THE RISE AND FALL OF GUYANA BAUXITE

by

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

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ABSTRACT

The discovery of bauxite in Guyana was coincident with the advent of the aluminium industry. Guyana's endowment with relatively large deposits of bauxite, rich in aluminium oxide and mineralogically compatible with the alumina technology used by the North American alumina industry, led to the country becoming the major supplier of bauxite to North America during the Second World War.

In addition to its high aluminium oxide content and gibbsite mineralogy, the Guyana bauxite deposits possessed the properties of low iron content and low levels of all the impure elements in bauxite. These properties conferred on Guyana a near monopoly in the refractory bauxite market which emerged from the increase in steel production and technologic developments in the post war steel-making process.

Guyana, however, never realised its potential as a bauxite producer, consistent with the quality of its resources. The discovery of bauxite with more favourable mining conditions in a number of other countries led to a diversion of investment from Guyana

The Guyana industry, however, while never achieving the size and degree of vertical integration as that in the new resource endowed countries, continued to operate profitably for four decades through its monopoly of the refractory bauxite market and the production of bauxite for other non-metallurgical applications.

Concerns by the Government over the lack of investment in the industry, led to its acquisition by the state. However, after a period of successful operation under state-ownership, production and revenues declined. Attempts to rehabilitate the industry forced the Government to change its policy on state-ownership and embark on a programme to divest itself of its share-holding in the industry.

The lack of investment in the industry for the production of aluminium has been attributable to uncompetitiveness of Guyana bauxite through high mining cost and shipping cost. This study has, however, undertaken a more comprehensive analysis of the contributory factors to competitiveness in bauxite production and has revealed a number of economic factors that seriously question the competitiveness paradigm with refererence to Guyana bauxite. The analysis also reveals a number of non-economic factors that were responsible for the diversion of investment from Guyana to other bauxite endowed countries. Guyana's loss of the refractory bauxite market has also been attributable to uncompetitiveness associated with inefficient management under state-ownership. While conceding a number of inefficiencies under state-ownership that had an impact on efficiency, the study has shown that a number of exogenous factors contributed to the developments in that market.

Despite its failures in the past, the Guyana bauxite industry manages bauxite resources with advantages over the resources in many other producing countries that could result in the country regaining its position as a major supplier of bauxite to the aluminium industry and to the refractories and abrasive industries.

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Chapter 1

INTRODUCTION

1.1 Guyana in World Bauxite Production

Guyana was among the world's first bauxite producing countries and the first Western Hemisphere country, after the United States, to become a major producer of bauxite for the aluminium industry. Production started toward the end of the First World War, and even with the wide fluctuations during the inter-war years, accounted for 9 per cent of world production for the decade of the 1930s, and by the beginning of the Second World War, Guyana assumed the position of the world's third largest producer. The situation changed dramatically over the decade of the 1940s with the increase in demand for aluminium during the War which led to a 225 per cent increase in ten-year average annual world bauxite production and to a nearly 600 per cent increase in Guyana. This elevated Guyana to the position of the world's second largest producer, accounting for 19 per cent of world production.

Guyana's position, however, changed over the next decade. After a steep decline in aluminium production following the end of the War, the metal found new applications and gained acceptance as an industrial metal. This led to an increase in production of 121 per cent over that of the decade of the 1940s and to a 126 per cent increase in bauxite production. The rate of increase in production in Guyana exceeded that of the world for the first two years of the decade, increasing its market share to 22 per cent. Production, however remained static for the rest of the decade, resulting in a fall in market share to 16 per cent. While production continued to increase over the decades of the 1960s and 1970s, the rate continued to fall below that of the world resulting in a further decline in market share to 10 per cent and 6 per cent respectively. World production increased a further 18 per cent over the decade of the 1980s; production in Guyana, however fell 33 per cent over this period resulting in a fall in the country's market share to three per cent and even with the commissioning of a new project in 1990 that maintained production at the level of the previous decade, its share fell further to 2.7 per cent for the next decade. Table 1.1 shows ten-year average Guyana and world bauxite production and Guyana's share of world production over the period 1920 to 2000.

Table 1.1 Guyana And World Bauxite Production

Ten Year Averages

(000 tonnes)

Period	Guyana	World	Guyana % of World	% Increase	
				Guyana	World
1920 -29	130	1,315	10	-	-
1930 -39	200	2,270	9	54	73
1940 -49	1,385	7,250	19	592	224
1950-59	2,670	16,350	16	93	126
1960-69	3,750	37,000	10	41	128.
1970-79	4,220	73,700	6	13	99,
1980-89	2,810	86,600	3	-33	18
1990-99	2,850	108,800	3	0	26

Sources

1. Guyana Geological Survey, Bauxites and Laterites Deposits of Guyana, 1968.
2. Overseas Geological Survey, Mineral Resources Division, Bauxite Alumina and Aluminium- 1962.
3. UN Technical Assistance Team Report, The Bauxite-Aluminium Industry of British Guiana, 1964.
4. The Commonwealth Economic Committee, Non-Ferrous Metals, 1966.
5. US Bureau Of Mines, Minerals Yearbook, Bauxite and Alumina, 1954-2000.
6. Bauxite Industry Development Company, Guyana, Statistics 1971-2000.

Bauxite is used for the production of aluminium, refractories, abrasives, aluminium chemicals, cement, and as a flux in a number of metallurgical processes. The catalyst for the increase in world production since the decade of the 1920s, however, was the rapid growth in primary aluminium production which increased at an average of 83 per cent each decade between 1920 and 2000. Guyana was one of the principal beneficiaries of the early stages of this development, especially the phenomenal increase in the decade of the 1940s when the demand for aluminium for aircraft production during the Second World War resulted in an increase in world aluminium and bauxite production of 280 per cent and 206 per cent, respectively. Production in Guyana over this period increased 512 per cent, attributable to: (1) its endowment with relatively large resources of high quality trihydrate bauxite compatible with the American Bayer technology used by the North American alumina refineries; (2) the existence of production capacity that could be rapidly expanded; and (3) its geographical location with respect to the North American continent in terms of distance and security of shipments during the War.After a steep decline in aluminium production toward the end of the War, new applications for the metal in electric power transmission, transportation, construction, packaging and consumer durable goods, led to a continuous increase in demand for aluminium and metallurgical bauxite over the next five decades. Guyana, however, participated only marginally in these developments, recording increases in each of the first three decades, and falling production in the next decade before a new project commissioned in 1990 led to a 250 per cent increase in production over that of the preceding decade. Table 1.2 shows ten-year average world aluminium and Guyana and world bauxite production for the period 1920-2000.

Table1.2 Guyana And World Metallurgical Bauxite And Primary Aluminium Production

(Ten Year Averages)

Period	Primary Aluminium		Metallurgical Bauxite				
				World		Guyana	
	Quantity	%	Total	Quantity	% Increase	Quantity	% Increase
1920 -29	170	-	1,315	1,315	-	130	-
1930-39	334	96	2,270	2,250	71	200	54
1940-49	1,270	280	7,250	6,890	206	1,225	512
1950-59	2,810	121	16,350	15,530	125	1,470	20
1960-69	6,530	132	37,000	35,150	126	1,650	13
1970-79	14,625	124	73,700	66,330	89	1,230	-25
1980-89	16,226	11	86,600	77,940	17	625	-49
1990-99	21,150	30	108,800	97,700	25	2,210	254

[1] Metallurgical bauxite for the production of aluminium is estimated at 100 percent of total world production for the decade of the 1920s and 1930s, 99 percent for the decade of the 1930s 95 percent for the decades of the 1950s and 1960s and 90 percent for the decades of the 1970s 1980s and 1990s.

Sources:

1.Metalgesselshaft, Metal Statistics,1975-1985.

2.Overseas Geological Survey, Mineral Resources Division Bauxite and Aluminium, 1962.

3 UN Technical Assistance,1964, The Bauxite-Aluminium Industry of British Guiana.

4.The Commonwealth Economic Committee, Non-ferrous Metals, 1966.

5.US Bureau of Mines, Minerals Yearbook, Bauxite and Alumina, 1954-1994.

6.Bauxite Industry Development Company, Guyana, Statistics,1972-1996.

7. Australian Mineral Economics, The World Aluminium Industry, 1982.

8.US Geological Survey, Minerals Year Book, Aluminium, 2000.

A more detailed analysis of the data on Guyana's bauxite production, shows that metallurgical bauxite, during the decade of the 1940s, accounting for almost 87 per cent of total crude bauxite production. However, over the next decade, the share of metallurgical bauxite fell to 54 per cent and by the decade of the 1980s, to 24 per cent. The industry, toward the end of the decade of the 1950s shifted its focus from the aluminium industry to the production of refractory bauxite to take advantage of the increasing demand for this product and its technical advantage in production through its endowment as the only source of bauxite that satisfied the technical specifications for refractory bauxite demanded by the consuming industries. This development placed Guyana in a near monopoly of the market for refractory bauxite. It, however, contributed to the country's failure to participate in the growth in world bauxite production between 1950 and 1975 since the higher return on investment in refractory bauxite induced the operating companies to direct most of their investment in the industry to that product. A series of developments over the decades of the 1970s, 1980s, and 1990s, which would be discussed in detail later in the study, affected both the demand for and supply of refractory bauxite and resulted in a dramatic decline in production and to the country losing its dominant position in the refractory bauxite market.

Table 1.3 shows a breakdown, by grades, of five-year average annual bauxite production for Guyana over the period 1935-2000.

Table 1.3 Guyana Bauxite Production By Grades

Five-Year Averages

(000 Tonnes)

. Products / Year	.Dried Bauxite (5% H_2O)[1]		Calcined Bauxite[2]		Dry Bauxite Equivalent		Total Dry Bauxite Equivalent	Percentage of Total	
	Metal- lurgical	**Chemi- cal**	**Refrac- tory**	**Abras -ive**	**Metal- lurgical**	**Non-Metl- lurgical**		**Metal- lurgical**	**Non-Metal- lurgiical**
1935-39	290	0	5		275	20	295	92	7
1940-44	1,130	25	10		1,075	60	1,135	95	5
1945-49	1,320	60	60		1,255	260	1,515	83	17
1950-54	1,450	60	270		1,380	985	2,335	58	42
1955-59	1,400	90	340		1,330	1,070	2,400	53	47
1960-64	1,350	125	380		1,280	1,410	2,690	48	52
1965-69	1,850	150	550	50	1,760	2,180	3,940	45	55
1970-74	1,700	170	670	20	1,615	2,510	4,125	42	58
1975-79	755	280	690	0	720	2,610	3,365	23	78
1980-84	530	335	470	25	500	2,084	2,585	19	81
1985-89	720	310	410	0	685	1,660	2,380	30	697
1990-95	1,550	240	260	0	1,470	1,705	3,175	46	54
1996-00	2,300	255	160	0	2,185	785	2,970	74	26

[1] Production of Metallurgical and Chemical bauxite classified as Dried bauxite is reported as bauxite with moisture content of 5% from crude bauxite containing 15% moisture. The quantity is then converted to Dry Bauxite Equivalent -bauxite with zero

[2] Refractory and Abrasive bauxite classified as Calcined bauxite are produced by washing and screening of crude bauxite containing 15% moisture, and removing approximately 20% of particles <150 microns. The washed product is then calcined at a temperature of around 1100-1700°C during which the free moisture and water of crystallization are driven off together with about 20% dust losses. The volume of finished product is then converted to crude bauxite equivalent by multiplying by a factor of 4 and the crude bauxite equivalent multiplied by a factor of .85 to arrive at dried bauxite equivalent

Sources

1.Bauxites and Laterites Deposits of Guyana, Guyana Geological Survey 1968.

2.Overseas Geological Survey, Mineral Rcsources Division, 1962.Bauxite Alumina And Aluminium.

3.US Bureau of Mines Minerals Yearbook, Bauxite and Alumina, 1954-1997.

4.Bauxite Industry Development Company Statistics, 1972-2000.

1.2 Industry Studies

The change in Guyana's position in world bauxite production led to the industry being the subject of studies by government, international agencies, and industry experts, over the period 1960 to 1990 to identify the factors responsible for its declining role in world bauxite production and to recommend measures for reversing the trend. These studies fall into two broad, time-related categories but in both periods significantly influenced government policy on the industry and its overall development

The first group of studies (United Nations Technical Assistance, 1964 and Guyana Development Corporation, 1968) were undertaken prior to 1970 when the industry was fully owned by two of the major multinational corporations in the aluminium industry. While both companies were expanding aluminium production, investing in new bauxite mining and alumina capacity, and expanding their operations in other parts of the world, they were making no investment in expansion in Guyana. The studies, therefore, analysed developments in the industry entirely in the context of the world aluminium industry even though, by 1963, bauxite for non-metallurgical applications accounted for more than 50 per cent of total production. The United Nations study attributed the cessation of investment in the industry entirely to loss of competitiveness associated with high mining and shipping costs for metallurgical bauxite, and recommended investment in expansion of existing alumina capacity and forward integration into the production of aluminium (UN Technical Assistance Team Report, Page 12). The Guyana Development Corporation study, accepted the impact of high mining and shipping cost, but identified a number of non-economic factors that influence the investment decisions of the multi-national corporations in the aluminium industry. and recommended increased government involvement in the industry and the granting of generous tax and fiscal incentives to the major aluminium companies to stimulate forward integration into alumina production, even at the expense of refractory bauxite.

The second group of studies were undertaken when the industry, after ten years of profitable operation under state-ownership, encountered declining production of metallurgical and refractory bauxite, declining alumina production and eventual closure of its alumina refinery, loss of its dominant position in the refractory bauxite market and a steep decline in its financial performance. The first three of these studies, (Kaiser Engineering, 1981; US Steel, 1983; and Reynolds, International, 1985), identified high cost of production associated with the cost of stripping overburden and shipping as underlying factors in the industry's competitiveness. They, however, attributed the steep decline in its performance since the latter years of the 1970s to inadequate investment in maintenance and replacement of equipment, and ineffective management under state ownership. The studies, therefore, recommended large injections of capital and various forms of foreign management involvement in the operations to restore production levels and return the industry to profitability.

In its approach to the European Union for financial assistance under its SYSMIN Intervention Fund, to implement the rehabilitation plan proposed in the Reynolds study, the European Union undertook a study of the operations (SYSMIN Report, 1989), while the Government, in an attempt to attract foreign investment and management back into the industry, commissioned a study by Alcan (Alcan, 1990). The SYSMIN study concentrated on refractory bauxite which was considered critical to the European Union steel industry and recommended financial assistance from SYSMIN for the rehabilitation of the industry with an emphasis on the Linden refractory bauxite facilities and a restructuring of the industry to facilitate the Linden Operations being placed under the management of a foreign private contractor. The Alcan study endorsed the concept of restructuring, but recommended investment to increase the overall scale of the Linden Operation, by increasing production of both metallurgical and refractory bauxite under the management of Alcan.

1.3 Objective of the Study

High production and shipping costs for metallurgical bauxite were relevant factors in the loss of competitiveness in the metallurgical bauxite market, while the industry was under the ownership of the transnational corporations. High production cost, inadequate investment and inefficient management under state ownership were also contributory factors to the loss of competitiveness and eventual decline in production of refractory bauxite. Nevertheless, the writer's hypothesis is that these factors do not provide a complete explanation of the developments in the industry since the decade of the 1950s and are not adequate indicators of the prospects for its future development.

The objective of this study, therefore, is to investigate the validity of the hypothesis. To achieve this, the study: (1) undertakes a more comprehensive analysis of the economic factors that determine competitiveness in the metallurgical bauxite market (2) analyses tnon-economic factors that influsnce investment decisions in metallurgical bauxite and alumina capacity ; (3) evaluates the impact of exogenous economic, technologic, and non-economic factors on the demand for and supply of refractory bauxite; (4) assesses the impact of state-ownership on the industry, with specific reference to the motivations for state ownership, loss of economies of vertical integration, the management structure, and the change in public policy on state-ownership and (5) projects the future prospects for the industry in light of its bauxite and other high alumina resources, world demand for its products, the changing structure in the industries and markets for its products, and a clearer definition of government policy on ownership and control of the industry.

1.4 Organisation of the Study

The study is organised around seven chapters. The first chapter is an introduction to the topic, and briefly traces the history of the industry over the period of its existence, sets out the hypothesis and objective with an outline of the issues to be addressed, and details its organisation. The second chapter reviews the evolution of the industry in the context of the world industry and undertakes a brief description of its products, their industrial applications and the markets in which they compete. The third chapter undertakes an analysis of the factors that led to the rapid rise of Guyana as a major producer of metallurgical bauxite and those that contributed to the loss of its position as a producer of this product. The focus is on: (1) the impact of the industry and market structure of the aluminium industry; (2) the economic factors that determine competitiveness in the market for metallurgical bauxite; and (3) the role of non-economic factors in determining the timing and location of investment in the bauxite and alumina industries. The fourth chapter analyses the economic, technologic and market developments that led to the increase in demand for refractory bauxite. It then evaluates the changes in those factors that resulted in stagnation in demand for refractory bauxite and contributed to Guyana's dramatic loss of market share for that product. The fifth chapter examines the impact of state ownership on the industry and traces the motivations for state ownership, and examines the effect of certain specific aspects of state ownership on the industry's performance. It also analyses the change in government policy on ownership and evaluates the results of government initiatives at divestment of the industry. The sixth chapter evaluates the future prospects for the industry in light of: (1) its bauxite and other high alumina mineral resources; (2) projections of world aluminium and bauxite demand; (3) the changing structure of the aluminium industry; (4) the changing demand for high alumina refractory materials; (4) the changing market conditions for abrasive bauxite and (5) changes in public policy on state ownership of the industry. The final chapter summarises the findings of the study and undertakes an assessment assesses the prospects for the industry.

Chapter 2

THE EVOLUTION OF THE GUYANA BAUXITE INDUSTRY

2.1 Historical Development of The Guyana Bauxite Industry

Bauxite production in Guyana started in 1917, the year when world aluminium production achieved the level of 140,000 tonnes and world bauxite production, one million tonnes. The country rose rapidly to the position of a major producer by the beginning of the Second World War, being ranked among the largest three producers, and for the decade of the 1940s as the second largest producer. Guyana's position, however, changed during the decade of the 1950s. Table 2.1 shows ten year average bauxite production for the major producing countries for the period 1920-2000 and the change in Guyana's market share over that period.

Table 2.1 World Bauxite Production Major Producing

Countries Ten -Year Averages

(000 Tonne)

Country	1920-2	1830-3	1940-49	1980-59	1960-69	1970-79	1980-89	1990-99
United States	370	270	1,940	1,690	570	1,920	830	n.a
Suriname	80	280	1,450	3,110	4,140	5,890	3,530	3,500
Guyana	130	190	1,385	2,670	3,750	4,220	2,810	2,850
Jamaica	0	0	0	2,516	8,105	11,000	8,559	11,545
France	440	770	630	1,380	2470	2,630	1,460	400
Hungary	110	260	570	1,929	1,590	2,650	2,890	1,100
India	0	5	20	100	690	1,480	2,570	5,450
Guinea	0	0	1	290	1,760	7,150	14,700	15,000
Australia	0	0	10	10	21,500	19,100	30,100	42,750
Brazil	0	0	0	10	220	990	5,720	10,420
USSR/CIS	0	130	410	1,730	2,920	3,940	6,170	6,200
Yugoslavia	60	190	1,380	1,590	1,960	2,880	3,360	n.a
China	0	0	90	660	320	860	2,800	5,080
Total World	1,315	2,270	7,250	16,350	37,000	73,700	86,600	108,800
Guyana %	10.00	8.50	19.00	16.30	10.10	6.00	3.20	2.60

Sources

1.US Bureau of Mines, Minerals Yearbook, 1955-1990.
2.Metallgesellschaft, Metallstatistik, 1980-1990.
3.IBA State of the Industry Reports, 1975-1994.
4.USGS, Minerals Yearbook, Bauxite and Alumina, 2000.

The aluminium industry, which was directly responsible for the increase in demand for bauxite, became organised during the last decade of the nineteenth century, following the development of the Hall-Heroult process for the conversion of alumina to aluminium in 1886 and the Bayer process for the economic extraction of alumina from bauxite in 1888. Simultaneously with these developments, geologists in Guyana were reporting occurrences of large deposits of high Al2O3 bearing rocks of similar chemical and mineralogical composition to the bauxite deposits of Georgia and Alabama in the United States in the geographical region of the country categorised as the Hilly Sand and Clay Belt. The juxtaposition of these two developments led to the commissioning of an investigation of these deposits to determine their extent and technical suitability for the production of aluminium. The first comprehensive reports on the geological and chemical properties of these deposits, published by the Guiana Geological Survey Department between 1910 and 1914 (Overseas Geological Surveys, 1962, Page 104), covered a group of deposits adjacent to the Demerara River. This report stimulated considerable interest in the United States and England and led to a rush by companies in those countries to acquire title to properties in the area. In 1914, a group headed by the Aluminium Company of America (Alcoa), entered into an agreement with the British Crown Agents for the right to exploit deposits at a location 65 miles up the Demerara River. In keeping with the terms of the agreement, that exploitation of the deposits be undertaken by a British or British Commonwealth entity, Alcoa, through its Canadian subsidiary Northern Aluminium incorporated Demerara Bauxite Company (Demba) in 1916. (Shahadudeen, 1981, pages 73-79).

Demba started operations in 1917 with mining at a location 70 miles up the Demerara River and processing at Mackenzie at the head of ocean navigation on the river, five miles north of the mine. This operation except for a brief cessation of production between 1921 and 1922, has continued uninterrupted since that time. Demba was joined in 1942 by Berbice Bauxite Company, a subsidiary of American Cyanamid that started exploitation of the extremely low iron deposits discovered at Kwakwani on the Berbice River in 1939, for the production of chemical bauxite. The operation was acquired by Reynolds Metals in 1952 and the two companies operated until the mid 1970s when they were acquired by the government.

The development of the industry since 1917 could be placed into five clearly defined eras: (1) initial development; (2) rapid growth and consolidation; (3) product diversification; (4) complete state-ownership; and (5) divestment.

2.1.1 The Initial Development Era 1917-1939

This era covers the period 1917-1939. The initial operation was a small quarry with little capital investment, undertaking the mining of bauxite ore outcrops, transporting the ore by a simple railroad to a crushing plant and ship-loading facility at Mackenzie where it was loaded on to small ocean-going vessels for shipment to Alcoa's refinery at St. Louis on the Mississippi River. Production increased from 4,200 tonnes in 1917 to 29,000 tonnes in 1921 when the steep decline in aluminium production during the recession of the early 1920s led to its discontinuation. Production resumed in 1923 following a resumption of demand for aluminium and recognition of the high quality of the Guyana ore for blending with Arkansas, Alabama, and Georgia ores to improve their Al2O3 and SiO2 content. The resumption was accompanied by an expansion of the size of the operation through the development of additional mines in the vicinity of the original mine, investment in more sophisticated mining equipment, crushing and drying facilities, and expansion of the port and ship-loading facilities.

The reorganisation of Alcoa in 1929 resulted in Demba becoming a subsidiary of Aluminium Company of Canada (Alcan) and started shipments to Alcan's alumina refinery in Arvida, Quebec. The level of production over the rest of this era fluctuated with the cycles in world aluminium production, rising to 185,000 tonnes in 1926, falling to 35,000 tonnes in 1933 and rising to 480,000 tonnes at the out-break of the Second World War. The total production over this period consisted of metallurgical bauxite for the production of aluminium except for small trial quantities of calcined bauxite for the production of abrasives and refractories in 1938.

2.1.2 The Era of Consolidation and Growth, 1940-1954

This era commenced with the increase in demand for aluminium for aircraft production during the Second World War. Average annual world primary aluminium production increased from 300,000 tonnes in the decade of the 1930s to 1.2 million tonnes for the succeeding decade with production reaching a peak of 1.94 million tonnes in 1943. Production fell sharply toward the end of the War to 750,000 tonnes in 1946, but with aluminium gaining acceptance as an industrial metal for applications in electrical transmission, transportation equipment, construction and packaging and consumer durable goods, demand increased and production increased steadily to average 3 million tonnes for the period 1950-1954.

The increase in aluminium production over this era resulted in average annual world bauxite production increasing from 2.27 million tonnes for the decade of the 1930s to 7 million tonnes in the decade of the 1940s, and 12 million tonnes for the period 1950-1954 with a peak of 14 million tonnes in 1943. Guyana, as a major supplier to the North American aluminium industry, benefited from these developments. With war-time conditions in Europe and European alumina and aluminium production capacity inoperable, most of the increase in world production took place in North America, which between 1940 and 1954 accounted for 65 percent of world production. (Overseas Geological Survey, 1962). Average annual bauxite production in Guyana, increased from 200,000 tonnes for the decade of the 1930s to 1.38 million tonnes for the succeeding decade, with production of 1.98 million tonnes in 1943. Production fell to 750,000 tonnes in 1945 but increased after 1946 to average 2 million tonnes for the period 1950-1954. with the introduction of refractory and abrasive bauxite, which were stimulated by the demand for steel and changes in steel making technology, and by the demand for abrasives for the finishing of metals in the expanding automobile and consumer durable goods industries and the increase in the production of chemical bauxite.

To meet the increase in production during this era, Demba extended its mining operations to Ituni, 40 miles south of Mackenzie, and constructed a railroad to link the two locations. New mines were also developed in the Mackenzie area and improvements undertaken in its mining and processing facilities. The company also made a major change in its shipping logistics to increase the size of shipments to North America with the establishment of a transhipment facility in Trinidad to load ships limited to loading to 40 per cent of capacity in Guyana to their full capacity

This era was also marked by diversification of the product mix of the industry. The first development in 1942 was the start by Berbice Bauxite Company of production s chemical bauxite from the extremely low Fe_2O_3 bauxite deposits near Kwakwani on the Berbice River as a replacement for kaolin for the manufacture of aluminium based chemicals in the United States. The company established a mining operation at Kwakwani 140 miles up the Berbice River and a drying and ship-loading facility at Everton 7 miles from the mouth of the river. The operation was acquired by Reynolds Metals, one of the new entrants to the expanding aluminium industry in 1952, renamed Reynolds Guyana Mines, and added metallurgical bauxite as its primary product. The second development, in 1947, was the installation by Demba of kiln capacity dedicated to the production of refractory and abrasive bauxite.

Production of metallurgical bauxite and alumina for the North American aluminium industry and alumina for export to Europe, started in 1952. This led to an immediate slowing of growth of metallurgical bauxite production in Guyana and, with increasing production of refractory, abrasive, and chemical bauxite, marked the beginning of the change in emphasis of the industry from bauxite for the production of aluminium to bauxite for non-metallurgical applications.

2.1.3 The Era of Product Diversification

The third era effectively marked the end of Guyana's role as a major producer of metallurgical bauxite and the establishment of refractory bauxite as the industry's primary product. The period started with a series of developments that led to a decided shift of metallurgical bauxite production from Suriname, Guyana and the United States, the major three world producers at the time, to Jamaica in the 1950s and to West Africa, Brazil and Australia in the 1960s. The first of these developments, promoted by the entry of Reynolds Metals and Kaiser Aluminium to the North American alumina industry, involved the modification of the Bayer technology to process the mixed monohydrate and trihydrate bauxites discovered in Jamaica, Haiti, and The Dominican Republic. The development was supported by a change in US Government policy that established bauxite and aluminium as strategic materials for the National Defence Stockpile and considered Jamaica a strategically safer location than Guyana and Suriname for the bauxite and alumina for their stockpile requirements. The government therefore provided Marshall Aid financing to companies for the establishment of bauxite mining and alumina capacity in Jamaica with repayment effected by means of purchases of aluminium from their smelters in the United States and bauxite for the Stockpile.

The first stage of vertical integration in the industry occurred during this era with Demba investing in a 350,000 tonnes per year capacity alumina refinery that was commissioned in 1961. This refinery was, however, of basic engineering design to produce low-grade alumina utilising as feedstock, the large volumes of tailings generated by the increase in refractory bauxite production. No expansion of alumina capacity was undertaken during the era even though world alumina capacity increased from 7 million tonnes to 18 million tonnes and alumina capacity was being increased in Jamaica, Suriname, Australia, the United States and Europe.

Refractory bauxite capacity, however, continued to increase, Demba increasing capacity from 375,000 to 525,000 tonnes in 1966 and Reynolds installing capacity of 125,000 tonnes in 1967. By the end of the era, the industry was vertically and laterally diversified producing metallurgical, chemical, refractory and abrasive bauxite and alumina with the share of non-metallurgical bauxite increasing from an annual average of 54 per cent for the first five years of the era to 60 per cent for the last five years.

2.1.4 The Era of Full State-ownership, 1971-1990

The fourth era, 1971-1990, was the period during which the industry came fully under state ownership and control with the nationalisation of Demba in 1971 and Reynolds Guyana Mines in 1975. Demerara Bauxite Company was renamed Guyana Bauxite Company (Guybau) and Reynolds Guyana Mines, Berbice Mining Enterprise (Bermine). While the motivation for the nationalisation of the industry was dissatisfaction with the development of country's bauxite resources in the context of the aluminium industry, Guybau discovered very early, its alienation from the aluminium industry and its near monopoly of the refractory bauxite market. Two market studies, (William Hill, 1972 and Arthur D Little, 1973), commissioned by the company, projected strong growth in demand for refractory bauxite over the next decade, and in response to this, the company directed its total investment programme to increasing production of refractory bauxite. The first phase involved improving the efficiency of the calcining kilns to achieve a 25 per cent increase in capacity between 1972 and 1975 and the second, investment in a new kiln and development of a new mine to increase capacity by a further 25 per cent by 1978. With the acquisition of Reynolds, the industry also increased production of chemical bauxite from around, 150,000 tonnes per year in 1975 to 400,000 tonnes per year by 1980, to take advantage of the increasing demand for this product and declining production in Suriname. These increases were all achieved at the expense of metallurgical bauxite, production of which fell from an annual average of 1.8 million tonnes in 1960-69 to 1.25 million tonnes in 1970-79. The increase in production of the higher value products, together with high metallurgical bauxite prices, resulted in the industry achieving a high degree of profitability over the period 1972-1980 as shown in Table 2.2.

Table 2.2 Guyana Bauxite Industry, Financial Performance

(1972-1980 -(US$)

Year	Sales	Cost of Sales	Gross Operating Profit	Financial, Mktg.& Admin. Exo, Expenses	Net Profit from Operations	Net Profit from Shipping Subsidiary	Other Revenue	Net Income before Tax	Tax	Net Income after Tax
1972[1]	59987	48373	11668	1310	10823	0	510	10870	10687	6034
1973	62083	52752	9328	2064	7604	0	394	7616	3602	3580
1974	96584	77852	18882	2987	16042	0	318	16493	74363	8612
1975[2]	197004	841122	22892	2836	20566	0	511	21077	9513	9875
1976[3]	127764	193793	18893	5207	18608	9714	1240	19849	9714	10134
1977	142992	113553	29412	5216	24233	11687	24760	24760	11687	13073
1978	153868	121830	33521	12613	20990	510	1616	22842	10285	12556
1979	140687	115269	21500	16064	9357	771	942	11071	2556	8515
1980	210214	171926	38288	21919	6360	272	1919	17899	622	12570

[1] Results for Guyana Bauxite Company Limited, only.

[2] Results for Guyana Bauxite Company Limited and Berbice Mining Enterprise Limited

[3] Consolidated results for Bauxite Development Company Limited, comprised of Guyana Mining Enterprise Limited and Guybulk Shipping

Sources:

1.Guyana Bauxite Company Limited. Audited Accounts 1972-1974.

2. Guyana Bauxite Company and Berbice Mining Enterprise Limited, Audited Accounts 1976.

3. Bauxite Development Company Limited Consolidated Accounts, 1976-1980.

The second decade of this era witnessed a dramatic decline in production of all the industry's products and a fall in its income, resulting in it being technically bankrupt by 1990. The change started with the deterioration of the industry's production capability through inadequate investment in the maintenance and replacement of equipment and a dramatic loss of managerial and technical skills. This resulted in refractory bauxite production remaining virtually static for the period 1976-1980, in spite of the increase in production capacity, the continuing high demand for the product and high prices made possible by the industry's monopolistic position in the market.

A fall in the demand for refractories and an increase in the supply of refractory bauxite from other sources and substitutes for refractory bauxite, led to a fall in the demand for Guyana refractory bauxite during the first half of the decade of the 1980s. These developments coincided with a change in demand for higher quality alumina (lower SiO2, and Fe_2O_3) for the production of 99.7 aluminium metal, and reduction in the percentage of fines (-325 mesh Tyler) demanded by environmental regulations. This made it necessary for the company's alumina refinery to be substantially modified and its inability to finance the necessary modifications resulted in the refinery being closed in 1982. The combined effect of lower levels of production on the industry's financial position and on the country's economy, led to the government having to resort to international lending agencies for financial assistance for the industry and having to change its policy on state ownership to satisfy the agencies' conditions for financial assistance and agree to structural and organisational changes in the industry that shaped its development over the next era.

2.1.5 The Era of Divestment 1990-2000

The change in government policy on ownership of the industry had the immediate effect of attracting investment in a major new bauxite project involving a 50:50 joint venture between Reynolds Metals and the Government with Reynolds undertaking the management of all aspects of the operation. This project was commissioned at the end of 1990, and by the end of 1992, resulted in a 40 percent increase in overall bauxite production. A second development during this period was the restructuring of the state-owned sector of the industry, Guymine was dissolved in 1992 and its two operating divisions Linden and Berbice, incorporated as separate companies, Linden Mining Enterprise (Linmine) and Berbice Mining Enterprise (Bermine). Linmine, in keeping with the international lending agencies' conditions for financial assistance, was placed under the management of a foreign contractor, Mining and Engineering Services (Minproc), of Australia with the objective of improving its attractiveness for divestment, while Bermine continued under local management pending its absorption by the joint-venture Reynolds project.

Both these developments were unsuccessful. The Reynolds joint venture project, while increasing metallurgical bauxite production, became unprofitable after 1995 through higher than projected investment and operating costs, and with the acquisition of Reynolds Metals by Alcoa in 2000 and the restructuring of Alcoa's alumina operations, Alcoa sold its shares in the project to the Government. The effect of this was that the entire industry came under state control at a time when the government was in the process of reducing its shareholding in the fully state owned companies. The management of Linmine by Minproc was also unsuccessful. The new management, immediately upon assuming control of the company reduced the scale of operations to an uneconomic level and adopted a strategy of confining its activities to the production of refractory bauxite, at a time of falling demand, increasing consumption of Chinese bauxite, the entry of Brazil to the market and falling prices for the product. Refractory bauxite sales fell continuously after 1992, and by 2000, had reached the point where production was only 15 percent of its 1975 peak and Guyana's share, 12 per cent of the world market.

In accordance with its new policy on ownership and control of the bauxite industry, the Government made two unsuccessful attempts to privatise Linmine and one to privatise Bermine. The reasons for the failure at privatisation would be discussed in greater detail in a later section of this study.

2.2 The Products of the Guyana Bauxite Industry

Bauxite is normally associated with the production of aluminium; approximately 94 per cent of world production in 2000 used for the production of alumina, 94-95 per cent of which, was used for the production of aluminium. Of the remaining 6 per cent of world bauxite production, about 30 per cent is used in crude form for the production of aluminium chemicals, Portland and high alumina cements, and as flux in a number of metallurgical processes. The remainder is calcined for the production of refractory bauxite for the production of high alumina refractories, and abrasive bauxite for the production of fused alumina for the production of abrasives, refractories, and proppants for the oil and gas extraction industries. The 5-6 per cent of alumina production not used for the production of aluminium is used in the manufacture of aluminium chemicals or further processed for use in the manufacture of refractories, abrasives and ceramics. The unique chemical, mineralogical composition and physical properties of the Guyana bauxite resources have resulted in the evolution of the diversified product mix that identifies the industry from those of the other bauxite producing countries. This has made the Guyana industry subject to different economic, technological and market forces from those of countries dependent on the aluminium industry. While the initial development of the industry was based on the production of metallurgical bauxite, and its later development on the production of refractory bauxite, it has also produced alumina, chemical and abrasive bauxite. This feature underlies the importance of a description of the products of the industry, their specific properties and industrial applications, and the dynamics of the markets in which they compete, for an understanding of the direction of its growth, its eventual decline and its future prospects.

2.2.1 Metallurgical Bauxite and Alumina

Metallurgical bauxite, or metal-grade bauxite, is a generic term applied to all bauxite used for conversion of bauxite to alumina (Al_2O_3) which is the raw material for the production of aluminium. While Al_2O_3 is found in nature in the minerals corundum, diaspore, boehmite and gibbsite, so far no process has been developed for the extraction of aluminium metal direct from any of these minerals, hence the Al_2O_3 must first be extracted and then converted to aluminium. The Bayer process that made it technically and economically feasible for Al_2O_3 to be extracted from bauxite, has undergone various modifications over the years to treat bauxite with different chemical, mineralogical and physical characteristics, and to improve process efficiency. The process has, however, remained basically unchanged since it was patented in 1888 and involves: (1) the digestion of bauxite in a hot, concentrated, caustic soda solution at elevated pressure to dissolve the hydrated aluminium oxides, (2) the separation of the hydrated aluminium oxides in the form of a liquor from which the insoluble residues are disposed as waste and the liquor washed to remove all traces of residues and caustic soda, (3) the seeding of the liquor with aluminium trihydrate to form aluminium trihydrate crystals and (4) calcination of the aluminium trihydrate in rotary or fluidised bed calciners to produce calcined alumina for conversion to aluminium metal. About 5-6 per cent of the alumina trihydrate is retained for the manufacture of aluminium chemicals, or sintered or fused for the production of sintered, tabular or fused alumina for abrasive, refractory and ceramic applications.

The Bayer process started with two major variations--the European process for refining boehmitic bauxites found in Europe and the American process for the gibbsitic bauxites found in the United States, Guyana and Suriname. The discovery of bauxite ores in the Caribbean Islands--Jamaica, Haiti, The Dominican Republic-- and Australia, after the War, with different chemical, mineralogical and physical characteristics led to modifications of the basic process to economically process a greater variety of ores, and to a change in the specifications for metallurgical bauxite which resulted in materials, initially not even classified as bauxite, currently accounting for nearly 50 per cent of world metallurgical bauxite production.

Metallurgical bauxite for export is normally shipped in crude form with beneficiation confined to crushing, to reduce lump size, washing and screening to remove clay and other extraneous minerals, and drying to reduce moisture content to improve handling and reduce shipping cost. Where bauxite is refined at the source, it is normally fed direct to the refinery except in the case of low grade bauxites which must undergo various forms of beneficiation to remove excess silica, organic chemicals, pyrites and other impurities.

Table 2.3 shows the United States Bureau of Mines specifications for metallurgical bauxite for the Government Strategic Stockpile, and the analysis of metallurgical bauxite from the major producing countries currently used for the production of alumina.

Table 2.3 Metallurgical Bauxite Specifications US Bureau of Mines and Industry Analyses

Source	(Al_2O_3 (% min.)		(SiO_2) (% max.)		(Fe_2O_3 (% max.)	(TiO_2) (% max.)	(P_2O_5) (%max.)	Total Alkalis (%max.)	$MnO_2+Cr^2O_3$ $+V_2O_5$ (% max.)	Loss on Ignition (L.O.I)
	Total	Available	Total	Reactive						
U.S.B.M 1946	55.00	n.s	7.0	n.s	8.0	4.0	-	-	-	-
U.S.B.M 1958 Surinane Type	55.00	n.s	5.00	n.s	8.0	-	I.0	1.0	2.0	50%/ Al_2O_3
U.S.B.M- 1958- JamaicaType	47.00	ns	4.0	ns	10.0	-	1.0	1.0	2	40% / Al_{203}
Guinea - Boke	55-60	52-56	2.0	1.5	3-8	2-3	-	-	-	22-25
Guinea -Kindia	48-52	47-49	2-4	1-3	17	1-3	-	-	-	25.0
Brazil - Trombetas	54-56	49-50	5,0	4.o	9-12	1.5	-	-	-	28.5
Brazil- Poco de Caldas C	46-54	4.4-5-0	5-6	3-4.5	11	2-3	-	-	=	28.5
Guyana - Bermine	57-58	52-53	6.0	4.5	5.5-7.0	2.5	-	-	-	30.5
Jamaica - Clarendon	48-50	47.0	2.0	I.0	17-20	1-2	-	-	-	25-26
Suriname -Onverdacht	58-59	52.0	5.0	4.0	4-5	2.5	-	-	-	30.0
Suriname -Moengo	56.0	50.0	5.0	4.0	5-8	2.5	-	-	-	29.6
Venezuela - Pijiguaos	48.0	46.0	12.0	1.5	1.0	1.50	-	-	-	28.5
Australia Gove	50.0	48.0	4.0	3.0	17.0	2.0	-	-	-	26.0
Australia -Jarrahdale	32.5	28-30	15-22	2-3	15	1	-	-	-	26.5
India - Gujuarat	52-56	49-51	4.5	3-4	8-10	4.5	-	-	-	27-29
India - Bihar	45-55	42-50	3-4	3	22.4	3.5	-	-	-	26.2

Sources:

1. Appraisal of Minerals Availability for 34 Commodities, U.S Bureau of Mines, Bulletin, Professional Paper 1076-B 692, 1987.
2. World Bauxite Resources, U.S Geological Services, 1986.
3. Bauxite Mines World-wide, U.S Bureau of Mines 1994..

All bauxite found in Guyana, and included in its resources, satisfy even the 1940 United States Government Stockpile specifications for metallurgical bauxite and could therefore be converted to alumina by any of the variations of the Bayer process utilised by the industry. The classification system used by the domestic industry, however, classifies only ore with Fe_2O_3 of two to 10 per cent, average available Al_2O_3 in excess of 50 per cent and total SiO_2 of 1-10 per cent as metallurgical bauxite. This very restrictive classification excludes, from the country's resources, large quantities of ore of similar quality to those included in the resources, mined as metallurgical bauxite and converted to alumina in the other major bauxite producing countries.

The high Al_2O_3 and low SiO_2 content of Guyana bauxite make it possible for most of the material mined to be shipped with only crushing and drying. However, washing was undertaken at the Linden Operations to increase the limit of SiO_2 in the ore being mined. The country's metallurgical bauxite has, however, throughout its history, maintained an available Al_2O_3 of 50-53 per cent, and, based on its identified resources, is capable of maintaining that quality for more than 300 years at the current level of exploitation.

2.2.2 Chemical Bauxite

The product classified as chemical bauxite varies considerably from one producing country to another--a wide range of bauxitic materials varying from 1-5 per cent F_2O_3, 45-62 per cent Al_2O_3 and 4-20 per cent SiO_2 categorised as chemical bauxite. The material produced in Guyana is of the highest quality with typical Al_2O_3, SiO_2, and Fe_2O_3 of 60 per cent, 6 per cent and 1.5 per cent, respectively, and is produced by selectively mining bauxite with the appropriate chemical composition, crushing to reduce lump size and drying to reduce free moisture. The process utilises the same facilities as those used for the production of metallurgical bauxite.

The major application for chemical bauxite is the production of aluminium sulphate for use in water clarification, paper manufacture and sewerage treatment. Small quantities are used for the production of aluminium chloride, activated bauxite, refractory grade calcium aluminate cement and white Portland cement. The high Al_2O_3 and lower SiO_2 content of chemical bauxite and consequently lower level of waste, led to it replacing bauxitic clays and kaolin in the United States and Europe as the source of Al_2O_3 for the production of aluminium sulphate in the 1940s. Consumption increased in the 1970s with the increase in environmental regulations and cost of waste disposal, improvements in the quality of water in both developed and developing countries and increase in paper production. It is, however, still in competition with kaolin and bauxitic clays at locations where these materials are available close to the aluminium sulphate production facilities or where environmental restrictions are less stringent. Lower quality bauxite and bauxitic clays found in Australia, India, Indonesia and several African and Latin American countries are also used for the production of aluminium sulphate and sometimes classified as chemical bauxite.

Alumina trihydrate produced from metallurgical bauxite by the Bayer process is the principal substitute for chemical bauxite, its high purity--

Fe_2O_3, SiO_2 and TiO_2, less than 0.03 per cent--making it more suitable for the production of low Fe_2O_3 aluminium sulphate for the manufacture of high quality paper. Increasing environmental regulations in North America and Europe have led to this product replacing chemical bauxite for the production of aluminium sulphate for water treatment over the past fifteen years. Current annual world production of chemical bauxite is estimated at 700,000 tonnes with 350,000 tonnes exported and the remaining 350,000 tonnes consumed in domestic aluminium sulphate production. Overall production has been considerably reduced since the 1980s through the replacement of chemical bauxite by aluminium trihydrate, replacement of aluminium sulphate for water purification by poly-aluminium chlorides, the use of higher Fe_2O_3 sulphate in sewerage treatment, and the conversion from acid to neutral and alkali processes in paper manufacturing.

Table 2.4 shows the typical chemical analysis of chemical bauxite from the major supply sources.

Table 2.4 Chemical Grade Bauxite, Major Sources
Detailed Chemical Analysis

Chemical Elements	**(%)**	**Guyana**	**Brazil**	**Malaysia**	**United States**
Loss On Ignition	(L.O.I)	31.0	29.00	27.50	32.0 0
Silicon Oxide	(SiO_2)	5.50	9.0.00	9.0 0	21.00
Ferric Oxide	(Fe_2O_3)	1.25	3.20-5.00	3.50	2.50
Titanium Oxide	($TiO_{2)}$)	3.00	1.00-3.00	2.00	3.00
Aluminium Oxide	($Al_2O_{3)}$)	60	57.00	57.50	42.00
Potassium Oxide	(K_2O)	< 0.02	n.a	n.a	n.a
Magnesium Oxide	(MgO)	< 0.01	n.a	n.a	n.a
Phosphorus	(P_2O_5)	< 0.10	n.a	n.a	n.a
Moisture	(H_2O)	5.00	5.00	7.00	n.a
Organics (Chemical Oxygen Demand)		<0.35	n.a	n.a	n.a

Source:
1. Bauxite Mines World-wide USBM 1994.
2. Analysis of Guyana Chemical Bauxite, General Chemical Corporation, Syracuse Laboratory.1988,

2.2.3 Refractory Bauxite

Production of refractory bauxite constitutes the second largest application for bauxite, current world production estimated at 1.1 million tonnes utilising approximately 3.5 million tonnes crude bauxite. Refractory bauxite is used as the raw material for the manufacture of refractory bricks and other shapes, and for monolithic refractory products, such as plastics, castables, cements and gunning and ramming mixes. Small quantities are also used as flux in welding rods and in a number of metallurgical processes, and for skid resistance on highways, airline parking aprons and industrial floors. The steel industry is the largest consumer of products made from refractory bauxite which find applications at every stage of the process; significant quantities are also used in the aluminium, cement, glass and ceramics industries. The desirable properties of bauxite based refractories in the steel-making process are high refractoriness (refractory bauxite having a PCE value of 38 and a melting temperature of 2200o C), resistance to thermal stress and other heat induced physical stress, high resistance to physical wear and corrosion by chemical agents, ability to withstand thermal shock and abrasion and the very desirable property of re-heat expansion.

Refractory bauxite is a product of the post-war era--commercial production starting around 1947. The product belongs to the group of naturally occurring materials classified as alumino silicates, ranging in aluminium oxide (Al_2O_3) content from 20 to 90 per cent on a calcined basis, and includes: (1) fireclays, flint clays and kaolin, with Al_2O_3 content of 20-45 per cent, (2) the sillimanite group minerals--sillimanite, andalusite and kyanite, classified as mid-aluminas, with Al_2O_3 content of 50-70 percent, and (3) bauxite with Al_2O_3 content of 70-90 per cent. Included in the group for refractory applications, are: (1) synthetic mullite, produced by blending and sintering alumina and silica to produce a material with 72 per cent Al_2O_3 and 28 per cent SiO_2 and (2) materials produced in the South-east United States by the homogenisation and sintering of mixtures of bauxitic clays, kaolin and bauxite to produce a range of products marketed under the brand name Mulcoa, with Al_2O_3 content of 50-70 percent. The synthetic alumina materials, classified as extra-high alumina with Al_2O_3 content of 93-99 per cent, comprising brown and white fused alumina produced by the electro-fusion of calcined bauxite or calcined alumina, respectively, and sintered and tabular alumina produced by high temperature sintering of calcined alumina- are also sometimes included in the alumino silicate group. While materials spanning the entire high alumina spectrum are used in refractory applications, the industry classification of refractory bauxite applies only to materials with Al_2O_3 content of 80-92 percent that are the materials covered by this study.

Refractory bauxite is produced by heating selectively mined or beneficiated bauxite ore of the appropriate chemical composition, in rotary, vertical shaft or round down-draught kilns, at temperatures of 1650-1750°C. This process, described as calcination, results in the complete elimination of free moisture and water of crystallization from the ore. The product is then held at the elevated temperature for an extended period to increase density and reduce porosity, resulting in a dense, dead-burned, volume-stable product with chemical and mineralogical composition and crystalline structure different from those of the original ore. The product is shipped, run-of-kiln or crushed and sized, to producers of refractory products, who undertake further crushing, grinding, sizing and blending to produce shaped refractories and materials for the production of monolithic refractory products.

Guyana's total production of refractory bauxite is undertaken in rotary kilns, in contrast to its main competitor, China, where the major part of the production is undertaken in vertical shaft and round down-draught kilns. The process in Guyana involves the mining of ore with Fe_2O_3 content of 0.5-2 per cent, SiO_2 of 1.5-10 per cent and Al_2O_3 of 59-61 per cent. The ore is first crushed and washed to achieve an average of 4 per cent SiO_2, then screened to eliminate particles less than

150 microns (100 mesh Tyler). The concentrated material is then fed to oil-fired rotary kilns heated to a temperature of 1700-1750°C, and cooled in a rotary cooling chamber after emerging from the kilns, for storage and shipment. This process results in a conversion factor from crude ore to finished product of 25 per cent.

Table 2.5 shows the detailed chemical analysis of the crude ore and the typical chemical, physical and mineralogical properties of the finished product resulting from this process, while Table 2.6 compares the chemical composition of Guyana refractory bauxite and that from the other major sources.

Table 2.5 Guyana Refractory Bauxite Detailed Chemical Analysis

Chemical	**Crude Ore**	**Finished Product**	
	Typical (%)	**Typical (%)**	**Range (%)**
Aluminium Oxide	60.00	89	87.25-91.20
Silicon Oxide	4.00	7.00	5.00- 7.00
Ferric Oxide	1.00	1.25	0.83-1.25
Titanium Oxide	2,20	3.20	2.82-3.60
Sodiun Oxide	<0.01	0.00	0.00-0.02
Magnesium Oxide	<0.00	0.00	-
Phosphorus Oxide	<0.05	0.00	0.04-0.07
Potassium Oxide	<0.01	0.00	0.02-0.00
Calcium Oxide	<0.01	0.01	0.00-0.03
Chromium Oxide	<0.09	0.00	0.08-0.13
Manganese Oxide	0.00	0.00	-
Zirconium Oxide	<0.00	0.00	-
Gallium Oxide	<0.05	0.00	0.01-0.15
Zirconium Oxide	0.165	0.15	0.150 -0.168
Barium Oxide	< 0.014	0.014	0.01-0.02
Lead Oxide	<0.001	0.001	0.000-0.003
Loss On Ignition	31	0	0.10 -0.20
Moisture	15.0	0.00	0.15-0.20
Physical			
Bulk Specific	2	3.15	3.1-3.25
Porosity	30.00	14.00	10.00-15.00
Mineralogy			
Gibbsite	100	-	-

Sources

1. Guyana Mining Enterprise, Internal Company Information
2. Laboratory For Multi-element Analysis, Sleeuwijk, Netherlands, 1995

Table 2.6 Refractory Bauxite, Major Sources
Typical Analysis

Chemical Elements (%)		**Guyana**	**China "A"**	**China "B"**	**Brazil**
Aluminium Oxide	(Al_2O_3)	89.00	88.00	83.00	84.00
Silicon Oxide	(SiO_2)	6.00	5.00	7.00	10.00
Ferric Oxide	(Fe_2O_3)	1.50	2.00	2.00	2.5-3.00
Titanium Oxide	(TiO_2)	3.20	3.90	4.50	2.00
Magnesium Oxide	(MgO)	< 0.02	na	na	< 0.05
Phosphorus Oxide	(P_2O_5)	< 0.04	0.10	0	< 0.05
Chromium Oxide	(Cr_2O_3)	< 0.025	0.10	0.10	< 0.04
Calcium Oxide	(CaO)	< 0.02	0.20	0,20	<0.04
Potassium Oxide	(K_2O)	< 0.03	0.10	0,15	< 0.06
Sodium Oxide	(Na_2O)	< 0.02	na	na	< 0.05
Zirconium Oxide	(ZrO_2)	0	na	na	n.a
Loss on Ignition	(L.O.I)	0.15	0	0	0.00
Moisture	(H_2O)	0	2.00	2.00	0
Physical Properties					
Bulk Specific Gravity (BSG)		3	3.30	3	3.05

Sources:

1. Refractories Production and Properties, J.H. Chesters, 1983.
2. Technology of Monolithic Refractories, Akira Nishikawa, 1984.
3. Evaluation of Markets for Calcined Bauxite in Westen Europe and Japan. Arthur D. Little, 1973.
4. Study of the North American Market for Refractory Bauxite, William Hill, 1972.
5. Bauxite Industry Development Company Guyana, Product Specifications 1975-2000.

2.2.4 Abrasive Bauxite

The production of abrasive bauxite constitutes the third largest application for bauxite, current annual world production estimated at 900,000 tonnes, utilising approximately 2.0 million tonnes crude bauxite. About 75 per cent of world abrasive bauxite is used for the production of brown fused alumina, which is produced by the electro-fusion of a mixture of abrasive bauxite and coke in an electric arc furnace at a temperature in excess of 2,000OC. The finished product is used for the production of coated abrasives, grinding wheels, abrasive papers and refractories. The remainder is used for the manufacture of ceramic proppants, which are spheres of 1.0 to 3.5 mm diameter, produced by sintering a mixture of abrasive bauxite and clay at a temperature of around 2,000OC. Proppants are used in the hydraulic fracturing of rocks in the oil and gas extraction industries. The spheres are mixed into a slurry which is pumped under very high pressure into wells to form a fracture in the rock formation. The hydraulic pressure is then released, and the proppants remain as a prop in the fracture, to keep it open and create a path through the flow of oil and gas is increased. Small quantities are abrasive bauxite are also used for the manufacture of calcium aluminate cement.

Abrasive bauxite is produced by a process similar to that for the production of refractory bauxite, the major differences being the chemical composition of the ore, the calcination temperature and calcination period. Material for the production of fused alumina could be produced from ores with Fe_2O_3 content as high as 5 per cent, SiO_2 of 5 per cent, and a calcination temperature of 1100-1200C compared with 1.5 per cent, 4 per cent 1,650-1,750^{o}C, respectively, for refractory bauxite; material for the manufacture of proppants could tolerate Fe_2O_3 and SiO_2 levels of 6 per cent and calcination temperatures of 900-1000o C. Technical and economic factors in the production of fused alumina, however, impose very stringent lower limits on Al_2O_3, upper limits on SiO_2 and TiO_2 and a very sensitive SiO_2:Fe_2O_3 ratio. These specifications restrict the production of acceptable material to a small number of bauxite producing countries and make it difficult from any one source to be used for the production of high quality fused alumina. The normal practice in the industry, therefore, is to use a blend of materials from various sources to achieve the best levels of Al_2O_3, SiO_2 and TiO_2 and add iron filings to the blend to control the SiO_2 : Fe_2O_3 ratio.

Production of abrasive grade bauxite started in Guyana in 1938 but never achieved a significant level since it utilises the same production facilities as refractory bauxite that was always in short supply and was a more profitable product. Production ceased between 1970 and 1980 and was only resumed on a limited scale after 1980 following the fall in demand for refractory bauxite. Suriname became the major producer in the early 1960s followed by Australia, but after the discontinuation of production in Suriname in the early 1980s, Guinea, United States, China and Brazil became producers. Guyana continued production on a limited scale, aimed at market niches where consumers are prepared to pay a higher price for material with low Fe_2O_3 and TiO_2 and low levels of other impurities for purposes of blending.Table 2.7 shows the chemical composition of the ore used for the production of abrasive bauxite in

Guyana and that of the finished product compared with those from the other producing countries.

Table 2.7 Abrasive Bauxite, Major Sources
Ore And Finished Product
Specifications

Chemical Elements (%)		**Guyana**		**Other Producing Countries - Product**				
		Ore	**Product**	**USA**	**Australia**	**Guinea**	**China**	**Brazil**
Aluminium Oxide	(Al_2O_3)	57.00	86.00	80.00	84.00	91.00	87.00	80.00
Silicon Oxide	(SiO_2)	4.00	5.50	7.50	7.00	1.70	6.00	8.00
Ferric Oxide	(FeO_3)	4.00	6.00	6.50	7.30	5.20	3.00	7.00
Titanium Oxide	(TiO_2)	2.50	3.60	3.25	4	5.00	6.0	1.50
Magnesium Oxide	(MgO)	< 0.02	< 0.02	n.a	n.a	n.a	n.a	n.a
Potassium Oxide	(P_2O_5)	< 0.025	< 0.025	n.a	n.a	n.a	n.a	na
Chromium Oxide	(CrO_2)	< 0.015	< 0.015	n.a	n.a	n.a	n.a	n.a
Calcium Oxide	(CaO)	< 0.01	< 0.01	n.a	n.a	n.a	n.a	na
Loss on Ignition	(L.O.I)	30.50	0.00	3.00	1.00	1.00	0.50	2.00
Moisture	(H_2O)	15.00	0.00	0.00	0.50	1.00 0	2.00	1.00

Sources:

1 Internal company data, Guyana Bauxite Company. Guyana.
2.Internal data on analysis of Refractory bauxite from various sources, Washington Mills, North Grafton Massachusetts.
3.Internal data on abrasive bauxite from various supply sources. Exolon/ESK Tonowanda, New York, United States.
4.Internal analysis of ABRASIVE bauxite from Triebacher Scheimetal, Villach, Austria.
5.Specifications of Australian abrasive Grade Bauxite for the manufacture. of Proppants, Carbo Ceramics New Iberia, Louisiana.
6.Specifications of Abrasive bauxite produced by Norton Proppants for the manufacture of proppants, Norton Proppants, Little Rock, Arkansas.

Chapter 3

COMPETITIVENESS IN METALLURGICAL BAUXITE PRODUCTION

3.1 Metallurgical Bauxite Alumina

The almost six-fold increase in bauxite production in Guyana and its rise to the position of supplying 19 per cent of world bauxite demand over the decade of the 1940s was directly attributable to: (1) the increase in the demand for aluminium for aircraft production during the Second World War, followed by increased demand for applications in electrical transmission, transportation, packaging, construction and consumer durable goods in the years immediately following the War; (2) Guyana's endowment with relatively large trihydrate bauxite resources, compatible with the American Bayer process utilised exclusively by the North American alumina refineries; (3) the high available Al_2O_3 content of the Guyana ore that made it desirable for blending with the Arkansas, Alabama and Georgia ore in the United States; (4) Guyana's geographical location in relation to the North American alumina refineries in terms of distance and the safety of shipping under war-time conditions; and (5) the existence of infrastructure and production capacity that could be rapidly expanded to meet the sudden increase in demand imposed by the War. Over this period the only bauxites that could be economically processed in the North American alumina refineries were those from the United States, Suriname, and Guyana, hence these three countries enjoyed a monopoly on bauxite supply to North America which accounted for almost two thirds of world aluminium production.

The rapid increase in demand for aluminium led to a desperate search by the aluminium industry for new bauxite resources and promoted research to modify the American Bayer technology to economically process the mixed trihydrate and monohydrate bauxites discovered in the Caribbean Islands just before the war. The size of the Jamaica resources, their low overburden, and the shipping advantages over Guyana and Suriname made them attractive to the North American companies who were prepared to invest in the modification of the existing alumina refineries to utilise the Caribbean Islands bauxite. They were also prepared to invest in new mining and refining capacity in Jamaica instead of investment in expansion of bauxite production in Guyana in the decades of 1950s and 1960s. The discovery of large, high grade, low overburden resources in Ghana and Guinea, the Cape York and Gove peninsulas in Australia, and South East Brazil and the later discovery of massive deposits of low grade trihydrate bauxite in South West Australia and high grade trihydrate resources in the Amazon region of Brazil, led to a total cessation of investment in Guyana.

World bauxite production continued to increase at a high rate over the next six decades, increasing 78 per cent each decade between 1940 and 1980, and a further 34 per cent between 1980 and 2000. Production in Guyana, however, increased only 12.7 per cent each decade between 1940 and 1980 and fell 18 percent over the next two decades. Guyana's performance in the production of metallurgical bauxite was even worse.

While metallurgical bauxite accounted for 94 per cent of the increase in world production over the period, average annual production of this product in Guyana remained static over the period 1950 to 1980. Production fell 50 per cent between 1960 and 1980 and increased only in the decade of the 1990s to return to the level of the decade of the 1950s.

The stagnation of production in Guyana and the diversion of investment have been attributed to loss of competitiveness through the high cost of mining ore deposits with overburden thickness of 30-70 metres compared with 1-3 metres in the new resource endowed countries, and the high cost of shipping associated with the limited draught at its bauxite loading ports. While there is validity to the argument of high mining and shipping costs, it is necessary to undertake a more comprehensive analysis of the economic factors that determine competitiveness of a product like metallurgical bauxite. It is also necessary to evaluate a number of non-economic factors that influence investment decisions on the timing and location of metallurgical bauxite and alumina capacity to determine the extent to which these factors contributed to the diversion of investment from Guyana.

3.1.1 Economic Factors

Metallurgical bauxite is not a standardised or a final product--its primary application being the raw material for the production of alumina, hence the cost of producing alumina should be the measure of competitiveness of bauxite from different sources. An evaluation of the elements of cost at the various stages of the production process from the mining of bauxite through the production of alumina, together with the pricing mechanisms for metallurgical bauxite are therefore essential to determine the true competitiveness of Guyana bauxite. The elements of cost to be considered are: (1) investment and capital cost for establishing bauxite mining operations; (2) operating and total cost for bauxite mining operations; (3) alumina production cost; (4) bauxite shipping cost; and (5) the pricing mechanisms for metallurgical bauxite.

3.1.1.1 Investment and Capital Cost

Bauxite production is a highly capital intensive activity, and hence the amortization of capital is a substantial component of total production cost. Comparison of the investment for the establishment of bauxite projects is therefore important to determine the impact of capital cost on total production cost. The size of bauxite mining projects has varied considerably over time and from one country to another; the start-up capacity of projects in the 1950s and 1960s being 500,000 - 1.0 million tonnes per year. The minimum economic start-up capacity of new projects at the current time is between 3 million and 5 million tonnes per year with projects expanded to capacities in excess of 12 million tonnes per year in Australia, Brazil and Guinea. Total and unit investment cost and capital cost for new projects and expansion of existing projects also vary widely for projects around the world.

The basic technology of bauxite production has not changed over the years--95 per cent of current world production still mined by open-cast techniques and beneficiation of metallurgical bauxite confined to crushing, washing, screening and drying, utilising variations of the same basic techniques. The production sequence and the scope of the various activities, however, vary significantly from one country to another and even from one operation to another in the same country. The production sequence involves: (1) clearing of vegetation by bulldozers; (2) construction of access roads to the mine and haulage roads or other facilities for the transport of ore to the port or processing plant; (3) establishment of infrastructure such as housing, water, power and roads; (4) stripping of overburden which, in deposits with low overburden, is undertaken by bulldozers, scrapers and power-shovels, and in deposits with high overburden, by scrapers, walking draglines, wheel-excavator and conveyor systems, power shovels or back-hoes and trucks and high-capacity suction dredges where deposits are located in swamps or close to large supplies of water; (5) mining of ore utilising draglines, power shovels, back hoes and front end loaders with blasting to loosen the ore in deposits where it is hard and compacted; (6) loading the mined ore to trucks, rail-cars, or conveyor systems for haulage to mine stockpiles, barge loading facilities, or direct to the processing plant; and (7) beneficiation which involves varying degrees of crushing, washing and screening to remove impurities such as clay and quartz, limestone and other extraneous minerals, and drying to reduce free moisture to improve handling and reduce shipping cost, where the ore is for export.

While the basic activities are similar, the cost of establishing new bauxite mining projects vary widely from one operation to another depending to the scale of the operation, the geographical location and geological structure of the deposits, the physical features of region, the physical characteristics of the overburden and the ore, the distance of the mines from the port, the operating sequence and nature of the activities at the various stages and the availability of infrastructure. The unavailability and unreliability of data on investment cost for the establishment of new bauxite projects and expansion of existing ones, especially in the 1950s and 1960s make precise comparisons of capital cost extremely difficult. A significant amount of data and information on investment in bauxite projects have become available since that time (US. Bureau of Mines 1983 and 1987; International Bauxite Association, 1978; Australian Mineral Economics, 1981 and 1993). But even these suffer from serious discrepancies and inconsistencies on critical parameters such as installed capacity, allocation of investment between infrastructure and productive assets, and between bauxite and alumina production in integrated projects. These deficiencies seriously limit the accuracy of much of the data for meaningful comparative cost analysis. Table 3.1, based on data on investment and installed capacity from Australian Mineral Economics, International Bauxite Association and US Bureau of Mines, and utilising the industry standard of a 20 year amortization period and a 15 per cent discount rate for evaluating projects, show total and unit investment and unit capital cost for new bauxite projects. The data show unit investment cost varying from US$3.50 to US$14.60 per annual tonne of capacity with the lowest cost being that for the Aroaima project in Guyana and the highest for Los Pijiguaos in Venezuela. Table 3.2 shows estimated investment and capital cost for expanding mine production at two existing locations in Guyana (Alcoa Minerals and Chemicals, 1999 Page 4) compared with the published estimated cost for expansion of production in Trombetas, Brazil (U.S Geological Survey, 1997).

The data reveal that, in spite of high investment in equipment for stripping overburden in Guyana, the investment and capital cost for the development of new, and for expanding existing bauxite projects are lower than those for most of the other bauxite producing countries. This is attributable to: (1) the geographical location and accessibility of the Guyana bauxite deposits; (2) the physical features of the terrain over which bauxite is transported; (3) the proximity of the bauxite deposits to navigable rivers for internal transport; (4) the existence of basic infrastructure; and (5) the availability of idle capacity that could be expanded at relatively low cost.

Table 3.1 Investment And Capital Cost
Major Bauxite Projects
1970-1990

Mine / Country	**Annual Capacity (000 mt)**	**Investment Cost**		**Amortization / US$ /tonne annual production**
		Total (US$000)	**Unit (US$ /tonne annual capacity)**	
Trombetas -Brazil *	6,000	230,000	38.33	6.10
Paragonias -Brazil	7,000	480,000	77	10.00
Lyledorp - Suriname *	2,500	85,000	34.00	5.40
Mt Saddlebrook- Australia *	8,000	500,000	62.50	10
Tougue - Guinea	8,000	242,000	30	4.85
Kidi - Ghana	2,000	184,000	92.00	14.70
Aroaima- Guyana *	2,500	50,000	20.00	3.20
Los Pijiguaos - Venezuela *	6,000	550,000	91.66	15
Ituni - Guyana	1,500	40,000	27	4.25
Boke - Guinea *	6,000	400,000	67	11.80
Weipa - Australia *	11,000	319,000	29.00	4.65
Orissa - India *	2,500	85,000	34.00	5.43

* Projects implemented.

Sources

1. U.S Bureau Of Mines, An Appraisal Of Mineral Availability For 34 Commodities, Bulletin 692, 1987.
2. Bureau of Minesu, Aluminium Availability, Market Economy Countries, Information Circular 8917, 1983.
3. Guyana Bauxite Company, Internal Records, Appraisal of Ituni Bauxite Project, Guyana, 1994.
4. Reynolds Metals Internal Records, Appraisal of Aroaima Bauxite Project, Guyana, 1989.
5. N.V Billiton Maatschappij, Suriname, Internal Records, Appraisal of Lyledorp Bauxite Mine, 1995.
6. Sierra Leone Mining Company, Internal Records, 1991..

Table 3.2 Expansion Of Bauxite Mining Projects Estimated Investment And Capital Cost

(1999 US$)

Mine / Country	**Annual Capacity (000 mt)**	**Investment Cost**		**Amortization (US$ /tonne annual production)**
		Total (US$000)	**Unit (US$ /tonne annual capacity)**	
Linden-Guyana[1]	2,500	31,200	125.00	2.00
Linden-Guyana	5,000	53,400	96.00	1.70
Kwakwani-Guyana	2,500	31,200	125.00	1.99
Kwakwani- Guyana	5,000	47,900	95.00	1.53
Trombetas (1998)	3,000[1]	90,000[2]	30`.00	5.80
Trombetas[2]	5,000	200,000	40.00	6.20

[1] The data for Guyana do not include the cost of expansion of processing capacity or improving shipping capability.The estimate for processing capacity is US$10 million and US$17.5 million for 2,500,000 tonnes and 5,000,000 tonnes respectively at either location. The estimated cost for improving shipping capacity is estimated at US$20 million for 2,000.000 and US$30 million for 5,000,000 tonnes at either location.

[2] The expansion of the Trombetas project is currently under construction and due to be commissioned by the end of 2002.

Sources:
1.Feasibility Study of Guyana Bauxite Mining Operations, Alcoa 1999.
2.Commodity Review, U.S Geological Survey, Mineral Industry of Brazil, 1997.

3.1.1.2 Operating and Total Cost

The primary elements of operating cost for the production of metallurgical bauxite are diesel fuel and electric power for the operation of mining and transportation equipment, fuel for drying, operating supplies and spare, maintenance of mining, transportation and processing equipment, labour and administrative expenses, while total cost includes the cost of amortizing capital. Published data on cost for bauxite production (US Bureau of Mines, 1987 and International Bauxite Association, 1984) show considerable variation and present difficulties of interpretation because of inadequate information on the production sequence, mining techniques, transportation methods, differences in data collection and classification, differences in costing methodology and the classification of cost elements associated with the mining, haulage and processing activities, the time period to which they apply, and the sources from which they are obtained. The values also are significantly different in several cases from those provided in discussions with the operating companies in some of the producing countries (Discussions with Sierra Leone Mining Company (Sieromco), 1991; Billiton, Suriname, 1997 and Guymine, Guyana, 1975-1990), and appear, in the case of Guyana, to have included some costs associated with the production of refractory bauxite.

Data on average operating cost for the operating mines in the major bauxite producing countries (US Bureau of Mines, 1987, Table 3.3) show Guyana having the highest cost for bauxite delivered to a load port or local refinery. The accuracy of this data is, however, questionable, since the cost shown for mine and mill cost is nearly three times that reported by any of the three operations in the industry. The mine and mill cost shown for Australia is also inconsistent with data provided by Australian Mineral Economics, and appears to have excluded capital cost.

Internal transport cost, or haulage, from the mine to the point of shipment or the domestic refinery is an important component of cost of production of bauxite, and is a critical element of comparative cost analysis. Data on internal transport cost are not readily available, hence it is difficult to compare this element of cost with any degree of accuracy. Estimates by the US Bureau of Mines, Australian Mineral Economics and International Bauxite Association, and information from discussions with executives and financial statements from the operating companies in Guyana are therefore used to make broad comparisons.

Internal transport cost is a function of the production sequence, the distance from the mine to point of local processing or export, and the mode of transportation. All these functions vary considerably for operations around the world and even for operations in the same country. In Guyana for instance, the production sequence, the location of the mines in relation to the processing facilities, and the location of the processing facilities in relation to the shipping port and the transportation mode are different for the three operations in the country. The operation involves combinations of truck, rail and barge with overall cost varying from US$5.00-US$7.00 per tonne (Financial data from Guymine, Linmine, and Bermine-1975-2000. and Aroaima Bauxite Company, 1990-2000). In Jamaica, the size of the island results in short haulage distances. The physical features of the country, however, result in different methods of haulage from mine to local refineries or processing plant and shipping port involving combinations of truck, rail, cable conveyor, and aerial tram, all of which involve high capital investment but low operating cost, with total cost varying from less than US$1.00 to US$3.00 per tonne. Internal transport cost for the different mines in Australia involve conveyor and rail over distances of 10 to 50 kilometres and vary from US$2.50 to US$ 7.00 per tonne. In Brazil, the haulage distance from the only exporting mine to the loading port is undertaken by rail over a distance of 16 kilometres at a cost of less than US$2.50 per tonne. Haulage distances for the various operations in Guinea vary from 130 kilometres for the Boke operation, to 500 kilometres for the Kindia operation with transportation cost by rail varying from US$5.00 to US$11.00 per tonne. (Australian Mineral Economics, 1981, Pages 41-42; US Bureau of Mines Information Circular, 8917, 1983, Page 13). The internal transportation mode for the Los Pijiguaos operation in Venezuela involves transportation by a 8-kilometres conveyor belt from the plateau where it is mined to the railhead, transport by rail for a distance of 40 kilometres from the rail-head to the river, then by barge over a distance of 450 kilometres on the Orinoco River which is navigable for only six months of the year. The estimated cost of the total operation is estimated at US$9.00 per tonne (discussion with representative of American Commercial Barge Lines, 1999).

The International Bauxite Association data (Table 3.4) appear to reflect total cost (capital and operating), for most of the countries covered, but only operating cost for the two operations in Australia. Table 3.5 which shows actual data from the financial reports of the Berbice Operations in Guyana over the period 1975-2000, more accurately represents the production cost for mining operations in Guyana.

Table 3.3 U.S Bureau Of Mines, Estimated Bauxite Production Cost

(1985 Prices US$/tonne)

Country[1]	**Mine and Mill Operating Cost**	**Transportation to Port or Refinery**	**Levy or SeveranceTax**	**Total Cost Local Port or Refinery**
Australia	4.82	541	0.89	11.11
Brazil	8.62	9.17	1.00	18.79
France	8.15	5.49	0.00	15.04
Greece	7.65	1.27	0	8.92
Guinea	10.09	14.82	9.13	34.05
Guyana	30.89	7.03	0.07	37.98
India	7.51	9.23	0.42	17.15
Jamaica	4.58	1.59	14.50	20.68

[1] According the the US Bureau of Mines, the cost shown for each country is the average for the mines operating in the country.

Source:
Apprasial of Minerals Availability for 34 Commodities, U.S Bureau of Mines, Bulletin 692, 1987.

Table 3.4 International Bauxite Association Bauxite Production Cost

Selected Mines (1978)

Mine/Country	Capacity (000 tpa)		Cost Elements (US$/tonne)								Total Cost
	Nominal	Operating	Geology and	Stripping	Mining	Mine	Benefic-iation	Drying	Internal	Out -loading	
Awaso	400	200		0.20	2.73	0.57	0.53	2.00	10.55	1.05	16.58
Mokanji-	1000	600	0.27	0.09	3.87	1.28	2.93	1.40	11.06	1.76	22.66
Trombetas	4000	4000	0.66	1.16	2.52	0.94	0.94	1.75	5.66	0.88	14.51
Mackenzie -	4000	1500	0.68	9.39	6.35	1.60	1.16	3.40	2.15	0,79	25.52
Dry Harbour	4000	1000	0.10	0.23	2.24	2.69		1.40	1.23	0.86	8.75
Lydford-Jama	4000	1000	0.20	0.10	2.24	1.92	0.45	1.40	1.23	0.88	8.42
Onverdacht -	3000	1000	0.54	10.09	5.00	1.16	0.45	1.40	6.41	1.18	20.34
Weipa	11250	7000	0.14	0.21	2.93	0.48	1.38	0	0.87	0.85	6.86
Gove -	5000	3000	0.08	0.25	2.12	0.53	0.40	0	0.64	0.85	4.87

Source:

Cost of Bauxite Production, 1978. International Bauxite Associationm, Quarterly Review.

Table 3.5 Metallurgical Bauxite Production Cost
Berbice Operations, Guyana

(US$/tonne)

Year	Stripping	Mining	Haulage	Blending	Crushing/ Out/Loading	Barging	Unload./Stock-piling-	Drying	Export-Ing	Total
1975	1.28	0.87	1.51	0	0.48	2.69	0.84	2.35	0.69	10.71
1980	2.64	3.00	0.83	0	0.58	4.71	1.36	4.33	1.29	18.74
1985	4.20	1.32	1.89	0	0.42	3.73	1.14	4.17	1.33	18.20
1990	7.92	1.29	0.60	0.45	1.55	2.93	0.76	2.97	0.60	19,07
1995	5.65	2.49	1.01	0.67	0.64	3.53	1.28	3.85	0.78	19.9
2000	2.48[1]	1.29	1.68	0.40	1,22	3.46	0.80	4.20	0.82	20.32

[1] Stripping levels reduced due to reduced level of sales and utilisation of inventories for production.

Sources:

1. Internal Financial Data, Guyana Mining Enterprise, Berbice Operations, 1975-1991.
2. Internal Cost Data, Berbice Mining Enterprise, 1992 -2000.

3.1.1.3 Alumina Production Cost

The cost of converting bauxite to alumina is the most critical element in the analysis of the comparative cost of bauxite from different sources. The Bayer process has, as its basic rationale the extraction of the maximum extractable alumina from particular bauxite. The efficiency with which this could be achieved is determined by a number of factors related to the process technology of the refinery and the mineralogy, chemical composition and physical characteristics of the bauxite.

Data on alumina production cost compiled by the US Bureau of Mines, 1983 and the International Bauxite Association 1980, and confirmed in discussions with Alcan, Kaiser Engineers, Reynolds and Alcoa, show capital cost for refineries processing mixed and monohydrate bauxites at approximately 10 percent and 15 per cent respectively higher than that for those processing pure trihydrate bauxites. The data also show operating costs between 10 and 20 per cent higher. Most modern alumina refineries are designed to use mixed trihydrate and monohydrate bauxites which results in higher capital investment while many of the older refineries, designed for pure trihydrate bauxites, have been modified to operate a two stage process for mixed bauxites, also resulting in higher capital and operating cost.

The mineralogical content of bauxite is the most critical factor influencing the technical efficiency and economics of alumina production and dictates plant and process design, digestion temperature, operating pressure, caustic soda concentration and the length of the digestion cycle. The principal minerals determining process design are the alumina and silica minerals and the form in which they occur. Refineries processing pure trihydrate bauxites utilising the American Bayer process, are of less complicated design, and require less capital investment than the more complex plants processing monohydrate bauxites utilising the European Bayer process or mixed trihydrate and monohydrate bauxites utilising the Modified Bayer process. The higher temperature, higher pressure and higher caustic soda concentration required for processing mixed and monohydrate bauxites result in higher fuel and caustic soda consumption, longer digestion cycles, lower alumina recovery, higher volumes of waste and consequent higher waste disposal costs. The processing parameters for refineries processing mixed bauxites are often so sensitive that even minor increases in the monohydrate content of the feed above that for which the refinery was designed, could result in reactions that severely reduce productivity. The Kaiser Gramercy, Louisiana refinery reported a 10 per cent loss of productivity with a one percentage point increase in the monohydrate content of the bauxite feed above the 6 per cent level for which the process was designed. The effect of this on production cost is so significant that the management was considering blending bauxite from their Jamaica mines with a pure trihydtate bauxite at a 25 per cent higher delivered price to off-set the loss of productivity (Private discussions with Kaiser Aluminium and Chemicals, Gramercy, 1999). The Alcan refinery in Quebec which is engineered for trihydrate bauxite, sets a rigid limit of 3 per cent on the monohydrate content of bauxite processed at the refinery, while the Ormet low temperature refinery in Burnside, United States, finds it technically and economically feasible to use a trihydrate bauxite with 7 percentage points lower available Al_2O_3 and 6 percentage points higher SiO_2, than increase the monohydrate content of their bauxite feed by one percentage point. The form in which SiO_2 occurs in bauxite is also critical in process design. At low digestion temperatures, only SiO_2 in the form of kaolinite reacts with caustic soda, while at high digestion temperatures, SiO_2, both in the forms of kaolinite and quartz, react with caustic soda. This results in only SiO_2 classified as reactive being critical in the low temperature process while total SiO_2 is critical in the high temperature process.

The chemical composition of bauxite is the second major factor affecting processing cost, the critical chemical elements being Al_2O_3 and reactive SiO_2 which combine to determine the percentage of extractable alumina from a particular bauxite. Bauxites with high available Al_2O_3 and low silica are generally the most cost effective in the digestion process since SiO_2 reacts with caustic soda and combines with Al_2O_3 to form sodium aluminium silicate which reduces the percentage of extractable alumina from the bauxite. High SiO_2 and the presence of organic carbon in bauxite also require preliminary treatment while other impurities such as titania, magnesia, phosphorous, iron, and the form in which they occur, could negatively affect processing efficiency and increase plant maintenance cost.

The productivity of alumina refineries and processing costs are also affected by the physical characteristics of bauxite that affect grinding cost, digestibility, filtratability and settling. Data to support these characteristics of bauxite in alumina refineries are not normally published and are often refinery specific. Information obtained through discussions with the Ormet refinery in Burnside, Louisiana, however, indicate a 10-15 per cent improvement in plant productivity with Guyana and Suriname bauxite compared with Brazilian bauxite, hence this company always tries to use Guyana or Suriname bauxite or bauxite with similar settling characteristics in their process.

The chemical and mineralogical composition and physical properties of Guyana bauxite, provide processing cost advantages over bauxite from other sources both in terms of capital and operating cost which are not usually accorded adequate consideration in evaluating the comparative cost of Guyana bauxite and bauxite from other sources. Table 3.6 shows the basic processing parameters for alumina refineries utilising the three variants of the Bayer process while Table 3.7 shows raw material and energy requirements for alumina refineries utilising pure trihydrate and mixed bauxites.

Table 3.6 Bayer Alumina Refineries,
Processing Parameters.

Bauxite Type	**Bayer Process**	**Digestion Temperature (^{0}C)**	**Operating Pressure (gr/cm^2)**	**Caustic Soda Concentration (g/litre)**	**Digestion Cycle (minutes)**	**Process Efficiency (%)**
Trihydrate	Conventional American	140-150	4000-4500	150-200	30	98.00
Mixed < 20% Monohydrate	Modified American	180-200	6,000-8000	200-250	90.00	96.00
Monohydrate	European	200-250	10000-15000	350-400	90.00	92.00

Source:
1. Bauxite, Alumina and Aluminium 1962, Overseas Geological Surveys, Mineral Resources Division.
2. World Bauxite Resources 1986 USGS, Professional Paper 1076B.
3. Internal Operating Data, Guyana Mining Enterprise.
4 Assessment of The Chemical and Metallurgical Properties of Guyanese Bauxites, Jamaica Bauxite Institute.1998.

Table 3.7 Bayer Alumina Refineries Raw Material And Energy Requirements

Bauxite Source	**Weipa**	**Jamaica Type**	**Guyana Type**	**Darling Range-Australia**
Bauxite Type	**Mixed - Up to 35% Boehmitre**	**Mixed-Up to 20 % Boehmite**	**Gibbsite < 1.5% Boehmite**	**Gibbsite <1% Bohemite**
Inputs				
Bauxite (Tonnes)	2.2-2.4	2.4-2.6	2.0-2.1	3.2-3.4
Caustic Soda (NaOH) (Tonnes)	0.11-0.13	0.11-0.13	0.09-0.11	0.10-0.11
Lime (CaO) (Tonnes)	0.03-0.05	0.02-0.05	0.02-0.05	0.03-0.05
Starch (Tonnes)	0.002	0.008-0.01	0.002	0.002 -0.009
Steam For Digestion (Tonnes)	3.6-4.0	3.6-4.0	3.4-3.6	3.4-4.0
Fuel Oil For Calcination (Tonnes)	0.13-0.16	0.13-0.16	0.13-0.16	0.03- 0.16
Electricity (Kwh)	240.00	240.00	240.00	240.00
Energy Requirements (million btu)				
Steam	14.0-17.2	11.3-17.2	11.4-14.3	11.4-14.3
Calcination	4.0-5.7	4.0-5.7	4.0-5,7	4.0-6.7
Miscellaneous	1.1-2,3	1.1-2.3	1.1-2.3	1.1-2.3

Sources:

1. World Aluminium Industry, Volume 1 1981, Australian Mineral Economics.
2. International Bauxite Association, Quarterly Review, 1980.
3. Cost of Production For Bauxite, Alumina and Aluminium(1980-1983), International Bauxite Association 1984.
4. The Aluminium Industry, Pre-Investment Data, UNDP 1966..

3.1.1.4 Bauxite Shipping Cost

The cost of shipping bauxite is an important element in the competitiveness of bauxite from different sources and is a critical factor in the location of bauxite and alumina capacity and in the determination of bauxite trade flows. Since a substantial part of Guyana's metallurgical bauxite production was exported in competition with exports from Jamaica, Haiti and the Dominican Republic in the late 1950s and 1960s and from Australia, Guinea and Brazil in the 1970s, 1980s and 1990s, an evaluation the comparative cost of shipping bauxite from these sources is necessary to determine its impact of on Guyana's competitiveness in the metallurgical bauxite market.

The two elements of shipping cost that must be considered in comparative analysis are: (1) the actual freight rate and (2) the quality of the bauxite shipped. The freight rate is a function of conditions in the market for bulk-carriers, the size of shipments, the shipping distance, fuel oil prices, ship loading and discharge rates and charges at the loading and discharge ports, while the quality of the bauxite determines the quantity that must be shipped for the production of a unit of alumina.

The size of bauxite shipments from Guyana have been seriously limited by the depth of its bauxite shipping ports that limits ships to loading to a draught of 6 metres. This has placed the country at a comparative disadvantage with other bauxite producing countries where ships could load to a draught of 12-15 metres. Alcan established a transhipment facility in Trinidad in 1942 with a natural draught of 10 metres to alleviate this problem, making it possible for ships that loaded 7,000-10,000 tonnes in Guyana to load to 20,000-30,000 tonnes. This, however only reduced the disadvantage, since additional cost had to be incurred to ship the top-off quantity of bauxite to Trinidad, and for storage, maintenance and operation of the transhipment facility. The disadvantage increased during the 1960s, as metallurgical bauxite shipments from competitive sources increased to 35,000-40,000 tonnes, and further, in the 1970s, to 55,000-60,000 tonnes. The increasing cost of transhipment in Trinidad that resulted from lower throughput volumes and higher operating costs made it feasible to deepen the entrance channel to the Demerara River in Guyana in 1988 to permit ships to load up to 30,000 Georgetown .This was followed by the deepening of the entrance channel to the Berbice river in 1996, to permit shipments of 40,000-45,000 tonnes from Guyana. While the deepening of the estuaries of rivers in Guyana and the transfer of transhipment from Trinidad increased the size of shipments and reduced transhipment costs, it has still not completely removed the cost disadvantage since shipment sizes from Guinea, Brazil and Australia are 55,000 to 65,000 tonnes.

Reliable data on bauxite freight rates in the mid 1950s to 1960s are not available. Data compiled for the period 1985 by US Bureau of Mines, (1983), and Guybulk Shipping, (1890-1985), a joint-venture shipping company between Guyana Bauxite Company and Bulkhandling Shipping of Norway, however, show quoted freight rates for that period (See Table 3.8).

Table 3.8 Quoted Bauxite Freight Rates, 1985-1995

(US$/Tonne)

Alumina Plant Location/ Bauxite discharge Port	**Guyana** [11]			**Jamaica**	**Brazil**	**Guinea**	**Gove Australia**
	1983	**1990**	**1995**	**1995**	**1995**	**1995**	**1995**
Corpus Christie-US Gulf	19.00	14.50	11.50	6.00	8.50	8.50	12.50
Port Alfred, Canada	20.00	16.50	12.00	8.50	8.50	8.00	14.00
Stade	25.00	19.45	13,75	15.00	10.00	7.50	14.00
Nikolayev, -Black Sea	28.50	24.00	19.00	17.50	14.00	10.00	16.00
Matanzas, Venezuela	8.50	9.00	6.50	5.00	8.50	8.50	15.00
Aughinish, Ireland	21.00	19.00	15.00	14.00	10.00	6.50	15.00
St Croix, Virgin Islands [2]	9.00	10.00	7.00	5.50	8.00	8.00	18.00

[1] Includes amortization of capital dredging cost, maintenance dredging, cost of shuttling to the transshipment station and capital and operation cost for thr

[2] Shipment sizes restricted to 35,000 tonnes by draught limitation at the port.

ources

1. Aluminium Availability, Market Economy Countries. USBM 1983, Information Circular 8917, 1983.
2. Freight Contracts, 1985-1995, Guybulk Shipping Limited, Bermuda and Bulkhandling Shipping Oslo, Norway.

Since the parameters for calculating freight rates have remained unchanged, current information from international shipping sources (Bulkhandling Shipping; Axion Shipping and Marine Research Inc.) are used in the study to establish the relationship between bauxite freight rates from Guyana, Jamaica, Brazil, Guinea and Gove, Australia, to the major importing ports. Table 3.9 shows calculated freight rates on bauxite shipments from Guyana, Brazil. Jamaica, Guinea and Australia to Port Alfred, Canada, Corpus Christie, United States, and Novorossiysk Ukraine based on established shipping parameters and 1999 cost variables. The data and the calculations show Guyana having a freight disadvantage on bauxite shipments to the major importing ports except against shipments from Australia to Port Alfred and Corpus Christie, with the greatest difference being on shipments from Jamaica to Corpus Christie. But while there is a disadvantage on freight rates, the other element of freight cost--the alumina content of the bauxite shipped--that determines the ratio of shipped bauxite to the production to alumina could eliminate this disadvantage. The main elements of that cost that enter into the comparison are available alumina and moisture with, the shipping cost of bauxite per unit of alumina expressed by the formula-

$$\frac{F}{A(1-M)}$$

Where:

F = Freight Rate for Bauxite as shipped ($/Tonne)

A = Available Al_2O_3 as a fraction of dried equivalent of bauxite shipped.

M = Moisture as a fraction of wet crude bauxite.

Metallurgical bauxite shipped from Guyana contains average available alumina of 52 per cent compared with 44 per cent for bauxite from Jamaica; Guyana bauxite, as shipped, also contains 5 per cent free moisture compared with 16 per cent for Jamaica bauxite. Application of this formula establishes a relationship of I:1.34 between the shipping cost per unit of alumina for Guyana and Jamaica bauxite which reduces Jamaica's advantage to Corpus Christie from US$6.95 to US$5.06 per tonne and reverses the advantage on shipments to Port Alfred and Novorossysk. Consumers in the United States also indicate a further 1-2 percent loss of the shipped bauxite weight through the removal of pyrites and limestone mixed with the bauxite that further reduces the freight disadvantage.

Table 3.9 Calculated Bauxite Freight Rates, Major Exporting And Importing Ports

(1999 US$/Tonne)

Discharge Port	**Port Alfred -Canada**[1]					**Cotpus Christie- U.S.A**[2]					**Novorossiysk- Ukraine**[3]				
Export Country	**Berbice Guyana**	**Kaizer Jamaica**	**Trombe-tas Brazil**	**Kamsar Guinea**	**Gove Australia**	**Berbice Guyana**	**Kaixer Jamaica**	**Trombe-tas Brazil**	**Kamsar Guinea**	**Gove Australia**	**Berbice Guyana**	**Kaizer Jamaica**	**Trombe-tas Brazil**	**Kamsar Guinea**	**Gove Australia**
Distance (miles)	2,980	2,575	3,861	3,700	11,970	2,650	1,312	3,807	4,829	10,500	5,537	6,104	6,041	4,159	8,434
Steaming Time (days)	18	16	23	23	72	16	8	23	28	64	33	37	36	25	51
Load/Discharge	6	6	6	5	6	8	6	7	8	9	9	7	11	10	11
Roundtrip Time(days)	24	22	29	28	78	24	14	30	36	73	42	44	47	35	62
Shipment Size	40,000	40,000	55,000	60,000	60,000	40,000	40,000	55,000	60,000	60,000	40,000	45,000	55,000	60,000	60,000
Time Charter (US$)	240,000	220,000	348,000		936,000	240,000	140,000	360,000	432,000	876,000	420,000	526,000	564,000		744,000
Intermediate Fuel	69,120	61,440	96,600	96,600	302,400	61,440	30,720	86,600	117,600	268,800	126,720	155,400	151,200		214,200
Diesel Fuel (US$)	9,600	8,800	11,800	11,200	31,200	9,600	5,600	12,000	14,400	29,200	16,800	17,600	18,800	14,000	24,800
Port-Expenses (US$)	120,000	65,000	60,000	60,000	65,000	105,000	45,000	60,000	60,000	65,000	180,000	125,000	125,000		125,000
Canal Dues (US$)	0	0	0	0	100,000	0	0	0	0	100,000	0	0	0	0	150,000
Transshipment (US$)	84,000	0	0	0	0	84,000	0	0	0	0	84,000	0	0	0	0
Total Freight Cost	527,720	435,525	516,400		1,434,600	500,040	221,320	518,600	624,000	1,339,000	827,520	824,000	859,000		1,245,000
Freight Rate	13.10.	10.9	9.40	.8.40	23.90	12.50	5.55	9.40	10.40	2,230	20.70	18.30	15.60	11.10	21.00

[1] Data for Corpus Christie representative for all other u.s bauxite inporting ports.

[2] Shipments from Australia to Port Alfred and Corpus Christie via Panama Canal and to Novorossiyki, via Suez Canal.

Source:
Calculations by the author based on established shipping parameters and information on cost variables provided by Bulkhandling Shipping, Norway, and Axion Shipping, New York and Fearnleys, Drybulk Market Quarterly

3.1.1.5 Metallurgical Bauxite Pricing Mechanisms

The aluminium industry is among the world's most vertically integrated industries; at the end of the 1960s, over 80 per cent of world bauxite and alumina and 70 per cent of aluminium were consumed by the producers. The effect of this was that there was effectively little arms-length dealings in bauxite, and consequently no market determined price for the product. Under this structure, the prices quoted for bauxite were transfer prices used for internal accounting, customs and taxation purposes. The emergence of a third-party bauxite market in the 1970s when significant quantities of metallurgical bauxite and alumina started being traded and the marketing arrangements under which the partners in the bauxite consortia set prices for their members and for third parties, led to the development of market-related bauxite prices. The imperfections of the bauxite market, however still result in managed rather than purely market-determined prices not directly related to cost of production. These prices are, however normally used in comparative cost analysis, hence an examination of the pricing mechanisms for metallurgical bauxite is necessary to demonstrate the extent to which prices could distort comparative cost analysis.

The more prevalent pricing mechanisms have a number of common parameters and variables. The basis of the parameters and application of the variables are, however, so different, often complicated, and their results so indeterminate, that it is difficult to use them in comparative cost analysis and evaluation of bauxite projects. Adequate consideration is seldom given to many of the components of price, the tendency being simply to use known or estimated base prices which could vary 20-25 per cent from the effective prices, and could significantly change the competitive advantage of one bauxite over another.

A review of metallurgical bauxite contracts reveal a variety of price clauses, varying from straight indexation to the price of metal, negotiated base price with partial indexation to the prices of metal and/or alumina, negotiated price with no indexation, and price indexed to metal, alumina and inputs to the industry. The one constant in all the existing pricing mechanisms is the application of a base price which includes total cost of production, royalties, taxes and levies and bonuses and penalties in respect of the major constituents of the bauxite, Al_2O_3, SiO_2 and H_2O, to establish equivalence in value of bauxites with different chemical composition and moisture content. The most prevalent formula involves adjustments to the established base price for Al_2O_3, SiO_2 and H_2O. The adjustment for Al_2O_3 reflecting the value of the alumina in the bauxite at the refinery where it is processed, the adjustment for SiO_2 reflecting the consumption and price of the caustic soda to the refinery, and that for moisture (H_2O) reflecting the weight of the bauxite represented and the additional shipping cost. But even the values attached to the elements in this formula vary significantly from one contract to another to reflect refinery specific conditions and bargaining strength of the negotiating parties. Detailed knowledge of the various formulae, parameters and variables is therefore necessary for any meaningful comparison of the effective price of different bauxites.

Table 3.10 compares the price of traded bauxites from Berbice, Guyana, Port Kaizer, Jamaica, Gove, Australia, Boke, Guinea and Trombetas, Brazil delivered to the Reynolds Sherwin refinery at Corpus, Christie, Texas, based on the prevailing pricing formula.

Table 3.10 Calculated Metallurgical Bauxite Prices, Most Frequently Used Industry Pricing Formula

(1999 Contract Prices)

Price Elements	**Available Al_2O_3 (%)**	**Reactive SiO_2 (%)**	**Moisture (HO_2) (%)**	**Negotiated BasePrice (US$ tonne, f.o.b)**	**Freight (US$ tonne)**	**Base Price (US$ c&f[1])**	**Quality Adjustments (US$/tonne per percentage point**			**Equivalent Guyana Price (US$)**	
							Av.Alumina	**R. Silica**	**Moisture**	**f.o.b**	**c&f**
Base Grade	50.0	4.0	5.0	-	-	-	0	0	0	-	-
Bauxite Source											
Berbice - Guyana	52.00	4.5	5.0	21.50	12.50[1]	33.50	1.50	-0.63	0 .00	22.85	35.35
South Coast -Jamaica	46.00	3.5	12.0	28.00	6.50	34.50	-3.00	0.63	-4.15	35.18	41.68
Gove - Australia	48.00	6.0	6.0	15.50	15.50.	31.00	-1.50	-1.88	-0.31	18.88	34.38
Boke - Guinea	54.50	2.5	5.0	27.00	8.50	35.50	3.38	-1.88	0.00	21,74	30.24
Trombetas- Brazil	49.00	4.00	6.0	23.50	8.50	32.00	-0.75	0	-0.32	24.57	33.07

[1] The negotiated price for bauxite containing 50 percent available Al_2O_3, 4,0 reactive SiO_2 and 5.0 percent H_2O, including total cost of production, royalties, taxes and levies.

Sources
1. Bauxite Contract between Aroaima Bauxite Company and Reynolds Metals, 1991-2000.
2. International Bauxite Association, Industry Pricing Studies, 1978 -1990.
3. Kaizer Aluminium and Chemicals, discussions on Bauxite supply, 1999 .
4. Alcan Bauxite Contract negotiations, October 1995..
5. Contract negotiations between Bidco and Interalumina, Venezuela, 1987-1990.

This formula is often subject to further variations for long-term contracts based on the prices of alumina and aluminium and prices of inputs to the industry. The MRN, Trombetas and CBG, Boke consortium, which account for 60 per cent of traded metallurgical bauxite, apply different formulae and variables for these adjustments in setting prices for the partners and for sales to third parties. The CBG formula uses adjustments only for the prices of alumina and aluminium with the Average Australian Alumina Export price and the London Metal Exchange aluminium price as the basis for adjustments that are applied on a rolling average for the three quarters preceding the quarter in which the shipments are made. The CBG formula is however extremely complicated, with adjustments for the price of aluminium, alumina, gas-oil, Bunker C fuel oil, wage rates in Guinea, and the US Industrial Commodities price index. It is further complicated by the use of two price indices for the aluminium component and three for the alumina component with the algebraic mean of the cost elements as a component of the formula.

The foregoing analysis shows that all the relevant data on bauxite and alumina production costs are not usually available, and even the available data reveal considerable inconsistencies in production cost reported by different agencies. A more detailed examination of the major economic factors that determine the final price of bauxite, however shows Guyana to be competitive with the major suppliers of metallurgical bauxite to the United States and Canada which are importers of the largest volumes and from the largest number of sources. The country has a definite disadvantage in the areas of mining and shipping. This is however considerably counterbalanced by low investment and capital cost for establishing new and expanding existing capacity. The quality of the bauxite which is reflected in the final price, its trihydrate mineralogy that reduces alumina processing cost and the filtration and settling characteristics of its ore which improve plant efficiency, also reduce processing cost, and help to reduce the overall cost disadvantage

3.1.2 Non-Economic Factors

Bauxite mining and alumina refinery projects normally involve large, long-term investments by foreign multi-national corporations whose decisions on timing, location, scale, financing and management of such projects are influenced by a number of factors which are not purely economic and are therefore classified as non-economic. These factors are evaluated in the study as follows: (1) resource endowment; (2) the strategic location of resources; (3) the political philosophy and prevailing political climate in resource-endowed countries; (4) the aluminium industry and market structure; (5) the global strategies of the multi-national corporations which have maintained a high degree of control over the industry throughout its existence; and (6) government intervention.

3.1.2.1 Resource Endowment

The existence of large mineral resources, whether classified as reserves or potential resources, is one of the most potent factors influencing large-scale investment in new mining projects. Dr. John Tilton (1983), established a coefficient of correlation of 95 per cent between the discovery of large bauxite resources and the development of major projects based on those resources, with an approximate ten-year lag, and a 71 per cent coefficient of determination between the size of bauxite resources and the size of projects based on those resources. A recent feasibility study on the development of a bauxite project in Guyana (Alcoa, 1999), supports the hypothesis of the impact of size of resources on the choice of projects for development. This study evaluated projects based on bauxite deposits at Linden and Kwakwani. The demonstrated Kwakwani resources contained more than twice the quantity of ore needed for the planned economic life of the project, in addition to substantial inferred resources and involved investment and cost of ore delivered to a processing facility, 17 percent and 8 per cent, respectively, lower those for the Linden resources. The study, however came out in favour of the Linden deposits because the larger demonstrated resources and their greater concentration.

The development of the bauxite industry in Guyana has been negatively affected over the years by the paucity of information and under-reporting of its bauxite resources. This has been attributed to a system where the only source of detailed information on bauxite resources was the two operating companies, who reported only reserves compatible with their very restrictive nomenclature of reserves, their budgeted exploration programmes, and their restriction of exploration to geographical areas capable of being exploited by their existing mining technology. The published data on world bauxite resources over the period 1950-1965 grossly understated Guyana's bauxite resources, while at the same time showing large proven reserves and potential resources for Jamaica, relative to total world resources, and then, current and projected world bauxite demand. The data also showed large resources for Australia and Guinea and large potential resources for Brazil and India. Published data on world bauxite reserves and potential resources (Overseas Geological Surveys, 1962), established Guyana's proven reserves and potential resources in 1958 at only 80 million and 70 million tonnes respectively, against Jamaica's reserves and resources of 550 million and 450 million tonnes, respectively, and total world reserves and resources at 3,225 million tonnes and 6,000 million tonnes, respectively. Published data (US Geological Survey, 1965), also showed Guyana's reserves at the same 80 million and potential resources at 250 million tonnes, against Jamaica's 600 million and 400 million tonnes and world total of 5,800 million and 9,000 million tonnes respectively. The size of the Guyana resources, made them unattractive for the location of large-scale, long-term investment by the integrated multinational corporations, at a time when the demand for aluminium and bauxite were projected to increase at almost 6 per cent per annum, and large resources were being reported in other parts of the world.

Upon the nationalisation of the industry, information was discovered that showed the country's reserves, classified as proven, probable and possible, based, on analysis of borehole samples, at 500 million, and potential resources another 500 million tonnes. These discoveries led to a revision of the data which stated the country's Demonstrated in situ material, as 519 million and Identified in situ material as 1,018 million tonnes, respectively, in only 11 deposits investigated. (US Bureau of Mines 1983, page 7), while the US Geological Survey, consistent with their new classification of bauxite resources, shows reserves of 700 million and sub-economic and undiscovered resources of 300 million tonnes (US Geological Survey, 1986, page B38). Table 3.11 shows the data on world bauxite reserves and resources in the Bureau of Mines and the Geological Survey studies.

Table 3.11 World Bauxite Reserves And Potential Resources, Selected Countries

Countries	Overseas Geological Survey 1958 (000,000 tons)		U.S Geological Survey 1965 (000,000 tons)		U.S. Bureau of Mines Information Circular Circular-1983		U.S.Geological Survey, Professional Paper	
	Reserves	Potential Resources	Reserves	Potential Resources	Demonstrat-ed in situ Material	Identified in situ Material	Reserves	Sub-economic and Undiscovered Resources
United States	50	350	45	300	36	40	38	275-300
Jamaica	550	450	600	400	2000	2000	2000	500
Suriname	200	200	200	350	578	600	575	225
Brazil	30	173	40	200	2270	4070	2250	2750
Guyana	80	70	80	250	519	1018	700	300
Hungary	250	n.a	150	n.s	n.s	n.s	300	50-100
Yugoslavia	128	172	200	100	n.s.	n.s	350	450-500
India	58	197	64	100	1181	1900	1000	2000-4000
Ghana	229	-	290	110	558	780	450	100
Guinea	600	2400	1200	2400	5625	8200	5600	2400-4400
Australia	600	400	2000	1000	4574	8000	4400	1500-3500
World	3224	5977	5800	9000	20236	31913	21000	35000-55000

Sources:

1. Overseas Geological Survey 1962, Bauxite, Alumina and Aluminium.
2. US Geological Survey, 1968,World Bauxite Resources.
3. US Bureau of Mines 1983, Mineral Information Circular 8917, Aluminium Availability, Market Economy Countries.
4. US Geological Survey Professional Paper 1076B. 1986, World Bauxite Resources.

However, even this revised data do not adequately reflect Guyana's resources, nor adequately compare it with the resources of other resource-endowed countries. All the quantities stated for Guyana as reserves, or demonstrated in situ material, comprise material with minimum 50 per cent available Al_2O_3 and a cut off point of 47 per cent available Al_2O_3, while those for Jamaica, Brazil and Venezuela, include material with 40-50 per cent and those for Australia, 27.5-50 per cent available Al_2O_3. A lowering of the Al_2O_3 cut-off point for classifying material as bauxite in Berbice, from 47 per cent to 45 per cent, for instance, resulted in an increase the reserves in a group of deposits studied by Alcoa, by 11 per cent (Alcoa 1999, page, 1), while still maintaining the average of 50 per cent available Al_2O_3. The same study also includes the readily accessible demonstrated Ituni laterite resources, not, in the past, were not classified as bauxite even though they were mined between 1961 and 1982 and blended with regular bauxite and used in the Linden alumina refinery. One of these deposits continue to be mined by Aroaima Bauxite Company since 1993 for blending with regular bauxite to increase Fe_2O_3 and reduce reactive SiO_2 content of ore for export. Technical studies conducted by Alcoa laboratories in Australia. also confirm these deposits as being comparable in chemical composition and processing properties, to the Western Australian resources from which nearly 10,000,000 tonnes of alumina is being produced each year. (private discussions and correspondence with Alcoa personnel, 1998). Inclusion of these resources, add 300,000,000 tonnes to the country's resources, while the potential for similar material is estimated at several billion tonnes.

Table 3.12 shows Guyana's current estimated bauxite resources including the readily accessible laterite reserves contiguous with the Ituni bauxite resources.

Table 3.12 Guyana Bauxite And Laterite Resources

Location	000 Tonnes			
	Proven[1]	Probable[2]	Possible[3]	Total
Linden	266,000	72,000	43,000	381,000
Ituni-Bauxite	12,000	119,000	0	131000
Ituni Laterite	50,000	300,000.	0	300,000
Aroaima	10,000	10,000	0	0
Kwakwani	25,000	30,000.	130,000	185000
Canje	0	0	32,000	32,000
Corentyne	0	0	85,000	85,000
Total	363, 000	531,000	290,000	1,184,000

[1] Proven Reserves- Deposits drilled to maximum 400 foot centres.

[2] Probable Reserve Deposits drilled to 400-800 foot centres.

[3] Possible Reserves- Deposits drilled to 800-1600 foot centres.

Sourcs
1. Linden Mining Enterprise Report, Bauxite Resources, 1999.
2. Berbice Mining Enterprise Report, Bauxite Resources, 1999.
3. Alcoa Final Report 1999, Feasibility Study of Guyana Bauxite Mining Operations.

3.1.2.2 National Security Interests

The importance of aluminium for the production of aircraft during the Second World War led to the metal being designated a strategic metal by the United States Government, and to the Government financing expansion of bauxite mining and construction of alumina refineries and aluminium smelters during the War. With air-power established as a critical component of the country's future military strategy, the dwindling United States bauxite reserves and the war-time experience of the vulnerability of bauxite shipments from Guyana and Suriname to submarine activity, the North American industry, supported by the United States Government directed its focus to the Jamaica bauxite reserves. These reserves, estimated at only 5-10 million tonnes in 1943 but with indicated resources of 250 million tonnes, were viewed as a potential source of supply for the industry. Attempts to utilise Jamaica ore during the war were, however, abandoned, since the existing refineries, designed to process pure trihydrate ore from the United States, Suriname and Guyana could not technically process the mixed monohydrate Jamaican ore. In response to the international political climate of the immediate post-war period, United States Government, established aluminium and metallurgical bauxite as commodities for its strategic stockpiles and promoted the Jamaica resources which were located 1,200 miles from its alumina refineries as the strategically safest location for supplies of bauxite for its refineries and strategic stockpiles and alumina for its domestic aluminium smelters. Even though the alumina refineries and aluminium smelters built by the Government during the war were sold to private enterprise at the end of the war, their profitability was guaranteed by Government contracts for the purchase of aluminium for the stockpile. The feasibility of new bauxite and alumina projects in Jamaica was also guaranteed through advances of Marshall Aid Funds, repayable by means of deliveries of bauxite and aluminium to the strategic stockpile. The developments in Jamaica, therefore, took place, even though substantial investment had to be made to modify the United States alumina refineries, and new refineries built in Jamaica and the United States to treat the different chemical, mineralogical, filtration and settling characteristics of the Jamaica ore. National security considerations were also paramount in the development of bauxite projects in Guinea, Ghana and Sierra Leone and expansion of production in France and Greece by the British, French, and German aluminium producers to supply Western European alumina refineries and aluminium smelters, in preference to Guyana and Suriname, located on the opposite side of the Atlantic Ocean. The Soviet Union also embarked upon a similar policy by providing finance and guaranteed markets for bauxite and alumina projects in Yugoslavia, Hungary, Romania and Guinea, while Japan provided finance, through the medium of long-term contracts, for the development of bauxite production in Malaysia, Indonesia and Australia.

3.1.2.3 Political Philosophy and the Prevailing Political Climate

The broad political philosophy of a resource endowed country is a major consideration in decisions on large scale investment in that country, by multinational corporations, while the prevailing political climate at a particular point in time, could further influence such decisions. The Guyana government that assumed power in 1953 adopted a Socialist philosophy that was considered unfavourable to private investment. The dismissal of the government and suspension of the constitution in that year led to a period of uncertainty and political instability between 1953 and 1964. This period coincided with the period during which world bauxite production experienced its highest growth rate, and during which the location of alumina capacity shifted substantially from aluminium producing to bauxite producing countries. The impact of the country's political instability was stressed in an interview with the Managing Director of the Alcan subsidiary in response to the United Nation Technical Assistance Team's question about the short-term and long-term policy for increasing or developing their operation in Guyana (United Nations Technical Assistance Team, 1964, page 271).

> “Owing to the current political instability, foreign investors have to be very circumspect. Whether after the forthcoming General Election the present government will remain in power or another will come, it will certainly have a marginal majority in the legislative assembly and this will hardly ease the situation. The present unrest in the country appears to be rather a racial than a political issue. It is feared that it may lead to further uprisings or strikes in the future apt to dislocate production and to endanger company property In view of this Demba has only a short-term policy which may be summed up as follows: (1) better utilisation of, and

> improvements in present productive capacities; (2) increase of calcined bauxite production; and (3) limited capital expenditure in the years to come amounting to $ 9.5 million B.W.I in 1964 on mining machinery for the development of new mining sites at Kara Kara, and following this, for a period of five years, an investment of about $5 million B.W.I annually to include the bridge across the Demerara River, further development of the Christianburg area, the purchase of a new bucket-wheel excavator, and numerous other mining equipment. These amounts do not include replacements or repairs. The company, for the time being, does not contemplate expanding alumina production."

The only investment made in the industry over that period was in the expansion of refractory bauxite capacity by Demba and the construction of an alumina refinery designed to utilise the large volume of tailings generated by the increase in refractory bauxite production. After just a brief period of change in the political climate, between 1965 and 1970, the country's new government embarked on a policy of integrating the industry into its development plan by trying to secure majority shareholding of Demba in 1971. The failure of this, resulted in the company being full acquired by the state, and with the acquisition of Reynolds Guyana Mines at the end of 1974, the entire industry fell under state control. This led to Guyana being further alienated from the developments in the industry and advanced the development of the Boke project in Guinea and later, the Trombetas project in Brazil as alternative sources of low monohydrate and trihydrate bauxite for the North American refineries.

The impact of political philosophy and the prevailing political climate is so pervasive that even Jamaica, where the major developments in both bauxite and alumina production took place during the second half of the 1950s and the decade of the 1960s, was alienated from further development during the decades of the 1970s and 1980s when its government adopted a Socialist philosophy even though it did not proceed as far as Guyana to state acquisition. In the case of Guinea, which adopted a Socialist philosophy and actually nationalised the Alcan operation in the early 1960s, a different element of strategic consideration led to the development of the Boke bauxite project by a consortium of all the major Western aluminium producers, to prevent the massive Sangaredi deposits falling under the control of the Soviet Union. Guinea, however continues to be mainly an exporter of bauxite with no addition to the 650,000 tonnes per year Frigua refinery established in the early 1960s, a period over which alumina capacity doubled in Jamaica and tripled in Suriname, Australia, Europe and Brazil.

3.1.2.4 Transnational Strategy

An established feature of the strategy of transnational mining corporations is the acquisition of various forms of control over mineral resources necessary for their operations, in various parts of the world. This strategy not only gives them control over resources but facilitates the spreading of political risk over a number of countries and business risk over a large number of operations.

World bauxite resources, especially high grade resources, were considered scarce during the 1950's in the context of the rapid growth of aluminium production and projections of future bauxite demand This influenced the transnational corporations to move rapidly to exercise control over bauxite resources wherever they were discovered, utilising the strategy of rapidly establishing bauxite operations that accorded them mining rights over resources considerably larger than they could exploit for several decades.

Transnational strategy could supersede even political philosophy and political climate as alluded to earlier in the study with the development of the Boke project. Guinea, upon gaining independence from France, openly adopted a Socialist philosophy and revoked the bauxite concessions operated by the Alcan. Shortly after the revocation of the Alcan concession, Harvey Aluminium of the United States, which was desperately in search of a guaranteed source of bauxite for its St. Croix, alumina refinery, assumed the management of the operation on behalf of the Guinea Government. Harvey identified the recently discovered Sangaredi deposits classified as the world's largest high-grade bauxite resource for possible future development but did not have the resources to undertake the investment in infrastructure needed for its development. The Soviet Union, which developed the Kindia bauxite mining project in a joint venture with the Guinea government for the supply of bauxite to its expanding aluminium industry, announced plans to significantly expand their operations with the Sangaredi deposit as a possible target. With Guinea openly Socialist and becoming closely allied with the Soviet Bloc, the Western aluminium companies could not risk having the Sangaredi resources falling under Soviet control. Instead of expanding production in Jamaica, which still possessed large proven and potential resources and where they had just made major investments, or in Guyana and Suriname where production could be expanded with relatively low investment, they opted to establish the world's first bauxite mining consortium in Guinea. This project involved all the major Western aluminium producers and a capital investment of US$400 million (US$66.67 per tonne of annual capacity), compared with US$30 per tonne for a new project in Guyana and less than US$25 per tonne for expansion of existing capacity.

3.1.2.5 Government Intervention

Government intervention is another significant factor in the development of new projects, the expansion of existing projects and the maintenance of marginal projects in resource-endowed countries. The development of the Los Pijiguaos bauxite project in Venezuela is a demonstration of the impact of government intervention. The government of Venezuela, as part of its plans for the development of its vast hydro-electric power resources, embarked on a policy of establishing an integrated aluminium industry. utilising the strategy of backward integration starting with aluminium smelting capacity. The second phase of this development was the establishment of an alumina refinery to supply the smelters, with the third stage, the development of its large relatively low grade bauxite resources to satisfy the requirements of the alumina refinery. The high capital cost of the bauxite project, involving an investment of US$ 550 million (US$96.66 per annual tonne of capacity) and unit capital cost of US$14.60 per tonne of production, together with the difficult logistics and high internal transport costs, made it uncompetitive with bauxite from Guyana, Brazil and West Africa. The government, however, financed the investment, and later granted the state-owned company that undertook the project, a write off of the investment to relieve it of the capital cost and thereby enhance its competitiveness to the extent that it became an exporter of bauxite.

The planned development of the Bakhuis bauxite deposits in western Suriname, is another example of government intervention. The Central Suriname deposits that supply the country's 2,000,000 tonnes per year alumina refinery are expected to be depleted by 2008. Among the alternative sources of supply evaluated, is the large low grade Bakhuis deposits in Western Suriname, for which the estimated development cost is US$150 million, in addition to an estimated cost of US$50 million for the modification of the refinery to treat the different properties of the ore. (information from discussions with Billiton Maatschappii, July 1998). The high capital cost, together with the mining and transport costs, would result in the cost of bauxite delivered to the refinery, being higher than that for bauxite from alternative sources. The 1999 study by Alcoa, one of the shareholders in the refinery, has established that the requirements of the refinery could be satisfied from an expansion of a bauxite project in Guyana at a total capital cost of US$60 million, with operating cost and freight, 15-20 per cent lower than those for the Western Suriname project. However, the government of Suriname has decided that the development of the domestic resources should proceed, and is pursuing the procurement of the necessary finance for the investment from bi-lateral lending sources and international lending agencies, to undertake the development.

3.2 Conclusion

The data and information on cost of production of metallurgical bauxite, confirm Guyana's cost disadvantage, in spite of its lower investment and capital cost for both new capacity and for expansion of existing capacity. While the data do not fully represent conditions existing in the 1950s and 1960s when investment ceased in Guyana and the country lost its ranking as a producer of metallurgical bauxite, high production cost cannot be discounted as a factor in this development. Reliable data on a number of the elements of the cost of production of alumina, which is the objective measure of the competitiveness of bauxite, are not readily available. Even when the data are available a number of critical elements in the cost of production of alumina, are not normally fully evaluated by companies in their analysis of the cost of production of alumina from bauxite from different sources. The study has confirmed, however, that alumina production technology, combined with the chemistry, mineralogy and physical properties of Guyana bauxite, provide cost advantages that could substantially counterbalance and even eliminate the disadvantage of higher bauxite production cost.

The data on freight rates also confirm higher freight rates from Guyana, compared with those from other sources. The study has demonstrated that when the element of quality of the bauxite shipped is factored into overall shipping cost, the freight disadvantage is significantly reduced, and in some cases, reversed.

The analysis also shows that the non-economic factors that operated against investment in Guyana during the most critical period of the development of the aluminium industry played a significant role in the reluctance of the multinational corporations to invest in the industry in Guyana.

Chapter 4

COMPETITIVENESS IN REFRACTORY BAUXITE

4.1 The Emergence of Guyana Refractory Bauxite

Refractory bauxite is a product of the post-war era--commercial production starting around 1947. The specific properties of the product were described in Chapter 2. Table 4.1 shows estimated world production of refractory bauxite for the period 1950-2000.

Table 4.1 Estimated World Refractory Bauxite Production[1] 1955-1995

(000 Tonnes)

Country/Year	**1950**	**1955**	**1960**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Guyana	60	220	450	650	800	650	500	300	200	125
Suriname	0	0	0	50	40	40	0	0	0	0
United States	40	50	60	0	0	0	0	0	0	0
China *	0	0	0	100	150	300	450	625	750	750
Italy	0	0	0	0	25	25	30	25	20	15
Denmark	0	0	0	0	20	40	10	0	0	0
West Germany	0	0	0	10	10	20	0	0	0	0
Brazil	0	0	0	0	0	0	0	60	100	140
Total	100	270	510	800	1045	1075	990	1010	1110	1030
Guyana % of World	65.0	82	88	86	77	67	51	30	18	12
China % of World	-		-[1]	13	15	28	46	62.0	68	72

[1] The data classifies only material with Al2O3 content in excess of 80%, as Refractorybauxite Materials with Al_2O_3 content of between 70 and 80%. produced in the United States after 1970 and in China between 1975 and 1990 and described as refractory bauxite are not included.

Sources:

1. The Bauxite-Aluminium Industry of British Guiana 1964, UN Technical Assistance Team.
2. Economic Survey of Guyana 1968, Ministry of Economic Development, Guyana
3. Study of The North American Market for Refractory Bauxite 1972. William Hill.
4. Evaluation of The Markets for Calcined Bauxite in Western Europe and Japan 1973, Arthur D Little.
5. Internal Statistical Information 1971-2000, Bauxite Industry Development Company.
6. China Minerals And Metals Corporation, Discussions, 1995.
7. Annual Statistical Information 1975-200, Nissho Iwai Coeporation, Japan.

Fireclay and kaolin and limited quantities of the sillimanite group minerals had prior to the Second World War constituted the largest single group of refractory raw materials for the metals, minerals, ceramics and chemical processing industries. The high capacity utilisation of steel-making equipment and technologic innovations in the steel-making process after the war, however, demanded higher refractory performance and led to a demand for higher Al_2O_3 in steel plant refractories. With the limited availability of the sillimanite group materials, and their limited Al_2O_3 content, bauxite was identified as the only economically viable source of higher Al_2O_3 for the new requirements. However, since high alumina (Al_2O_3), low iron (Fe_2O_3). low silica (SiO_2), low titania (TiO_2) and low levels of alkali elements, potassium (K_2O), and sodium (Na_2O) found in bauxite were critical for high temperature performance, Guyana was identified as the only source of adequate bauxite resources with the chemical and mineralogical properties that could be economically developed to satisfy the specifications for the new high performance applications. This led to Guyana refractory bauxite, with the brand name Refractory Alumina Supercalcined (RASC), becoming the principal high alumina material for the refractories industry over the period 1950 to 1975. This product was used as the raw material for the production of alumina-based refractories with Al_2O_3 content in excess of 70 per cent and for blending with fireclay and kaolin and the mid alumina materials to improve their alumina content, for lower Al_2O_3 applications.

While there are reports of production of calcined bauxite in Guyana for refractory and abrasive applications as early as 1938, and small quantities appear in shipment statistics during the war, production on a permanent basis started only in 1947 when a kiln dedicated to the production of calcined bauxite was installed. Both refractory and abrasive grades were initially produced, but the increasing demand for refractory bauxite and its higher profitability, led to the capacity being increasingly utilised for that product only. As the demand increased during the 1950s, attempts were made to develop other sources of supply. These efforts led to the production of small quantities in Suriname and the United States, but the resources in those countries were inadequate and did not satisfy some of the specifications demanded by the consuming industries for the more critical applications. Production in Guyana, therefore, increased rapidly, from around 100,000 tonnes in 1950 to 350,000 tonnes by 1960 and 800,000 tonnes in 1975, and as early as 1960, over 50 percent of the bauxite mined, was converted to refractory bauxite. This resulted in Guyana accounting for 70-88 per cent of world production of refractory bauxite between 1950 and 1975.

Guyana's rise to the position of near monopoly of the refractory bauxite market was the direct result of: (1) the increase in the demand for steel stimulated by increasing intensity of use during the period of reconstruction after the war, (2) the increase in the growth of Gross Domestic Product (GDP) in the industrialised and newly developing countries, (3) technologic innovations in the steel making process that demanded higher performance refractories and (4) Guyana's endowment with a unique mineral resource that could be economically exploited to satisfy the new requirements.

4.1.1 Increase in Market Economy Steel Consumption and Production

Tables 4.2, 4.3 and 4.4, respectively, show five-year average annual steel consumption, steel production, and growth rates for crude steel, intensity of use of steel, real GDP, and GDP per capita for the Western Economy countries over the period 1950 to 2000.

The data in Table 4.2 show steel consumption in the Market Economy Countries increasing from a five year average of 197 million tonnes in 1950-1955 to 517 million tonnes in 1971-1975, an average increase of 27.8 per cent in each period and 3.9 per cent per annum for the entire period. Table 4.3 shows production increasing from 166 million tonnes to 500 million tonnes over the same period. This high growth rates over the period have been attributable to: (1) increase in intensity of use of steel which was positive for the first three five year periods; (2) sustained high GDP growth rates in the major consuming countries created by post-war reconstruction in Western Europe and Japan; (3) capital investment in infrastructure, new industrial facilities and housing in both the industrialised and industrialising countries; (4) increased production of automobiles and durable consumer goods in North America, Western Europe and Japan; and (5) general economic and industrial development in a number new developing countries in Asia and Latin America and the Middle East.

Table 4.2 Market Economy Countries Steel Consumption

Five Year Averages

(million Tonnes)

Region	1951-55	1956-60	1961-65	1966-70	1971-75
W Europe	50	77	114	123	146
Japan	6	19	35	52	71
Other Developed Lands	9	13	17	22	27
Africa	1	2	2	3	5
Asia	4	10	12	15	29
Latin America	5	9	14	15	25
United States	91	90	106	133	135
Total	166	220	300	362	438

Sources:

1. William Malenbaum, World Demand for Raw Materials in 1985 and 2000.
2. US. Bureau of Mines, Minerals Yearbook, 1955-1992.
3. Japan Iron and Steel Federation, Annual Statistical Review 1975-1990.

Table 4.3 Market Economy Countries
Crude Steel Production
Five Year Averages
(Million Tonnes)

Major Producing Countries	**1951-1955**	**1956-1960**	**1961-1965**	**1966-1970**	**1971-1975**	**1976-1980**	**1981-1985**	**1986-1990**	**1991-1995**	**1996-2000**
United States	94	92	102	123	120	116	83	85	88	98
Japan	8	15	34	72	105	107	101	104	102	96
Germany	17	29	34	42	46	43	39	39	40	43
United Kingdom	18	22	24	26	19	19	15	18	17	17
France	19	15	18	23	24	22	19	19	18	20
Italy	3	7	10	16	21	24	24	24	26	26
Spain	1	2	3	5	10	11	13	12	13	15
Belgium	8	6	8	16	20	17	14	11	11	11
Canada	3	5	7	10	13	15	14	14	14	16
South Korea	0	1	1	1	2	3	12	19	32	41
Brazil	1	2	3	5	7	12	7	23	25	26
Mexico	1	1	2	4	5	6	7	8	10	15
Australia	2	3	5	7	7	8	6	7	8	9
South Africa	2	2	3	5	6	8	9	9	9	8
Others	20	27	65	88	95	102	94	96	104	95
Total	197	229	285	443	500	513	457	488	517	536

Sources:
1. Minerals Yearbook, 1955-1992,. US. Bureau of Mines.
2. Annual Statistical Report, 1960-1990,American Iron and Steel Institute.
3. Annual Reports, 1975-1992, International Iron and Steel Institute.
4.Annual Statistical Review, 1975-1990, Japan Iron and Steel Federation.

Table 4.4 Market Economy Countries

Five Year Average Growth Rates

(Percentage)

Period	Crude Steel Demand	Crude Steel-Intensity of Use	GDP-	GDP-Per Capita
1951-55	5	1.1	5	4
1956-60	3	1	4.0	3
1961-65	4	1	5	4
1966-70	2	0.5	4	3
1971-75	2	0	3	2
1976-80	2	-1	3	2

Sources:

1. World Demand For Raw Materials in1985 and 2000, Wilfred Malenbaum.
2. Annual Statistics 1976-1080, International Iron and Steel Institute.

4.1.2 Technologic Innovations in the Steel-making Process

Steel-making comprises a number of separate and distinct processes, involving complex thermo-chemical and thermo-dynamic reactions. The overall process has undergone fundamental technologic innovations and incremental changes in furnace construction and operating techniques since the war. The variety of steel-making techniques, the wide range of crude, semi-finished and finished steel products, and the different alloying and refining processes, make the contemporary steel industry extremely complex, and modern steel mills, the world's largest and most technically complex production facilities. Refractories are essential at every stage of the steel-making process and the volume, specific consumption and types of refractories consumed are considerably influenced by the basic process, the fundamental technologic innovations and the incremental process changes in the industry.

The process involves four separate stages that could be undertaken in physically separated facilities or in one continuous process in an integrated facility. The substantial savings in cost for heating and reheating and handling have, however, resulted in most of the world's steel being produced in integrated facilities, even though recent structural changes in the industry have reduced the proportion of steel produced in such facilities. The stages of the process are: (1) the conversion of iron ore to metallic iron, (2) the conversion of metallic iron to steel, (3) the casting of finished steel into convenient shapes for further processing and shaping and (4) the production of finished shapes for structural and industrial applications and the production of final steel-based products.

4.1.2.1 The Conversion of Iron Ore to Metallic Iron

The first stage of the steel-making process is the conversion of iron ore to metallic iron by the elimination of oxygen and chemical impurities from the iron ore. This process is undertaken either in the blast furnace or by direct reduction. In the blast furnace process a charge comprised of iron ore, coke or coal and limestone or dolomite, is heated in a refractory-lined furnace fitted with stoves at the bottom for heating air, which is blown into the furnace. The raw material charge enters the furnace at the top while the blast of hot air, at temperatures in excess of

1,1000°C, enters near the bottom. The counter-current flow of the rising hot blast and the descending charge raises the furnace temperature to over 1600°C and melts the raw material charge. Carbon monoxide produced by the combination of the carbon in the coke and the oxygen in the air blast acts as a reducing agent which drives out the oxygen from the iron ore resulting in molten metallic iron, while the limestone combines with impurities in the iron ore to form slag which floats to the surface and is drained off and discarded. The molten iron, called pig iron, is then poured into pig-shaped moulds and either solidified for use in the production of cast iron products or collected in torpedo-shaped metal transfer cars, (torpedo cars), or ladles, for conversion to steel. In the direct reduction process, coal or gas is used as the reducing agent to drive out the oxygen from the iron ore in the form of water vapour and carbon dioxide, resulting in a solid sponge-like metallic iron called direct reduced iron (DRI), which is then converted to steel.

The fundamental technologic developments at this stage of the process that have changed the mix of refractories and refractory practices in the industry are:

(1) The increase in the size of blast-furnaces from around 1,500 tonnes per day in 1950 to over 10,000 tonnes per day by 1970.

(2) Increase in blast temperatures from 850-1200oC to 1500-1600oC; (3) pressurization of the air blast to increase temperature.

(4) Oxygen injection into the furnace to increase the melting temperature.

(5) Pre treatment processes, such desilication, desulphurisation and dephosphorisation of the metal in the ladles and torpedo cars.

The increase in blast furnace size resulted in reduction of the number of blast furnaces, increased volumes of raw materials and finished product handled by each furnace, longer production campaigns, and increase in the capacity of torpedo cars and ladles for the transfer of hot metal. These changes demanded greater hot strength, corrosion, abrasion, spalling and thermal shock resistance in refractories while the increase in the blast and melting temperatures and the reagents used for pre-treatment demanded higher refractoriness and increased resistance to chemical and aggressive slag attack in the refractory linings of the hot metal transfer equipment. These developments led to the replacement of fireclay and silica refractories by the mid aluminas and bauxite at the blast furnace stage.

4.1.2.2 The Conversion of Metallic Iron to Steel

The second stage of the process is the conversion of pig-iron, or DRI, to steel, and involves, basically, a removal of excess carbon and other impurities from the iron to produce steel which is a stronger and more malleable material. The conversion of metallic iron to steel is undertaken by a number of processes; those in universal use until the end of the war, being the Bessemer, and Open-hearth processes. During the post-war period, the Bessemer and Open-hearth processes have been being replaced by the Basic Oxygen and Electric Arc Furnace processes, which, currently, account for over 95 per cent of steel produced in the Market Economy countries. These fundamental technologic changes have been accompanied by a number of incremental changes in the process, in furnace construction and operating of the steel-making furnaces and in the operating practices at all stages of this part of the process. In the Basic Oxygen process, oxidization of the carbon, silicon, magnesium, other reactive elements and residual slag in the pig iron, are eliminated by intense heat generated by blowing oxygen through a lance into the molten pig iron, in a refractory lined furnace. In the Electric Arc process, a charge comprised of steel scrap, direct reduced iron, limestone and a carburiser are mixed in a shallow refractory-lined furnace with a detachable roof. Heat generated by an electric arc formed between the charge and electrodes descending into the furnace through holes in the roof melts the charge, oxidizes, the reactive elements, and eliminate them as slag. The Electric Arc process currently accounts for approximately 35 percent of steel produced in the Market Economy countries, and the precision with which temperatures could be controlled, and its efficiency in the utilisation of alloying materials, have made it the principal process for the production of alloys, tool, stainless, and other speciality steels. Table 4.5 shows steel production by furnace type for the United States, Japan and Germany.

Table 4.5 Crude Steel Production
By Furnace Type
1950-2000

Year	United States (%)			Japan (%)			Germany (%)		
	Open Hearth	**Basic Oxygen**	**Electric Arc**	**Open Hearth**	**Basic Oxygen**	**Electric Arc**	**Open Hearth**	**Basic Oxygen/ Besseme**	**Electric Arc**
1950	99	1.0	1	81	4.0	1,6	76	24	1.0
1955	90.0	9	1,5	83.0	4	2	65.0	33.0	2.0
1960	88	3	9	68	12	2.0	55	42.0	3..0
1965	74	15	11	25	55	20.0	43	50	9
1970	37	48	15	4	76	17	26	64.0	10
1975	19.0	62	19	1.0	83	20	24	64.0	12..0
1980	12	60	28	0	73	25	2.0	80.0	18.0
1985	7	59	34	0	na	na	0	78.0	22
1990	4	59	37	0	69	31	0	76. 0	24.0
1,995	2.0	39.3	60	0	32	68	0	76	24

Sources
1. Technology and Steel Industry Competitiveness, 1980.
   U.S. Office of Technology Assessment.
2. Annual Statistical Reports , 1974.1983, 1990,.American Irom and Steel Institute.
3. Steel Statistics 2000, International Iron and Steel Institute.
4. Steel Statistics 1993,.Japan Iron and Steel Association.
5. Evaluation of The Markets For Calcined Bauxite In Western
   Europe and Japan, 1973., Arthur D.Little.

The fundamental technologic innovations at the steel-making stage that have affected the consumption of refractories are:

(1) The almost total replacement of the Open Hearth process by the Basic Oxygen process, which, with its higher melting temperatures, increased turbulence and chemical reactions, required higher refractoriness and resistance to corrosion and chemical attack in the ladles.

(2) The increase in the proportion of steel produced by the Electric Arc process, which requires removal of the roof for pouring and recharging and subjects the roof refractories to intense thermal shock, increased the demand for refractory materials with high refractoriness and high resistance to thermal shock.

(3) The practice of ladle metallurgy, under which most of the steel refining and alloying processes are undertaken in the ladles, has led to ladles being converted to miniature furnaces, and consequently requiring refractories capable of withstanding increased physical, mechanical and chemical reactions.

(4) The almost total replacement of refractories by water cooling in the roof of Electric Arc furnaces.

4.1.2.3 The Conversion of Molten Steel to Semi-finished Shapes

The third stage of the process is casting, where the steel from the previous stage is formed into suitable shapes--ingots, slabs or bars--that could be pressed, rolled or extruded into finished shapes. Ingot casting, was the most common form of casting prior to 1960. This process involved pouring of molten steel into cast iron or sand moulds in which the steel solidifies; the moulds are then stripped and the ingots lowered into pit-like furnaces called soaking pits, where they are heated to a uniform temperature before being rolled to form the intermediate shapes. The fundamental technologic change at the casting stage is the replacement of ingot-casting by the continuous casting process, in which molten steel is poured into a refractory lined chamber called a tundish, fitted with an oscillating water-cooled copper mould and a cooling chamber containing water sprays. The casting forms within the mould, where it cools and solidifies as it descends through the water sprays and emerges from the caster as a solid continuous band of steel which is then cut into lengths to produce the semi-finished shapes. Continuous casting currently accounts for approximately 90% of the steel cast in the Western Economy producing countries, since by eliminating the mould stripping, soaking pit and primary rolling stages associated with ingot casting, it results in higher quality, higher yields, and savings in capital, energy, refractories and handling costs. The main features of the process that impact on refractories are: (1) the longer residence time of super heated molten steel in the charging ladles, which completely eliminated low and mid-alumina refractories in ladles and (2) the erosive effect of the continuous rapid flow of large volumes of turbulent molten steel through the casting equipment, which demanded the properties of high refractoriness, and high resistance to corrosion and chemical attack in the refractories.

4.1.2.4 The Manufacture Of Finished Steel Shapes

The final stage is rolling, forging and extrusion, where the semi-finished shapes, produced at the casting stage, are subject to further processing in rolling, forging or extrusion mills to produce flat rolled products, rails, bars, wire-rod, pipe or tubing and structural shapes for the manufacture of finished steel products. Rolling involves the production of finished steel by subjecting hot or cold ingots to continuous rolling through heavy rollers until the correct thickness has been achieved, while under forging, the semi finished shapes are re-heated and hammered by steam, compressed air or electro-mechanical hammers, or pressed by hydraulic or mechanical presses with a die to control the shape. Extrusion involves shaping by the use of a machine driven ram that shapes metal confined within a tubular container by pushing it through a die opening at the opposite end of the container. Improvements in the techniques in all these processes have resulted in the use of higher performance refractories.

4.2 The Fall in Demand for Refractory Bauxite

Refractory bauxite had a short product life cycle. Data on demand prior to 1970 are not available but market information from discussions with consumers in all the major consuming countries, indicate that over the period 1965 to 1970, annual demand for refractory bauxite outstripped supply by approximately 200,000 tonnes, with Guyana and Suriname, the only countries producing a technically acceptable product, unable to satisfy the demand. Demand between 1970 and 1979 remained consistently between 1.0 million and 1.2 million tonnes, with demand still exceeding supply, in spite of increased production in Guyana, the use of certain grades of Chinese bauxite, and small-scale production in Germany, Denmark and Italy based on ore from Guyana, Suriname and China. The situation however changed dramatically after 1979 with annual demand in 1980 falling to 900,000 tonnes and to an excess of supply over demand for the first time since 1965 and deteriorated further between 1980 and 1983, with demand falling to around 700,000 tonnes in 1983.

This steep decline in demand led to a rapid restructuring of the refractory bauxite market. Chinese bauxite which entered the market in the mid 1970s, had just started gaining market acceptance, and, with projections of a continuing increase in demand, and declining production in Guyana, the Chinese authorities promoted the production of refractory bauxite at the village and regional levels. Faced with an increase in supply and a fall in world demand, the Chinese, in 1982, instituted a 25 per cent price reduction to increase sales volumes. The substitution effect of this price reduction, together with the overall fall in demand for refractory bauxite, had an immediate impact on the market. Sales from Guyana fell from 650,000 tonnes in 1980 to 300,000 tonnes in 1983 while Suriname and the European producers utilising imported bauxite, were forced to discontinue production. While demand improved after 1984, it never returned to the pre 1980 levels, and in the new competitive environment, Guyana's market share which had already fallen from 76 per cent in 1975 to 66 per cent in 1980, fell to 50 per cent in 1985 and 30 per cent in 1990. The demand for Guyana bauxite at the lower level continued to be strong, but deterioration of the country's production capability made it unable to satisfy the demand This created the opportunity for the entry of Brazil into the market and to Guyana's share falling to 17 per cent in 1995 and 12 per cent in 2000. The decline in world demand for refractory bauxite after 1980 has been attributable to a combination of demand and supply factors which need to be discussed in detail, to evaluate their impact on the overall market and on Guyana's share of the market.

4.2.1 Demand Factors

The principal demand factors are identified as: (1) stagnation and decline in Market Economy countries steel production, (2) reduction in the specific consumption of refractories in steel-making, (3) restructuring of the steel industry, (4) technologic changes in steel-making and (5) improvements in the manufacture of refractory products

4.2.1.1 Stagnation and Decline In Western Economy Steel Production

Refractory bauxite is used in a large number of metallurgical and chemical processes; the catalyst for its development and growth, however, was the economic and technologic developments in the post-war steel industry in the Market Economy steel producing countries. The steel industry in these countries, consumes more than 60 percent of all categories of refractories, 75 per cent of all mid, high and extra high alumina refractories and 80 per cent of all refractory bauxite based refractories. Developments in the industry are used by the producers of refractory raw materials and refractory products as the barometer of demand for refractories in general and high alumina refractory materials in particular.

Table 4.6 shows Western Economy annual crude steel production for the period 1970-1985. The data show steel production moving through cycles of high growth, stagnation, slow growth, and decline, followed by slow growth over the period. The quadrupling of oil prices between 1973-1994, brought a halt to the high post-war economic growth rate in the Market Economy countries with the real GDP growth for the OECD members of the group declining from 5.7 per cent in 1973 to -0.3 per cent in 1975. This decline had a direct effect on steel production for the countries of the group that fell 14 per cent between 1973 and 1975. After a brief recovery between 1976 and 1978, the doubling of oil prices in 1979, again resulted in a decline in OECD members' real GDP growth from 4.5 per cent in 1978 to -0.6 per cent in 1982, and 2.6 per cent in 1983. The decline in GDP growth was accompanied by a decline in the intensity of use of steel that fell 3.7 per cent per annum over the period. Through improvements in the quality and techniques for using steel, the downsizing of automobiles, changes in the structure of GDP and substitution of steel by other materials such as aluminium and plastics (National Economic Development Office, 1986, page 2). The direct effect of these developments was an overall fall in Western Economy steel production of 18 percent between 1978 and 1983. The decline was, however, greater, in the countries that were the largest consumers of refractory bauxite:

(1) Production in the United States fell 52 per cent, from 137 million tonnes in 1973 to 66 million tonnes in 1982, and returned to only 80 million tonnes in 1985.

(2) Production in the United Kingdom fell 52 per cent, from 27 million tonnes in 1973 to 13 million tonnes in 1982, and returned to only 16 million tonnes in 1985.

(3) Production in West Germany fell 32 per cent, from 53 million tonnes in 1974 to 36 million tonnes in 1983, and returned to 40 million tonnes in 1985.

(4) Production in Japan fell 18 per cent from 119 million tonnes in 1978 to 97 million tonnes in 1983 and returned to 103 million tonnes in 1985.

Table 4.6 Annual Crude Steel Production

Market Economy Countries

1970-1985

(Million. Tonnes)

Countries	1970	1971	1972	19731	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
United States	122	112	124	137	132	105	116	114	124	123	102	110	68	77	84	80
Japan	93	89	97	119	117	102	106	102	102	112	112	102	100	97	106	103
Germany	45	40	44	50	53	40	42	40	41	46	44	42	36	36	39	40
United Kingdom	28	24	25	27	22	20	21	21	20	22	20	16	15	16	15	16
France	24	23	24	25	27	22	23	22	23	23	23	21	18	18	19	13
Belgium	18	20	21	26	23	16	17	16	13	13	15	13	13	15	11	15
Italy	17	120	21	21	23	22	23	23	24	24	27	25	24	22	25	30
Canada	11	12	13	13	14	14	13	14	15	16	15	15	15	15	15	145
Spain	7	10	11	11	12	1	12	11	11	12	12	12	10	10	14	15
South Korea	1	1	1	1	2	2	3	4	5	8	6	8	7	12	13	14
Brazil	5	7	7	7	8	8	9	12	12	14	13	13	13	14	18	21
Australia	7	7	8	8	8	8	8	7	8	8	8	8	6	6	6	7
South Africa	4	4	5	5	6	6	7	7	8	9	9	9	8	7	78	9
Mexico	34	5	4	5	5,1	6	5,3	6	7	7	7	8	7	7	8	8
Netherlands	5	5	6	6	6	5	5	5	6	6	5	6	4	5	6	6
Total	411	386	476.0	492	493	424	454	442	505	473	481	470	413	421	454	461

Sources:
1. U.S Bureau of Mines Minerals Yearbook1976, 1980 and 1986.
2 International Iron and Steel Institute, Annual Statistics, 1980 and 1985.
3. U.S. Iron and Steel Institute, Annual Statistics, 1975.

The developments in these countries, which consumed 53 per cent of Guyana's bauxite production, combined with the substitution of Guyana refractory bauxite which Chinese bauxite and lower alumina refractory materials, resulted in sales falling from 600,000 tonnes in 1980 to 325.000 tonnes in 1983 and never returning to the 600,000 tonnes level since that time. Table 4.7 shows the distribution of Guyana refractory bauxite sales over the period 1975-1985.

Table 4.7 Guyana Refractory Bauxite Sales

Major Consuming Countries,1975-1985

(000 Tonnes)

Countries	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**
North America	189	190	171,0	168	137	166	110	47.2.	72	106	102
Japan	56	42..5	63	34	45	40	43	67	33	52	68
West Germany	64	79	53	53	39	54	55	43	49	56	55
France	59	41	49.0	53	38	34	37.0	28	29	44	45
United Kingdom	113	116	112	52	54	46	49	29	33	50.0	42
Italy	40	38	35	38	27	38	20	24	18	35	38.0
Spain	14	18	19	13	16.00	23	12	15.8	6.8	4	5
Mexico	35	34.2	25	38	45	39	24	14	14	24	22
World Total	784	743	705.0	588	552	603,2	497	371	325	470	447

Source:
Bauxite Industry Development Company, Statistical Reports, 1972-1986

4.2.1.2 Reduction in Specific Consumption of Refractories

Although refractories account for less than 5 per cent of the cost of production of steel, (discussions with R Hubble, US Steel Research, 1982), the reduction of specific consumption of refractories at all stages of the process has been a pre-occupation of the steel industry since the middle of the 1960s. The largest reduction in specific consumption of refractories at the steel-making was caused by thc replacement of the Open Hearth process by the Basic Oxygen processes. This change led to a reduction from 30-35 kilograms per tonne of steel to less than 5 kilograms per tonne, while the introduction of the Electric Arc Furnace resulted in a further 20 per cent reduction (Laming, 1982, page 11). The increase in international competition following the recession in the industry in 1975 intensified the effort to reduce specific refractories consumption in all the steel producing countries while the process was accelerated by technologic innovations and operating practices in the industry, improvements in the quality of refractories and improvements in refractory installation techniques in the industry. Refractory bauxite initially benefited from these developments, but the increase in the production of higher quality synthetic aluminas, magnesia, silicon carbide and zirconia, soon led to its replacement in the continuous casting process, while the perfection of the use of water cooling in the roof of electric arc furnaces completely replaced bauxite by the end of the 1980s. The combined effect of these developments was a reduction in the specific consumption of refractories as shown in Table 4.8 for the Japanese steel industry which is representative of developments in the industry for the countries of the group. The data show specific consumption of refractories falling from 28.1 kilograms per tonne in 1965 to 11.5 kilograms per tonne in 1990.

Table 4.8 Japanese Steel Industry, Specific Refractories Consumption

Year	**Refractories Consumption (kg/Tonne**		
	Shaped	**Unshaped**	**Total**
1,965	25	3	28
1970	21	3	24
1975	14	7	21
1980	10	5	15
1985	7	6	14
1990	6	6.0	12

Sources
1. Annual Statistics,.Refractory Society of Japan,
2. Evaluation of the Market for Calcined Bauxite in Europe and Japan, 1993. Arthur D. Little.
3. Paper presented at 9th International Industrial Minerals Congress 1986, K Yoshida, Nissho Iwai Corporation, Japan.
4. Internal Statistics,1995-2000, Nissho Iwai Corporation, Japan.

4.2.1.3 Steel Industry Restructuring

The decline in steel consumption, which started with the 1975 recession and accentuated by that of 1981-1983, led to a major restructuring of the steel industry in all the Market Economy countries. A feature of this restructuring was the closure of old steel-making capacity and a shift in production from integrated to non-integrated facilities. Since the non-integrated facilities utilise exclusively the electric arc furnace process, the result of this development has been an increase in the percentage of steel produced by this process. The consequence of this was a reduction in the demand for pig iron and in blast furnace production, since the electric arc furnace uses mainly scrap and DRI as raw materials. The total replacement of refractory bricks by water cooling in the roof of the large high, and ultra-high power electric arc furnaces installed in the non-integrated plants, resulted in a further reduction of the specific consumption of refractories and in the consumption of Guyana refractory bauxite based bricks for which this was the largest application.

4.2.1.4 Improvements in Refractories Manufacturing Technology

Refractories manufacturing technology underwent major changes between 1960 and 1990. Prior to 1960, the production of refractories was a relatively low technology process involving a narrow range of standardised products based on processes controlled almost entirely by the types and quality of the available raw materials. The changes in steel-making technology, and demands by the industry for improved refractory performance, led to a change in the variety of refractory products, and to the manufacturers being forced to improve their processing techniques and produce a wider range of high technology products. The major developments in refractories technology that have affected raw material usage in their manufacture are: (1) increase in the production and consumption of monolithic refractories; (2) chemical bonding of refractory bricks and (3) the development of composite refractory raw materials and refractory products.

The development of unshaped or monolithic refractories in the form of plastics, castables, mouldables, cements and ramming and gunning mixes as replacements for bricks resulted in savings both in the cost of refractories, the cost of down-time on equipment and the cost of labour for the installation. The methods of application of monolithic refractories in the form of masses which are fired in service, also eliminate the cost of forming and firing and increase the service life of refractory linings by making it feasible for linings to be repaired several times while the equipment is still in service. The development of complete monolithic linings in furnaces and ladles has further increased the service life of refractory linings by eliminating joints that are vulnerable to slag and chemical attack. The development of monolithics has resulted in a significant reduction in the production of bricks, and over the period 1960 to 1985, the percentage of monolithics in the steel industry has increased from under 15 percent to nearly 50 per cent in the United States and from under 10% to around 35 percent in Japan. The later development of low, ultra-low and no-cement castables has made it possible for monolithic refractories to be used in steel-making furnaces and in applications where the calcium content of the cement in the mix initially restricted their performance.

Until the end of the 1960s, ceramic bonding, involving blending of the basic refractory material with other oxides to form a ceramic bond upon firing was the standard method for the production of refractory bricks. The introduction of tar impregnation and chemical bonding made it possible for bricks to be produced without firing and to be produced from almost pure oxides, without the addition of bonding materials, which reduce the oxide content of the brick. Chemical bonding also facilitated the production of composite refractories that optimise the desirable properties of different refractory materials, and has resulted in the availability of a range of new high performance refractory materials and refractory products such as alumina-chrome, alumina-zircon, alumina-graphite, magnesia-alumina spinels, magnesite-graphite, zircon-graphite and magnesia-zircon, that are increasingly being used in applications in the steel and other industries and are replacing refractory bauxite based and other refractory materials.

4.2.2 Supply Factors

The major supply factors that affected refractory bauxite were (1) increased production of mid and extra-high alumina refractory materials, (2) the development of Chinese bauxite and (3) the replacement of refractory bauxite by non-alumina and composite refractory materials.

4.2.2.1 The Development of Mid and Extra-High Alumina Refractory Raw Materials

Prior to the early 1970s the only source of high alumina refractory materials in the mid-alumina category (50-70 per cent Al_2O_3), was the naturally occurring sillimanite group materials, sillimanite, andalusite and kyanite. The limited availability of these materials and the high cost of beneficiation, confined their consumption to only critical industrial applications where their unique mullite structure was required. The unavailability of these materials to satisfy the increase in demand for higher alumina in steel plant refractories led to the extensive use of Guyana refractory bauxite for blending with kaolin and fireclay, for the production of refractories with Al_2O_3 content of 50-70 per cent. The continuing increase in demand for these materials, not only for their refractoriness, but for their hot strength under load and volume stability inherent in their mullite structure, led to increased production of andalusite in South Africa and France, the development of homogenised and non-homogenised bauxite and kaolin based materials with the appropriate Al_2O_3 content. in the United States, and production of lower Al_2O_3 bauxite based materials in Brazil. The persistent unavailability of refractory bauxite, and the more than tripling of its price during the decade of the 1970s, stimulated production of these materials especially those in the 50-60 per cent Al_2O_3 category. By 1980 andalusite and the Mulcoa range materials in the United States had almost completely eliminated the use of refractory bauxite for improving the Al_2O_3 content of kaolin and clay. These materials also replaced refractory bauxite in a number of furnace applications, and in hot metal transfer cars and steel ladles.

The increased consumption of monolithic refractories during the decade of the 1970s also stimulated the use of high alumina refractories and increased the consumption of refractory bauxite. The requirement for homogeneity and high purity in monolithic refractories, and the movement toward clean steel in the 1980s, which required minimal SiO_2

absorption from ladle and continuous casting tundish refractories, however, promoted the replacement of bauxite by synthetic alumina products--brown and white fused alumina, sintered and tabular alumina--in the manufacture of monolithic refractories. The 40 per cent reduction in the price of brown fused alumina from China, further made it possible for this material, with its higher Al_2O_3 content, and higher purity and density, to be blended with lower Al_2O_3 materials for the production of refractory products in the 80-90 per cent Al_2O_3 categories.

Table 4.9 shows the increase in production of mid and synthetic extra-high alumina refractory raw materials for selected years between 1955 and 2000.

Table 4.9 Mid and Extra-High Alumina Materials
Estimated Production
1955-2000

Product (000 mt)	**1955**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2,000**
Mid - Alumina (50-70% Al_2O_3)									
Kyanite	40	110	165	130	180	140	115	125	125
Sillimanite	10	20	50	25	30	15	25	25	30
Andalusite	20	40	45	90	225	240	220	275	240
Mulcoa and (60 &70)	-	-	0	125	180	225	200	200	200
ucal	-	-	0	0	25	15	15	15	0
Brazil (50&60%)	-		0	0	0	25	30	30	40
Total Mid-Alumina	70	170	260	372	665	660	610	620	630
Extra -high Alumina (93-99% Al_2O_3)									
Brown Fused Alumina	20	40	50	100	150	175	180	180	200
White Fused Alumina	10	10	20	40	50	75	70	70	70
Calcined Alumina	10	30	50	75	75	100	125	100	120
Sintered Alumina	5	25	50	50,	50	75	75	100	80
Tabular Alumina	10	30	40	40	50	40	75	60	60
Syntethic Mullite	40	75	100	50	80	100	125	120	120
Total - Extra High	95	210	310	355	455	565	625	630	620

Sources:

1 Japan Firebrick Association- Annual Statistics.

2 US Refractories Association- Statistics.

3 Discussions with major producers fused aluminium oxide, Washington Mills and Exolon E.S.K, U.S.A and Treibacher, Austria.

4 Discussions with major producers of sintered alumina, Alcoa, Kaiser Aluminium and U.S.A.

5 Private Discussions with the major producer of the Mulcoa group of materials, C.E Minerals, U.S.A.

4.2.2.2 The Development of New Sources of Refractory Bauxite

The increasing demand for refractory bauxite in the 1970s, projections for increasing demand in the 1980s, and the chronic shortage of Guyana refractory bauxite during the 1970s, led to the entry of China into the market toward the middle of the 1970s and to efforts to produce refractory bauxite in Brazil toward the middle of the 1980s.

High alumina refractory materials from China, varying in $A1_20_3$ content from 50 per cent to over 85 per cent, and variously classified as bauxite, aluminous shale, calcined diaspore, and calcined clay, have been in use by the refractories industry in Europe and Japan since the early 1970's. The uncertain nomenclature of these materials, and the paucity of data and information on production, exports and imports, however made it difficult to determine which of them could be technically classified as refractory bauxite. While the major chemical constituents -- Al_2O_3, SiO_2 and Fe_2O_3--in Chinese products classified as refractory bauxite are similar to Guyana refractory bauxite; the impurities, TiO_2 is, however 40-60 per cent higher, and the critical alkali elements, Potassium Oxide (K_2O) and Sodium Oxide (Na_2O), 6-10 times higher. The mineralogical structure of Chinese bauxite is also different, being diaspore compared with gibbsite in Guyana bauxite. The high level of impurities, especially the alkalis reduce the refractoriness, hot strength and chemical resistance properties of Chinese bauxite and initially confined its use to applications outside the steel industry and to less demanding steel industry applications. The mineralogical structure that results in shrinkage with increasing temperature also make Chinese bauxite inherently inferior to Guyana bauxite in applications in the steel industry where thermal expansion is critical. The major deficiencies of Chinese bauxite that delayed its acceptance by the Western Economy refractories producers were: (1) inconsistent calcination which resulted in variable density, (2) inadequate quality control which resulted in variable chemistry and (3) rudimentary production techniques that resulted in large lump size that could not be crushed by the available equipment at the consumers' plants. These deficiencies, together with the marketing arrangements for the product until the mid 1970s, where sales were conducted through a bidding process at the Canton Fair, resulted in difficulty in its entry into the markets of the major consuming countries. The persistent shortage of Guyana bauxite and the steep increase in price following the first round of oil price increases in the early 1970s, resulted in some of the European, and the Japanese trading companies undertaking selective buying to guarantee Al_2O_3 content, reduce the variability in chemistry and degree of calcination, and the installing crushing and sizing capacity at the ports to reduce lump size. This led to greater market acceptance, and by 1980, the higher grades of the Chinese bauxite were being used widely in Europe, and Japan even though, in many cases, they had to be blended with other materials to make them suitable for the more demanding applications. The 30 per cent increase in the price of Guyana bauxite after 1979, caused by the steep increase in oil price in that year, led to further increases in the consumption of Chinese bauxite. The large price differential, made it economical for the product to be blended with the higher priced refractory bauxite, synthetic mullite, fused and sintered alumina and chromium oxide to over its chemical and structural deficiencies. The decline in demand for refractory bauxite during the recession of the 1980s induced the Chinese to implemented a 25 per cent price reduction on the price of refractory bauxite in a attempt to maintain their sales volume. This further increased the price differential between Chinese and Guyana bauxite making it economical for the consumers to increase consumption of the material and providing a further incentive for them to undertake research to utilise it in other steel industry applications. Later improvements in the selection of raw material and in processing, including investment in rotary kilns, better organisation of the industry at the regional level, and implementation of quality control measures to ensure consistency of quality, resulted in the material becoming generally accepted, and by 1985 accounted for nearly 50 percent of world consumption.

Table 4.10 shows estimated sales of Chinese refractory bauxite by major consuming areas over the period 1975-1985.

Table 4.10 Chinese Refractory Bauxite Sales

Major Sales Areas

(000 Tonnes)

Countries	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
North America	14	25	-	-	24	116	177	95	65	111	175
Japan	n.a	n.a	n.a	65	71	74	69	55	65	68	64
Germany	16	24	26	30	24	76	59	45	56	65	67
France	15	2	14	22	19	31	19	21	27	27	30
United Kingdom	14	11	14	11	17	23	15	35	38	40	43
Italy	30	24	19	29	25	23	16	23	26	35	31
Spain	n.a	n.a	n.a	n.a	n.a	n.a	10	12	17	23	28

Sources:

1 Nissho Iwai -Sales Statistics, 1975-1985
2 Japan Firebrick Association, 1975-1983.
3 US Bureau of Mines, Minerals Yearbook, 1978-1985.
4 Discussions with consumers in United Kingdom, Germany and Italy, 1980-1985.

Even with the lower demand for Guyana bauxite in the 1980s, the deteriorated condition of the production facilities made it incapable of satisfying the market demand for its products. The continuing demand for a gibbsitic bauxite by the refractory manufacturing and steel industries, and their willingness to pay a premium, induced Brazil to enter the market in 1990, with a product of similar mineralogical structure to Guyana bauxite, and chemical composition as shown in Table 2.6. This material has been accepted by the industry as a substitute for Guyana bauxite in a large number of steel industry applications, and has replaced nearly 50 per cent of Guyana's market share between 1990 and 2000. Table 4.1, above, shows the impact of

Chinese and Brazilian refractory bauxite on the market between 1980 and 2000.

4.2.2.3 Increased Production of Non Alumina Refractory Materials

Non-alumina refractory materials, have always constituted a significant part of the refractories mix, those in common use in the steel and other industries being: (1) the basic group comprised of natural magnesite (Mg_3O_4) and synthetic magnesia (MgO), dolomite, and chromite (CrO), and (2) the non-basic materials, natural zircon, synthetic zirconia, silicon carbide, carbon and graphite. The basic materials are essential to basic steel-making processes, where they are used in the lining of basic oxygen and electric arc steel-making furnaces. They could, however, at the appropriate price, compete with the alumino silicate refractories in other applications in the process.

The high demand for the higher quality basic refractories for the lining of Open Hearth furnaces resulted in a shortage in supply and consequent high prices for these materials until the mid 1970s. This stimulated investment in the United States, Europe and Japan, for the production of synthetic magnesia from natural magnesite and sea-water. Simultaneously with these developments, the massive replacement of the Open Hearth furnace by the Basic Oxygen and Electric arc furnaces, and the reduction in the specific consumption of refractories in these furnaces, resulted in an over-supply of magnesite and magnesia and to a fall in their price. This made it feasible for These materials, therefore become competitive with high alumina for ladles and metal transfer cars applications, and, because of their higher refractoriness and resistance to chemical attack, they were technically superior to high alumina in many of the new ladle applications, and replaced refractory bauxite in processing and continuous casting ladles and tundishes. Investment by Australian and Japanese investors in the increased capacity for the production of zircon sand and synthetic zirconia in Australia, also increased the supply and reduced the price of these materials, making them competitive with refractory bauxite in the lining of steel ladles.

4.2.3 Competitiveness of Guyana Refractory Bauxite

The rapid decline in the demand for Guyana refractory bauxite and loss of market share, were influenced by its competitiveness with Chinese refractory bauxite, the two elements of competitiveness of particular significance being cost of production and pricing.

4.2.3.1 Refractory Bauxite Production Cost

It is extremely difficult to undertake a meaningful comparison of cost of production between Guyana and Chinese refractory bauxite, since the structure of the two industries and the production process are vastly different and data on operating parameters and elements of cost are not available for the Chinese industry.

Refractory bauxite production in Guyana is highly capital intensive at all stages of the process. At the mining stagelarge capital investment is needed for equipment such as large walking draglines and bucket wheel excavator systems for stripping overburden of 60 to 80 metres, with an overburden to crude ore ratio of around 5.5:1, and a crude ore to finished product ratio of 4:1. Substantial investment is needed for equipment for haulage of the large volume of ore, and at the processing stage for washing and screening and rotary kilns for calcination. The major elements of operating cost are fuel oil and electricity for the mining equipment, diesel fuel for the transportation equipment, electricity for the crushing, washing and screening operation, electricity and fuel oil for the operation of the kilns, refractories maintenance, operating supplies, labour and administration. Table 4.11 shows estimated production cost based on Linmine's standard costing practices

Table 4.11 Guyana Refractory Bauxite
Estimated Production Cost[1]
(Linmine, 2000)

Operating Parameters		**Production Cost (US$/Tonne)**	
Production (tonnes)	200,000	Stripping	21.85
Stripping Ratio-(bcm/Tonne)	5.75	Mining	17.00
Conversion Ratio-Ore/Product (%)	25	Trammimg	6.00
Fuel Oil (bbl/Tonne)	1.30	Fuel Oil	23.40
Fuel Oil Price (US$/bbl)	18.00	Repairs and Maintenance	10.00
Stripping Unit Cost (bcm)	0.95	Operating Supplies	5.50
Mining Unit Cost (Tonne)	4.25	Labour	5.00
Tramming Unit Cost (Tonne))	1.5	Power	12.50
1		Capital	12.50
		Administration	1.50
		Exporting	.50
		Total	115.75

[1] Estimated from information from Linden Mining Enterprise

Source:
Calculations undertaken by the author based on data provided by Linden Mining Enterepri se

The occurrence of the bauxite deposits, the structure of the Chinese refractory bauxite industry and the domestic culture, make it nearly impossible to obtain reliable data and information that could be used to estimate production cost:

(1) The Chinese bauxite deposits occur as rock outcrops with negligible overburden. Minimal investment is therefore needed for stripping overburden while mining involves essentially blasting and removal of the ore.

(2) The industry is comprised of small primitive operations with little capital investment at any stage of the process; medium-sized operations, with little capital investment at the mining stage and some capital investment at the processing stage; relatively large technically efficient operations involving capital investment at the processing and rotary kiln operations requiring substantial investment at the processing stage.

(3) The production process utilises a mix of shaft, round and rotary kilns, all of which have different operating cost parameters and variables.

(4) The operations produce a mix of products comprised of refractory bauxite, abrasive bauxite, which is usually off-grade refractory bauxitehy and lower Al_2O_3 materials classified as chamottes, shale and clay.

(5) The cost of major inputs to the industry, such as fuel and labour, are not subject to economic rates. Coal for calcination is supplied in

relatively crude form from local quarries, and labour provided by workers on a communal basis.

(6) No credible data or reliable information on any of these inputs, are available or could any be obtained from the management of the operations or officials at the Ministry with responsibility for the industry who are generally reluctant to discuss matters related to cost of production.

But, where the consumers of refractory bauxite are concerned, cost of production from mining to point of export shipment is never considered in their evaluation of the comparative cost of refractory bauxite from different sources, especially since price, in what is effectively a duopolistic market, is not normally related to cost of production. The customers' measure of comparative cost is the price they pay for materials delivered to their plant, plus costs that may be incurred in preparing them for final processing. Discussions with consumers of refractory bauxite and technical personnel in the refractories industry, world-wide, between 1980 and 1990, revealed a number of additional costs associated with the final preparation of Chinese bauxite which were not applicable to Guyana bauxite. These included preliminary crushing to reduce lump size before in-plant processing, drying to remove excess moisture which is normally present in Chinese bauxite, and the need for the addition of high cost synthetic refractory materials and oxides, for correcting chemical and mineralogical deficiencies in the material.

Table 4.12 shows the comparative cost of production of similar final products based on Guyana and Chinese bauxite, estimated by refractories producers in the United States (National Refractories and

Table 4.12 Refractory Based Bauxite Products

Comparative Bauxite Cost

1985-1990

Cost Elements	**United States-**		**United Kingdom**		**Japan**	
	Chinese Round Kiln	**Guyana RASC**	**Chinese Round Kiln**	**Guyana RASC**	**Chinese Round Kiln**	**Guyana RASC**
	US$mt c.i.f U.S Gulf	**US$mt f.o.b barge**	**US$ mt cif-**	**US$mt c.i.f**	**US$mt f.o.b China.**	**US$mt f.o.b Guyana**
Bauxite	102.00	155.00	95,00	160.00	75.00	140.00
Freight	0.00	0.00	0.00	0	10.00	45.00
Fuel Oil Adjustment	0.00	9	0.00	9.25	0.00	9
Discharge	4.20	0,00	5.00	5.00	5.00	5.00
Unloading and Trucking	8.00	8.00	12.00	12.00	5.00	5.00
Drying	8.00	0.00	10.00	0.00	15.00	0.00
Preliminary Crushing	13	0.00	8.50	0.00	15.00	0.00
Crushing losses	5.50	0.00	7.00	0.00	0.00	0,00
Additives	10.00[1]	0.00	20.00[2]	0..00	25,00[3]	0.00
Total	151	172.25	157.50	186	150.00	204.25
Difference(%)	14[123]		18.3		36.6	

[1] Chinese bauxite blended with fused Al_2O_3 to reduce TiO_2 content.

[2] Chinese bauxite blended with CrO_2 to induce residual expansion.

[3] Chinese bauxite blended with RASC to reduce and alkali content

Sources:

1 National Refractories and Minerals Inc., United States, Private Discussions-1987.
2 D.S.F Refractories, United Kingdom, Private Discussions 1987
3 Kurosaki Refractories, Japan, Private Discussions 1989

Another dimension of the analysis of comparative cost of refractory materials that is normally overlooked in comparative cost analysis, is cost-performance, which is the measure used by the final consumers of refractory products in making techno-economic choices among refractories made from competing raw materials. This measure compares the cost of different refractory products with their service life in a particular application and considers, not only cost of the refractory product itself, but the cost of down-time on equipment, the cost of installation and repairs arising from refractory failure, and even possible loss of product resulting from such failure. However, this is an extremely difficult measure since factors other than the basic raw material, such as other materials in the blend, the preparation of the raw materials, the bonding materials and the manufacturing techniques, could affect the service life of a refractory product. It is, however, the measure most widely used by the steel industry as the basis of comparison of the cost of refractory products made from Chinese and Guyana bauxite. Discussions with North Western Steel in Middleton, Ohio, (1991), revealed a 33.3 per cent longer life for a Guyana bauxite based brick compared with a Chinese bauxite based brick in their steel ladles. The cost of the Guyana bauxite based brick was, however 50 per cent higher than that of the Chinese bauxite based brick, hence the latter was more cost effective in their operation even when the additional installation costs were added.

Consideration of all these factors show the difficulty of using cost of production of the raw material in comparing competitiveness of Guyana and Chinese bauxite. The additional pre-processing cost, especially the cost of additives, could completely cancel the advantage of low Chinese price, while at the refractory application stage, lower service life and the associated costs could have a similar effect.

4.2.3.2 The Pricing of Guyana Refractory Bauxite

The pricing of Guyana refractory bauxite was a significant factor in the decline in sales and consequent production volume of this product. The shortage of Guyana bauxite during the entire decade of the 1970s and the unavailability of viable substitutes resulted in almost zero price elasticity of demand for the product. Under these market conditions, Guyana was able, not only to pass on all its cost increases to customers in the form of higher prices, but to use its monopolistic position to increase prices to absorb increased costs arising from its lower scale of operations and other inefficiencies.

The element of cost that had the greatest impact on the price of refractory bauxite was the price of oil. The production of Guyana refractory bauxite is highly energy intensive, specific consumption in all stages of the process estimated at 2.5 barrels Bunker C fuel and 0.25 barrel diesel fuel per tonne of product. Changes in the price of oil therefore have a significant direct impact on the cost of production. The production process utilises Bunker C fuel for the production of electricity for mining, crushing and screening, and calcination, and diesel fuel for mining and transportation equipment. The average increases in the price of Bunker C fuel from around US$3.00 per barrel in 1972 to US$22.00 per barrel in 1979 and diesel fuel from US$5.00 to US$30.00 over the same period, therefore, resulted in an overall increase in cost of production of approximately US$55.00 per tonne. The industry was able, through the application of a built-in fuel escalation clause in all its contracts, to pass on the total increase to the customers. In addition to the increase in direct production cost, the general world-wide inflationary conditions created by the increase in oil prices resulted in increases in the price of equipment and spares, in interest rates, and freight rates which are also sensitive to fuel prices. The company was able to pass all these increases on to customers in the form of annual price increases.

Guyana's total dependence on imported oil for its production, placed its product at a competitive disadvantage vis-à-vis most of the competing materials at the time. High alumina materials produced in the United States are less susceptible to oil prices since they use natural gas, the price of which is generally lower, and subject to less volatility than that of oil. Production of Chinese bauxite has a lower energy content at the mining stage, and less fuel intensive at the calcination stage through its mineralogy which results in loss of ignition 50 per cent that of Guyana bauxite. The price of fuel for calcination is also low being provided by cheap locally produced coal. Andalusite, although requiring beneficiation involving energy intensive high-density media separation, needs no fuel for calcination since its mineralogy and crystalline structure make calcination unnecessary. The competitive materials were also less affected by the increase in freight rates since most of the United States produced materials were consumed in the domestic market and Chinese bauxite was shipped mainly in national flag carriers, immune from market forces, and transporting bauxite at marginal rates, as back-haul cargo on ships transporting Chinese imported products.

Guyana was also able, in the volatile currency market of the late 1970s and early 1980s, to exploit its monopolistic position to impose a pricing mechanism involving a composite currency unit (CCU) comprised of a basket of currencies to maintain its foreign exchange earnings from payments effected in different currencies. The CCU was comprised of the US Dollar, the Pound Sterling, the Deutsche Mark, and the Swiss Franc and had as its base the sum of US$1.00 and the equivalent of US$1,00 of each of the other currencies as of 1 January 1976. All refractory bauxite prices were fixed in CCU with the price paid in the various currencies being those reflected by their value in relation to the CCU on the due payment date.

The combined effect of these measures was an average 100 percent increase in price of refractory bauxite in the various markets between 1975 and 1980 with increases of almost 150 percent at various periods in market areas where currency values were heavily depreciated. This steep increase in the price of Guyana refractory bauxite together with the chronic short supply between 1972 and 1980 led to concerted efforts by the refractories producers to find substitute materials, both alumina and non-alumina, and also improved the economic feasibility of producing the sillimanite group and synthetic high alumina materials. These developments, together with the reduction in Chinese bauxite prices after 1981, resulted in a permanent change in Guyana's dominant market position and contributed in a significant way to the decline in absolute sales between 1980 and 1985.

Table 4.13 shows prices for Guyana and Chinese refractory bauxite over the period 1976-1985.

Table 4.13 Refractory Bauxite, Average Prices

1976 -1985

Sales Area	**1976**		**1977**		**1978**		**1979**		**1980**		**1981**		**1982**		**1983**		**1984**		**1985**	
	Guy-ana	**Chi-na**	**Guy-ana**	**Chi--na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**	**Guy-ana**	**Chi-na**
North America (US$ f.o.b. barge)	120.85	n.a	139,15	n.a	151.66	na	157.01	170	222.65	170	251,42	1981	214.53	175.00	175.01	155.00	164.28	135.00	155.60	130.00
Latin America (US$f.o.b Guyana)	99.00	n.a	116.25	n.a	123.38	n.a	132,15	n.a	192.47	n.a	217.71	175.00	185.45	180.00	150.09	160	140.32	140.00	140.20	140.00
Rotterdam (DM c.i.f)	122.30	n.a	139.59	300.00	314.40	300	322.83	325.00	412.63	325.00	523.21	n.a	450.89	300.00	444.97	300	450.09	300.00	420.00	275.00
Mediterranean (DM c.i.f)	136.70	n.a	147.70	n.a	345.92	315.00	380.62	350.00	446.04	350.00	561.84	325.00	524.85	320.00	483.65	320.00	490.68	315.00	460.00	275.00
United Kingdom (Stg.c.i.f)	130.25	70.00	147.20	70.00	84.54	75.00	82.49	75.00	106.52	75.00	112.44	350.00	118.05	75.00	110.00	70.00	112.85	65.00	115.50	68.00
Japan US$f.o.b Guyana	102.3	65.00	113.40	65	122.98	70.00	130.63	90.00	188.77	90.00	213.59	75.00	181.67	90.00	160.00	90.00	144.5	80.00	140.00	82.00
[1]Far East (US$f.o.b Guyana)	102.30	n.a,	113.40	113.40	123.38	n.sa	132.15	n.a	192.47	n.a	217.71	n.a	185.45	95.00	150.09	n.a	140.32	n.a	140.00	n,a

[1] No sales recorded for China in 1975

Sources:

1. Annual Statistics, Bauxite Industry Development Company. 1970-1990.
2. Annual Sales Information, Nissho Iwai Trading Corporation,.1975-1985.
3. Discussions with Chosun Refractories, South Korea. 1980-1985.
4. Discussions with Hepworth Refractories United Kingdom 1975-1990.
5. Discussions with Magnesital GMBh Refractories- Germany 1975-1985.
6. Discussions with Cometals, Trading Inc. United States, 1980-1990,

4.3 Conclusion

The foregoing analysis confirms the impact of economic and technologic developments in the steel industry of the Western Economy countries, on the emergence of refractory bauxite as a critical raw material for high performance refractories for the industry. Guyana's endowment with large reserves of a resource that satisfied the technical and economic requirements of the steel industry for this product led to the rapid development of refractory bauxite as its major product, and to the country accounting for over 80 per cent of world production between 1950 and 1980.

The dramatic economic developments of the decade of the 1970s and early 1980s caused by the increase in oil prices led to a steep decline in steel production in the major refractory bauxite consuming countries. This resulted in a fall in the demand for the product and to a restructuring of the industry that led to a further decline in demand. This was compounded by technologic developments in the steel industry that reduced the consumption of refractories and added to the reduction in demand for all refractory materials and for refractory bauxite in particular.

The increase in oil prices in the decade of the 1970s also had an impact on cost of production of Guyana refractory bauxite that is very fuel intensive compared with the substitute products. The steep increase in the price of Guyana refractory bauxite, in the industry's attempt to recover increased cost and to protect its revenue in the volatile currency market of the period, promoted the development a major new source of refractory bauxite and other substitute materials. These developments changed the market dynamics for the product, leading to falling prices and to a fall in Guyana's market share from over 80 per cent in the decade of the 1970s, to 50 per cent by the middle of the next decade. Guyana's market position deteriorated further after 1985, as lower sales volume and lower prices reduced its production capability, and by 2000, its market share had fallen to 12 per cent.

Chapter 5

STATE OWNERSHIP OF THE GUYANA BAUXITE INDUSTRY

5.1 State Aquisition of the Bauxite Industry

Prior to 1971, the Guyana bauxite industry was 100 per cent owned by two of the major transnational corporations in the aluminium industry -- Alcan owning Demerara Bauxite Company (Demba) and Reynolds Metals, Reynolds Guyana Mines. In July 1971, the Government of Guyana acquired the assets of the Demba, which accounted for 70 percent of the country's bauxite production, and incorporated a new company, Guyana Bauxite Company (Guybau), to own the assets and manage the operation, and in January 1975 acquired the assets of Reynolds Guyana Mines, and incorporated Berbice Mining Enterprise (Bermine), to own the assets of that operation.

The unavailability of competent administrative and technical personnel to manage Bermine, which was formerly managed as a department of Reynolds Metals in the United States, led to the company being placed under the management of Guybau, and for a period of two years, the two companies, while maintaining separate corporate identities, were fully integrated administratively. In 1976, the Head Office Division of Guybau, was incorporated as a separate company, Bauxite Industry Development Company (BIDCO), to function as a holding company for Guybau and Bermine, and assigned responsibility for development for the two subsidiaries, in addition to its original functions of marketing, shipping, customs, communications, and legal affairs. In 1978, Guybau and Bermine were merged to form one company, Guyana Mining Enterprise (Guymine) that acquired the combined assets and managed the two operations as its Linden and Berbice Operations.

The decline in metallurgical bauxite production after 1978 (see Table 1.3) followed by the decline in production and sales and price of refractory bauxite after 1980 (see Tables 4.8 and 4.14) and the closure of the alumina refinery in 1982 led to the industry engaging a number of consultants to identify the reasons for its declining performance and to recommend measures for its rehabilitation (see Chapter 1, pages 11-12). These studies, in general, identified inherent high cost of production as an underlying factor but concluded that this was acerbated by inefficiency arising from inadequate maintenance and replacement of plant and equipment, and ineffective management associated with state-ownership. They therefore recommended substantial capital investment for the rehabilitation of the plant and mining equipment, and various forms of foreign private-enterprise involvement in the management to restore efficiency.

The inability of the industry to obtain finance from normal financing sources, made Government intervention necessary. This resulted in the Government obtaining finance through the European Community Special Finance Facility (SYSMIN) Lome 2 Fund, co-financed by the European Development Bank (EDB), The World Bank (IBRD) and the Industrial Development Agency (IDA). Among the conditions stipulated for the loan were (1) restructuring of the industry to facilitate the Linden Operation concentrating on the production of refractory bauxite which was considered critical to the European Community and North American steel industries, and (2) the Linden Operations be managed by a foreign management contractor, with the objective of returning the entity to profitability in preparation for privatisation. In keeping with these conditions the industry was restructured in 1992. Guymine was dissolved and its Linden and Berbice Operations incorporated as separate companies, Linden Mining Enterprise (Linmine) and Berbice Mining Enterprise (Bermine), respectively. Linmine was placed under the management of a foreign contractor, Mineral Engineers of Australia (Minproc), while Bermine continued under local management.

While the decline in production volumes and financial performance of the industry coincided with the period of state ownership and features of its management strongly support the state ownership paradigm of bureaucratic and inefficient management that eventually resulted in diminished performance (Radetski, 1985, Page 41), this study has, identified a number of factors, unrelated to state-ownership, that directly contributed to the industry's loss of competitiveness in the markets for its major products (Chapters 3 and 4). The study identified a number of specific features associated with state-ownership that negatively affected the industry's performance and made a significant contribution to its decline. The study would evaluate the impact of these features, starting with an examination of the motivations for state-ownership, since many of these features, had their genesis in the rationale for state-ownership.

5.2 The Motivation for State-Ownership

The economic literature cites the motivations for state-ownership of industries as ideological, economic, or political. (Radetzki, 1985, pages 8-16; Kirkpatrick, Lee and Nixson pages 156-163). The ownership of industries and major services in Socialist states, is an intrinsic feature of their ideology, hence there is no need for specific motivations for state-ownership of industries in such states. In states with free market systems, however, the motivations for state-ownership are normally economic or political.

The economic motivations have, as their foundation market failure, both static and dynamic, and externalities and linkages that make state intervention necessary for optimization of welfare to the society. Static market failure occurs when the free market, left to its own, may develop imperfections that result in less than optimal levels of society welfare. Dynamic market failure occurs when private enterprise is constrained in undertaking the investment necessary for the provision of vital infrastructure and essential services, or for the development of industries, or the exploitation of natural resources, considered critical to national development. Economic externalities exist when the consumption or production decisions of private enterprise are not coincident with optimum society welfare, while linkages are important in areas of economic activity where limited interaction between different sectors make public investment necessary, for industrial growth and optimisation of benefits to the society.

The political motivations are often combinations of ideology and economics and focus on concepts such as political emancipation. In the case of newly independent states, the sovereignty of states over ownership and control of their natural resources and control over economic activities are considered so vital to national economic development that decision-making on those activities cannot be left entirely to private enterprise.

The political history of Guyana over the period of limited self-government in 1953 to full independence in 1966 has already been traced in this study (Chapter 3, Sec 3.1.2.3). The socialist oriented government which assumed power in 1953, identified the bauxite industry for government intervention entirely from an ideological standpoint. Even though the government was replaced after only three months in office by a nominated governing body the fear of government intervention remained, and with the return of the socialist oriented government in 1967 the ideological position with regard to the industry remained for the remainder of the colonial period, which ended in 1966. However, the only attempt at intervention was the establishment of a committee in 1962 to investigate an economic pricing model for bauxite for purposes of taxation. The report of the committee, which recommended indexation of the price of bauxite to the price of aluminium ingot, was seen by the companies as an attempt at government intervention and was used by them, together with the unstable political climate, to limit investment in the industry during a period when the same companies, on their own, or in consortia arrangements with other companies in the industry, were making major investments in bauxite and alumina capacity in Jamaica, Suriname, Australia, Brazil, and in bauxite production, in Haiti, the Dominican Republic, and West Africa. The recommendations of the committee were endorsed by the 1964 United Nations Technical Assistance Team and the 1968 Guyana Development Corporation study, both of which pointed to the failure of the transnational corporations to invest in the industry which had the potential for full vertical integration in the aluminium industry, and recommended various forms of Government intervention to promote its development. Table 5.1 shows data provided by the Guyana Development Corporation study on the industry's contribution to the economy in terms of Gross Domestic Product and Government revenue over the period 1958-1967.

Table 5.1 Contribution of the Bauxite Industry to the Guyana Economy

1958-1968

	Contribution to Gross Domestic Product (000US$)						Contribution to Government Revenue (US$)						
	Gross Domestic Product			Wages and Salaries				Rent		Taxes			Av./ton
Year	Total	Bauxite Industry	%	Total	Bauxite Industry	%	Royalty	E.Ps	Leases	Export	Income	Total	
1958	n.a	n.a	n.a	n.a	n.a	n.a	43174	23467	11297	341071	2756027	3510295	1.20
1959	n.a	n.a	n.a	n.a	n.a	n.a	36714	20206	11297	361166	2261066	268212	1.60
1960	149388	11897	7.96	71962	4454	6.19	88020	19745	13563	523729	2021987	2664778	1.07
1961	160991	15880	9.86	78895	9237	11,71	103901	19123	11297	401557	1259601	1795481	0.76
1962	170656	22114	12.86	78583	6603	8.40	108701	16338	11297	457885	2198093	2782315	1.03
1963	153026	16513	10.79	78831	7361	9.34	105740	16951	11297	340723	1404728	187944	0.76
1964	162777	25988	15.43	86931	9336	10.74	68266	15627	11297	393275	173295	2228993	0.89
1965	183111	23709	12.95	96694	10022	10.34	78822	13253	11297	439456	1774498	2277332	0.79
1966	169494	27237	13.97	105212	12172	11.57	155871	13103	11297	910524	2211197	2897704	1.00
1967	209722	31383	14.96	107778	13891	12.89	170659	13088	11297	n.a	395555	4722127	-
1968	247696	38572	17.56	112222	15192	15.54	196001	10808	11297	482859	n.a	-	-

Source:
The Guyanese Bauxite Industry, Guyana Development Corporation 1968.

Attempts by the government to induce the companies to expand their operations met with little success, Reynolds, citing higher production costs than those in Jamaica, and both Alcan and Reynolds, high political risk for major investment, even with the prospect of a change of government and an end to political instability following the pending 1964 elections.

A new political party assumed power in the country following the elections of 1964, and immediately entered into negotiations with the companies for implementation of the tax proposals recommended by the 1962 committee. Agreements were concluded in 1965 with both Alcan and Reynolds, providing tax and fiscal incentives and concessions on leases and exclusive exploration permits as inducements for investment in the industry. (Shahabuddeen, 1981, pages 141-144). These concessions resulted only in investment in refractory bauxite, Reynolds investing in new capacity for this product and Alcan investing in additional capacity. Neither company made any attempt to satisfy the government's goal of expansion within the aluminium industry, especially forward integration into aluminium smelting, with its potential for developing the country's vast hydro-power resources, and providing linkages with the development of industries in the rest of the economy.

In keeping with the prevailing wave of nationalism in former colonial states, and its broad socialist political orientation, the new government embraced the concept of central planning of the economy as the policy for economic development. Under the existing economic structure, where the bauxite industry, the largest foreign exchange earner, and the second largest employer of labour and contributor to GDP, remained totally under foreign control and its planning integrated into the international plans of its owners, it was difficult to undertake meaningful economic planning with that industry totally outside the domestic planning mechanism. The government therefore set out to establish a rationale for implementing measures to impose some degree of control over the planning in the industry. Since the industry was totally export oriented, the purely economic argument of static market failure was not relevant Dynamic market failure could, however be justified where investment in the country's primary natural resource was not being undertaken in the areas of expansion of metallurgical bauxite and alumina production, and forward integration into aluminium smelting. The government therefore advanced the dynamic market failure argument along with the political argument of ownership and control of a critical natural resource to justify direct participation in the industry to ensure that its plans were consistent with the country's economic development plans. To achieve this, the government entered into negotiations with Alcan for acquisition of a majority share in its subsidiary, Demba.

Alcan did not object to the concept of majority shareholding by the government, but at the opening of the negotiations established a distinction between ownership and control. They pointed out that while Alcan was conceding majority ownership of the new joint entity, they must retain management control over the operation and have veto powers over critical areas of policy. (Shahabudeen, 1981, Page 171). This position led to the break-down of the negotiations over two fundamental issues:

(1) Management of the new entity on which Alcan insisted on the right to appoint the total management team, while the Government iknsisted on a joint management team comprised of executives appointed by the two partners.

(2) Medium and long-term planning for the industry. In this area, Alcan tried to prescribe expansion of refractory bauxite production as the strategy for medium-term investment with them having a veto on the direction of long-term expansion. The Government's position was that the basis for expansion should be viability of projects determined by feasibility studies undertaken by the partners.

Failure to reach agreement on these issues led to a decision by the Government to acquire the total assets of the company, with compensation being the only issue for negotiation.

Thecompensation negotiations were long and intense (Shahabuddeen, 1981, pages 245-275). The Government had, in its proposal to Alcan, set out compensation based on written-down book value of the assets for purposes of taxation, as a non-negotiable condition, but conceded to arguments advanced by Alcan that this was not a true representation of the value of the assets. All the conventional methods of asset valuation, future earnings, market price, replacement cost, and book value were examined in an attempt to arrive at an acceptable level of compensation. But, in recognition of the problems of methods for verification of the value, ranging from independent valuation to arbitration, the parties agreed on a negotiated value which combined elements of all the conventional methods. On the question of payment, agreement was reached on a period between that corresponding with the useful life of the assets, proposed by Alcan, and the Government's proposed period that did not make payment onerous for the company. Upon reaching agreement on compensation, the Government assumed control of the operation on 15 July 1971. With the acquisition of Demba by the state, Reynolds Metals, the owners of the smaller Reynolds Berbice Mines, saw state acquisition as inevitable, and agreed to enter into negotiations with the Government for the acquisition of their assets, with compensation as the only negotiable issue. Since this company's investment was guaranteed by OPIC, the negotiations on valuation were conducted between the Government and OPIC, and, upon reaching full agreement, the Government assumed ownership of the assets on 1 January 1975. Therefore, the entire industry fell under state-ownership and control until 1990 when a new 50:50 joint venture project between the Government and Reynolds International (RII) was established, with Reynolds assuming full management and effective control of the operation.

5.3 The Impact of State-ownership on the Industry

It was shown earlier in this study that a number of exogenous economic, technologic and market forces directly affected the volume of production and Guyana's market share for its major products. In addition to these forces, state ownership, through alienation of the industry from the mainstream of the world aluminium industry, and introduction of an ineffective management structure, negatively affected its performance. The principal features directly attributable to state-ownership, to be evaluated are (1) loss of economies of vertical integration within the aluminium industry; (2) loss of efficiency resulting from the organisational and management structure of the industry; (3) absence of clear definition of objectives for the industry; (4) lack of management accountability and (5) loss of managerial and technical skills.

5.3.1 Loss of Economies of Vertical Integration

Prior to its acquisition by the state, the industry was fully integrated into the world bauxite-alumina-aluminium industry through the ownership of the two companies by Alcan and Reynolds, respectively, the second and third largest world integrated aluminium producers. During the negotiations for the acquisition of Demba, Alcan advanced arguments, supported by data, to show the extent to which the company's viability was dependent on the linkages with the Alcan system in the areas of marketing, shipping, purchasing, management, technical support, and financing. (Shahabudeen, 1981, page 181).

Under the existing industry structure, Demba's total metallurgical bauxite production was consumed in Alcan's Quebec alumina refinery, while its total alumina production was consumed in Alcan owned aluminium smelters in Canada and associate smelters in Norway. The company's refractory bauxite production, which was not consumed by the aluminium industry, was sold internationally through the Alcan world wide marketing system. In the case of Reynolds Berbice Mines, the total metallurgical bauxite production was consumed in Reynolds Corpus Christie and Hurricane Creek alumina refineries in the United States and its chemical and refractory bauxite sold and distributed through the Reynolds international marketing system. These arrangements provided guaranteed markets for the industry's main products and removed the need for the operating companies to maintain expensive overseas marketing organisations and incurring high marketing costs for their output.

In the area of shipping, the total logistics for Demba's products were integrated into the Alcan shipping system with ships owned or under long-term charter by the Alcan shipping subsidiary Saguenay Shipping. Saguenay undertook shuttling of bauxite from Guyana to the Alcan transhipment facility in Trinidad and loading bottom cargoes in Guyana and topping off at the transhipment station to increase the size of shipments to Canada. The company's alumina shipments to Canada and Norway benefited from increased shipment size through ships loading to the limited draught in Guyana, and topping off with alumina at Alcan's alumina shipping terminal in Jamaica. The company's refractory bauxite shipments to North America and Europe were also shipped as back-haul cargoes on Saguenay ships providing liner services to these areas, thereby allowing the company to achieve more favourable freight rates.

The major inputs to the company's operations were also integrated into the purchasing contracts of the Alcan group and therefore participated in the economies of large scale purchasing enjoyed by the group. This was of particular significance in the purchase of fuel oil, caustic soda, items of machinery and equipment and spare parts. The shipment of these inputs was also integrated into the Alcan shipping system. The Alcan ships shuttling bauxite to Trinidad were specially equipped to carry oil as return cargo. Machinery and equipment and spares imported from North America and Europe were transported in ships of the Saguenay liner service, while caustic soda for the alumina refinery was combined in shipments on Alcan chartered ships which first discharged at the Alcan discharge terminal in Jamaica before proceeding to Guyana, with its limited draught, as the final port of discharge.

Demba benefited from the Alcan Technical and Engineering Services for its bauxite mining and processing and for its alumina refinery operations. These services included the constant involvement of Alcan technical personnel in the Guyana operations to provide supervision, training and technical advice to the local personnel, and the secondment of personnel from the Guyana operations to the Alcan facilities in Canada for training and acquiring experience. The Alcan Laboratories in Canada also provided research and development services for Demba, with personnel from that facility undertaking training of personnel for the Guyana operations.

While Demba, over the years, had established its own competent management team who were familiar with local conditions, the full strength of the Alcan international management organisation was available to the company to deal with specific management problems. Top level Alcan management personnel became involved in areas such as long-term planning, financial planning and project management, while personnel from the Guyana operations acquired valuable experience from working along with Alcan management personnel both in Guyana and in their Canadian and Jamaica operations.

In addition to the direct linkages with the parent companies, the subsidiaries benefited from external economies of scale through the inter-company relationships that existed between their parent companies and other majors in the aluminium industry. These included product exchange agreements under which the companies supply products against each other's contracts to reduce freight costs, swapping arrangements to smooth supply and demand fluctuations, and joint shipping arrangements for both products and inputs to the industry.

The acquisition of the two entities by the state resulted in the companies becoming vertically disintegrated from the systems of the former parent companies and Guyana being alienated from the mainstream of the world bauxite-alumina-aluminium industry. Between 1971 and 1990, Guyana became the only bauxite producing country, outside the Eastern Bloc that had no linkages with the systems of the six major international aluminium companies. The industry, therefore, lost the guaranteed markets for its metallurgical bauxite and alumina even though the prevailing short to medium term state of the market for those products reduced the impact of this loss--Alcan itself continuing to buy a substantial part of the metallurgical bauxite for a period of ten years after nationalization--and new customers readily found for the remainder. The company was also able to find lucrative new markets for its alumina in the Soviet Union, United Kingdom, Germany and Brazil. In the case of refractory bauxite, which was not consumed by the parent companies, the position was completely different. The industry's monopoly of the market for this product, and the excess of supply over demand for the 10 years following the first state acquisition made it easy for the total production to be sold at higher prices than those obtained before acquisition by the state. However, the industry lost the benefits of the economies of marketing within the integrated Alcan and Reynolds systems and had to find markets for its products and establish a domestic marketing and shipping organisation together with the appointment of agents for the international marketing of its products.

The companies also lost the economies of large-scale purchasing enjoyed by the groups to which they originally belonged and, therefore, paid higher prices for their major inputs. Guybau, for instance, from its inception, had to pay a 10 per cent premium on the price of fuel oil, a 50 per cent increase on the cost of shipping it from Trinidad, and an increase of 25 percent on the price of caustic soda for its alumina refinery. (Guybau purchase and freight contracts 1971-1973). The company, through its inability to utilise the Alcan-owned transhipment facility in Trinidad and the Saguenay liner ships, initially had to resort to the use of small ships for its refractory bauxite sales which increased its shipping cost by 30-40 per cent on sales to Europe. The company was able later to negotiate an agreement with Alcan for the use of the

Trinidad facility, but found that the reduction of the throughput resulting from Alcan changing its bauxite supply sources, increased its handling costs by 20-25 per cent.

The most significant impact of loss of vertical integration was in financing. Under the Alcan system, the total group finances were managed by the Alcan subsidiary, Alcan Fiduciaries, which managed the allocation of funds for projects to the operating subsidiaries. Because of the size of its internal resources and established creditworthiness, Alcan wa able to secure finance for investment at the lowest market rates. While Demba had to compete with other companies in the group for finance for project development, such financing was readily available once the projects were approved with the company enjoying the favourable interest rates. As a company outside the Alcan system, the new company lost the benefits of the Alcan financial pool and the Alcan creditworthiness and therefore had to raise finance on the strength of the viability of its projects and on its financial performance, often needing government guarantees for its loans. The industry had no problem raising finance for the expansion of refractory bauxite capacity with a demonstrated high rate of return, but even this was obtained at a rate of interest two percentage points higher than Alcan would have paid. It was also able to secure financing from foreign state sponsored financing agencies, like the Netherlands Export Credit Guarantee Organisation for the improvement of its bauxite loading ports, and from the European Union and other International lending agencies for resuscitation of the operations after its decline following the harsh economic conditions of the early 1980s. It was, however, unable to secure financing for investment in the expansion of its metallurgical bauxite and alumina operations and for the replacement of critical items of mining equipment to improve its mining capability. The industry's inability to secure finance for modification of the alumina refinery to improve the quality of the product to meet new market requirements, led to its permanent closure since 1982. Also, its inability to secure finance for projects to reduce production cost of refractory bauxite and diversify its refractory bauxite product stream contributed to the deterioration and eventual loss of its position in the refractory bauxite market.

The loss of the Alcan Technical and Engineering, services, the Alcan management services, and the research and development services, made it necessary for the company to engage the services of high cost consulting organisations to provide these services and to it having to establish and staff its own research and development facilities.

5.3.2 Ineffective Organisation and Management Structure

A fundamental feature of state-ownership is the prerogative of the government, as representative of the shareholders, to appoint the members of the board of directors of the company. The degree of government involvement in appointment of the senior management and in the day-to day management of the companies could, however, vary according to the role of the industry in the national economy and the inclinations of the political directorate. The effect of this, in the context of Guyana, has been a preponderance of political appointees on the board and, over the past ten years, increasing government involvement in the appointment of management, and in day-to-day operations of the companies in the industry.

Upon the acquisition of Demba, the government appointed a completely non-executive board with the Chief Executive Officer and Chief Finance Officer of the company as the only executive members. While a number of individuals from the private business sector were appointed to the board, they were mainly individuals sympathetic to the governing party and not selected on their ability to contribute to policy formulation and to deliberations on major company issues. The government also delegated very limited policy-making authority to the board. The Chairman of the board was appointed by the government and was accountable to the Minister with responsibility for the industry and not to the board. He functioned, initially, in a quasi executive position, holding the position of head of the company's head office and charged with executive responsibility for marketing and shipping, communications, public relations and legal affairs, while at the same time holding the substantive position of Chief Executive Officer of another state agency. The real locus of authority in the organisation was therefore vested in the Chief Executive Officer, who was appointed by the Government and not the board.

In drafting the organisational structure and appointing top management personnel, the Government violated a fundamental principle of effective management--failure to establish a clear and identifiable line of authority running through the organisation. The Chief

Executive Officer had an ambiguous reporting relationship, de jure, reporting to the Chairman of the board, but de facto having a parallel reporting relationship with the Chairman, to the Minister, and accountable to the Minister and not to the Chairman. Shortly after the acquisition, the position of Chairman of the board was converted to that of a full-time executive. This, however, did not change the authority, accountability relationship between him and the Chief Executive Officer.

Following the acquisition of Reynolds Guyana Mines and the incorporation of Bermine as a separate company, the Head Office division of Guybau was incorporated as separate company, Bauxite Industry Development Company (BIDCO), to function as a holding company, for the two separate entities in the industry and was assigned responsibilities as outlined earlier in the study (see section 5.1), with the Chairman as its full-time Chief Executive Officer. Under the new structure, the subsidiary, Bermine, however, had its own board of directors with an independent non-executive chairmen appointed by the Government, and de jure, subordinate to the Chairman of the Board of BIDCO, but de facto, maintaining a direct reporting relationship with the Minister.

The merger of the two companies in 1977 to form Guymine, further strengthened the position of the Chief Executive Officer of the former Guybau who assumed the role of Chairman and Chief Executive Officer of the merged company. While still, de jure, reporting to the Chairman of the holding company, the chairman of the subsidiary, de facto, maintained the direct reporting relationship with the Minister. This ambiguous management structure persisted throughout the entire period of state-ownership, deteriorating after 1986 to the point where the Chief Executive Officer of the subsidiary and the Chairman of the holding company, reported separately to the Minister on crital aspects of the industry's operations. With the restructuring of the industry in 1992, involving the dissolution of Guymine and the incorporation of Linmine and Bermine, the composition of the boards became more politicised and the authority relationships less clearly defined. The membership of the boards was comprised totally of persons affiliated to political parties and trade unions, except for the ex officio members. Under this new structure, the chairmanship of the board of the holding company, BIDCO, was converted to a non-executive position with the former chairman designated as Chief Executive Officer and the board assigned certain residuary powers over the boards of the subsidiaries. The de facto position, emerged as one in which the boards of the subsidiaries assumed greater involvement in the day-to day operations of the companies, with their chairmen and even individual members reporting direct to the Minister on issues of company policy and operations.

The chaotic top management structure, with unclear placement of responsibility, authority and accountability that persisted in the industry for 30 years has been a major contributory factor to its decline. The absence of a clear locus of decision making in the organisation made policy formulation and implementation, and planning in the industry, nearly impossible, and resulted in slow implementation of decisions and to long and indeterminate discussions on the solution to problems that needed quick decisive action. The greater involvement of the Minister in the day-to day management of the industry also led to purely management decisions often having to await cabinet decision for implementation consequently to the cessation of decision making by the management.

5.3.3 Unclear Definition of Objectives

The industry, consistent with state enterprise world wide, suffered from failure by the Government to establish clear definitive objectives for the industry, often "simultaneously embracing multiple and sometimes conflicting objectives" (Radetzki, 1985, page 38). This accorded management almost unlimited discretion in setting and interpreting industry objectives. While broadly embracing the objective of profitability, the very concept of profitability was diluted and not viewed in terms of quantifiable return on investment or capital employed, but in terms of qualitative benefits to the community in which the enterprise was located or to the society in general, with no attempt being made to quantify even those benefits in cases where they were quantifiable. In this context, when the industry's rate of return on capital employed started falling below conventional commercially acceptable levels, it was easy for the management to promote the qualitative social benefits in vindication of its performance.

5.3.4 Inadequate Accountability

The ambiguous organisation structure resulted in difficulties in the placement of responsibility and accountability for performance in the industry. Under the private enterprise system, in spite of the dilution of ownership and the increasing control of management over the operations of companies, the shareholders are still seen as having the ultimate power of sanction over the management. In the case of the industry--a characteristic of state-owned organisations--the identity of the shareholders is never clearly defined (Radetzki, 1985, pages 38-30), the tendency in Guyana being to conveniently use the term "shareholder", when referring to the government, and "shareholders" when referring to the populace. In neither case is it a clearly identifiable group, which makes it difficult to identify the sanctioning body.

The board of directors who were appointed by the government in its capacity as shareholder was, throughout the entire period of state-ownership, comprised of individuals with limited business experience and were never in a position to properly evaluate the limited information provided by the management. The board was also delegated limited authority over normal board functions such as policy formulation and decision-making on issues such as expansion or contraction of production, plant closures, and the appointment and dismissal of senior management personnel. It was, therefore impossible to hold the board accountable for the industry's performance.

At the top executive management level, the absence of a clear line of authority, made it impossible to attach accountability to any one individual, hence, since the entire top management could not be sanctioned for poor industry performance, sanctions were generally not applied. The management of the industry was therefore never motivated to strive for the highest level of performance, since accountability could not be attached to any group or even to any individual.

5.3.5 Loss of Skills

The loss of skills at managerial, technical, and operative levels was an area in which the industry suffered greatest during the period of state-ownership. While this phenomenon cannot be blamed entirely on state-ownership but was related to the general economic and political climate in the country during the period, public policy contributed in a significant way to the exodus of skills from the industry. Soon after the acquisition of the industry by the state, the Government embarked on a policy of state acquisition of the other major industries, and, by the end of the decade, the state, through its control of the civil and public services and its ownership of most of the major industrial enterprises, became the largest employer in the country. The oil crisis of the 1970s had a devastating effect upon the country's economy leading to high inflation, loss of foreign exchange earnings, devaluation of the currency, and the imposition of controls on imports and foreign exchange. The Government, in an attempt to control the high rate of inflation, instituted controls on wages and implemented a policy of standardisation of wages and emoluments in the state controlled sector. This led to a rapid lowering of the standard of living in the bauxite communities, which prior to state acquisition, operated as economic enclaves with the emoluments of senior and technical managers and skilled personnel, three times and two times, respectively, those of their counterparts in the public service and other sectors of the economy. The effect of these developments was an exodus, first of management, and later of skilled technical personnel who were capable of finding employment in foreign countries. As the situation deteriorated after the second oil crisis and the world recession that followed between 1981 and 1983, the high inflation rates that characterised the period and the consequent rise in the cost of living, there was a further exodus of skills from the industry. Between 1975 and 1985 it had lost nearly the whole of its top management and a significant portion of its technical, middle management, and trained skilled personnel.

5.4 Change in Government Policy on State Ownership

The decline in the country's economy, and in the bauxite and other state-owned industries, together with pressure from international lending agencies and the general decline of the Socialist philosophy, led to the Government, after 1985, revising its policy on state ownership. Under the new policy, the bauxite industry was open to all levels of private ownership and control ranging from management by foreign private contractors to full ownership and control of entities in the industry. This change in policy resulted in the return of Reynolds Metals to the industry, in a joint venture with the Government referred tc earlier in the study. Other companies in the bauxite-alumina-aluminium industry also expressed interest in the development of new projects and undertook per-feasibility and feasibility studies on possible new mining projects and the rehabilitation of the alumina refinery. None of these projects, however, materialised.

A central feature of the change in Government policy was the divestment the existing state-owned entities in the bauxite industry which it sought to implement under a framework of re-capitalisation under which the government would continue as a 40 per cent shareholder in the divested entities. All the attempts at divestment of the entities have, so far, been unsuccessful. The reasons for the failure of these attempts have not been fully analysed. It appears, however, that the strategy of presenting the entities for privatisation under public tender, is not consistent with the modus operandi of the multinational corporations, whose preference is to approach such negotiations on a bi-lateral basis. The Government's approach to the divestment of the industry, also appears to be consistent with the development of small scale projects with a low probability of being economically viable:

(1) Linmine has control over 800 million tonnes of bauxite resources that could be used for both the development of a large-scale metallurgical and alumina operation in addition to the production of refractory bauxite and other grades of non-metallurgical bauxite. The Government, however promoted the divestment of the entity as a producer of refractory bauxite at a time of contraction of the refractory bauxite market, falling prices, and widespread bankruptcy and re-organisation of the international refractories industry. This

strategy had the effect of restricting the field of prospective investors to companies in the refractories and refractory raw materials industry, a field comprised essentially of small and medium sized companies lacking the financial resources to acquire the assets of the entity and secure the capital necessary for its resuscitation and expansion.

(2) No attempt was made to pursue the findings of a feasibility study undertaken by Alcoa (Alcoa, 1999) that established the economic feasibility of large-scale bauxite mining projects both in Berbice and Linden, involving capital investment lower than that for developing similar capacity in any other bauxite producing country. The invitation for bids for Bermine in 2000 presented the company as a small diversified bauxite producer and consequently attracted interest only from Aroaima Bauxite Company, the joint-venture company between the Government and Reynolds. Aroaima Bauxite Company's interest appeared to be acquisition of the company's bauxite resources hence their business plan involved only a merger of the two companies and rationalization of their operations with no plans for expansion.

(3) Timing is a critical factor in decisions by the transnational corporations on major new investments or acquisitions. The timing of the attempt to divest the entities in Guyana was inappropriate in the unsettled state of the aluminium industry, which at that time, was in the process of undergoing the most comprehensive restructuring in its history. The industry is still in the process of

rationalising capacity and production levels, supply sources, marketing and management to accommodate its new structure and ownership. In the current depressed state of the industry, it is highly improbable that any of the majors in the industry would be prepared to commit to a major investment, especially in an entity experiencing difficulties and needing large inputs of capital.

(4) Statements emanating from the Government have led to uncertainty in the minds of prospective foreign investors about its commitment to the industry. These statements create the impression, that the Government is resigned to the failure of projects in the industry, through its perceived inherent uncompetitiveness in the metallurgical bauxite and alumina markets.

(5) Attempts to privatise Linmine as a disintegrated entity has also created the impression that a new investor would be faced with monopolies for the supply of vital services such as power and maintenance or may have to undertake additional investment to re-establish such services.

(6) The proposed privatisation model under which the government plans to retain a substantial share in the new entities may have been influenced by the model initiated by Reynolds for the 50-50 joint-venture Aroaima project soon after the new policy on ownership was implemented late in the decade of the 1980s. While prospective transnational investors have not completely rejected a formula with Government involvement, they are reluctant to accept a model where

the level of that involvement is imposed on them and leave them uncertain of the degree of control they would have over the entity.

The divestment of the state-owned companies is unlikely in the current state of the aluminium and refractories industries. The situation in the aluminium industry however could change after 2005 when the current rationalisation of the industry is complete and its economic state improved. The situation with the refractories industry is somewhat different since the inherent structure of this industry is not conducive to the undertaking of large overseas investments. The Government, therefore, may need to completely re-assess its position on divestment of the industry and undertake the investment necessary to maintain the existing levels of production until there is a change in the investment environment in the aluminium industry.

5.5 Conclusion

State ownership of the Guyana bauxite industry started in 1971. The probability of state intervention, which emerged during the political campaign for the 1953 elections and fear of acquisition by the state, however, continued over the entire period 1953-1970 when the aluminium industry was experiencing its most rapid growth and shifting the locus of alumina production from aluminium producing to bauxite producing countries. This development contributed to the diversion of investment in the industry away from Guyana. The unstable political environment in the country between 1961 and 1964 and fears of continuing instability after the 1964 elections also created a high risk investment environment while state-acquisition of the industry between 1971 and 1975 led to a complete cessation of foreign investment between 1971 and 1990.

The decline of the industry which started in the early 1980s and continued through the decade of the 1990s, can be attributed to a number of indigenous and exogenous economic factors that reduced its efficiency and competitiveness. State ownership, however, introduced features that negatively affected the industry's performance and accelerated its decline. The separation of the industry from the vertically integrated structure of the aluminium industry removed the benefits of the linkages in the areas of marketing, shipping, purchasing, management, technical and engineering services, research and development, and finance. The industry was able to overcome the effects of some of these losses through favourable markets for metallurgical bauxite and alumina and its monopoly of the refractory bauxite market and earn a relatively high rate of return on its investment during the first 10 years under state-ownership. The effect of loss of the linkages, especially in the areas of markets and finance, was, however, realised in the 1980s when it tried to re-enter the metallurgical bauxite market, to secure finance for the modification of its alumina refinery, and to develop new products to retain its position in the refractory bauxite market.

The management structure imposed under state-ownership, by failing to establish clear lines of responsibility, authority and accountability, made it difficult to implement decisions critical to the industry's survival. Failure to clearly define objectives and establish quantifiable goals further resulted in difficulties of measuring performance and applying sanctions to management for the non-achievement of targets. The introduction of measures to standardise wages in state-owned industries and public sector enterprises, also affected the industry's performance by causing a loss of managerial, technical and skilled personnel, that resulted in diminished performance, and eventually to inefficiency that resulted in a fall in production levels and increase in production cost.

The change in Government policy on ownership of the industry that initially attracted new investment in the industry failed to gain momentum. The Government failed to clearly define its policy on the role of private enterprise in the economy in general and the industry in particular. It also failed to establish the legal and institutional framework to implement its policy of private ownership. The divestment model adopted by the Government, and the timing of the divestment programme, also contributed to the failure of attempts to privatise the state-owned entities in the industry.

Chapter 6

FUTURE PROSPECTS FOR THE INDUSTRY

6.1 The Product Mix of the Guyana Bauxite Industry

The unique chemical and mineralogical properties of the Guyana bauxite deposits resulted in the country's bauxite industry, at a very early stage in its development adoptimg a diversified product mix that differentiated it from the industry in other bauxite producing countries. The country rose to the position of the world's second largest bauxite producer during the decade of the 1940s with metallurgical bauxite for the aluminium industry as its major product. Early in the same decade, chemical bauxite, and later in the decade refractory and abrasive bauxite, were added to the product stream, and, by the end of the decade of the 1950s, bauxite for non-metallurgical applications had replaced metallurgical bauxite as the major portion of the industry's output.

While aluminium provided the basis for the rapid growth of the world bauxite industry after 1950, expansion of the Guyana industry was based on the increase in production of refractory bauxite, which, together with metallurgical bauxite, alumina and chemical bauxite, allowed the industry to maintain a reasonable degree of growth and high profitability between 1960 and 1980. The decline in the industry's growth and profitability, however, started in the early 1980s with the programmed reduction of metallurgical bauxite, the closure of the alumina refinery in 1982, the steep decline in refractory bauxite production after 1982, and a decline in chemical bauxite production during the second half of the 1980s. As stated earlier in the study, the decline in production of all the industry's products is often attributable to loss of competitiveness in the various markets and has led to the thesis that the geological structure of the bauxite resources, and the severe restrictions on shipping, would increasingly affect its competitiveness and lead to its inevitable demise.

The hypothesis of this study does not support this thesis, hence, the study evaluates the future prospects for the industry in the context of (1) the country's large high-grade bauxite resources; (2) the projected growth in demand for aluminium and alumina based products; (3) structural changes in progress in the aluminium industry and consequent changes in the market for alumina and metallurgical bauxite; (4) developments in the market for refractory bauxite and other high alumina refractory materials; (5) developments in the market for abrasive bauxite; and (6) government policy on state-ownership and involvement in the industry.

6.1.1 Bauxite Resources

Guyana possesses large, high grade, bauxite resources which have been unexploited over the years especially for the production of metallurgical bauxite. As stated earlier in the study, while only a small proportion of the country's resources are classified as metallurgical bauxite, the total resources are technically and economically suitable for the production of alumina and should be considered as bauxite for the aluminium industry. However, a number of features of the resources could improve their competitiveness and make them attractive for exploitation for the aluminium industry over the next two decades while their chemical and mineralogical properties could be exploited to improve their competitiveness in the refractories and abrasive industries. These features are: (1) the size of the resources, (2) the quality of the ore, (3) the accessibility of the deposits, and (4) low investment cost.

6.1.2 Size of Resources

Table 3.12 shows Guyana's identified bauxite resources that could be considered for immediate exploitation to be in excess of 1,100 million tonnes. The size of a country's mineral resources is an important determinant of the prospects for their exploitation and the size of projects that are likely to be developed around them as been demonstrated by the large bauxite projects developed in Jamaica, Australia, Guinea and Brazil. (Tilton, 1983). The under-statement of Guyana's bauxite resources over the years, as discussed earlier in this study (Chapter, Section 3.1.2.1), has been a factor that may have contributed to their under development since all the major bauxite projects developed since 1950 have occurred in countries with resources that could sustain very large projects for several centuries and in deposits that could maintain large-scale production over several decades.

Bauxite resources in Guyana are classified as Proven, Probable and Possible, which broadly correspond with the sub-groups Economic and

Marginally Economic of the Identified Resources category under the US Geological Survey Resource Classification (US Geological Professional Paper 1076 B, World Bauxite Resources, 1986). According to this classification, the resources are large enough to provide the basis for a large-scale industry producing a full range of bauxite-based products for a long period of time. The thick overburden cover of the identified resources would be a continuing disadvantage for the production of metallurgical bauxite in competition with the vast low overburden deposits of Guinea, Australia and Brazil. A more critical examination of the resources show large sections of the deposits having overburden to ore ratios below 10:1, considered as the economic limit for stripping with existing stripping technology, the physical properties of the overburden, the geographical location of the deposits, the quality of the ore and current bauxite prices. The inclusion in the resources of the aluminous laterite deposits which are free of overburden could eliminate the high cost of stripping if these deposits are used as feed for alumina production. They could also be mined and blended with regular bauxite to increase the Fe_2O_3 content of the feed and reduce the average stripping ratio and the overall stripping cost.

6.1.3 Ore Quality

The very stringent specifications applied in Guyana for classifying ore as bauxite have resulted in all ore included in the identified resources being bauxite with minimum 50 per cent available Al_2O_3 and maximum 5 per cent reactive SiO_2. The effect of this has been that the Guyana production of alumina, (US Bureau of Mines, Aluminium Availability, 1983). The average available alumina is higher than that of some of the Guinea deposits and most of the Brazil, north-east Australia, and Jamaica deposits which comprise almost 80 percent of world export bauxite. It is also considerably higher than that of the Western Australia, Jamaica, Indian, and Venezuelan deposits that account for over 40 percent of world alumina production. The Guyana resources are also of pure trihydrate mineralogy (less than 1.5 per cent monohydrate), and are compatible with all the variants of the Bayer process, and suitable for blending with high monohydrate bauxites to improve processing efficiency and reduce processing cost. The low $Fe^2O_{3,}$ low SiO_2 and low levels of impurities also make them suitable for all other applications for bauxite. The bauxitic clays associated with the resources and currently discarded as overburden have been identified as being technically suitable for the production of a full range of high alumina mullite-based refractory products for which current demand is strong and supply limited.

Metallurgical bauxite accounts for nearly 95 per cent of world bauxite production and constitutes the only feasible prospect for large scale production and growth over the next two decades. The utilisation of the resources for the production of metallurgical bauxite and alumina should, therefore, be the base for the future development of the industry, providing the critical scale economies necessary for its competitiveness and for enhancing the competitiveness of the other products.

6.1.4 Accessibility

All the Identified bauxite and laterite resources in Guyana are located between 60 and 100 miles of the ocean and accessible by the existing road and river systems. The Linden deposits are all located within 5 miles of the Demerara river where ships could load bottom cargoes to a draught of 19 feet and 20,000 tonne barges could be used for transport over a distance of 65 miles to a transhipment facility at the mouth of the river which has already been dredged to a draught of 32 feet could be dredged to 42 feet to permit 60,00-65,000 tonne shipments. The Kwakwani and Canje deposits are located between 5 and 15 miles of the Berbice river which, with minimal dredging, could permit ore to ve transported by 10,000 tonne barges over a distance of 140 miles to a transhipment station at the estuary of the Berbice River which has been dredged to a draught of 35 feet and could to 42 feet be further dredged to accommodate Panmax size ships. Ore from the Ituni deposits could be transported by rail for a distance of 40 miles to Linden on the Demerara river or by truck or rail over a distance of 15 miles to the Berbice river and transported by barge to the appropriate transhipment facility. The Corentyne deposits located 40 miles up the Corentyne river could be transported in 15,000-ton barges to the transhipment station at the mouth of the Berbice river. All these internal transport distances compare favourably with those for the large Boke, Guinea, and Los Pijiguaos Venezuela projects already discussed in section 3.1.1.2 of the study. The relatively short internal transport distances and the low cost transportation modes provide Guyana with an advantage over competitive sources of export bauxite. With additional dredging of the entrance channels to both the Berbice and Demerara river to accommodate Panmax ships of 60,000 to 65,000 tonnes capacity could make it competitive on ocean freight with shipments from all the other bauxite exporting countries.

6.1.5 Investment Cost

The favourable location of the Guyana bauxite deposits, most of which are located close to areas with basic infrastructure, the topography of the terrain for the construction of mine roads, and the distances from the mines to the loading port result in a considerable reduction of investment for their development, both in terms of capital and development period. These features contributed in a significant way to the capital investment and unit capital cost for the new Reynolds joint venture project being among the lowest for the major bauxite projects developed since 1970 (See Table 3.1).

The existence of substantial idle capacity at two of the existing locations in Guyana would also result in low investment for expansion of metallurgical bauxite production. This has been confirmed by the Alcoa study (Alcoa 1999) which shows the cost of expanding mining capacity at Linden from the existing level of 600,000 tonnes to 5 million tonnes, at US$57 million and in Berbice from the current 750,000 tonnes to 5 million tonnes at US$48 million. With estimated additional cost of US$20 million in each case for the installation of additional processing capacity and improved loading facilities, the total cost for expansion at each of these facilities would be about 60 per cent that of the expansion currently in progress at Trombetas, Brazil (see Table 3.2).

6.2 The Demand for Bauxite for the Aluminium and Alumina-Based Industries

The demand for metallurgical bauxite is derived from the demand for alumina which, in turn, is derived primarily from the demand for primary aluminium and marginally for other alumina-based products such as aluminium sulphate and fluorides, refractories, abrasives and ceramics. The production of primary aluminium, however, consumes such a large proportion of metallurgical bauxite and alumina that it is generally used as the basis for projecting their demand. Aluminium is also a globally traded metal, hence world demand and supply need to be evaluated in projecting developments in the industry while the location of new production capacity could have a significant impact on the sources of alumina and bauxite.

6.2.1 The Demand for Aluminium.

Aluminium is the only metal for which the intensity of use has been increasing since 1975. It has also exhibited the highest growth rate of all the industrial metals over the period 1952 to 1996 (See Tables 6.1 and 6.2).

Table 6.1 Intensity-Of-Use, Primary Aluminium
Five Year Averages, 1951-2000
(Tonnes per billion $GDP/1971 Prices)

Region	1951-55	1961-65	1971-75	1985[1]	2000[1]
West	1,565	2283	3056	3300	3,500
Japan	866	2258	4863	560	6,000
Other	1,287	1803	2876	3200	3,500
U.S.S.R	1,363	2106	2413	2450	2,500
Africa	37	163	559	600	900
Latin	369	879	1656	1900	2,300
China	44	1033	1630	1,950	2350
U.S.A	2174	3002	3911	4400	4,900
Total	1478.	2239	3,093	339	3730.

[1] Projected

Source:
World Demand For Raw Materials in 1985 and 2000, Malenbaum 1978

Table 6.2 Metal Consumption Growth Rates
1950-1992

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Period	Aluminium	Copper	Zinc	Lead	Silicon.	Nickel	Magnesim	Steel
1952-62	10.0	4	5	6	3	7	14	5
1963-73	10	5	6	4	2	8	7	6
1974-84	2	1	1	1	-1,2	2	1.0	0
1982-92	3	2	1	0	0	0	1,00	0

Source:

Australian Mineral Economics, The World Aluminium Industry.1993

Table 6.3 shows estimated world demand for primary aluminium for 1985 and 2000 based on the projected intensity of use and GDP growth in the Malenbaum study.

Table 6.3 World Demand For Primary Aluminium

Five-Year Averages

(000 tonnes)

Region	1951-55	1961-65	1971-78	1985	2000
West Europe	609	1,381	2,862	4,637	7,791
Japan	38	228	254	2,414	4,874
Other Developed Countries	94	200	528	890	1,565
U.S.S.R	286	805	1490	2252	3,868
Africa	1	7	40	65	160
Asia	11	92	294	453	884
Latin America	25	98	333	599	1,217
China	3	86	234	431	827
United States	1,211	2,321	4,388	7.410	9,073
Total World	2,351	5,535	12,249	20,590	36,516

Source:

World Demand for Raw Materials in 1995 and 2000.Malenbaum 1978, While actual world primary aluminium demand in 2000 was 50 per cent lower than the quantity projected in the Malenbaum study, Table 6.4 showing projections the ten year period 1995-2005 by Australian Mineral Economics (AME, Aluminium,1993), utilising consumption models based on end-use sector analysis for the metal and intensity of use on a country and regional basis, shows that the projections for the first five years of the period have been broadly achieved.

Table 6.4 Estimated World Primary Aluminium Consumption 1995-2005

(000 Tonnes)

Country/Region	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
United States	5080	5270	5420	5690	6030	5980	5790	5770	6840	6000	6250
Japan	2470	2570	2650	2780	2970	2990	3000	3010	3120	3260	3440
Other OECD Majors	4210	4310	4420	4560	4740	4880	4950	5010	5070	5170	5300
Other Industrialised. Countries	1690	1730	1780	1830	1900	1960	2000	2040	2070	2120	2170
Devwloping Asia	2180	2330	2490	2670	2850	3050	3270	3490	3740	4000	4280
Latin America	790	820	840	870	900	920	950	970	1000	1030	1060
Africa	140	140	150	150	160	160	170	170	180	180	190
Total Western World	16,560	17170	17750	18550	19550	19940	20130	20460	22020	21760	22690
Former East Bloc	4000	4100	4300	4650	5000	5000	5000	5100	5300	5500	5800
Total World	20550	21260	2250	23200	24550	24940	25120	25550	26320	27250	28480

Source:
Australian Mineral Economics, 1993. The World Aluminium Industry.

The growth rate projected in the AME study were largely achieved between 1995 and 2000, but with the steep fall in production in 2001, and the projected decline in the major consuming sectors the industry view is that the projected industry medium to long-term annual growth rate, would be 2-3 per cent. (Sturgell, 2002). Using the median growth rate of 2.5 per cent per annum, and consumption of 24 million tonnes in 2000, projected world aluminium demand and production for the period 2000-2010 would be as shown in Table 6.5.

Table 6.5 Estimated World Alumina And Metallurgical Bauxite Demand[1]

2000-2010

(000 Tonnes)

Year	**2000**	**2001**	**2002**	**2003**	**2994**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Aluminium Demand	24000	24600	25215	25845	26490	27150	27830	28550	29240	29970	30720
Alumina Demand	45600	46740	47910	49125	50330	51585	52875	54240	55560	56940	59370
Non Aluminium Demand	3700	3755	3820	3870	3930	3985	4045	4105	4170	4230	4300
Total Alumina Demand	49300	50455	51730	52995	54260	55570	56920	58390	59730	61170	63670
Capacity based on 90 % Operating Rate (Rounded)	55000	56000	57500	59000	60300	61750	63250	64900	66350	68000	70750
Bauxite Demand 2.6:1	128000	131200	134500	137800	141000	14450[1]	148000	152000	155300	159000	165500

[1] Calculations by the Author based on actual 2000 aluminium productionand established:alumina:aluminium ratio and average bauxite:alumina ratio.

6.2.3 The Demand for Alumina

With the technically established alumina:aluminium ratio of 1.95:1 and production of 24.0 million tonnes aluminium in 2000, approximately 47 million tonnes or 95 percent of world alumina production of 49.3 million tonnes were utilised in the production of aluminium. The demand for the non-aluminium applications is projected to increase at an annual rate of approximately 1.5 per cent over the next decade with alumina trihydrate for the production of aluminium sulphate being the largest area of growth. (Discussions with executives of Alcoa, Ormet, General Chemical and Holland Chemical). Table 6.5, above, shows estimated demand for alumina for the period 2000-2010 based on the projected growth rate of aluminium production and that for the minor alumina applications.

6.2.4 The Supply of Alumina

Until 1998, 90 per cent of Western World alumina capacity was controlled by the six major integrated producers in the industry, Alcoa, Alcan, Reynolds, Alusuisse, Kaiser, and Pechiney in fully owned or consortia refineries among themselves and smaller aluminium producers. Most of the alumina produced in these refineries was consumed by the majors and their consortia partners with small quantities sold to third parties. Except for short periods of imbalance between supply and demand, the majors ensured that alumina production capacity was adequate to satisfy their demand, that of the third party aluminium producers, and demand for the minor industry applications, based on an operating rate of approximately 90 per cent. The structural change in the industry over the past four years has resulted in approximately 25 percent of Western World capacity falling outside the ownership and control of the major aluminium producers and owned by companies that may not have the technical competence or the desire or resources to invest in brownfield or greenfield expansion. This could result in a dramatic change in the market dynamics for alumina. The impact of China as a major producer of aluminium and a possible long-term third-party market for alumina is another factor that could affect the market. However, the industry view at this time is that the large integrated aluminium producers would, on their own, or in consortia arrangements among themselves and the smaller alumina and aluminium consumers, undertake the necessary investment to guarantee adequate capacity over the next 10 years.(King, March 2002).

World alumina capacity increased from 27 million tonnes in 1975 to 40 million tonnes in 1985 with greenfield capacity accounting for almost the total increase. Between 1975 and 2000 only about 50 per cent of the net increase in capacity of 23 million tonnes was supplied by greenfield refineries with the remainder contributed by productivity increases and brownfield expansion. Current industry plans for capacity expansion between 2000 and 2005 involve only two greenfield refineries of 2.4 million tonnes capacity with productivity increases and brownfield expansion, some of which are already in progress accounting for the remainder. While further productivity improvements and brownfield expansion are feasible in existing refineries, problems of management, efficiency losses, environmental regulations and high unit investment cost, indicate that this form of expansion is approaching its technical and economic limits, hence greenfield expansion would be essential for a substantial part of the increase in capacity between 2005 and 2015. The ownership and location of the new greenfield capacity would influence the source of bauxite and would depend on the comparative investment and operating cost and the investment environment in bauxite producing countries.

The emphasis for the future of the Guyana industry, should, therefore be the production of alumina which adds value to the resources and reduces unit shipping cost and for which the country's Identified and readily accessible resources could sustain capacity equivalent to that of the United States for over 90 years. The Alcoa study referred to earlier in the study shows investment cost for a project producing 2.5 million tonnes bauxite per year (the feed requirement for a 1.2 million tonnes per year alumina refinery), based on the Linden or Kwakwani resources at US$31.2 and 31.6 million, respectively and total cost of ore delivered to a refinery at Linden or Kwakwani of US$10.31 and US$10.21 respectively. (Alcoa 1999, pages 1 and 4). The investment cost for such a project compares favourably with that for projects of similar size in any other bauxite producing country (See Tables 3.1 and 3.2), while the cost of ore per ton of alumina of US$22.50 is lower than the US$26.00 stated by Reynolds for the Worsely refinery in Australia (Reynolds 1999 Page) considered as the lowest world's lowest cost bauxite delivered to an alumina refinery. The investment for a refinery in Guyana should also compare favourably with that for any other refinery, since it would be processing a pure trihydrate with available Al_2O_3 and reactive SiO_2 of 50 and 4.5 per cent respectively. Guyana could be a viable location for new greenfield capacity over the next 10 years. However, the investment environment would be the most critical factor to such a development.

6.2.5 The Demand for Metallurgical Bauxite

Projected demand for alumina for the period 2000-2010 based on projections for aluminium production and for the minor non-aluminium applications has been shown in Table 6.5. The relationship between alumina production and bauxite demand is more difficult to establish than that between alumina and aluminium since the Al2O3 content of bauxite for the production of alumina varies from 1.95:1 for the highest grades of bauxite from Guinea, and Guyana, to 3.8:1 for the lowest grades in the Darling ranges in Australia. The data on world bauxite production also, do not distinguish between bauxite for the production of alumina and that for other applications, making it difficult to accurately determine the proportion of world bauxite production consumed by the aluminium industry. The available information on consumption of bauxite for the production of refractories, abrasives, aluminium chemicals and cement and other minor applications (discussions with producers of refractory, abrasive and chemical grade bauxite) indicate a maximum of 7 million tonnes per year for these applications suggesting 130 million tonnes used for the production of alumina and a ratio of 2.6:1. Assuming the maintenance of this ratio, world demand for metallurgical bauxite over the period 2000-2010 would be as shown in Table 6.5

The data suggests an increase in the demand for metallurgical bauxite from 130 million tonnes in 2000 to 166 million tonnes in 2010, an increase of 36.0 tonnes or 3.6 million tonnes per year.

6.2.6 The Supply of Metallurgical Bauxite

The supply of metallurgical bauxite to satisfy the projected alumina production over the period 2001-2010, is a function of world bauxite resources, the location of existing and new world alumina capacity and the comparative delivered prices of bauxite to refineries dependent on imported bauxite. World alumina capacity is increasingly being located in countries with bauxite resources, only 14.0 million tonnes of 56 million tonnes of world capacity in 2000, located in non-bauxite producing countries. While productivity increases in refineries dependent on imported bauxite could be expected over the next decade, discussions with refineries in North America and Europe indicate no plans for Brownfield or Greenfield expansion over the next decade; the only planned Brownfield expansions in bauxite importing countries being in Russia and Ukraine. The prospects for increased bauxite exports over the next decade are therefore not attractive. There are, however, good prospects for changes in the current export flows that could increase the demand for Guyana metallurgical bauxite including:

(1) Increasing monohydrate content of Guinea and Jamaica bauxite, two major sources of export bauxite to the United States which is already leading to companies planning to import trihydrate bauxites for blending.

(2) Refineries in the former Eastern Bloc countries which utilised domestic bauxite and other alumina bearing minerals, substituting high grade imported bauxite, with Guyana identified as a prospective source for such bauxite.

(3) The planned expansion of alumina capacity in Brazil which would absorb increasing quantities of domestic bauxite thereby creating a market vacuum that could be filled by Guyana.

(4) Lower investment cost for expansion of production in Guyana compared with other producing countries.

(5) Operating costs comparable to those in the other bauxite producing countries.

(6) The feasibility of reducing shipping costs with relatively small investment in improving the port facilities.

6.3 Structural Changes in the Aluminium Industry

The aluminium industry, which is one of the world's most vertically integrated industries, is currently undergoing structural and ownership changes that would result in rationalization of production and changes in the market structure and in the market flows for bauxite and alumina.

Until 1997, six conglomerates--Alcoa, Alcan, Reynolds, Alusuisse, Kaiser and Pechiney--through outright ownership or various forms of consortia and share-holding agreements controlled approximately 50 percent, 60 percent and 90 percent, respectively, of Western World aluminium, alumina, and metallurgical bauxite production. A number of changes in the ownership and control of capacity at all stages of the industry, especially at the alumina and bauxite stages, over the past four years, have dramatically changed the structure of the industry. The developments starting in 1998 being:

(1) The sale of Alcan's 1.5 million tonnes per year Aughinish, Ireland, alumina refinery to Glencore International of Switzerland. Glencore, for a brief period between 1986 and 1991 had a 100 percent ownership of the 650,000 tonnes per year St Croix refinery which was sold to Alcoa and, at the time of the purchase from Alcan, held only a 45% share in the 800,000 tonnes per year Euralumina refinery in Sardinia, Italy. The purchase, in 2001, of the 1.3 million tonnes per year Alcan Ewarton and Kirkvine alumina refineries by Glencore, together with the earlier acquisition of Aughinish, has resulted in that company assuming the position of the Western World's fourth largest alumina producer with ownership of 3.2 million tonnes per year alumina capacity.

(2) In 1999 Alcan, the second largest aluminium producer, attempted to acquire Alusuisse and Pechiney, the fourth and fifth largest producers. This acquisition that would have made Alcan the world's largest aluminium producer. The initiative ended with the acquisition

of only Alusuisse and in Alcan assuming control of all its bauxite resources, and bauxite, alumina and aluminium operations including its 2.2 million tonnes per year Gove alumina refinery and 6.5 million tonnes per year bauxite mining operation.

(3) In 1999, Alcoa, the largest aluminium producer, in response to the Alcan initiative, acquired Reynolds Metals, the third largest producer and took control of its bauxite resources, bauxite mining operations, and aluminium smelters. The conditions for the merger imposed by the United States Justice Department forced Alcoa to relinquish control of all Reynolds holdings in alumina refineries in the United States, Australia and Germany.

(4) The Justice Department conditions for the Alcoa acquisition, resulted in a major change in the ownership structure of world alumina capacity. (1) a completely new entity, BPU-Reynolds, formed by former Reynolds and Alcoa executives, acquired the 1.6 million tonnes per year Reynolds, Corpus Christie alumina refinery in the United States, (2) Billiton which owned 45 per cent of the 2.1 million tonnes per year Suriname alumina refinery in partnership with Alcoa, and 30 per cent of the 3.3 million tonnes per year Worsley refinery in Australia, acquired Reynolds 56 per cent share of the Worsely refinery increasing its share to 86 per cent, making it the world's third largest alumina producer with ownership of 4.2 million tonnes per year capacity. (3) in 2001 Dadco Alumina and Chemicals, a completely new entrant to the aluminium industry, acquired the former Reynolds 50 percent share in the 800,000 tonnes per year

Stade, Germany, refinery and in 2002, Hydro Aluminium of Norway, through its acquisition of VAW of Germany, acquired VAW's 50 per cent share in the refinery.

(5) Alcoa, which acquired the St. Croix Virgin Islands 650,000 tonnes per year capacity refinery from Glencore in 1995, operated it for just two years before announcing its permanent closure.

These developments removed 8.0 million tonnes per year or 20 percent of Western World alumina capacity from the integrated system of the major aluminium producers and resulted in a re-arrangement of their bauxite holdings. With the relinquishment of ownership of the Corpus Christie refinery in the United States, its share of the Stade in Germany, the closure of the St Croix refinery, and the acquisition of Reynolds share in the MRN, Brazil, bauxite project, Alcoa found itself with excess bauxite supply and sold its 50 per cent share of the Aroaima bauxite project in Guyana to the Guyana Government. This effect of this development, together with the relinquishment of the Reynolds share in the Boddington bauxite operations associated with the Worsley refinery, and Alcan's ownership of the bauxite mining operations associated with the Kirkvine and Ewarton refineries, was the transfer of 15.0 million tonnes or 11 percent of world metallurgical bauxite production capacity from the control of the integrated sector. The change in ownership of alumina capacity and some of the changes in bauxite capacity create a major free market for metallurgical bauxite that could be satisfied from independent sources such as Guyana.

6.4 Developments in The Refractory Raw Materials Industry

Even though Guyana has alumino silicate resources that could produce refractory materials spanning the entire mid, high, and extra-high alumina spectrum, over the past 50 years it has produced only refractory bauxite in the 86-90 per cent Al2O3 category. The market for refractory raw materials has declined over the past 20 years with the demand for refractory bauxite static over that period. There has, however been a change in the structure of demand for the alumina based refractory materials. While the low price of Chinese bauxite was a contributory factor to the loss of competitiveness of Guyana bauxite, this study has already shown that the development of higher priced, high, and synthetic alumina materials was a significant factor in the decline of consumption of Guyana refractory bauxite. Changes in steel-making technology and refractory practices also led to a change in the structure of demand for high alumina refractory materials with refractory bauxite being replaced by the homogenised high-alumina, and synthetic alumina materials.

Guyana, over the years, failed to modify the properties of its refractory bauxite to meet new industry requirements and to develop lower alumina-high mullite products which were replacing refractory bauxite and could be produced from raw materials currently mined in conjunction with its refractory bauxite and discarded with the overburden. An internal industry study to determine the industry's product mix for the decade of the 1980s (Guybau, Project Team, 1978), projected a decline in the growth rate for refractory bauxite and recommended production of mid alumina, high mullite materials to increase production volumes and maintain the industry's share of the broader high alumina refractory materials market. The strategy for the future of the industry in the refractory raw materials market should therefore, involve a shift from the production of the existing product to a diversified range of high alumina refractory raw materials utilising the same raw material and technology base. The product stream should include (1) refractory bauxite (RASC) as currently produced; (2) homogenised refractory bauxite; (3) homogenised mid-alumina, high mullite refractory materials; and (4) homogenised extra-high alumina refractory materials. A requirement for the production of this product stream is that installation of equipment for homogenisation of the raw materials. The advantage is that once installed, the same equipment would be suitable for the production of the full range of homogenised products. The same handling and kiln facilities would be used for all the products.

6.4.1 Refractory Bauxite (RASC)

Guyana refractory bauxite (RASC) has remained unchanged since it was developed in the decade of the 1940s, in spite of the refractories and steel industry requirements for a product with physical and mineralogical properties that increased its versatility, and improved performance in a number of applications. This resulted in the product losing market share in these applications to other alumina based and to non-alumina refractory materials. The properties of the existing product, especially that of re-heat expansion, is still highly desired by the industry. Hence it should remain as a part of the new product mix.

6.4.2 Homogenised Refractory Bauxite

Refractory bauxite (RASC) as currently produced, is variable in mineralogical composition and relatively low in density and high in porosity. While these properties make it ideal for certain refractory applications, marketing studies undertaken by the industry during the late 1970s identified a growing demand for a refractory material with the chemical composition of RASC but with higher density lower porosity and a higher mullitization. Laboratory tests undertaken by the industry confirmed that these properties could be induced in the material by the homogenisation of the ore before calcination. The increasing demand for products with these properties, evidenced by the increasing consumption of fused aluminium oxide as a blend to produce the higher density and lower porosity, led to the 1978 study recommending the inclusion of homogenised refractory bauxite in the product mix. This product should be included in the industry's future product mix.

6.4.3 Homogenised Mid-Alumina Refractory Materials

The mid-alumina refractory materials, with Al_2O_3 of 50-70 percent such as the sillimanite group and the homogenised bauxitic-clay and kaolin-based materials produced in the south eastern part of the United States and Brazil started replacing refractory bauxite in the steel industry in the mid 1970s. While the Al_2O_3 content of these materials is lower than that in refractory bauxite, their higher mullite content result in improved volume stability, hot strength, and resistance to corrosion, abrasion, and chemical attack. The demand for these materials has continued to increase for applications at all stages of the steel-making process and is being suppressed only by their limited supply and high price.

It was recognised since the early 1960s that the bauxitic clays associated with the Guyana refractory bauxite deposits contain combinations of Al_2O_3 and SiO_2 and low levels of impurities that make them suitable for the production of the full range of the mid-alumina-high-mullite materials. Pilot plant-scale tests undertaken by the Demba in the late 1960s, utilising blends of bauxitic clays and dust from refractory bauxite production, confirmed the suitability of these materials for the production of a material with an Al_2O_3 content of 70-72 percent. Laboratory studies undertaken at the University of Leeds, Department of Mining and Mineral Sciences. (Garrett, 1974) demonstrated that these materials could be processed to produce mid-alumina high mullite materials with properties similar to the sillimanite group and south eastern United States materials. A plant scale test undertaken on these materials by Guybau in 1978 also confirmed the chemical and mineralogical suitability of the materials for the production of a full range of mid-alumina refractory materials with homogenisation of the raw material before calcination necessary for the development of the mullite properties. Cost studies also revealed low cost of production for these products since the raw materials for their production were by-products of the refractory bauxite stream. Market studies for these products also revealed a less competitive market than that for refractory bauxite since the unsuitability of the mineralogical composition of Chinese bauxite unsuitable for their production, thus removing the element of low Chinese price competition. No further work was done on the development of these products even in the light of increasing demand and the expansion of production of andalusite in South Africa and France and Mulcoa and similar materials in the United States. They should, however be an integral part of the industry's future product mix.

6.4.4 Synthetic Alumina Refractory Materials

Technological developments in the steel and refractory products industries have led to an increasing demand for higher alumina and higher purity alumina based refractories and to the development of synthetic alumina refractory products based on brown fused alumina made from abrasive bauxite and white fused, sintered and tabular alumina made from Bayer process alumina.

The industry undertook successful research and development work in the mid 1980s on the production of a homogenised material with Al_2O_3 content of 92-93 per cent produced from beneficiated tailings from the refractory bauxite stream and selectively mined low SiO_2 refractory bauxite ore to compete with fused alumina. A study of the market for this product undertaken by Guymine in 1987 (The Market fir Guycor '93) confirmed the technical and cost competitiveness of this material with brown fused alumina in most industry applications. This material should, therefore, be an integral part of the future refractory product mix since it could be produced with raw materials from the same production stream and utilises basically the same equipment and process technology.

6.5 Abrasive Grade Bauxite

Guyana's high cost of production, the declining demand and depressed prices for abrasive bauxite, and the lower returns from this product compared with refractory bauxite with which it competes for production capacity, reduced the country to the position of an intermittent producer of this product even though it has the world's largest reserves of suitable raw material for its production. In addition, the fall in demand for refractory bauxite has released production capacity that could be rehabilitated at relatively low to convert Guyana to a major producer of abrasive bauxite.

6.5.1 The Demand for Abrasive Bauxite

The demand for abrasive bauxite is derived from the level of production of brown-fused alumina and proppants. The demand for brown-fused alumina has fallen from the levels of the 1970s and has been relatively static since the mid 1980s. The demand is not expected to increase over the next decade (Discussions with major producers 1995-2002). Production over the past ten years has fluctuated between 800,000 and 1.000,000 tonnes per year in accordance with the level of industrial activity and sales of raw material and processed grain from the US [Defence Logistics Agency] Stockpile world production of Brown-fused alumina and consumption of abrasive bauxite in 2000, based on a conversion factor of .85, are shown Table 6.6.

Table 6.6 World Brown Fused Alumina Production and Abrasive Bauxite Consumption

(Tonnes)

Region	**Consumption (Tonnes)**	
	Brown Fused Alumina	**Abrasive Bauxite Demand**
North America	150,000	170,000
Western Europe	125,000	150,000
Eastern Europe	200,000	235,000
China	300,000	350,000
South America	80,000	95,000
Total	855,000	1,000,000

Sources:

1. Tribacher Scheimetal, Villach, Austria.
2. Norton Proppants, Little Rock Arkansas.
3 Washington Mills, Niagara Falls, New York
4. Exolon ESK, Tonowanda, New York.

The major development in the production of brown fused alumina over the past 15 years is the shift in the locus of production from North America and Europe to China whose prices are 40-50 per cent lower than those for the other regions. This development has resulted in a change in the sources of supply for abrasive bauxite, since the total Chinese production is based on domestic raw materials.

The demand for proppants has increased by almost 50 per cent over the past 10 years and is expected to continue increasing at an annual rate of approximately 5 per cent over the next 10 years. The demand for premium grade ceramic proppants made from abrasive bauxite has doubled over the same period (discussions with representatives of Carbo Ceramics and Norton Proppants). The reasons advanced for the increase being: (1) the increasing trend in the oil and gas industries to utilise high pressure fluid injection to increase recovery from reservoirs; (2) the need for a material capable of withstanding the high compressive strength of the rocks in the deeper wells; (3) the requirement for a material with the capability of retaining volume stability under the high temperatures at depths in excess of 3,000 feet and (4) the need for a material with the capability of surviving the highly corrosive environment at the greater depths.

6.5.2 The Supply Of Abrasive Bauxite

The stringent specifications for abrasive bauxite that confine its production to a small number of bauxite producing countries has already been discussed in this study (section 2.2.4). The major supply sources, since 1982, when Suriname the largest producer, discontinued production, have been Australia, Guinea, China and recently Brazil, which consumes its total production. China in 2000 accounted for approximately 50 per cent of world production which an estimated 60 per cent used for domestic brown fused alumina production and the remainder exported. Table 6.7 shows estimated world production of abrasive bauxite in 2000.

Table 6.7 World Abrasive Bauxite Production

(Tonnes)

Country	**Quantity**
United States	50,000
Australia	150,000
Guinea	100,000
China	500,000
Brazil	100,000
Eastern Europe	2500,000
Total	1,100,000

Sources:
1. Discussions with Alcoa Aluminium and Chemicals, Pittsburgh.
2 Discussions with Tribacher Scheimetal, Villach, Austria.
3. Discussions with Norton Proppants, Little Rock Arkansas.
4. Discussions with representatives of Curimbaba, Brazil

The supply of abrasive bauxite changed significantly over the past two years:

(1) Guinea, which produces material with the lowest SiO_2 content needed for blending with the high SiO_2 material from Australia, reduced production by 50 percent in 2001 and completely discontinued production at the end of the year citing as the reason the difficulty of selectively mining suitable raw material.

(2) Norton Production in the United States, which produced abrasive bauxite for its own proppants manufacture from residual bauxite

deposits in Arkansas, has been forced to reduce and then eventually to cease production because of the exhaustion of the existing raw material resources and the high cost of continuing production with imported raw materials.

With the cessation of production in Guinea, there is a requirement in the market for a material with properties close to the Guinea product. The properties of the Guyana material are close to that from Guinea, hence Guyana is viewed by the customers as the best prospective source for the replacement of Guinea. The manufacture of proppants demands a material with properties which are found only in abrasive bauxite from gibbsitic bauxite. With the departure of Guinea, and the depletion of the United States resources, the only bauxites that are considered technicall suitable are those from Weipa, Australia, South-eastern Brazil and Guyana.These changes in the market make it feasible for Guyana, which has adequate raw material resources and idle production capacity, to re-enter the abrasive bauxite market with this product becoming an permanent component of the industry's medium to long-term product mix.

6.1.3 Definition of Government Policy

The future prospects for the industry, with the proposed product mix, requires substantial capital investment especially for the increase in metallurgical bauxite production and the establishment of alumina refining capacity. Foreign investment is the only feasible source of capital for such development with the major integrated companies in the industry, the most likely investors. A clear definition of Government policy on the role of private investment in the industry is a prerequisite to attracting such investment. While the Government has since 1985 announced a policy of privatisation of the state-owned bauxite enterprises and full private ownership of new developments in the industry, the unsuccessful attempts at privatisation suggest that a mere declaration of a change of policy with regard to ownership is not a sufficient condition for attracting the large-scale, long-term investment, needed for its future development. A more comprehensive change and clearer definition of government policy on ownership of industry in general, and the bauxite industry in particular, together with evidence of a commitment to the industry, active promotion of its development, and even financing of the infrastructure facilities necessary for the proposed future developments are necessary to attract foreign investment. The Government must also convince prospective foreign investors that the prevailing political environment is conducive to the safety of their investment.

A number of developments over the past ten years (See Section 5.4 of this study) have led to concerns about Government's policy on private ownership of industry, its policy on privatisation of the bauxite industry, its commitment to the industry, and its ability to maintain a safe political environment for foreign investment.

The development of metallurgical bauxite and alumina would be virtually impossible without involvement of the integrated aluminium producers and probably the second-round operators and international traders who are becoming increasingly involved in the bauxite, alumina, and aluminium markets. The normal practice in the industry is for the initiative for the establishment of the necessary consortia arrangements to be taken by at least one of the major companies. In the context of the new structure of the industry and the international competition for such projects it may be necessary for the government to undertake the necessary feasibility and investment studies and actively set out to promote and organise the consortia for the development of the projects.

The development of the refractory and abrasive bauxite sectors may require a different approach since the fragmented structure of the refractory raw materials and refractory products industries would preclude large-scale investment from entities in these industries. Neither has the abrasives industry shown any interest in foreign investment in the production of raw materials. Therefore, it may be necessary for the Government to adopt the leading role in securing finance for the development of this sector, even being prepared to provide guarantees for such investment.

A development that is critical to the future of the industry is the removal of the shipping constraints that continue to impose a severe penalty on the country's bauxite shipments. The large-scale production of metallurgical bauxite and alumina would require competitive shipping costs that could only be achieved by increasing the size of shipments closer to that from the other exporting countries. This could be achieved over a very short period of time by undertaking the necessary investment in the further deepening of the entrance to one of the rivers, and the establishment of an efficient bulk-materials handling facility to facilitate the rapid loading of vessels. Technical and economic feasibility studies confirming the viability of such a project have already been undertaken. Since such a project could be considered as a development of the country's infrastructure and qualify for international institutional financing, the government's willingness to undertake its financing and development could be seen as a declaration of its commitment to the industry and act as an incentive to foreign private investment at the production stages.

Chapter 7

CONCLUSION

Guyana's rapid rise to the position of the world's second largest producer of bauxite in the decade of the 1940s was the direct result of its endowment with relatively large deposits of high grade bauxite, compatible with the technology utilised by the North American aluminium industry for the production of alumina and the increase in demand for aluminium for the production of aircraft during the Second World War. However, the country lost its prominent position as a supplier of bauxite to the aluminium industry over the next four decades, when aluminium became established as an industrial metal and world production increased at an average annual rate of 6.8 per cent. By the decade of the 1990s, Guyana had become an insignificant supplier to the industry.

The unique chemical and mineralogical properties of its bauxite resources made it feasible for the country to continue as a bauxite producer with the production of refractory bauxite. demand for which stimulated by post war economic and technological developments in the steel industries of the Market Economy Countries between 1950 and 1075. This development propelled Guyana to the position of the world's largest producer of refractory bauxite with a market share of over 80 per cent during the decade of the 1970s. The country lost its dominant position in the refractory bauxite market during the decade of the 1980s and by the end of the decade of the 1990s its market share had fallen to only 12 per cent.

Studies of the industry, undertaken in the decade of the 1960s, attributed the loss of share of the metallurgical bauxite market to loss of competitiveness through high mining and shipping costs compared with those in other bauxite endowed countries. Studies in the decade of the 1980s attributed the decline in production and loss of share in the refractory bauxite market to inherent high production cost, inadequate investment in maintenance and replacement of equipment, and inefficient management associated with state ownership.

The hypothesis of this study is that while the reasons for the decline advanced in the earlier studies are relevant, they do not provide an adequate explanation of the developments in the industry since the decade of the 1950s nor are they an indicator of the prospects for its future development. The thesis of loss of competitiveness in the metallurgical bauxite market through high mining and shipping costs fails to evaluate a number of critical elements of cost of production of bauxite and alumina that influence the competitiveness of bauxite from different sources, and fails to assess the impact of a number of non-economic factors on investment decisions in the aluminium industry, of which bauxite production is a component. The paradigm of inefficiency associated with state-ownership as the reason for loss of competitiveness in the refractory bauxite market also does not adequately analyse a number of exogenous economic, technological, and market factors that impinged on the demand for and supply of refractory raw materials in general and refractory bauxite in particular. Therefore, the study sets as its objective the undertaking of a comprehensive analysis of the economic, technological, market and non-economic factors that influenced the development of the Guyana bauxite industry over the past 50 years both in the areas of metallurgical and refractory bauxite.

To achieve this objective, the study evaluated the significance of a number of elements of cost and pricing in the evaluation of the competitiveness of bauxite from different sources, such as (1) the quality of the bauxite; (2) capital investment and cost; (3) operating and total cost; (3) alumina production cost; (4) shipping cost; and (5) the pricing mechanisms for metallurgical bauxite. The study also evaluated the impact of non-economic factors such as: (1) resource endowment; (2) political philosophy and the prevailing political climate; (3) investment strategies of multinational corporations; (4) public policy on investment and ownership of industry; (5) national security interests on investment and location of capacity; and (6) government involvement in the development of mineral resources and on the location and timing of investment in the bauxite and alumina sectors of the industry. The study concluded that while the production of bauxite in Guyana suffered inherent disadvantages in mining and shipping, inclusion of the other elements of cost in the comparative analysis shows a significant reduction of the disadvantage in some areas and a complete reversal in others. It also concluded that the non-economic factors played a significant role in the diversion of investment in the industry from Guyana, to other bauxite-endowed countries.

The study also analysed the factors that stimulated the demand for refractory bauxite and contributed to Guyana's dominant position in the supply of this product and found that macro economic developments in the Market Economy countries after the Second World War that increased the demand for steel, together with technologic developments in the steel-making process, were responsible for the increase in demand for refractory bauxite which, for 25 years, Guyana was the only viable supplier. The analysis identified (1) changes in the macro economic variables in the Market Economy countries; (2) technologic developments in the steel-making process; (3) structural changes in the steel industry; (4) development of alternative sources of refractory bauxite; and (5) development of substitutes for refractory bauxite as being responsible for a dramatic change in the dynamics of the refractory raw materials market that reduced the demand for refractory bauxite in general and Guyana refractory bauxite in particular.

The impact of the superimposition of state-ownership on the industry was also analysed. The study examined the motivations for state ownership and evaluated the effect of specific elements of state-ownership on the industry; (1) loss of economies of vertical integration within the aluminium industry; (2) loss of efficiency resulting from the organisational and management structure; (3) failure to establish clearly defined industry objectives; (4) absence of management accountability; and (5) loss of managerial and technical skills. to the industry. It also examined changes in public policy on state ownership of the industry and analysed the contributory factors to the failure of recent attempts to divest the industry and reduce the level of state ownership.

The study then assessed the future prospects for the industry and concluded that it could be re-established as a competitive and viable bauxite producer with a diversified product mix comprised of metallurgical bauxite, alumina, a range of refractory materials spanning the entire high alumina spectrum, and abrasive bauxite. The basis of its future prospects, in the aluminium industry, is its large high grade bauxite resources, the projected growth of demand for aluminium and other alumina based products, structural changes in progress in the aluminium industry and consequent changes in the market for alumina and metallurgical bauxite. The basis for the production of a complete range of high alumina and synthetic alumina products, its large bauxitic clay deposits associated with the bauxite resources, and changes in the structure of demand for alumina based refractory materials. The increasing demand for abrasive bauxite for proppants in oil and gas extraction, changes in the sources of supply of abrasive bauxite, the availability of suitable raw material and the existence of idle processing capacity, create new prospects for the large-scale production of abrasive bauxite.

The study identified a number of changes in public policy as prerequisites for the future development of the industry. The critical areas identified are a clear definition of public policy on the role of private investment and ownership and control of entities in the industry,, the establishment of the appropriate legal and institutional framework for the implementation of the investment policy, active promotion of the development of the industry by the Government, the establishment of clearly defined incentives for investment in the industry, a commitment by the Government to facilitate the establishment of infrastructure critical to the viability of projects in the industry, and maintenance of a stable political and safe social environment to reduce to a minimum, the element of political and social risk.

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