

ARCELOR/CORUS MERGER INQUIRY

Background paper on the production processes of the main producers

Introduction

1. The European producers of hot-rolled sheet steel piling (HRSSP) are all steelmakers with heavy section mills. They produce steel by two distinct process routes with different cost drivers and process it into the finished product with varying degrees of efficiency.
2. There is a wide variety of grades of steel. As HRSSP is produced from carbon steel¹ this paper does not consider the production of the more specialized alloy and stainless steels. It outlines the production technologies involved in making carbon steel, casting it into semi-finished products and rolling them into HRSSP. It also considers some factors that affect the competitiveness of the various HRSSP producers and potential market entrants.
3. The steel industry is extremely capital intensive and many of its processes have large economies of scale. As it also has high fixed costs, it is important (although difficult) for producers to keep their works fully loaded. This can lead to them seeking sales at close to their variable production costs when demand is low. The resulting low prices can then lead to low investment, followed by capacity shortages and rapidly rising prices when demand increases. Demand for many steel products is related to the level of investment in the economy. Steel is consequently severely affected by cyclical economic changes.
4. Over a long period producers have faced an environment in which, on trend, costs have increased more rapidly than prices. This 'price squeeze' has forced them to

¹Carbon steel is also known as mild (or low carbon) steel if the carbon content is less than about 0.25 per cent (as is the case for HRSSP and heavy sections). The production of carbon steel relies on controlling the carbon content to achieve the right combination of internal structure and physical properties.

find year-on-year efficiency improvements. In advanced economies, the steel industry has also been under pressure to reduce the environmental impact of its large-scale energy-intensive processes. Finally, customers' product requirements have become steadily more exacting as they have demanded higher quality steel, lighter products and improved product dimensional tolerances.

5. As a result, the steel industry has had to become innovative in developing new process technologies and improving the efficiency of existing processes. In recent decades much effort has been concentrated on developing technologies that combine a number of process steps and both reduce heat losses and improve the product yield per unit of raw materials. For example, the International Iron and Steel Institute (the IISI) has estimated that energy costs per tonne, which amount to about 17 per cent of operating costs, have been reduced by about a half in the last 35 years. Between 1980 and 2003 the output per employee of European (EU15) steel producers increased from under 200 liquid steel tonnes per employee to nearly 600 tonnes per employee.

6. There are five main stages in the integrated production of steel products:

- raw material processing;
- pig iron production;
- steel production;
- casting into semi-finished products; and
- rolling and shaping final products.

In the electric arc furnace (EAF) production route (see paragraph 17) the first two stages are absent.

7. All these production processes are energy intensive owing to the high temperatures involved in the chemical and rolling processes and the need for several cooling and reheating steps.

Raw materials and iron and steelmaking

8. Until the 1960s most steel was made by the open hearth process—a slow inefficient method that has now been replaced in almost all countries by basic oxygen steelmaking (BOS) and EAF steelmaking. There are now two distinct types of producer making carbon steel:

- integrated steelworks with blast furnaces and BOS furnaces making steel using iron ore and steel scrap as their ferrous raw materials and coal to reduce the iron ore and provide energy; and
- smaller steelworks (also referred to as ‘mini-mills’) with electric arc furnaces (EAFs) making steel using recycled steel scrap as their ferrous raw material and electricity as their energy source.

Each European HRSSP producer uses one or other of these two alternative technologies or a variant of them. Corus, Huta Katowice and Vitkovice use the blast furnace/BOS production route. Arcelor and Salzgitter use EAFs (but Salzgitter buys in a large proportion of its semi-finished products and also uses the blast furnace/BOS process route for part of its production). In the European Union (15 members) in 2002, 59 per cent of liquid steel was made by the BOS process and 41 per cent by EAFs.

The blast furnace/BOS process route

Raw material preparation

9. The main raw materials for integrated steelworks are metallurgical coal,² iron ore³ and scrap steel. The selection of high quality coal and ore is important to maximize the efficiency of blast furnace operation. As a result only the best quality sources are now normally used and it is usual for both coal and ore to be shipped in very large bulk carriers from distant locations, such as Australia and Brazil.

10. The first stages of the process route involve transforming the coal and ore into a form suitable for charging into blast furnaces. Coal is transformed into metallurgical coke by baking it in coke ovens in the absence of oxygen. This drives off volatile impurities, leaving chemically reactive coke with a very high proportion of carbon. Ore is prepared by grading it into lumps of the right size to charge into a blast furnace and converting finer material into either sinter⁴ or pellets.

The blast furnace

11. Iron ore,⁵ coke and limestone are next charged into the top of the blast furnace. Smaller quantities of various materials, such as natural gas, pulverized coal and oil, are injected into the base of the blast furnace to increase productivity, reduce the amount of coke required and optimize the economic performance of the furnace. Hot air at about 1,200 C is blown into the base of the furnace through nozzles (known as 'tuyeres'). Oxygen in the air reacts with the coke to produce heat and carbon monoxide. The carbon monoxide then reduces the iron ore to liquid metallic iron. This 'pig iron' (also known as 'hot metal' when liquid) has a high content of carbon (about 4 per cent) and contains other impurities that also need to be removed in the steelmaking process.
12. Figure 1 shows a blast furnace.

²Metallurgical coal must be mechanically strong and have low levels of undesirable impurities, such as sulphur.

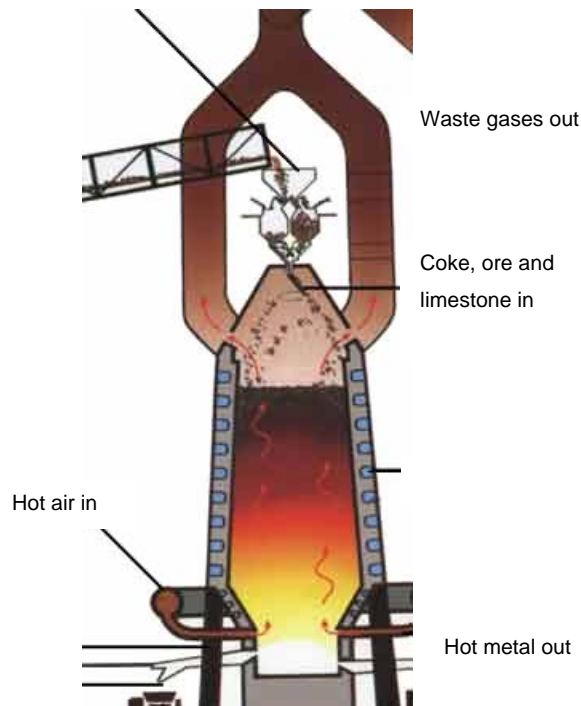
³Ore consists mainly of various iron oxides; high quality ores have high levels of metallic iron (Fe) and low levels of undesirable impurities.

⁴Sinter is made by baking a mixture of powdered iron ore, coke and limestone. Limestone is required in the blast furnace to act as a flux that forms a slag which removes some of the unwanted impurities.

⁵The ore may be in the form of lumps, sinter and/or pellets.

FIGURE 1

A blast furnace



Source: Corus.

13. Liquid hot metal at about 1,300 C is tapped at the base of the furnace about every 2 hours. It is then often desulphurized by adding magnesium to reduce the level of sulphur. It is taken to the steelmaking plant in an enclosed 'torpedo' ladle.

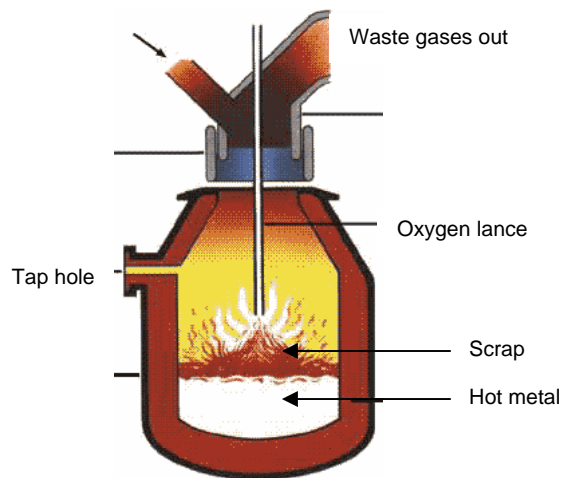
Basic oxygen steelmaking

14. The hot metal is charged into a BOS furnace together with some fluxes. The carbon level in this mixture is then lowered to about 0.25 per cent by blowing a large tonnage of oxygen into the top of the furnace at high speed through a water-cooled lance. This produces heat and so raises the temperature; to control the temperature, and hold it at around 1,700 C, scrap is added during the process. Typically about 25 per cent of the steel is derived from scrap melted in this way. The liquid steel is tapped out of the furnace by tilting it. The process cycle time (the 'tap-to-tap' time) is about 40 minutes and BOS furnaces typically produce between 200 and 350 tonnes of steel in each batch (referred to as a 'heat').

15. Figure 2 shows a BOS furnace.

FIGURE 2

A BOS furnace



Source: Corus.

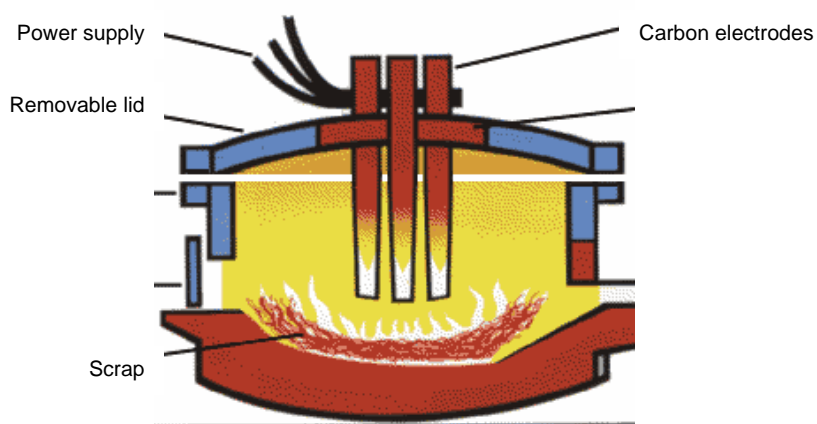
16. HRSSP producers that use the BOS process include Corus, Huta Katowice and Vitkovice. Vitkovice uses a variant of the process called Q-BOP that involves blowing oxygen through a water-cooled lance mounted in the bottom of a small 75-tonne furnace.

Electric arc steelmaking

17. EAFs make steel by melting recycled scrap using the energy produced by striking an electric arc between carbon electrodes at the top of the furnace and the scrap at its bottom. There are two different EAF technologies, using alternating current (AC) and direct current (DC) power. The principal material costs of the EAF process are thus very different from those of the blast furnace/BOS route: they consist of scrap, electricity and carbon electrodes. As for BOS furnaces, EAFs are tapped by tilting the furnace. EAFs typically produce up to 150 tonnes of steel in each heat. Figure 3 shows an EAF.

FIGURE 3

An electric arc furnace



Source: Corus.

18. Until the 1970s EAFs were normally only used to produce high grade steels (for example stainless and alloy steels). For these high-value products, the disadvantage of long melting times (up to 4 hours) was more than compensated for by the higher degree of control over the composition of the steel given by this process compared with BOS. In the 1970s a new type of small scale steelmaker arose. These producers were known as 'mini-mills' and initially concentrated on producing low-grade steels, such as reinforcing bar, in EAFs. Because of the undemanding nature of their products they were able to use cheap low quality scrap and to achieve low production costs.
19. EAF technology has advanced a great deal in the last 20 years. As a result EAFs are now able to make many grades of steel and products competitively that previously could only be made economically in large BOS furnaces. Techniques that have been introduced include oxy-fuel burners, post-combustion, coal injection, scrap pre-heating and oxygen lances. Many EAF steelmakers now obtain about 35 per cent of the energy requirements from chemical sources as opposed to electricity. The major gain has been a reduction in the process 'tap-to-tap' time from several hours to about 40 minutes. Some estimates suggest that the capital cost per tonne

of annual capacity for a new EAF steelmaking plant may now be less than one-quarter of the equivalent cost for integrated steelmaking. Mini-mill producers have consequently been able to challenge the integrated steelmakers over a wide range of products, including piling and heavy sections. Some integrated producers, such as Arcelor's Esch-Belval works, have replaced their integrated iron and steelmaking with EAFs.

20. Unlike integrated steel plants, which can source virgin iron ore and coal with low levels of undesirable impurities, EAF producers are highly dependent on the level of impurities (eg contamination by 'tramp' elements such as copper, nickel and tin, dissolved gases and stray material) in the recycled scrap they can obtain.
21. Some EAF producers supplement their raw material supply by using scrap substitute materials, such as cold pig iron or directly reduced iron (DRI) that have low levels of impurities. (Direct reduction plants reduce iron ore to a solid sponge iron material at comparatively low temperatures using either natural gas or coal as the reducing agent. In Europe they make a very minor contribution to the overall supply of ferrous materials.)

Comparative economics of the two process routes

22. The production costs of the two process routes are driven by different raw material costs, capital costs and operating technologies. Which route is the lower cost method of producing a particular product will depend on cyclical changes in raw material costs as well as the operating and capital costs of each process route. Scrap prices tend to be more affected by cyclical factors than the prices of coal and iron ore. It is therefore often the case that integrated producers have a cost advantage at the peak of the steel cycle, when their high-fixed-cost plants are fully loaded, and EAF-based producers have a cost advantage in the trough of the cycle.

23. EAF capacity may be constrained by the amount of scrap available at a reasonable price. In most countries this is below the level of steel consumption and depends on many factors, such as the maturity of the steel economy, the amount of manufacturing industry in the region concerned and the life cycles of products manufactured from steel. As a result it is likely that the most efficient overall mix of steel capacity in a large advanced economy will continue to include either a significant proportion of integrated steelworks or EAF producers using scrap substitute materials.

Secondary steelmaking

24. Since the 1970s there has been substantial investment in a further stage of steelmaking to help satisfy increasingly stringent steel quality requirements. Steel from BOS and EAF furnaces is now normally processed in one of various types of secondary steelmaking furnace. These range from vacuum degassing plants designed to remove dissolved gases such as oxygen to more elaborate furnaces that allow the steel to be stirred using argon, its composition to be adjusted very precisely and its temperature to be increased by means of an electric arc. These also have the advantage of allowing a heat of steel to be held at the appropriate temperature for casting if the continuous casting machine is not ready to receive it. Overall, the main purposes of secondary steelmaking are to adjust the chemical analysis and casting temperature of the steel and to perform a buffer function.

Continuous casting

25. Before 1960 nearly all liquid steel was cast into large ingots, which then had to be allowed to cool before being reheated and rolled into semi-finished products (eg slabs, blooms and billets⁶) in primary rolling mills. Between 1970 and 2000 continuous casting processes replaced this traditional ingot route for nearly all steel

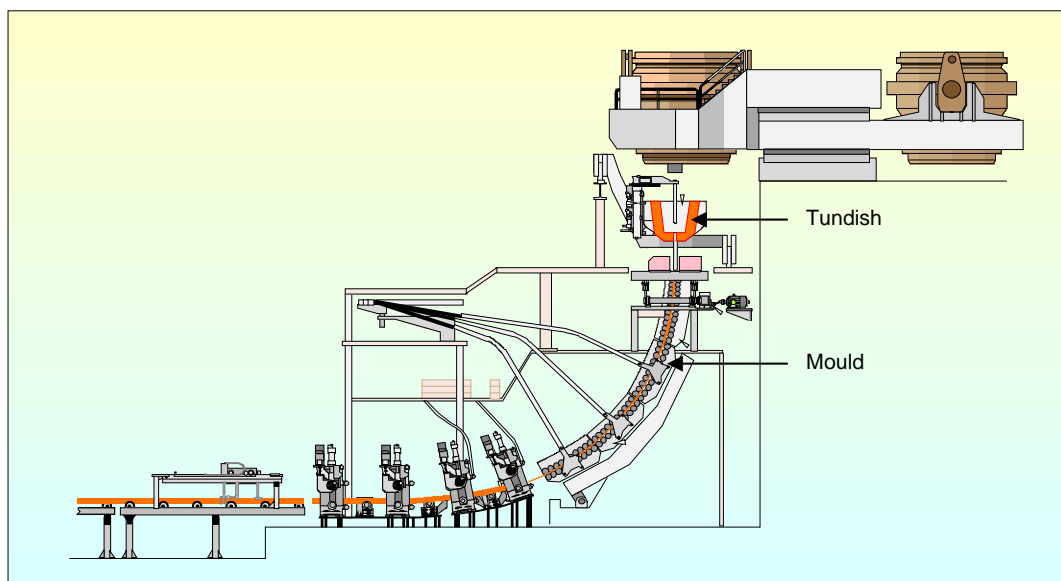
⁶Slabs are normally up to 3,000 mm wide and up to 320 mm thick; blooms are normally up to 500 mm across and may be either square or rectangular in cross-section; and billets are normally up to 180 mm square.

production in advanced countries. This resulted in such large production cost savings (about one-quarter of the energy required to produce a tonne of semi-finished product was saved) and improvements in the quality of semi-finished products that it became difficult for producers without continuous casting to remain competitive. The IISI estimated that 88 per cent of world liquid steel production was continuously cast in 2003 and that the corresponding figures for the EU (15 members) and for the rest of Europe were 97 per cent and 89 per cent, respectively. All the European HRSSP producers use continuous casting.

26. Figure 4 shows a continuous casting plant.

FIGURE 4

A continuous casting plant



Source: Arcelor.

27. A ladle of liquid steel at a precisely controlled temperature is brought from the secondary steelmaking plant and poured into the tundish at the top of the continuous casting machine. (A tundish is a holding vessel that releases the liquid steel into the machine at a constant rate and at constant pressure.) The steel is then poured into a number of curved, vibrating, water-cooled moulds. Many ladles of steel can be processed in a sequence by casting machines without any break in production for

periods of several days. As the steel passes through the moulds it solidifies from the outside inwards. At the bottom of the machine, the blooms are gripped by withdrawal rolls and pass into the finishing area where they are cut to length. Bloom casters often have as many as six moulds mounted in parallel. (The number of moulds is largely determined by the need to achieve compatible average production rates in the continuous caster and in the steel plant.)

28. Continuous casting is developing rapidly and many techniques have been introduced in recent years to reduce operating costs and yield losses and to improve product quality. There is a trend towards casting shapes that are closer to the cross-section of the finished product. Many heavy sections and piling producers, including Arcelor but not Corus, have introduced moulds that cast 'beam blanks' rather than blooms. These have a dog-bone shaped cross-section that reduces the amount of work required to produce the finished product in the heavy section mill (and thus the rolling cost).

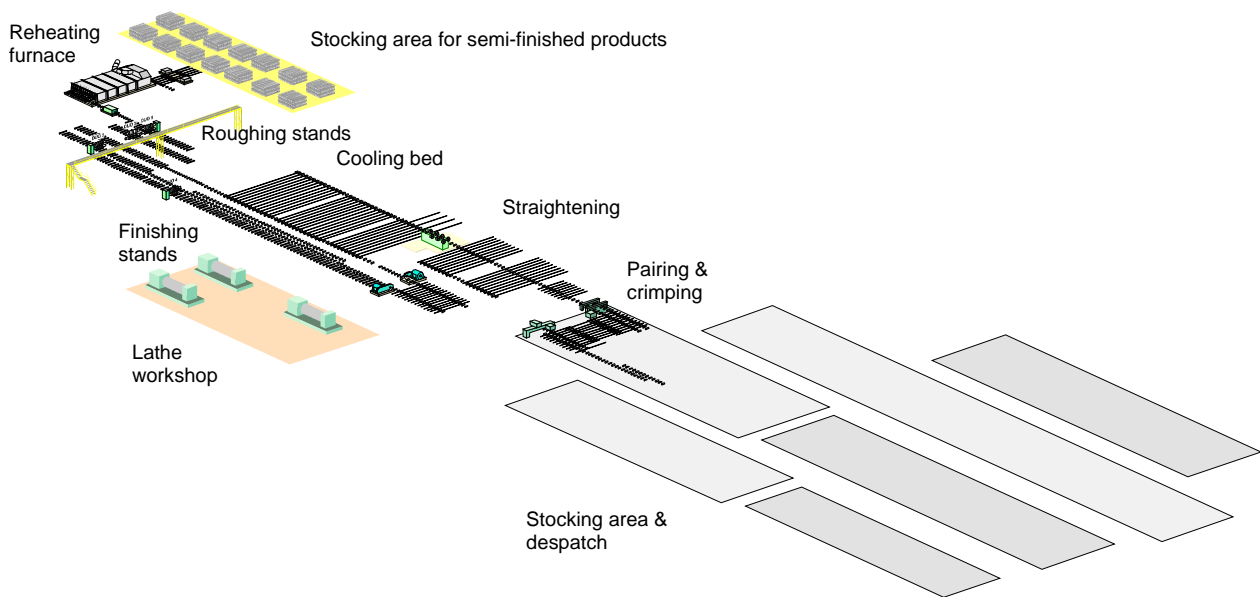
Rolling

29. In brief, semi-finished products are converted into most finished products by rolling in one or more rolling mills. To produce HRSSP, the blooms or beam blanks⁷ are reheated to a carefully controlled temperature and then rolled on a heavy section mill.
30. Figure 5 shows the layout of Mill 2 at Arcelor's Belval works.

⁷Some large sizes may also be made from slabs.

FIGURE 5

Mill 2 at Belval

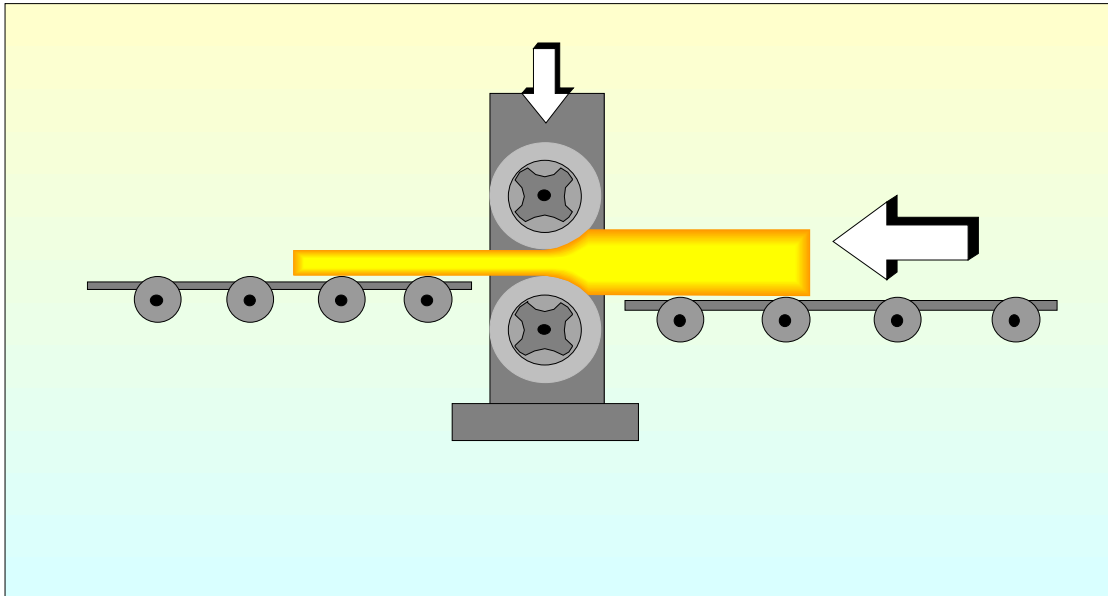


Source: Arcelor.

31. After reheating, the semi-finished products are passed through a number of 'roughing' mill stands with two horizontal rolls. Figure 6 illustrates how the thickness of the product is reduced on passing through each of these mill stands. The product is fed into the mill stand where it is gripped by two rolls driven by a powerful electric motor. The degree of reduction of thickness or change of cross-section that can be achieved is dependent on the power of the motor, the diameter of the two rolls (and thus their resistance to deformation) and the gap between the rolls. The most common and efficient technique for rolling HRSSP uses several stands with two large horizontal rolls (known as 'duo' stands). The product is passed between closed grooves in these stands; the size and shape of the grooves are calibrated to form the product in steps into its final state.

FIGURE 6

A mill stand



Source: Arcelor.

32. The product may be passed a number of times through each roughing stand in alternate directions. It is then passed to the next stand, typically mounted beside the first stand,⁸ for further rolling. After the product has achieved substantially the final cross-section it is then passed on to a series of in-line finishing stands, cut to length, allowed to cool and finally passed through a straightening machine that removes any bending caused by the rolling and/or cooling process.
33. The final stages of finishing consist of inspection and preparation for despatch. Where required by the customer, piles may be linked into pairs and crimped to fix the positions of the two piles.
34. The rolling rate for heavy section mill products depends on the amount of mechanical work that the mill has to do to reach the final product shape. As HRSSP requires heavy transformation and special finishing, it normally has a comparatively slow

⁸This is referred to as a 'cross-country' layout. Some mills use an in-line layout in which the stands are placed in a straight line. Such layouts are efficient in terms of plant operating costs but expensive in capital costs as a much longer building is required.

rolling rate. As a result the annual capacity of a mill is likely to be lower than the capacity of a similar mill rolling standard types of sections.

Competition Commission

15 November 2004