenth of an inch thick, and the fact that slabs could only be processed one by one. Steelmakers continued, therefore, to look for better casting technologies. About 30 research programs on directly casting steel into sheet were being pursued around the world by 1986, but none were projected to yield a commercial process until the 21st century. This projection fueled interest in the idea of casting thin slabs two or fewer inches thick to shrink the production chain from liquid steel to flat sheet by reducing reheating and rolling costs compared to conventional continuous casting.

The Hazelett caster was regarded as the most promising approach to thin-slab casting in the early 1980s, and was being tested at five pilot plants in 1986 when Nucor began looking for thin-slab technology for its planned new plant. Its design dated back to the 1950s and involved pouring molten steel between parallel water-cooled conveyor belts spaced one inch apart. The skin of the molten steel was supposed to solidify upon contact with the belts, which would then peel away from it, yielding a slab one inch thick. This twin-belt design assumed that high casting speeds, required for thin-slab casting to process tonnages comparable to conventional casting, could not be achieved with conventional fixed molds. But in trying to solve the problem of casting speed, it created new ones: the conveyor belts were very expensive and needed to be changed frequently, resulting in considerable down-time; steel poured between the belts was subject to turbulence, which marred product quality or, even worse, let to breakouts; and the large number of moving parts complicated breakout clean-ups and increased maintenance costs.

While experiments with Hazelett casters were yielding mixed result, SMS Schloßmann-Siemag A.G. of Germany, a leading designer of conventional casting and rolling equipment,
began to promote another thin-slab casting technology that it called Compact Strip Production (CSP). CSP was less ambitious than Hazelett casting: casting slabs that were two inches thick based on just one departure from conventional casting -- the use of a lens-shaped rather than a rectangular mold. SMS set up a stationary device in 1984 to test the new mold and, encouraged by the results, spent $7 million in 1985 to build a pilot plant. Armed with data on the performance of this pilot operation, which was reported to experience breakouts only one out of every ten casts, SMS began to promote CSP to as many steelmakers as possible. More than 100 companies sent engineers or executives to observe SMS’s pilot thin-slab caster in operation. Finally, however, only Nucor contracted with SMS to commercialize CSP.

SMS’s basic design for a commercial CSP installation envisaged a plant with 800,000 tons to 1 million tons of flat rolling capacity at a capital cost of about $250 to $300 per ton. The thin-slab caster makes it possible to reduce number of rolling stands drastically. It requires only 4 or 5 rolling stands to be crushed into flat sheet based on thinner slab instead of the 7 to 10 that were the norm for thicker slabs at integrated mills. Furthermore, it achieves labor and energy savings and higher yield that would reduce operating costs below those of integrated mills.

Although the traditional integrated steelmaking configuration can produce a full product range, the high construction costs per ton and large optimal plant size mean that a capital outlay using traditional technology would cost $6-$7 billion. Clearly, this is an unimaginable capital commitment for even the largest producer.

The new technology has lowered the entrance costs on both a unit and absolute basis. The smaller optimal plant size allows for plant locations near end-users and in growing markets such as the South. With a one-step process from melting to finishing, the new technology reduces production cycle times from days to hours. Combined with a variable cost structure, the new technology producers have dramatically increased their production flexibility and can be quicker to react to changes in market conditions. By slashing labor requirements, these producers have a cost advantage over domestic integrated and most of overseas
producers who have relied on cheap labor as their major cost advantage. Finally, it is said that the new technology improves the demand outlook for steel by increasing its cost competitiveness with alternative materials.

Someone in the industry said that Nucor's achievement with SMS technology was "steel's second technological revolution," the first being Bessemer's development of the steelmaking furnace and methods to produce rolled steel products on an automated basis.

However, it cannot be said that there is no weakness in this technology. "The higher aspect ratio\(^2\) in this technology results in greater turbulence in the mold for a given volume of liquid steel passing through the machine. With greater turbulence, mold flux can be entrained in the slab and slabs can solidify unevenly. Both problems can cause surface defects."\(^3\) Although there has been a great improvement in this regard, it has not been completely resolved. At this stage, flat-rolled products using this technology still cannot be applied to high-end segment such as the surface material of automobile where superior surface quality is essential. Much of Nucor's flat-rolled products, for instance, goes to the low-end segment mainly for construction, tubing, and similar applications.

This technology continues to evolve through the efforts of several companies, including SMS, Mannesmann-Demag Huttentechnik (Mannesmann, Duisburg, Germany) and Voest-Alpine Industrieanlagenban A.G. (Voest, Austria).

3.2 Market Saturation

As discussed previously, raw steel production by the EAF process has increased dramatically in the last two decades mainly because of the decreased use of the OH process

\(^2\) Aspect ratio compares mold width to mold thickness. For example, the molds of Nucor's SMS machines are 60 inches wide and 2 inches thick, for an aspect ratio of 30:1.

and the minimills' increased participation in integrated steelmakers products segment. However, when looking at EAF production share since 1986, it has increased steadily into the range of 36 to 39 percent. In particular, during the period between 1986 and 1989 when Nucor started flat-rolled production, EAF production share was 37.3 percent, 38.1 percent, 36.9 percent, 35.9 percent, respectively. Since most of the production by EAF process is done by minimills, it appeared that minimill production share had hit the ceiling.

Minimills' traditional products are rebar, merchant bar, light and medium sections and wire rod. Exhibits 3-1 through 3-4 show the movement of production and its share, minimills' production divided by apparent consumption, of wire rod and bar steel, respectively, since 1973. These products are considered to be typical traditional minimill items.

**Exhibit 3-1**

*Wire Rod:
Apparent Consumption vs. Minimill Production vs. Imports*

![Graph](image)

*Source: World Steel Dynamics*
Exhibit 3-2
Wire Rod - Share of Minimills and Imports

Source: World Steel Dynamics

Exhibit 3-3
Bar Steel:
Apparent Consumption vs. Minimill Production vs. Imports

Source: World Steel Dynamics
In the case of wire rod, minimill market share reached a high of 66.6 percent in 1991, and since then has declined somewhat, while market share of import material has increased gradually. In 1993, market share of minimills and import materials was 60.6 percent and 25.4 percent, respectively, or a total of 85.9 percent of the U.S. market. Apparent consumption of this product has been steady through cyclical ups and downs. In 1993, it marked 7.48 million tons which is almost same level as that in 1973.

In the case of bar steel, minimill market share is still growing although the pace of growth has slowed recently. It reached 75.1 percent in 1993 which is the highest figure in the history. Market share of import materials stayed in the 8 to 11 percent range over the last ten years. In 1993, market share of minimills and import materials was 75.1 percent and 9.7 percent, respectively, or a total of 84.8 percent of the U.S. market. Apparent consumption
of this product marked 19.46 million tons in 1974, and has remained at the level of 14 to 16 million tons over the last ten years.

These figures indicate that minimills are finding it difficult to expand their business based only on their traditional product segment. Therefore, it is natural that minimills would be keenly interested in the flat-rolled segment, which represents around 60 percent of domestic deliveries.

3.3 Capacity Contraction of Integrated Mills

The gross capacity of the U.S. steel industry to make raw steel reached a high of 159.9 million tons in 1977. It has since dropped dramatically, and in 1994 was 119.6 million tons. In terms of iron making, the number of blast furnaces in operation fell from 159 to 42 during the same period.

In 1973, gross production capacity of BOF and OH was 84.9 million tons and 40.8 million tons, respectively. Since then, the capacity of both has been drastically reduced, and in 1994, these figures were 73.2 million tons and 0.0, respectively. Although EAF capacity had increased during the same period, it was not enough to offset the integrated mills' decrease. This tendency is clearly shown in Exhibit 3-5 and 3-6.
Exhibit 3-5
Raw Steel Production Capacity by Furnace Type

Source: American Iron and Steel Institute

Exhibit 3-6
Share of Raw Steel Production Capacity by Furnace Type

Source: American Iron and Steel Institute
In the early to mid-1980s, the entire steel industry, including EAF operations, suffered from over-capacity due primarily to a shrinking market and the increasing penetration of imports. Capacity reduction was notable, especially among major integrated steelmakers, who tried to rationalize their operations and to stabilize their product prices. Exhibit 3-7 shows the capacity reduction among the major integrated steelmakers.

**Exhibit 3-7**

U.S. Gross Steelmaking Capacity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USS</td>
<td>33.1</td>
<td>23.6</td>
<td>17.7</td>
<td>16.4</td>
<td>14.2</td>
<td>14.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Bethlehem</td>
<td>21.3</td>
<td>18.4</td>
<td>16.6</td>
<td>15.5</td>
<td>15.5</td>
<td>14.1</td>
<td>12.8</td>
</tr>
<tr>
<td>LTV</td>
<td>25.0</td>
<td>21.5</td>
<td>10.8</td>
<td>10.7</td>
<td>10.7</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>National</td>
<td>8.7</td>
<td>5.6</td>
<td>6.5</td>
<td>7.2</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>AK Steel</td>
<td>9.3</td>
<td>6.7</td>
<td>5.5</td>
<td>5.5</td>
<td>6.4</td>
<td>6.4</td>
<td>4.6</td>
</tr>
<tr>
<td>Inland</td>
<td>8.6</td>
<td>9.4</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Wheeling Pitt.</td>
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<td>4.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Weirton</td>
<td>4.0</td>
<td>3.9</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Rouge</td>
<td>3.6</td>
<td>3.5</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Subtotal Majors</td>
<td>118.1</td>
<td>97.1</td>
<td>72.6</td>
<td>70.8</td>
<td>68.7</td>
<td>67.2</td>
<td>64.2</td>
</tr>
<tr>
<td>Others</td>
<td>35.2</td>
<td>36.4</td>
<td>49.8</td>
<td>51.5</td>
<td>51.3</td>
<td>53.8</td>
<td>55.4</td>
</tr>
<tr>
<td>Total</td>
<td>153.2</td>
<td>133.5</td>
<td>122.5</td>
<td>122.2</td>
<td>119.9</td>
<td>121.0</td>
<td>119.6</td>
</tr>
</tbody>
</table>

(unit: million short tons)


Crude-to-finished yield represents the finished product shipments divided by the raw steel production quantity. Since the U.S. imports semi-finished products which were domestically processed to finished products, it is more appropriate to use raw steel production quantity plus imported semi-finished products as a denominator. In 1994, quantities of raw steel production, imported semi-finished products, and finished product shipments were 99.9 million tons, 7.9 million tons, and 95.1 million tons, respectively. Therefore, crude-to-finished yield was 88 percent.
When the 86 percent of effective capacity rate, discussed earlier, and the 88 percent of crude-to-finished yield are taken into account, the theoretical steelmaking capacity in 1994 was equivalent to 90.5 million tons of finished product production. Since finished product shipments in 1994 were 95.1 million tons, it is apparent that raw steel production in 1994 was not enough to support finished product shipments without imported semi-finished products. In other words, the existing raw steel capacity in the U.S. could not cover its apparent consumption quantity without tremendous quantities of imports of both finished and semi-finished products.

Blast furnace and related facilities needed to make iron are exceptionally expensive to build, at over $350 per ton of hot metal for a 3.5 million metric tons per year complex. For this reason, as well as the minimum-optimum scale and environmental concerns, new blast furnaces are unlikely to be built. Also, the supply of domestic coke has continually decreased due to aging coke ovens and environmental concerns. In view of these factors, capacity increase among integrated steelmakers is highly unlikely although it must be noted that the productivity of blast furnaces in the U.S. has improved in recent years through the application of several operating improvements.

For the sake of hypothetical argument, if all the production capacity of the BOF process was concentrated on flat-rolled production in 1994, it would be equivalent to 53.74 million tons of finished products based on the formula discussed earlier. Imported semi-finished products made it possible to meet 59.8 million tons of flat-rolled product shipments in 1994 which, however, still could not cover 72.4 million tons of flat-rolled product apparent consumption in the same year.

In short, the existing capacity of integrated steelmakers does not support flat-rolled product demand in the U.S. This argument can be supported by the fact that some of the mills categorized as integrated steelmakers, such as LTV, have decided to enter minimill operations for flat-rolled products.

---

4 61.0 million tons of BOF-based raw steel production x 88 percent of crude-to-finished yield.
CHAPTER 4

CONSUMPTION, SUPPLY AND
PRICE TRENDS OF RAW MATERIALS

In this chapter, I will review consumption, supply, and price trends of metallic raw materials for minimills. The basic question to be considered is whether the supply of raw materials is large enough to support the minimills' desire to expand capacity. Since low residual steel scrap and/or its substitutes are absolutely required for producing flat-rolled products, the availability of these materials is a crucial matter.

4.1 Basic Consumption Patterns of Raw Materials

Minimills throughout the U.S., with one exception, are tremendously dependent on scrap as their raw material, although some substitute materials such as molten pig iron, direct reduced iron, and hot briquetted iron are also used to supplement steel scrap.

The exception is GS Industries' (formerly Georgetown Steel) direct reduced iron production facility in South Carolina. Direct reduction is a process whereby deoxidized iron pellets are produced without the use of a blast furnace. Iron pellets with approximately 60 percent iron content are fed into a shaft furnace. Natural gas is also introduced and removes much of the oxygen from the iron ore so that the resultant pellet contains approximately 90 percent iron. This pellet is relatively free of contaminants and is then charged in an EAF. At Georgetown, this currently represents about half of the furnace charge with the other half made up of scrap.

By contrast, the raw materials for integrated plants are primarily iron ore and coal, which must be converted to coke. Both of these are then charged in the blast furnace along with limestone to produce molten pig iron. The resultant molten pig iron is charged in a BOF
along with scrap to produce steel; the ratio is generally 75-80 percent molten pig iron to 20-25 percent scrap.

Thus, both the minimills and the integrated mills use scrap in order to make steel. However, the dependence of the integrated plant on scrap is much less than that of the minimills. Exhibit 4-1 shows consumption pattern of steel scrap, DRI and pig iron by furnace type for the period from 1989 until 1993. Since data available is only until 1993, it does not show recent features. However, overall consumption pattern can be seen in the Exhibit.

**Exhibit 4-1**
Consumption of Raw Materials by Furnace Type

<table>
<thead>
<tr>
<th></th>
<th>Steelmakers</th>
<th>Foundries &amp; Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scrap</td>
<td>Pig Iron</td>
<td>DRI</td>
</tr>
<tr>
<td>1989</td>
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</tr>
<tr>
<td>BF</td>
<td>3.6</td>
<td>n.a.</td>
<td></td>
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<tr>
<td>BOF</td>
<td>18.5</td>
<td>60.0</td>
<td>n.a.</td>
</tr>
<tr>
<td>OF</td>
<td>1.1</td>
<td>1.9</td>
<td>n.a.</td>
</tr>
<tr>
<td>EF</td>
<td>33.4</td>
<td>0.4</td>
<td>n.a.</td>
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<tr>
<td>Others</td>
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<td>n.a.</td>
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<tr>
<td>Total</td>
<td>57.0</td>
<td>62.7</td>
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</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>BF</td>
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<tr>
<td>BOF</td>
<td>17.9</td>
<td>57.5</td>
<td>n.a.</td>
</tr>
<tr>
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<td>Others</td>
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<tr>
<td>Total</td>
<td>63.1</td>
<td>60.5</td>
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</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>BF</td>
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<tr>
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<tr>
<td>EF</td>
<td>36.9</td>
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<tr>
<td>Others</td>
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<td>0.1</td>
<td>n.a.</td>
</tr>
<tr>
<td>Total</td>
<td>57.4</td>
<td>53.6</td>
<td>n.a.</td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF</td>
<td>2.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BOF</td>
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<td>57.4</td>
<td>0.2</td>
</tr>
<tr>
<td>OF</td>
<td>-</td>
<td>-</td>
<td></td>
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<tr>
<td>EF</td>
<td>41.3</td>
<td>1.0</td>
<td>7.9</td>
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<td>0.1</td>
<td>8.0</td>
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<tr>
<td>Total</td>
<td>60.9</td>
<td>57.5</td>
<td>1.2</td>
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<tr>
<td>1993</td>
<td></td>
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<tr>
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<td>-</td>
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</tr>
<tr>
<td>Total</td>
<td>64.5</td>
<td>58.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Source: U.S. Bureau of Mines
4.2 Steel Scrap

Steel scrap is generally available throughout the country, although more heavily concentrated in some areas compared to others. It generally comes from three sources:

(1) **Mill-generated scrap**, commonly called **home scrap**, which is produced first as raw steel, then is cropped and sheared while passing from one process to another on the way to a finished product. These scraps are recycled and account for a large portion of the scrap used by integrated plants. Home scrap has declined in tonnage because of the installation of continuous casting, which improves the yield of finished product from raw steel. Prior to the adoption of continuous casting, yield was about 72 percent with 28 percent of raw steel as mill-generated scrap throughout the steel industry (including minimills and integrated mills). Today, the yield has improved considerably, and in 1994 finished product yield was 88 percent. Home scrap is considered as excellent scrap, particularly those generated in the mills that concentrate on the production of carbon steel products.

(2) **Prompt industrial scrap**, which is generated as steel users fabricate the steel into finished products, such as automobiles, refrigerators, and machinery. This is usually very good scrap, since its content is known.

(3) **Obsolete scrap**, which consists of discarded items that contain steel ranging from automobiles, to old machinery, to multistory buildings that are demolished. This source provides a substantial amount of scrap which must be processed before it can be used in the steelmaking furnaces.

Mill-generated scrap (home scrap) and prompt industrial scrap are the main source of what the industry call "low residual scrap," while obsolete scrap is the main source of "ordinary scrap." Depending on the quality, steel scrap is further divided into various grades.
Auto bundles, which are part of the category of prompt industrial scrap, are typically low residual scrap. There are a number of grades of obsolete scrap, ranging from No. 1 heavy-melting scrap down through No. 2 bundles. Based on the type and grade of scrap, prices cover a reasonably wide range.

Greater demands have been placed on electric furnaces to produce higher quality steel such as sheet products. As a consequence, it is necessary for the operators of these units to be more selective in the scrap they charge in the furnaces in order to keep the contaminants at a minimum. This has given rise to problems for some producers. It is a fact that any and all steel products can be made from EAF-based steel provided it is pure enough. Thus, scrap must be virtually free of contaminants or have been diluted sufficiently by the addition of pig iron, direct reduced iron or hot briquetted iron so that the contaminants are rendered harmless.

As long as there is an abundance of scrap in the U.S., the issue then becomes one of quality, not quantity. In order to ensure their supply of scrap, a number of minimills have tied in with scrap dealers as exclusive suppliers. Florida Steel, for example, uses the David Joseph Company as a sole supplier.

4.2.1 Supply of Steel Scrap

Supply of steel scrap in the U.S. are shown in Exhibit 4-2.
### Exhibit 4-2
Supply of Steel Scrap in the U.S.

(unit: million short tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Receipts from Brokers, Dealers, &amp; Others</th>
<th>Home Scrap</th>
<th>Supply</th>
<th>Low Residual Scrap out of Total Supply</th>
<th>Export</th>
<th>Import</th>
<th>Consumption</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Quantity</td>
<td>Percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>39.4</td>
<td>31.7</td>
<td>71.1</td>
<td>16.0</td>
<td>22.5%</td>
<td>7.1</td>
<td>0.7</td>
</tr>
<tr>
<td>1984</td>
<td>43.1</td>
<td>34.4</td>
<td>77.5</td>
<td>16.6</td>
<td>21.5%</td>
<td>9.8</td>
<td>0.6</td>
</tr>
<tr>
<td>1985</td>
<td>47.3</td>
<td>35.9</td>
<td>83.2</td>
<td>16.9</td>
<td>20.3%</td>
<td>11.0</td>
<td>0.7</td>
</tr>
<tr>
<td>1986</td>
<td>46.6</td>
<td>30.6</td>
<td>77.3</td>
<td>16.5</td>
<td>21.4%</td>
<td>11.8</td>
<td>0.8</td>
</tr>
<tr>
<td>1987</td>
<td>51.1</td>
<td>35.1</td>
<td>86.2</td>
<td>17.1</td>
<td>19.8%</td>
<td>10.5</td>
<td>0.9</td>
</tr>
<tr>
<td>1988</td>
<td>55.4</td>
<td>32.4</td>
<td>87.9</td>
<td>19.0</td>
<td>21.6%</td>
<td>10.3</td>
<td>1.0</td>
</tr>
<tr>
<td>1989</td>
<td>54.0</td>
<td>30.3</td>
<td>84.3</td>
<td>18.7</td>
<td>22.2%</td>
<td>12.2</td>
<td>1.1</td>
</tr>
<tr>
<td>1990</td>
<td>59.5</td>
<td>25.4</td>
<td>84.9</td>
<td>18.2</td>
<td>21.4%</td>
<td>12.8</td>
<td>1.4</td>
</tr>
<tr>
<td>1991</td>
<td>54.0</td>
<td>23.1</td>
<td>77.2</td>
<td>15.4</td>
<td>20.0%</td>
<td>10.5</td>
<td>1.2</td>
</tr>
<tr>
<td>1992</td>
<td>55.1</td>
<td>23.1</td>
<td>78.3</td>
<td>14.8</td>
<td>18.9%</td>
<td>10.3</td>
<td>1.4</td>
</tr>
<tr>
<td>1993</td>
<td>58.4</td>
<td>24.3</td>
<td>82.7</td>
<td>18.0</td>
<td>21.7%</td>
<td>10.8</td>
<td>1.5</td>
</tr>
<tr>
<td>1994</td>
<td>59.5</td>
<td>22.0</td>
<td>81.6</td>
<td>17.7</td>
<td>21.8%</td>
<td>9.7</td>
<td>1.9</td>
</tr>
<tr>
<td>1995</td>
<td>56.2</td>
<td>23.7</td>
<td>79.9</td>
<td>17.6</td>
<td>22.1%</td>
<td>12.7</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Notes:
1. Brokers and dealers tonnage includes tonnage from all outside sources and other company-owned sources for all manufacturers.
2. Home scrap tonnage includes recirculating scrap from operations plus mill-generated obsolete scrap for all manufacturers.
3. Low residual scrap includes the following grades for all manufacturers:
   a) Low-phosphorus plate and punchings
   b) Cut structural and plate
   c) No. 1 and electric furnace bundles
   d) No. 1 busheling
4. 1995 estimates were based on actual data from the first six months of 1995 using steel mill data only and estimating foundry tonnage based on 1994 actual data plus 10 percent increase because foundry data is not currently available. The same procedure was used for the 1995 estimate of low residual scrap.

When considering supply of steel scrap in the U.S., the following characteristics can be noted, which are related to a decrease in the supply of low residual scrap.

A. **Decrease in Supply of Home Scrap.** In the U.S., continuous casting facilities have been installed to both reduce costs and upgrade product quality (in areas such as flat-rolled steel for automotive and can-making application). U.S. continuous casting capacity rose from 30 million tons in 1981 to 92 million tons in 1994. Continuous casting per crude steel ratio has increased from 39.6 percent in 1984 to 89.0 percent in 1994 and, consequently, crude to finished yield has improved from 79.7 percent in 1984 to 88 percent in 1994. As a result, the generation of home scrap, which is the biggest source of the low residual steel scrap, has continued to decrease. This trend is clearly shown in Exhibit 4-2 above. It is estimated that the continuous casting per crude steel ratio will increase even further. Therefore it is not expected that supplies of home scrap will increase in the future.

B. **Decrease in Supply of Prompt Industrial Scrap.** Since consumption of steel products in the fabrication process of final products such as automobiles, refrigerators and machinery has decreased, the supply of prompt industrial scrap is also decreasing.

C. **Deterioration of Obsolete Scrap Quality.** The amount of coated steel products such as galvanized steel, which is included in obsolete scrap is increasing as a result of an accumulation of these kinds of sophisticated steel over the past decades. This has resulted in a deterioration of quality in obsolete scrap, and consequently, a decrease in the supply of good-quality obsolete scrap.

The quantity of low residual scrap has stabilized in the range of 17-18 million tons in recent years after it peaked at 19 million tons in 1985; meanwhile, demand for low residual scrap has increased. This indicates that the supply of low residual scrap may have reached its upper limits. This situation is shown in Exhibit 4-3.
In the meantime, it appears that the supply of steel scrap as a whole is not a problem when quality can be ignored. As shown in Exhibit 4-4, apparent consumption of steel scrap has fluctuated according to the quantity of crude steel production using the EAF process.
4.2.2 Price

Swings in supplies of steel scrap are usually a good indicator of changes in steel output. Steel scrap is one commodity with a highly volatile price which can fluctuate drastically from week to week or even, day to day. However, over the long term, certain trends can be noticed. In order to review such trends, prices for Auto Bundles and No. 1 Heavy Melt are examined. Price movements for these grades are shown in Exhibit 4-5.
### Exhibit 4-5

**Price History of Auto Bundles and No. 1 Heavy Melt**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Bundles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>$ 112.13</td>
<td>$ 101.65</td>
<td>$ 88.14</td>
<td>$ 146.19</td>
<td>$ 148.16</td>
<td>$ 149.87</td>
</tr>
<tr>
<td>Lowest</td>
<td>$ 90.22</td>
<td>$ 80.53</td>
<td>$ 76.90</td>
<td>$ 96.03</td>
<td>$ 111.82</td>
<td>$ 135.37</td>
</tr>
<tr>
<td>No. 1 HM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>$ 102.08</td>
<td>$ 93.79</td>
<td>$ 79.14</td>
<td>$ 120.89</td>
<td>$ 122.62</td>
<td>$ 124.85</td>
</tr>
<tr>
<td>Lowest</td>
<td>$ 89.30</td>
<td>$ 76.49</td>
<td>$ 75.00</td>
<td>$ 87.92</td>
<td>$ 95.09</td>
<td>$ 116.96</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>$ 10.05</td>
<td>$ 7.87</td>
<td>$ 9.00</td>
<td>$ 25.29</td>
<td>$ 25.54</td>
<td>$ 25.02</td>
</tr>
<tr>
<td>Lowest</td>
<td>$ 0.92</td>
<td>$ 4.04</td>
<td>$ 1.90</td>
<td>$ 8.11</td>
<td>$ 16.73</td>
<td>$ 18.40</td>
</tr>
</tbody>
</table>

**Note:** Prices for each grade are published by the American Metal Market on a monthly average basis. Prices shown are the highest and lowest monthly average in the same year. The timing of the highest price for Auto Bundles is not necessarily the same as that for No. 1 Heavy Melt.

**Source:** American Metal Market

In general, prices for both grades show the same tendency. Exhibits 4-6 and 4-7 show this tendency more clearly. For both grades, prices increased rapidly after reaching a low in 1992. The highest price for Auto Bundles in 1992 was $88.14 per ton, while in 1995 it was $149.87 per ton, representing a 70 percent price hike. The same occurred with No. 1 Heavy Melt, which in 1992 was $79.14 per ton, and in 1995 increased to $124.85 per ton, representing a 58 percent price hike.
Exhibit 4-6
Auto Bundles Price History

Source: American Metal Market

Exhibit 4-7
No. 1 Heavy Melt Scrap Price History

Source: American Metal Market
One notable phenomenon is that the difference between the highest price and lowest price for both grades has shrunk in the last three years. This means that price has tended to stabilize at higher levels. The difference between highest and lowest price for Auto Bundles in 1993, 1994 and 1995 was $50.16 per ton, $36.34 per ton and $14.50 per ton, respectively. Prices for No. 1 Heavy Melt in 1993, 1994 and 1995 were $32.97 per ton, $27.53 per ton and $7.89 per ton, respectively.

Another notable phenomenon is that the price difference between Auto Bundles and No. 1 Heavy Melt has stabilized at a higher level. The highest prices for both products has been stable for the last three years at $25 per ton. On the other hand, the lowest prices in 1993, 1994 and 1995 were $8.11 per ton, $16.73 per ton, and $18.40 per ton, respectively. It is possible that the premium for low residual steel scrap is being recognized clearly in dollar terms. It may also indicate that the price range for low residual steel scrap is being established at a higher level with strong downward rigidity. This tendency is shown in Exhibit 4-8. The indication of limited supplies of low residual steel scrap mentioned previously also supports this trend.

**Exhibit 4-8**

*History of Price Difference Between Auto Bundles and No. 1. HM Scrap*

![Graph showing price difference between Auto Bundles and No. 1. HM Scrap from 1990 to 1995.](image)

Source: American Metal Market
During the 1980s, there were some cases where the lowest prices for Auto Bundles were lower than those for No. 1 Heavy Melt. Since differences in the two grades were clearly recognized in those years, this phenomenon seems strange. Although it cannot be explained, the reason may be that the concept of a premium for low residual steel scrap was not as strong then as it is now.

4.2.3 Factors Determining Steel Scrap Price

There are several factors which influence the price of steel scrap, among them, raw steel production, steel product price, and consumption of steel scrap. Exhibits 4-9, 4-10 and 4-11 show the relationship between steel scrap prices and those factors. As anticipated, steel scrap prices move generally in the same direction as those factors, albeit with a certain time lag. This tendency seems to be quite natural since, generally, an increase in the price of steel products indicates higher demand for those products; higher demand for steel products indicates higher production of raw steel by both BOF and EAF; and higher production of raw steel indicates higher consumption of steel scrap. In other words, these factors are closely interdependent.

Exhibit 4-9
Raw Steel Production vs. Scrap Price

Source: American Iron and Steel Institute, American Metal Market
Exhibit 4-10
Price Movement: Hot-Rolled Sheet and Steel Scrap

Source: World Steel Dynamics, American Metal Market

Exhibit 4-11
Scrap Quantity vs. Scrap Price

Source: U.S. Bureau of Mines, American Metal Market
However, there are a few exceptions, which appear in the Exhibits. In 1995, the price of steel scrap kept moving upward while the price of hot-rolled sheet declined drastically. This may be attributable to a time lag, and the steel scrap price will follow the direction of the hot-rolled sheet price later. Or the price of steel scrap, especially low residual scrap, may have entered a new era. The price for such scrap may remain at the higher level with relatively small price fluctuations no matter what the price is of hot-rolled sheet. This argument can be supported by the fact that minimills' new production capacity for flat-rolled was increased in 1995 while the supply of low residual steel scrap may have reached its upper limit, as discussed previously.

4.3 Scrap Substitutes

Direct reduced iron (DRI) and hot briquetted iron (HBI) are two representative scrap substitute materials. While the chemical characteristics of these two materials -- high total iron content and low levels of residual elements -- are similar, there is a difference in the shape of the two materials. DRI is in the form of original iron ore pellets or lumpy, and HBI is in briquette form. Because of handling and shipping requirements for the traditional form of DRI, its use is limited primarily to those melt shops adjacent to a direct reduction plant. The briquetted shape is much easier to transport to melt shops that are a long distance from a direct reduction plant. For the remainder of this chapter, the word of DRI will represent both DRI and HBI.

The first DRI process was commercialized 40 years ago by Hylsa S.A. de C.V. (Hylsa, Monterrey, Mexico). Most plants operating today use technology licensed from Midrex Direct Reduction Corp (Midrex, Charlotte, N.C.) or Hylsa. Following is the typical Midrex DRI production process:

(a) **Natural Gas Reforming** - Steam and natural gas are fed to the reformers, which produce a process gas with high carbon monoxide and hydrogen content. This
gas mixture is then cooled to remove the excess steam, reheated, and fed to the shaft furnace for use as the reduction process gas.

(b) **Iron Ore Reduction** - Lump iron ore and Iron oxide pellets are conveyed from nearby supply yards to the plant, where they are screened and fed to the charge hopper of the reduction furnace. The iron materials flow downward by gravity through the furnace where they react with the reduction gas. The result of this reaction is highly metallized form of iron known as DRI.

(c) **Hot Briquetting and Quenching** - The hot DRI is discharged from the furnace directly into briquetting machines where it is compacted and molded into briquette shapes. This process densifies the material, thereby improving its surface-to-mass ratio and thermal conductivity and reducing its tendency to be reoxidized. The hot briquettes are quenched in water, screened, and conveyed to the storage area.

Several other scrap substitute technologies have been established or are under development. These include: Fastmet; Iron Carbide; Finmet; Circored; etc. The following is a brief explanation of each process. (Note: Since the Corex process and Hismelt processes, etc are categorized as a new iron-making technology rather than scrap substitute technology, the explanations of these processes have not been covered in this thesis.)

1. **Fastmet process**: Developed by Midrex. Pulverized coal and iron ore fines are mixed and formed into pellets. The pellets are then fed into a doughnut-shaped rotary hearth furnace and heated. The pulverized coal acts as a reductant and burns off the oxygen in the iron ore, leaving behind pellets with a very high iron content. Iron ore fines require less preparation than pellets or lumpy ore. Also coal is a less expensive fuel source than natural gas in the U.S.

2. **Iron Carbide process**: Developed by Iron Carbide Holdings (ICH, Lakewood, Colo). Iron ore fines of 0.1 to 1.0 millimeters are fed into a fluidized bed reactor, together with methane and hydrogen. The hydrogen drives off oxygen, then the ore absorbs carbon from the methane, leaving carbon monoxide,
carbon dioxide and water. An advantage of iron carbide is that it contains about 6 percent weight of carbon, which provides enough energy to reduce electricity demand.

(3) **Finmet process:** Developed jointly by Fior de Venezuela (FIOR, Venezuela) and Voest-Alpine (Voest, Austria). Iron ore fines are dried and fed into a series of four descending reduction vessels. Ore is reduced in each of the four fluidized bed reactors by reducing gas that flow up through the reactors. Off-gas from the top reactor is recycled and reused which improves process efficiency.

(4) **Cincofered process:** Developed by Lurgi AG (Lurgi, Frankfult, Germany). Iron ore fines are reduced from hydrogen generated by natural gas reforming. A 70 percent metallization is first achieved in a circulating fluidized bed. Final reduction is then carried out in a stationary fluidized bubbling bed reactor, achieving a 93 percent metallization. The company’s Cincofer process uses coal to produce reducing gases to make DRI.

Other than the Finmet process, these processes have not been proven commercially.

4.3.1 **Supply of DRI Materials**

The current operable capacity of DRI is around 41 million tons. Developing countries dominate this production with an 88 percent share, followed by the developed countries with 7 percent, and the ex-communist countries with 5 percent share. In 1994, DRI production was only 30 million tons; of this, it is estimated that only 6 to 7 million tons were sold on a merchant basis.

DRI plants are generally built in locations with easy access to energy, iron ore, and natural gas, in order to supply these materials to melt shops adjacent to DRI plants. For example, the DRI plant at Georgetown Steel in South Carolina produces about 550,000 tons
of DRI only for its electric furnace mill. Therefore recognition of DRI as merchant commodity was established quite recently.

According to statistics published by the U.S. Bureau of Mines, imports of DRI into the U.S. from 1989 to 1993 were 168,000 tons, 298,000 tons, 402,000 tons, 597,000 tons, and 993,000 tons, respectively. Throughout this period, main source was Venezuela. Although the pace of the growth is rapid, quantities remain small compared to steel scrap.

Current supplies and sources of DRI for the North American market are shown in Exhibit 4-12. Since the 1.3 million tons produced by Sidbec-Dosco is basically only for its own electric furnaces in Canada, the existing suppliability for the U.S. are approximately 2.0 million tons.

Exhibit 4-12
DRI Suppliers for North American Market

<table>
<thead>
<tr>
<th>Name of Supplier</th>
<th>Location</th>
<th>Process</th>
<th>Product</th>
<th>Production Capacity</th>
<th>Suppliability to N. America</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPCO*</td>
<td>Venezuela</td>
<td>Midrex</td>
<td>HBI</td>
<td>992</td>
<td>882</td>
</tr>
<tr>
<td>Venprecar</td>
<td>Venezuela</td>
<td>Midrex</td>
<td>HBI</td>
<td>661</td>
<td>110</td>
</tr>
<tr>
<td>FIOR</td>
<td>Venezuela</td>
<td>FIOR</td>
<td>HBI</td>
<td>441</td>
<td>331</td>
</tr>
<tr>
<td>Georgetown</td>
<td>U.S.A.</td>
<td>Midrex</td>
<td>DRI</td>
<td>551</td>
<td>551</td>
</tr>
<tr>
<td>Sidbec-Dosco</td>
<td>Canada</td>
<td>Midrex</td>
<td>DRI</td>
<td>1,323</td>
<td>1,323</td>
</tr>
<tr>
<td>OEMK**</td>
<td>Russia</td>
<td>Midrex</td>
<td>DRI</td>
<td>1,764</td>
<td>110</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>5,732</td>
<td>3,307</td>
</tr>
</tbody>
</table>

(unit: million short tons)

Note:  
* Operaciones al Sul del Orinoco CA  
** Oskolskiy Electrometallurgicheskiy Kombinat Plant

Source: Various publications compiled by Mitsui & Co., Ltd.
4.3.2 Price

DRI is positioned as a substitute for low residual steel scrap. Therefore the price of DRI fluctuates in relation to that of low residual steel scrap. However, in most cases, the price of DRI is fixed between a buyer and supplier on an annual basis. An annual contract, including quantity and price, is usually negotiated prior to the commencement of the buyer's fiscal year. When price is negotiated, the price of low residual steel scrap at that time is used as a reference.

Since the history of commercial sales of DRI is brief, there is insufficient data available to indicate a possible relationship between DRI price and low residual steel scrap price. I developed Exhibit 4-13 as a way to illustrate such a relationship. The unit price of DRI is equal to the total import value divided by total quantity as reported by the U.S. Bureau of Mines. The price of Auto Bundles is an average price for the same year. It appears that prices of DRI in each year are almost equivalent to that of Auto Bundles price in the preceding year. This may indicate that the price of DRI was fixed taking into account the price of Auto Bundles in the previous year.

In 1995, the price of DRI ranged from $132 to $136 per ton on the basis of f.o.b. barge in New Orleans. On the other hand, the average price of Auto Bundles for the period from October 1994 to March 1995, when prices for DRI are normally discussed, was $141 per ton on the basis of f.o.b. automotive factory. The price of DRI is $5 to $10 per ton lower than that of Auto Bundles. Depending on the destinations, the difference in delivered price to users can be wider or narrower.
Notes: The unit price of DRI is equal to the total import value divided by total quantity as reported by the U.S. Bureau of Mines. The price of Auto Bundles is an average price for the same year.

Source: American Metal Market

4.3.3 Cost

The cost of producing DRI varies depending on its production location. Exhibit 4-14 shows the theoretical cost of Midrex-based DRI in two different locations as estimated by Midrex. Since Midrex is the license holder, i.e., they are sellers of the technology, the figures in the exhibit tend to be optimistic. It is generally expected that the actual cost will be higher than the figures.
<table>
<thead>
<tr>
<th>Plant Location</th>
<th>U.S. Gulf Coast</th>
<th>Venezuela</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Gas Based</td>
<td>Gas Based</td>
</tr>
<tr>
<td>Product Type</td>
<td>HBI</td>
<td>HBI</td>
</tr>
<tr>
<td>Plant Capacity (million short tons)</td>
<td>1.38</td>
<td>1.10</td>
</tr>
<tr>
<td>Production Cost</td>
<td>104.33</td>
<td>79.83</td>
</tr>
<tr>
<td>Ship To Gulf Coast</td>
<td>-</td>
<td>13.61</td>
</tr>
<tr>
<td>Product Cost Gulf Coast</td>
<td>104.33</td>
<td>93.44</td>
</tr>
<tr>
<td>Ship To Upper Midwest</td>
<td>9.07</td>
<td>9.07</td>
</tr>
<tr>
<td>Product Cost Upper Midwest</td>
<td>113.40</td>
<td>102.51</td>
</tr>
</tbody>
</table>

Source: Midrex

4.3.4 Construction Plans for Scrap Substitute Production Facilities

There are many plans for constructing scrap substitute materials production facilities aimed at the U.S. market, reflecting a growing shortage of low residual steel scrap and an expansion of minimill capacity for flat-rolled products. Except for Nucor’s iron carbide plant, none of the plans have started construction. Nucor’s iron carbide plant in Trinidad began production in the third quarter of 1994 but encountered several plumbing problems requiring outages and some rebuild and equipment replacements. Other plans have decided to go ahead, but most of them are in the stage of feasibility study. The various construction plans are shown in Exhibit 4-15.

When all of the above construction is completed, additional supplies of scrap substitute materials for the U.S. will be increased by 8.2 million tons. However, it is questionable whether all of these plans will be realized, since some of the processes have not yet been commercially proven. Even if technical issues are resolved, it may take some time to achieve capacity increases to the needed level.
### Exhibit 4-15

**Construction Plans for Scrap Substitute Materials Production**

(unit: 1,000 short tons)

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Process</th>
<th>Product</th>
<th>Production Capacity</th>
<th>Supplyability for USA</th>
<th>Startup</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucor</td>
<td>Trinidad</td>
<td>Iron Carbide</td>
<td>I.C.</td>
<td>364</td>
<td>364</td>
<td>1994</td>
<td>1</td>
</tr>
<tr>
<td>OPCO</td>
<td>Venezuela</td>
<td>Midrex</td>
<td>HBI</td>
<td>165</td>
<td>165</td>
<td>1998</td>
<td>2</td>
</tr>
<tr>
<td>Qualitech</td>
<td>USA</td>
<td>Iron Carbide</td>
<td>I.C.</td>
<td>728</td>
<td>728</td>
<td>1998</td>
<td>3</td>
</tr>
<tr>
<td>GSI-Birmingham</td>
<td>USA</td>
<td>Midrex</td>
<td>DRI</td>
<td>1,323</td>
<td>1,323</td>
<td>1997</td>
<td>3</td>
</tr>
<tr>
<td>BS PLC</td>
<td>USA</td>
<td>Midrex</td>
<td>DRI</td>
<td>1,213</td>
<td>1,213</td>
<td>1997</td>
<td>2</td>
</tr>
<tr>
<td>Comsigua</td>
<td>Venezuela</td>
<td>Midrex</td>
<td>HBI</td>
<td>1,102</td>
<td>772</td>
<td>1998</td>
<td>2</td>
</tr>
<tr>
<td>Fastmet</td>
<td>USA</td>
<td>Fastmet</td>
<td>HBI</td>
<td>992</td>
<td>992</td>
<td>1998</td>
<td>3</td>
</tr>
<tr>
<td>FIOR-BHP</td>
<td>Venezuela</td>
<td>FIOR</td>
<td>HBI</td>
<td>2,205</td>
<td>1,653</td>
<td>1999</td>
<td>3</td>
</tr>
<tr>
<td>Steel Dynamics</td>
<td>USA</td>
<td>Circored</td>
<td>DRI</td>
<td>551</td>
<td>551</td>
<td>N.A.</td>
<td>3</td>
</tr>
<tr>
<td>National Steel</td>
<td>USA</td>
<td>Lurgi</td>
<td>DRI</td>
<td>551</td>
<td>551</td>
<td>1998</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>9,083</strong></td>
<td><strong>8,201</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key:**
1) Construction completed, but still under plant modification  
2) Decision to go ahead  
3) Under serious feasibility study

Source: Various publications compiled by Mitsui & Co., Ltd.

---

### 4.4 Pig Iron

As discussed earlier, pig iron is an intermediate product derived during the process of blast furnace/BOF steelmaking. Therefore it is produced largely by integrated steelmakers. Prepared iron ore and coke are charged along the line with limestone in a blast furnace. Iron ore flows downward by gravity through the furnace when they react with the reduction gas. Since iron ore is melted together with other additives such as manganese, silicon, sulphur, phosphorus and carbon as reduction agents, typical pig iron includes 3.0 to 4.5 percent carbon, 0.5 to 3.0 percent silicon, 0.5 to 2.0 percent manganese, 0.02 to 0.5 percent phosphorus, and
0.01 to 0.1 percent sulphur. Since pig iron includes a large portion of carbon, it does not have tenacity and malleability which are required characteristics for steel. Therefore, it is fed into a basic oxygen furnace for refining. In some countries like Brazil, there are steelmakers who produce pig iron based on a charcoal blast furnace process.

Historically, consumption of pig iron at minimill plants has been very small. However, over the past few years, use has increased well beyond its historical role as a basic feedstock for integrated steel production. It is increasingly a part of the standard requirement in EAF steelmaking as steel scrap prices have risen and more EAFs are starting up. Because of its high carbon characteristics, it cannot be a substitute for low residual steel scrap. However, minimills can use pig iron as an attractive iron source with certain upper limits of consumption volume.

4.4.1 Supply of Pig Iron

As a result of capacity reduction by integrated steelmakers, domestic production of pig iron is inadequate when steel demand is booming. Exhibit 4-16 shows domestic production and import quantities of pig iron since 1986. Imports of pig iron totaled 0.8 million tons in 1993, but rose to 2.5 million tons in 1994. It is notable that more than 90 percent of imports came from Brazil and ex-USSR in 1994. Other exporting countries include South Africa, Canada, and Switzerland.

For 1995, actual monthly figures are available only until September. Therefore, the actual quantity for the period from January to September is annualized by simply multiplying by 12/9. It appears that demand for pig iron weakened in 1995 reflecting a weakening demand for finished steel products.
**Exhibit 4-16**

**U.S. Production and Imports of Pig Iron**

(unit: million short tons)

<table>
<thead>
<tr>
<th></th>
<th>U.S. Production</th>
<th>Imports</th>
<th>U.S. Raw Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From Brazil</td>
<td>From ex-USSR</td>
<td>Total Imports</td>
</tr>
<tr>
<td>1986</td>
<td>43.95</td>
<td>0.14</td>
<td>-</td>
</tr>
<tr>
<td>1987</td>
<td>48.41</td>
<td>0.12</td>
<td>-</td>
</tr>
<tr>
<td>1988</td>
<td>55.75</td>
<td>0.49</td>
<td>-</td>
</tr>
<tr>
<td>1989</td>
<td>55.87</td>
<td>0.29</td>
<td>-</td>
</tr>
<tr>
<td>1990</td>
<td>54.75</td>
<td>0.18</td>
<td>-</td>
</tr>
<tr>
<td>1991</td>
<td>48.64</td>
<td>0.30</td>
<td>-</td>
</tr>
<tr>
<td>1992</td>
<td>52.22</td>
<td>0.31</td>
<td>0.01</td>
</tr>
<tr>
<td>1993</td>
<td>53.08</td>
<td>0.41</td>
<td>0.18</td>
</tr>
<tr>
<td>1994</td>
<td>N.A.</td>
<td>1.18</td>
<td>1.10</td>
</tr>
<tr>
<td>1995</td>
<td>N.A.</td>
<td>1.09</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Source: U.S. Bureau of Mines

Supplies of imported pig iron are highly dependent on the status of the steel industry in the exporting countries. When steel demand is sluggish, integrated steelmakers in exporting countries try to sell pig iron in order to maximize their blast furnace production. Therefore it cannot be stable all the times. Supplies of imported pig iron do not necessarily match a demand increase in the U.S.

**4.4.2 Price**

As in the case of DRI, there is not enough data available to indicate the price of pig iron. Also, since total import quantities reported by the U.S. Bureau of Mines includes some premium grade materials for foundries who command $20 to $30 per ton higher than that of
basic grades, the calculated unit price\textsuperscript{1} does not represent the price of basic grade for steelmakers.

"Basic grade pig iron f.o.b. New Orleans, loaded on barge, sold for about $151 per ton in December 1994. $160 per ton was reported in the Midwest. This compares with prices in the mid-$130s reported at the beginning of 1994. By summer and early autumn, prices had risen to $152 to $160 per ton, settling down to $151 to December."\textsuperscript{2}

It appears that there is a certain relationship to the price of low residual scrap. The price of Auto Bundles was $150 per ton in January 1994. It declined to $112 per ton in June which was the lowest level in 1994. In August 1994, it jumped to $135 per ton and gradually increased through the end of the year. This indicates that the rapid price hike of low residual scrap recorded in late 1993 and early 1994 accelerated imports of pig iron and pushed import prices to the higher level. Imports of pig iron influenced the reduction of scrap prices at one point in the year. At the end of 1994, prices of low residual scrap and pig iron were at almost same level. This trend shows that demand and price of pig iron are highly related to those of low residual scrap.

4.5 Recent Raw Material Consumption Trends

There are several changes in consumption patterns for both minimills and integrated steelmakers.

\textsuperscript{1} The total import value divided by the total import quantity.

4.5.1 Trends Among Minimills

For the production of minimills’ traditional items such as merchant bar, rebar, light and medium sections and wire rod, only 30 percent of low residual scrap or an equivalent material is required for the metallic charge. On the other hand, in order to produce flat-rolled products, minimills use about 70 percent low residual scrap or an equivalent product such as DRI or pig iron for the metallic charge. For those products, it is necessary to reduce levels of residual elements in raw materials. For example, at Nucor Crawfordsville, total residuals in the raw materials is controlled at 0.16 percent maximum (Cu, 0.10 percent maximum; Cr, 0.03 percent maximum and Ni, 0.03 percent maximum).³

Under current circumstances, minimills are trying hard to secure the required material for flat-rolled production. However, it appears there is not enough low residual scrap, scrap substitute materials, and pig iron to adequately supply flat-rolled production needs.

One notable event in this regard is Nucor’s iron carbide plant in Trinidad. In 1995, it continued testing to optimize operations and to learn how to run this new technology. If successful, this will be a revolutionary development. First, it is the first effort to produce iron carbide on a commercial scale. Second, and more importantly, it is the first time that minimill has its own captive facilities for scrap substitute material overseas.

Pig iron is another option for minimills for flat-rolled production. It is estimated that electric furnace mills consumed more than 1.5 million tons of pig iron in 1994. This was a huge jump when compared with 0.15 million tons for 1993.⁴ This is further evidence of how demand and supply of low residual scrap or its substitute was tight in 1994. However, because of its higher carbon content, it is considered that 25% is the maximum mixture of pig iron in the total metallic charge for electric furnaces.

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³ Information obtained in an interview with Nucor Corp.

⁴ E. Hoeffer, op.cit.
4.5.2 Trends Among Integrated Steelmakers

As a result of capacity contraction, especially upstream capacity, of integrated steelmakers, their raw steel production capacity is not at an adequate level. The biggest concern for integrated steelmakers is a shortage of coke. They are faced with the decline caused by the sharply declining supply of coke on the one hand, and rapidly falling coke usage on the other hand. Principal contributing factors are the decline of cokemaking capacity due to aging facilities and sharply higher pulverized coal injection in blast furnaces.

U.S. gross cokemaking capacity is currently about 22 million tons. The capacity outlook is not promising as: only 29 percent of the capacity is less than 15 years old; a number of companies will not replace units that are wearing out, and pollution control regulations are increasingly adding downward pressures. Moreover, the life of many 6-meter high ovens is no more than eleven years in many cases.

Coke production in the U.S. in 1994 is estimated at about 20 million tons. Output had dropped from 58 million tons in 1973 to 23-30 million tons range during 1982-1990 period. In this 1982-1990 period, the peak was 30 million tons in 1989. The U.S. imported about 3.0 million tons in 1994 versus the recent low of 0.9 million tons in 1990 and the recent peak of 2.4 million tons in 1988.

Integrated steelmakers have been making efforts to improve performance in their blast furnaces. These improvements have occurred at the same time as coke rates have been reduced by injecting natural gas, increasing blast furnace temperatures (usually only possible at the time of rebuilding), adding more oxygen, injecting pulverized coal, using higher grade ores, and charging steel scrap or DRI.

As a result, the requirement of steel scrap or an equivalent material for integrated steelmakers is trending upward.
4.5.3 The Battle Over the Steelmakers' Raw Materials Procurement

As explained in previous sections, both EAF-based flat-rolled producers and integrated steelmakers have their own distinct problems concerning raw materials procurement. The battle to supply the steelmakers' metal needs is growing more intense. Minimills are putting more pig iron into their electric furnaces, and at the same time, integrated steelmakers are putting more steel scrap or equivalent materials into their blast furnaces. An illustration of these demand factors is shown in Exhibit 4-17.

### Exhibit 4-17
Summary of Qualitative Factors

<table>
<thead>
<tr>
<th></th>
<th>Minimills</th>
<th>Integrated Steelmakers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metal Source</strong></td>
<td>Steel scrap or an equivalent material</td>
<td>Iron Ore</td>
</tr>
<tr>
<td><strong>Reduction Agent</strong></td>
<td>No need</td>
<td>Coke</td>
</tr>
<tr>
<td>**Steel Scrap or an</td>
<td>Demand is increasing due to increasing capacity. Especially,</td>
<td>Demand is increasing due to improved productivity in blast</td>
</tr>
<tr>
<td>equivalent material</td>
<td>supply of low residual material is inadequate. Price is in</td>
<td>furnace. Less requirement for low residual material than</td>
</tr>
<tr>
<td></td>
<td>uptrend and volatile.</td>
<td>minimills since scrap is blended with mostly low residual</td>
</tr>
<tr>
<td><strong>Iron Ore</strong></td>
<td>No need (iron ore is raw material for DRI. In this sense,</td>
<td>Supply is more than adequate. Price is stable. Most iron</td>
</tr>
<tr>
<td></td>
<td>&quot;yes&quot;)</td>
<td>ore mines are owned by steelmakers.</td>
</tr>
<tr>
<td><strong>Coke</strong></td>
<td>No need</td>
<td>Supply is less than adequate. Price is in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>uptrend and increasingly volatile.</td>
</tr>
<tr>
<td>**Requirement of Critical</td>
<td>0.7 ton of low residual scrap or an equivalent material per 1</td>
<td>0.4 ton of coke per 1 ton of finished product</td>
</tr>
<tr>
<td>Material**</td>
<td>ton of finished product</td>
<td></td>
</tr>
</tbody>
</table>

Source: The author
CHAPTER 5

PRODUCTS MARKET

In this chapter, I will review the past and current market for products coming from the mills. The question to be considered is whether the market size is large enough to absorb newly established or future expanded capacity.

As discussed earlier, it is difficult to define the market size for the minimills' additional capacity. Ultimately, it would not be surprising if eventually the minimills supply all of the flat-rolled product items in the long term.

Exhibit 5-1 shows the finished product quantity of each type of item produced by integrated mills, minimills, and processors in 1993. Some of the finished product quantity of Other Processors was deducted in order to avoid double counting since those are processed material of domestically produced steel products. Although some small quantity of cold-rolled sheet and coated sheet were produced by minimills (Nucor), most of the production was plate products and hot-rolled sheet.

<table>
<thead>
<tr>
<th></th>
<th>Hot-Rolled Sheet &amp; Coil Plate</th>
<th>CR Sheet</th>
<th>Coated</th>
<th>EGL</th>
<th>Tinmill</th>
<th>Plate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Steelmaker</td>
<td>17.6</td>
<td>13.5</td>
<td>10.6</td>
<td>3.3</td>
<td>4.1</td>
<td>3.0</td>
<td>52.1</td>
</tr>
<tr>
<td>Minimills/Other EAF</td>
<td>2.1</td>
<td>0.4</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
<td>1.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Other Processors</td>
<td>-2.4</td>
<td>0.3</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-1.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17.3</strong></td>
<td><strong>14.2</strong></td>
<td><strong>11.4</strong></td>
<td><strong>3.3</strong></td>
<td><strong>4.1</strong></td>
<td><strong>4.8</strong></td>
<td><strong>55.1</strong></td>
</tr>
</tbody>
</table>

Source: Steel Strategist No. 21, World Steel Dynamics, May 1995.
5.1 Market Size of Hot-Rolled Sheet

The most noticeable impact is expected in the hot-rolled sheet market. When quantities for sheet products produced by new hot-strip mills are summed, 16 million tons of new capacity was added to 1994 levels. This impact was enormous, at least for the short term, in view of the total apparent consumption of 20.7 million tons in 1994.

In 1973, apparent consumption of hot-rolled sheet was 20.1 million tons. Since then, it decreased to a low of 10.9 million tons in 1982. After 1982, it recovered to the level of 15 to 16 million tons until the early 1990s. In 1994, it marked 20.6 million tons which exceeded the previous record in 1973. This trend is exactly the same as the trends among total steel products and total flat-rolled products, as shown in Exhibit 5-2 and 5-3.

Exhibit 5-2
Apparent Consumption:
Total Steel Products vs. Total Flat-Rolled Products vs. Hot-Rolled Sheet

Source: American Iron and Steel Institute

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1 For the sake of convenience, I will use apparent consumption as the measure of market size of finished products.
2 0.65 million tons of Beta Steel’s capacity is not included since it simply replaced its upstream process from imported slabs to EAF.
3 In this thesis, when giving numeric quantities of apparent consumption of hot-rolled sheet, the figure includes both hot-rolled sheet and hot-rolled strip.
Exhibit 5-3
Apparent Consumption of Hot-Rolled Sheet

Source: American Iron and Steel Institute

The composition of apparent consumption is shown in Exhibit 5-4. When compared with 1973, dependence on imports has increased drastically while apparent consumption has increased slightly.

Exhibit 5-4
Composition of Apparent Consumption - Hot-Rolled Sheet

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>18.8</td>
<td>9.0</td>
<td>16.4</td>
<td>-2.4</td>
</tr>
<tr>
<td>Export</td>
<td>0.5</td>
<td>0.0</td>
<td>0.2</td>
<td>-0.3</td>
</tr>
<tr>
<td>Import</td>
<td>1.8</td>
<td>1.4</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>20.1</td>
<td>10.4</td>
<td>20.7</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Source: American Iron and Steel Institute
The figures over the past six years are shown in Exhibit 5-5. As the exhibit shows, 1991 was the worst year for the past ten years.

**Exhibit 5-5**  
Apparent Consumption of Hot-Rolled Sheet in Recent 6 Years  

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td>(0.76)</td>
<td>(1.67)</td>
<td>(0.48)</td>
<td>(0.20)</td>
<td>(0.25)</td>
<td>(1.81)</td>
</tr>
<tr>
<td>Import</td>
<td>2.38</td>
<td>2.23</td>
<td>2.81</td>
<td>2.42</td>
<td>4.52</td>
<td>3.47</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>15.70</td>
<td>14.25</td>
<td>16.24</td>
<td>17.72</td>
<td>20.64</td>
<td>18.65</td>
</tr>
</tbody>
</table>

(unit: million short tons)

Source: American Iron and Steel Institute

Domestic demand for hot-rolled sheet has slowed rapidly in 1995. While product shipments themselves are equal to or slightly higher than 1994, export quantities have increased and import quantities decreased. As a result, the apparent consumption quantity decreased by 2 million tons in 1995.

It appears that domestic production attempted to cope with the rapid growth experienced in 1994, and an adjustment for demand decrease was made by decreasing imports and increasing exports. Export quantities were the highest in history.

Based on the above analysis, the historical market size for hot-rolled sheet in the U.S. ranges from 15 million tons in bad years to over 20 million tons in good years.

### 5.2 Market Size of Plate Products

When looking at construction plans for flat-rolled plants, two facilities were designed for plate products, namely Tuscaloosa Steel’s Tuscaloosa plant with 0.8 million tons of
capacity and Ipsco's Muscatine plant with 1.25 million tons of capacity. Tuscaloosa has been producing plate product by processing imported steel slabs, mainly from British Steel in the U.K.; their ultimate plan is to install a melt shop and caster in order to replace purchased slabs. Therefore their new capacity will actually be replacement capacity in terms of finished products. From the viewpoint of impact on the plate products market, only Ipsco's new plant will have an impact, with 1.25 million tons of new capacity.  This will certainly impact the market in view of apparent consumption which was 10.8 million tons in 1994.

In 1974, apparent consumption of plate products was 12.1 million tons. Since then, it has decreased, reaching a low of 4.8 million tons in 1983. After 1983, it recovered to the level of 8 to 9 million tons in the late 1980s to early 1990s. In 1994, it reached 10.8 million tons, still not as high as 1974. These movements in relation to total steel products and total flat-rolled products are shown in Exhibits 5-6 and 5-7. Although the general movement is same, the depressed period for plate products was longer than for other products.

Exhibit 5-6
Apparent Consumption:
Total Steel Products vs. Total Flat-Rolled Products vs. Plate Products

Source: American Iron and Steel Institute

Although there are some plans for expansion of the existing facilities, such plans were not considered in this thesis.
The composition of apparent consumption is shown in Exhibit 5-8. When compared with 1974, dependence on imports has increased while product shipments have decreased. As a result, apparent consumption in 1994 was 1.4 million tons lower than in 1974.

### Exhibit 5-8

**Composition of Apparent Consumption - Plate Products**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>10.9</td>
<td>3.8</td>
<td>8.6</td>
<td>-2.3</td>
</tr>
<tr>
<td>Export</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Import</td>
<td>1.6</td>
<td>1.1</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>12.2</td>
<td>4.8</td>
<td>10.8</td>
<td>-1.4</td>
</tr>
</tbody>
</table>

*Source: American Iron and Steel Institute*
Exhibit 5-9 shows figures for 1990 through 1995. Apparent consumption in 1995 maintained the same pace as that in 1994 although export quantity was slightly higher.

**Exhibit 5-9**  
**Apparent Consumption of Plate Products in Recent 6 Years**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td>0.5</td>
<td>0.7</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Import</td>
<td>1.6</td>
<td>1.3</td>
<td>1.6</td>
<td>1.4</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>9.0</td>
<td>7.5</td>
<td>8.3</td>
<td>8.6</td>
<td>10.8</td>
<td>10.9</td>
</tr>
</tbody>
</table>

Source: American Iron and Steel Institute

Based on the above analysis, it can be seen that historically the market size for plate products in the U.S. ranges from 8 million tons in poor consumption years to over 11 million tons in good years.

### 5.3 The Impact of Minimills on Entire Flat-Rolled Markets

It is apparent that the minimills' added capacity will have an immediate impact on the hot-rolled sheet and plate markets. It is also reasonable to assume that this increased capacity will sooner or later have an impact on the entire flat-rolled products market. The following are several factors that support this conclusion.

#### 5.3.1 Minimills' Investment for Additional Downstream Facilities

As steelmakers, minimills prefer to sell value-added sheet just as Nucor did when it entered the cold-rolled sheet and galvanizing sheet market. For example, Steel Dynamics is
planning to install pickling, cold reduction, and coating facilities to enable it to produce a diverse array of products totaling about 1 million tons. Nucor's third flat-rolled plant in South Carolina, which is scheduled to start operation in 1997, includes a cold-rolling mill with a capacity of 0.8 million tons per year.

5.3.2 Technology to Develop Thinner Material

As a result of new technology development, coils from new strip mills may be able to compete with cold-rolled products. In order to meet rigorous demands by consumers of cold-rolled sheet, numerous rolling operations are required. In the existing facilities, slabs had to be hot-rolled to about a 0.08 inch thickness, then pickled in hydrochloric acid to remove scale. Further cold-rolling and other processes were required to reduce the sheet to about 0.03 inch and develop hardness or formability characteristics. Coils from new hot-strip mills start out at 0.08 inch or less thick and require less downstream rolling to achieve the same thickness and characteristics. Gallatin Steel and Steel Dynamics could capture some of the cold-rolled sheet market.5

5.3.3 Capacity Expansion by Intermediate Steel Processors

Some intermediate steel processors are about to begin building new processing capacity adjacent to new minimill plants. For example, Worthington Industries Inc. will build its first hot-dipped galvanizing line facility and processing center adjacent to the North Star/BHP minimill to process about one-third of the mill's capacity. Steel Technologies Inc. started pickling operations at its new steel processing facility which it built near Gallatin Steel with capacity of 0.6 million tons per year. The plant is their first facility with pickling capabilities. These examples illustrate that the capacity of intermediate steel processors will expand along with capacity increases by minimills.

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5.3.4 Integrated Steelmakers' Concentration on High-End Product

Flat-rolled production by minimills is becoming a major threat to integrated steelmakers. In particular, whenever minimills and integrated mills are located in the same geographical market, competition is bound to be intense. In such cases, integrated mills will have to shift their product mix to higher value-added steel which is minimills cannot produce using current technology. For example, Nucor's next plant in South Carolina will be major threat to Bethlehem Steel's Sparrows Point plant since Nucor is quite capable of producing products equally about one-third of Bethlehem's 3 million tons of annual steel production using its existing technology. To combat this direct competition, the Sparrows Point plant is increasing its market in specialized flat-rolled products such as coated steel.

5.3.5 Crossover between Plate and Sheet

Plate products traditionally are more than 3/16 inch thick and sheet products are less than 3/16 inch. However, some plate producers like Tuscaloosa and Ipsco can produce products well into the range of hot-rolled sheet thickness. At the same time, many hot-rolled sheet producers have a foot in both markets. The crossover between plate and sheet production will increase as new sheet and plate mills begin production.6

This type of news indicates that plate and sheet markets are beginning to blend somewhat.

5.4 Price Trends

While the primary minimill product in the flat-rolled segment is hot-rolled sheets, as I discussed earlier, some quantity of hot-rolled sheets are processed further, mainly to cold-rolled sheets, by the minimills themselves and/or intermediate steel processors. Hot-rolled sheet and cold-rolled sheet are representative items which account for more than 50 percent of the total flat-rolled products apparent consumption. Following is review of price trends for these two items.

5.4.1 Price Trend of Hot-Rolled Sheets

The major integrated mills announce prices for their products, including hot-rolled sheets, as list prices and then change them from time to time. However, these prices do not necessarily reflect spot market prices. Since actual spot prices are not widely available, "U.S. Spot Steel Prices", published by PaineWebber World Steel Dynamics was used as a source for examining price trends among these products. Exhibit 5-10 shows spot price movements of hot-rolled sheets in relation to apparent consumption. This price is for the base grade of the products on an f.o.b. steel plant basis and does not include a premium for higher-quality grade products (usually assessed on products in the high-end segment).

Therefore it does not necessarily represent steelmakers’ actual revenue. It is obvious that the spot price of hot-rolled sheets is quite volatile. During the period from 1985 to 1995, prices ranged from a low of $300 per ton to a high of $440 per ton.

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7 It is estimated that $15-20 of the cost per ton is required to produce high-end products. Although a premium charge for this product is supposed to cover such cost, it is the steel buyer who recognizes its value and decides what the extra level will be. Therefore, in this thesis, the extra factor for price is not covered.
Also it appears that price is not necessarily related to quantity. In 1988, the spot price of hot-rolled sheet hit $438 per short ton when annual apparent consumption was 15.6 million tons. Since then, the price has gradually declined settling at $306 per ton in early 1992. After that, it improved along with an increase of volume and reached $407 per ton in 1994 when annual apparent consumption was 20.7 million tons. Despite the fact that the 1994 quantity was about 5 million tons higher than 1988, the 1994 price was about $30 per ton lower than the peak in 1988. In 1995, quantity decreased by 2 million tons to 18.6 million tons -- still about 3 million tons higher than 1988 which is a very high volume. In spite of that, the price has dropped to $348 per ton which is about $90 per ton lower than the peak in 1988.
Since hot-rolled sheet is internationally traded, and the demand/supply situation is highly interdependent among various nations, it is understandable that the U.S. spot price does not completely correspond to domestic demand.

However, when looking at the relationship between spot price and apparent consumption in the 1990s, it would appear that the spot price remained more closely aligned with volume closer than it did in the 1980s. One factor contributing to this trend is Nucor's entry into the hot-rolled sheet segment in 1989. Nucor, like other integrated steelmakers, posts its list prices from time to time based on order volume levels. However, unlike other list prices, Nucor is renown for setting its prices very close to spot market prices. Since Nucor prices are sensitive to the order volume level, Nucor has established itself as a price leader in the hot-rolled sheets market.

Under the oligopolistic market that was dominated by the integrated steelmakers until 1980s, price movement often did not reflect volume. Prior to the entry of Nucor, the integrated steelmakers' only competitor was the international market and, to some extent, they were protected from international rivals by legislative actions on their behalf (trade case filings).

Exhibit 5-11 shows the movements of spot price and Nucor's list price since it began quoting list prices in May 1989. For the first couple years, there were certain price differences between the two prices. However, since 1993, when Nucor's reputation as a hot-rolled sheet producer became established, Nucor's price has moved at almost the same level as spot price. Such accurate pricing flexibility supports Nucor's price leadership position. An excellent example can be seen in 1995, when the market changed rapidly, and Nucor continually changed its prices to reflect the market demand.
There are some unique factors at work for the 1995 price scenario. First, early in 1995, high customer inventories contributed to a weakening of prices. Customers built up their inventories in advance of an expected price increase, but then demand began to slacken. Second, Nucor first cut prices in March, and eventually lowered prices seven times on various types of sheet steel. It appears that Nucor's practice of posting its prices and shifting them according to order levels also helped push prices down because customers simply held off ordering until Nucor cut prices. It is anticipated that an aggressive pricing approach by new entrants such as Gallatin Steel, which is trying to increase its market penetration, influenced Nucor's price policy.
5.4.2 Price Trend of Cold-Rolled Sheets

There is little difference between hot-rolled sheets and cold-rolled sheets in terms of price volatility. During the same period, prices ranged from a low of $384 per ton to a high of $523 per ton. In late 1985, the spot price hit $384 per ton when annual volume was 17.4 million tons. Since then, the spot price gradually improved, reaching $501 per short ton in 1989 despite a volume decrease to 16.2 million tons annually. The spot price hit $414 per ton in 1991 when volume declined to 13.8 million tons annually. After that, both price and volume have improved and prices reached $523 per ton in early 1995. The market situation for 1995 was similar to hot-rolled sheets, and in late 1995 the price level was $493 per ton. Exhibit 5-12 shows spot price movements of cold-rolled sheets in relation to apparent consumption.

As indicated for hot-rolled sheets, it seems that the link between spot price and volume has been getting tighter in the 1990s. Nucor posts its list price for cold-rolled sheets, and although their presence in cold-rolled sheets market is not as strong as that in hot-rolled sheets, their influence on the market cannot be ignored.

Exhibit 5-12
Cold-Rolled Sheet: Spot Price vs. Apparent Consumption

Source: World Steel Dynamics and American Iron and Steel Institute
CHAPTER 6

POSSIBLE EFFECTS OF INCREASED MINIMILL CAPACITY

Minimills have greatly increased their production capacity in the flat-rolled products segment, and this growth will undoubtedly have a significant impact on both the product market and the raw materials market. With the information provided in the previous chapters, I will now analyze possible effects on the flat-rolled segment as well as the industry as a whole and then suggest possible future scenarios growing out of this increased capacity.

6.1 Impact on the Total Flat-Rolled Products Market

6.1.1 Ability to Absorb New Capacity

If all the potential plans for construction of new hot-strip mills actually become reality, by the end of this century 17 million tons of hot-rolled sheets and plates will be added to the level already produced in 1994 (taking the replacement factor into consideration). One cannot reasonably assume that this quantity will be applied only to the hot-rolled sheets and plates market in view of 31.5 million tons of apparent consumption recorded in 1994 and the factors discussed earlier. However, this quantity can definitely be absorbed by the entire flat-rolled products market. Exhibit 6-1 shows the composition of apparent consumption assuming that apparent consumption in 2000 will be the same as that of 1994.
Exhibit 6-1
Composition of Apparent Consumption in Year 2000 -
Total Flat-Rolled Products

<table>
<thead>
<tr>
<th></th>
<th>1994</th>
<th>2000</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>59.8</td>
<td>76.8</td>
<td>17.0</td>
</tr>
<tr>
<td>Trade Balance</td>
<td>-12.6</td>
<td>4.4</td>
<td>17.0</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>72.4</td>
<td>72.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>

As the exhibit shows, the trade balance needs to be improved by 17 million tons, from 12.6 million tons of net import to 4.4 million tons of net export. If one assumes that the trade balance will not change, apparent consumption needs to grow an average of 4 percent annually from 1994 to 2000.

I do not believe that these assumptions are realistic. Therefore, the rest of this discussion will be based on the following assumptions:

Assumptions:

1. 11 million tons of flat-rolled product capacity will be added to 1994 levels. This capacity includes only what is already constructed, under construction, or for which a firm decision has been made.

2. Apparent consumption will be the same as 1994. 11 million tons will be added to product shipments in 1994.

3. Import quantities will be 10 percent of apparent consumption each year. The ratio of imports to apparent consumption for traditional minimill items such as light shapes, structurals, hot-rolled bar and reinforced bar was less than 10 percent in 1994 following a gradual decrease over the past decades. It is reasonable to assume that even if price is competitive with imported materials, it may not be able to eliminate import materials completely from the U.S. market.
The composition of apparent consumption based on these assumptions is shown in Exhibit 6-2.

Exhibit 6-2
Composition of Apparent Consumption in Year 2000 - Total Flat-Rolled Products

<table>
<thead>
<tr>
<th></th>
<th>1994</th>
<th>2000</th>
<th>Comparison with 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Shipments</td>
<td>59.8</td>
<td>70.8</td>
<td>11.0</td>
</tr>
<tr>
<td>Export</td>
<td>1.7</td>
<td>5.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Import</td>
<td>14.3</td>
<td>7.2</td>
<td>-7.1</td>
</tr>
<tr>
<td>Net Export</td>
<td>-12.6</td>
<td>-1.6</td>
<td>11.0</td>
</tr>
<tr>
<td>Apparent Consumption</td>
<td>72.4</td>
<td>72.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>

(unit: million short tons)

Exhibit 6-2 suggests that 11 million tons can be absorbed only if the trade balance is improved and assuming that apparent consumption will be the same as 1994. The increased minimill capacity will force the U.S. steel industry to pay more attention to the export market. The industry will have to provide a consistent flow of product to the export market through both good and bad times in order to foster customer relationships and reduce hefty price discounts. In the past, the U.S. steel industry has not been committed to the export market.

Most of them [steelmakers] are taking a short-term view of the export market and use it as an escape valve rather than a long-term relationship. Their philosophy was typical in 1995: exports surged when international prices rose, while U.S. prices declined. When foreign prices have dropped, they have announced sharp reductions in their export tonnage and will redirect it into the domestic market.¹

6.1.2 **Effect on Price Trends**

Possible effect on prices of this new flat-rolled product capacity will be as follows:

**Effects:**

1. The price of hot-rolled sheet, especially the basic grade, will be greatly impacted. Price levels will stay at relatively low levels, at least for the short term. In particular, when a new entrant comes into the market, they will take an aggressive approach to pricing in order to secure the market (e.g., as Gallatin Steel did in 1995). Also, in order to operate plants at full capacity, steelmakers will have to improve trade balances, i.e., they will have to compete on a continuing basis with foreign products.

2. The overall impact will be distributed among all the flat-rolled products. The price of flat-rolled products will fluctuate based on demand. However, price elasticity in an increasing-price situation may be less than in the past.

The lowering price trend for flat-rolled products will be good news for steel end-users and will increase the ability of U.S. manufacturing industries to compete in the international market. It is estimated that the trade deficit of steel in steel-containing goods was about 7 million tons in 1994. If that deficit can be reduced, it will effect the apparent consumption of flat-rolled steel. The following quotation from an article in *World Steel Dynamics* illustrates this trend:

Indirect trade in steel-containing goods is a huge swing factor for the steel industry. In 1994, U.S. export of steel in steel-containing goods (cars, trucks, machinery, components) amounted to about 16 million tons. The steel in these exports was included in domestic steel consumption in 1994 of about 110 million tons. In the same year, import of steel in steel-containing goods amounted to about 23.5 million tons. The steel in these goods was not included in domestic steel consumption figures. Let’s assume a 20 percent improvement in exports of steel-containing goods and a 20 percent reduction in imports: exports of steel containing goods would rise from 16 to 19 million tons; imports of steel-containing goods would decline from 23.5 to 19 million
tons. This is a net gain of 7.5 million tons. If so, the U.S. would no longer be a net importer of steel-containing goods.²

6.2 Impact on the Raw Materials Market

6.2.1 Effect on Supply

In order to support 13 million tons of additional EAF capacity, about 14 million tons of additional metallic raw materials are required if one assumes that 1.075 ton of raw material is required for one ton of liquid steel. Of 14 million tons, 10 million tons (which represents 70 percent of total metallic raw material) must be low residual steel scrap or an equivalent material in order to produce flat-rolled products. If the supply of low residual steel scrap becomes less flexible, minimills will have to rely heavily on low residual scrap substitute materials (SSM). Exhibit 6-3 summarizes the SSM’s new demand and new supply scenarios based on the following assumptions:

Assumptions:

(1) For both minimills and SSM plants, only 50 percent of capacity occurs in the year construction is completed; full operational capacity occurs the following year. For example, 4.8 million tons of new EAF capacity was completed in 1995. However, it is assumed that only 50 percent of that capacity was actually operational in 1995 and full capacity will be reached the following year.

(2) All possible construction plans for SSM plants will be realized on schedule. Construction of plants whose completion year is not specified are assumed to be completed in 1999.

² P.F. Marcus, "Weak greenback a stoplight for foreign steel mill products and foreign steel-containing manufactured goods," World Steel Dynamics, April 10 1995.
Exhibit 6-3
Scrap Substitute Materials - New Demand and New Supply

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimill New Capacity</td>
<td>3.73</td>
<td>3.88</td>
<td>2.50</td>
<td>-</td>
<td>-</td>
<td>10.16</td>
</tr>
<tr>
<td>SSM New Requirement</td>
<td>2.87</td>
<td>2.95</td>
<td>1.90</td>
<td>-</td>
<td>-</td>
<td>7.73</td>
</tr>
<tr>
<td>SSM New Capacity</td>
<td>0.36</td>
<td>1.27</td>
<td>2.87</td>
<td>2.70</td>
<td>1.10</td>
<td>8.30</td>
</tr>
<tr>
<td>Short Supply</td>
<td>2.51</td>
<td>1.68</td>
<td>(0.97)</td>
<td>(2.70)</td>
<td>(1.10)</td>
<td>(0.58)</td>
</tr>
<tr>
<td>Accumulated Short Supply</td>
<td>2.51</td>
<td>4.19</td>
<td>3.22</td>
<td>0.52</td>
<td>-</td>
<td>(0.58)</td>
</tr>
</tbody>
</table>

As shown in Exhibit 6-3, new SSM capacity will not meet requirements until 2000.

6.2.2 Effects of Increased Demand/Capacity

As minimills increase their capacity, the possible effect on raw materials may be as follows:

**Effects:**

(1) Until the SSMs’ capacity equals minimill requirements, the market for low residual scrap or its equivalent will remain extremely tight.

(2) Tough competition among steelmakers over the procurement of raw materials can be anticipated. Prices for low residual steel scrap, SSM, and pig iron will stay at higher levels. Price will fluctuate but to a much smaller degree than in previous years. It is possible that prices for those materials will be equal to or higher than 1994 and 1995 levels. In early 1995, the price of Auto Bundles was $150 per ton, which was the highest price in the last 15 years.

(3) The price of SSM will be equivalent to low residual scrap. However, SSM will actually help to cap the price of low residual scrap since, in general, it is traded on the basis of an annual contract instead of a spot contract.
(4) Based on potential price levels for SSM and its cost as discussed earlier, the production of SSM would become an attractive business. It is quite likely that other companies will elect to participate in this business. From the longer-term viewpoint, the capacity of SSM will continue to expand until demand is satisfied.

(5) Until the SSM capacity equals demand, imports of pig iron will continue to be important. Possible U.S. prices paid for pig iron would be attractive to overseas integrated steelmakers, thereby encouraging them to export more pig iron rather than finished products.

(6) Minimills that have either direct or indirect relationships with scrap substitute production will be in an advantageous position, at least for the time being. Examples of such minimills are:

a) Nucor owns an iron carbide plant in Trinidad. It has the potential to expand its capacity from 0.36 million tons per year (1 unit) to 1.44 million tons per year (4 units).

b) BHP is involved in an HBI project with capacity of 2.2 million tons per year. A minimill involved in a joint venture between BHP and North Star would have the same priority for the materials coming from this project.

c) British Steel will relocate its DRI plants, with capacity of 1.2 million tons per year, from the U.K. to U.S. Tuscaloosa Steel, which is owned by British Steel, will have first priority for this material. British Steel is also a 25 percent participant in TRICO Steel. Therefore TRICO Steel will have same priority for this material also.

d) Steel Dynamics is planning to build its own HBI plant.

(7) The effect of all these factors together will affect the minimills’ new capacity. If they are unable to secure enough material, it may result in a lowering operating ratio or postponement of start-up operations.
6.3 The Viability of Minimills

Due to the expansion of minimill capacity, a situation of over-supply for flat-rolled products may occur which will result in lowering prices. At the same time, a tight supply of raw material will result in increased raw materials prices. An analyst illustrated the market size and price for hot-rolled sheet and price of low residual scrap this way: "....looking through the end of this decade, our best estimate answers to these questions are: around 15 million tons, around $270 per ton and around $140 per ton."

6.3.1 Minimill Cost - Without Captive SSM

In order to determine the bottom line for minimills, cost for hot-rolled sheet is estimated as shown in Exhibit 6-4.

---

## Exhibit 6-4

**Minimill Cost Structure - Without Captive SSM Plant**

<table>
<thead>
<tr>
<th>Metal Inputs</th>
<th>120.00</th>
<th>130.00</th>
<th>140.00</th>
<th>150.00</th>
<th>160.00</th>
<th>170.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Residual Scrap</td>
<td>120.00</td>
<td>130.00</td>
<td>140.00</td>
<td>150.00</td>
<td>160.00</td>
<td>170.00</td>
</tr>
<tr>
<td>SSM (1)</td>
<td>120.00</td>
<td>130.00</td>
<td>140.00</td>
<td>150.00</td>
<td>160.00</td>
<td>170.00</td>
</tr>
<tr>
<td>Ordinary Scrap (2)</td>
<td>95.00</td>
<td>105.00</td>
<td>115.00</td>
<td>125.00</td>
<td>135.00</td>
<td>145.00</td>
</tr>
<tr>
<td>Weighted Average (3)</td>
<td>112.50</td>
<td>122.50</td>
<td>132.50</td>
<td>142.50</td>
<td>152.50</td>
<td>162.50</td>
</tr>
<tr>
<td>Metal Cost (4)</td>
<td>120.94</td>
<td>131.69</td>
<td>142.44</td>
<td>153.19</td>
<td>163.94</td>
<td>174.69</td>
</tr>
</tbody>
</table>

**Process Cost**

<table>
<thead>
<tr>
<th>Process Cost</th>
<th>9.41</th>
<th>9.94</th>
<th>10.48</th>
<th>11.02</th>
<th>11.56</th>
<th>12.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Loss on Metal (5)</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Metal to LS (6)</td>
<td>16.00</td>
<td>16.00</td>
<td>16.00</td>
<td>16.00</td>
<td>16.00</td>
<td>16.00</td>
</tr>
<tr>
<td>LS to CC (6)</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Overhead (6)</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>Process Cost</td>
<td>102.41</td>
<td>102.94</td>
<td>103.48</td>
<td>104.02</td>
<td>104.56</td>
<td>105.09</td>
</tr>
</tbody>
</table>

**Operating Cost**

| Operating Cost                        | 223.34 | 234.63 | 245.92 | 257.21 | 268.49 | 279.78 |

**Financial Cost**

<table>
<thead>
<tr>
<th>Financial Cost</th>
<th>16.00</th>
<th>16.00</th>
<th>16.00</th>
<th>16.00</th>
<th>16.00</th>
<th>16.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation (7)</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
</tr>
</tbody>
</table>

**Total Cost Before Tax**

| Total Cost Before Tax                  | 251.34 | 262.63 | 273.92 | 285.21 | 296.49 | 307.78 |

**Notes:**

1. A minimill does not have a captive SSM plant. Price for merchant SSM is equivalent to low residual scrap.
2. Price difference between low residual scrap and ordinary scrap is $25 per ton.
3. Mixture of total metal inputs is: 35 percent of low residual scrap, 35 percent of SSM, and 30 percent of ordinary scrap.
4. 1.075 ton of metals are required for 1.000 ton of liquid steel.
5. In the process, there is yield loss on metal. It is assumed that 1.5 percent, 1.5 percent, and 2.0 percent during the process of thin slab casting, hot-rolled band, and hot-rolled temper/finish respectively, according to World Steel Dynamics.
6. Process costs and overhead are not related to cost for metallurgical input. These figures are estimated by World Steel Dynamics.
7. It is assumed that plant cost is $280 million which will be written off over 12 years.
8. It is assumed that $150 million is borrowed at 8 percent interest.

**Source:** The author

---

4 "Steel’s Thin-Slab/Flat-Rolling Revolution: Provoking Change," World Steel Dynamics, January 1996.
When Nucor lowered its list price for hot-rolled sheet to $300 per ton in September 1995, the price for Auto Bundles was $147 per ton. According to the estimated cost calculation, Nucor could make a profit at this level. However, it is also clear that strong pressure will be put on minimill profitability in the future as discussed earlier.

6.3.2 Minimill Cost - With Captive SSM

Cost structure of minimills who owns captive SSM plant is shown in Exhibit 6-6:

| Exhibit 6-6 |
| Minimill Cost Structure - With Captive SSM Plant |

| Metallics Inputs | 120.00 | 130.00 | 140.00 | 150.00 | 160.00 | 170.00 | 180.00 |
| Low Residual Scrap | 120.00 | 130.00 | 140.00 | 150.00 | 160.00 | 170.00 | 180.00 |
| SSM (1) | 120.00 | 130.00 | 140.00 | 150.00 | 160.00 | 170.00 | 180.00 |
| Ordinary Scrap | 95.00 | 105.00 | 115.00 | 125.00 | 135.00 | 145.00 | 155.00 |
| Weighted Average | 112.50 | 119.00 | 125.50 | 132.00 | 138.50 | 145.00 | 151.50 |
| Metallics Cost | 120.94 | 127.93 | 134.91 | 141.90 | 148.89 | 155.88 | 162.86 |
| Total Cost Before Tax | 251.34 | 258.68 | 266.02 | 273.36 | 280.69 | 288.03 | 295.37 |

Note:  
(1) Cost for SSM is $120 per ton, unrelated to low residual scrap price.
(2) Other assumptions are exactly same as in previous examples.

Source: The author

As shown in the Exhibit, when low residual scrap price increases, minimills that own captive SSM plants will have a big advantage over other minimills. It is clear that Nucor's intention to build an iron carbide plant is just for this purpose. Those minimills will realize
a profit even in a situation where prices for hot-rolled sheet and low residual scrap are $300 per ton and $180 per ton, respectively.

6.3.3 **Comparison with Integrated Mill Cost**

For the purpose of comparison, Exhibit 6-7 shows the typical cost structure of a low-cost integrated mill that produces hot-rolled sheet.

**Exhibit 6-7**
Integrated Mill Cost Structure

<table>
<thead>
<tr>
<th>Metallics Inputs</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>135.00</th>
<th>145.41</th>
<th>147.63</th>
<th>149.85</th>
<th>152.07</th>
<th>154.29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Pig Iron (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Residual Scrap</td>
<td>120.00</td>
<td>130.00</td>
<td>140.00</td>
<td>150.00</td>
<td>160.00</td>
<td>170.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordinary Scrap</td>
<td>95.00</td>
<td>105.00</td>
<td>115.00</td>
<td>125.00</td>
<td>135.00</td>
<td>145.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted Average (2)</td>
<td>129.00</td>
<td>131.00</td>
<td>133.00</td>
<td>135.00</td>
<td>137.00</td>
<td>139.00</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Metallics Cost (3)</td>
<td>142.19</td>
<td>145.41</td>
<td>147.63</td>
<td>149.85</td>
<td>152.07</td>
<td>154.29</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Process Cost</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Loss on Metallics</td>
<td>13.00</td>
<td>13.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td>14.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metallics to LS (3)</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td>46.00</td>
<td></td>
<td></td>
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<tr>
<td>LS to CC (4)</td>
<td>25.00</td>
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<td>CC to HSM (4)</td>
<td>32.00</td>
<td>32.00</td>
<td>32.00</td>
<td>32.00</td>
<td>32.00</td>
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<td>Overhead (4)</td>
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<td>23.00</td>
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<td>Cost Above</td>
<td>139.00</td>
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<td>140.00</td>
<td>140.00</td>
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<tr>
<td>Operating Cost</td>
<td>282.19</td>
<td>284.41</td>
<td>287.63</td>
<td>289.85</td>
<td>292.07</td>
<td>294.29</td>
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<td>Financial Cost</td>
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<tr>
<td>Depreciation (5)</td>
<td>20.00</td>
<td>20.00</td>
<td>20.00</td>
<td>20.00</td>
<td>20.00</td>
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<td>Interest (5)</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
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<tr>
<td>Total Cost Before Tax</td>
<td>314.19</td>
<td>316.41</td>
<td>319.63</td>
<td>321.85</td>
<td>324.97</td>
<td>326.29</td>
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Note:  
(1) Cost for liquid pig iron is an average figure for a Great Lakes mill according to *World Steel Dynamics*.  
(2) The mixture of total metallics input is: 80 percent liquid pig iron, 12 percent ordinary scrap, and 8 percent low residual scrap and/or SSM.  
(3) 1.11 ton of metallics are required for 1.00 ton of liquid steel.  
(4) Process costs and overhead are not related to cost for metallics input. These figures are estimated by *World Steel Dynamics*.  
(5) In line with industry averages, according to *World Steel Dynamics*.  

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Prices for low residual scrap and SSM do not have much affect on the cost of hot-rolled sheet since only 20-25 percent of scrap or SSM is required. Also, the cost of metallics for an integrated mill is not that much different from minimills. In particular, when scrap prices increase, metallics cost becomes lower for an integrated mill than for minimills. However, their process and overhead costs are much higher than the minimill and, consequently, total costs are much higher no matter what the scrap price. Since prices for scrap and/or SSM do not affect the mills' total costs, they tend to purchase these materials in order to increase liquid steel output.

6.3.4 Minimill's Viability in the Flat-Rolled Products

There is no way to estimate the price level of hot-rolled sheet when competition gets fierce. However, it is reasonable to assume that the price level will be approximately $300 per ton in view of the fact that this price is the lowest in the last ten years. In case of minimills who do not own a captive SSM, the cost of low residual scrap or an SSM plant up to $160 per ton can be absorbed. If the minimill owns a captive SSM plant, the cost of low residual scrap up to $180 per ton can be absorbed. In any case, minimills' production cost is much lower than that of typical integrated steelmakers.

Therefore, I conclude that there will be reasonable viability of minimills in flat-rolled segment although level of profitability will be heavily dependent on the market price of products and raw materials.

6.4 Possible Scenario

Based on the information presented earlier, I believe the following scenario is reasonable. As for the timing and the period of each stage, naturally, there is no concrete estimation.
The First Stage: The capacity of minimills will expand. The price of flat-rolled product, especially basic grade hot-rolled sheet, will be lower, and the price of raw material will be higher. Trade balances of flat-rolled product needs to improve (imports need to decrease, while exports need to increase). Unless there is a huge demand increase by overseas producers, increased exports will not help the domestic price level. SSM production will be a highly attractive business and new entrants will join. Competition between integrated steelmakers, minimills, and foreign steelmakers will become fierce. Integrated steelmakers will tend to focus on high-end segment. During this period, some capacities of the high-cost steelmakers -- whether integrated steelmakers or minimills -- may be eliminated or, at least idled as a result of natural selection. Minimills who own captive SSM plants will have an advantage over those who do not have their own SSM plants.

The Second Stage: SSM capacity will reach equilibrium with demand and supply, perhaps even creating an over-supply situation. Raw material prices will be lower than peak. Minimills' profitability will be improved in comparison with the first stage.

The Third Stage: Steelmaking capacity via blast furnace/BOF process will be replaced by the EAF process. The speed of such replacement will be closely related to the supply of coke and SSM. By that time, perhaps another new revolutionary steelmaking technology will be developed.

6.5 Conclusion

Through the research done for the thesis, I am convinced that minimills' capacity for the flat-rolled segment will be expanded, despite the knowledge that profitability will not be good for a certain period of time. However, it is questionable whether all the potential building plans will be realized. There are many variables that will affect the situation.
Some may ask if the increasing power of minimills in the flat-rolled segment is a favorable phenomenon or not. For integrated steelmakers and unions, the answer would probably be "no." However, for the rest of the industry, the answer must be "yes." From a long-term viewpoint, it is an unavoidable next step for the U.S. steel industry. Given the fact that U.S. steel industry cannot fulfill domestic demand without heavy dependence on imports, I believe this is a logical next step.

This phenomenon is just part of the ongoing transition in the steelmaking process, namely, from the blast furnace/BOF process to the scrap and/or SSM/EAF process. As far as this process is economically justified, I believe that increased dependence on it will occur naturally.

A technology evolution always changes basic world understanding. It is obvious that a technology termed "thin-slab casting and hot-strip" created the current situation. This technology will continue to evolve toward "direct-thin-strip" technology. It has been generally believed that the U.S. steel industry is an incompetent industry. However, new technologies as well as minimills' management culture has made it possible to make steel at low cost without reliance on cheaper labor. It will no longer be thought of as the domain of developing countries. Also, perhaps, it is time for the term "minimill" to disappear, as size becomes less important to the function.

Ultimately, I firmly believe that the U.S. steel industry will revive as a competitive steelmaker in the world.


Beatty, J. "Scrap buyers still have lots to worry about; Electric Furnace Steel," *American Metal Market*, February 8, 1995.


*Business Wire*, "Worthington announces processing plant and supply agreement with North Star/BHP Steel," May 9, 1995.


BIBLIOGRAPHY
(continued)


Kerfoot, K., "Steel Technologies opens steel processing facility in Gallatin," Kentucky Manufacturer, October 1995.


Nucor Corporation, 1994 Annual Report


PaineWebber, "Steel OrderTrack," World Steel Dynamics, February 1, 1996.


BIBLIOGRAPHY
(continued)


Purchasing, "Miners fear pellet shortage; direct-reduced iron pellets, November 9, 1995.


Ritt, A., "World standards in productivity; Plant manager Rodney Mott of Nucor Steel's Hickman, Arkansas; Plant Manager of the Year Cover Story," New Steel, November 1995.


Sterner, B., "Rolling: pressure from competitors, customers propelling cold-rolled to higher levels," American Metal Market, April 12, 1995.


Stundza, T., "Is there enough steel scrap?", Purchasing, November 9, 1995.


Waters, R., "Nucor seeks to recapture its heady past - Group must overcome several obstacles if it is to repeat its earlier success," *Financial Times*, November 16, 1995.