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A STUDY OF THE IRON AND STEEL INDUSTRY IN LATIN AMERICA

Volume I

Report on the meeting of the Expert Working Group held at Bogotá

UNITED NATIONS

Table IV

APPARENT CONSUMPTION OF IRON AND STEEL IN COLOMBIA

Years	Imports (thousands of tons)	Population (thousands of inhabitants)	Per capita consumption (kilograms)
1925	50.4	6,687	7.5
1926	65.8	6,832	9.6
1927	61.3	6,972	8.8
1928	89.1	7,111	12.5
1929	77.6	7,262	10.7
1930	45.4	7,412	6.1
1931	27.7	7,563	3.7
1932	30.0	7,726	3.9
1933	40.9	7,880	5.2
1934	53.4	8,038	6.6
1935	53.6	8,199	6.5
1936	75.4	8,363	9.0
1937	90.9	8,531	10.6
1938	98.6	8,702	11.3
1939	102.4	8,886	11.5
1940	80.5	9,076	8.9
1941	60.9	9,269	6.6
1942	12.0	9,469	1.3
1943	35.5	9,673	3.7
1944	78.8	9,883	8.0
1945	94.4	10,098	9.3
1946	120.2	10,318	11.6
1947	164.0	10,545	15.5
1948	98.6	10,777	9.1
1949	109.8	11,015	10.0
1950	152.2	11,260	13.5

Source: Economic Commission for Latin America.

Table V

APPARENT CONSUMPTION OF IRON AND STEEL IN CUBA

Years	Imports of iron and steel (thousands of tons)	Population (thousands of inhabitants)	Per capita consumption (kilograms)
1925	151	3,431	44.0
1926	126	3,519	35.8
1927	142	3,606	39.4
1928	107	3,692	29.0
1929	117	3,778	31.0
1930	70	3,886	18.0
1931	31	3,946	7.8
1932	24	4,028	6.0
1933	28	4,108	6.8
1934	38	4,187	9.1
1935	57	4,264	13.4
1936	71	4,339	16.4
1937	83	4,411	18.8
1938	58	4,480	12.9
1939	69	4,547	15.2
1940	65	4,611	14.1
1941	72	4,671	15.4
1942	31	4,728	6.6
1943	39	4,782	8.2
1944	74	4,851	15.2
1945	86	4,923	17.5
1946	105	4,995	21.0
1947	146	5,065	28.8
1948	121	5,135	23.6
1949	128	5,204	24.6
1950	136	5,276	25.8

Source: Economic Commission for Latin America.

Table VI

APPARENT CONSUMPTION OF IRON AND STEEL IN MEXICO

Years	Production	Imports	Consumption	Population (thousands of inhabitants)	Per capita consumption (kilograms)
	(thousands of tons)				
1925	61.3	104.6	165.9	15,232	10.9
1926	65.1	104.0	169.1	15,465	10.9
1927	54.9	94.4	149.3	15,702	9.5
1928	69.2	92.0	161.2	15,942	10.1
1929	86.9	137.8	224.7	16,186	13.9
1930	88.8	79.1	167.9	16,553	10.1
1931	62.0	66.5	128.5	16,841	7.6
1932	48.7	44.6	93.3	17,134	5.4
1933	64.7	71.8	136.5	17,432	7.8
1934	114.0	114.7	228.7	17,735	12.9
1935	134.3	114.1	248.4	18,044	13.8
1936	129.5	131.1	260.6	18,852	13.8
1937	185.1	182.6	367.7	18,737	19.6
1938	108.1	66.4	174.5	19,071	9.1
1939	131.6	85.0	216.6	19,413	11.2
1940	130.1	92.0	222.1	19,763	11.2
1941	131.7	102.9	234.6	20,208	11.6
1942	132.5	73.4	205.9	20,657	10.0
1943	126.0	119.7	245.7	21,165	11.6
1944	142.5	232.6	375.1	21,674	17.3
1945	203.9	226.7	430.6	22,233	19.4
1946	268.3	270.6	538.9	22,779	23.7
1947	300.2	314.0	614.2	23,440	26.2
1948	249.1	173.7	422.8	24,129	17.5
1949	334.6[a]	167.1	501.7	24,825	20.2
1950	348.2[a]	226.8	575.0	25,706	22.4
1951	394.7[a]	342.3	737.0	26,332	28.0

Source: Economic Commission for Latin America.

[a] Estimates.

Table VII

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN ARGENTINA
(Thousands of tons)

Years	*Total*	*Rails and accessories*	*Bars, strip, shapes and structural steel*	*Wire and wire products*	*Sheet*	*Tinplate*	*Tubes*	*Other products*
1925	734.4	73.5	245.2	123.8	175.1	31.2	75.4	10.2
1926	728.3	89.4	274.9	104.4	147.8	30.4	70.2	11.1
1927	850.9	127.7	321.4	118.3	141.2	50.8	78.6	12.9
1928	1,091.4	222.2	411.7	155.2	178.9	40.8	81.4	1.2
1929	1,054.0	182.9	413.9	134.2	175.2	47.8	99.2	0.8
1930	858.1	162.8	334.1	103.7	129.0	39.6	88.2	0.7
1931	437.7	20.9	182.8	60.7	84.1	33.4	54.9	0.9
1932	321.9	4.6	137.5	51.8	59.0	37.4	30.7	0.9
1933	416.1	10.7	162.6	62.0	100.1	46.3	33.6	0.8
1934	520.7	56.0	188.3	75.8	80.5	66.2	52.7	1.2
1935	612.9	35.1	277.6	87.5	115.4	53.3	42.8	1.2
1936	606.1	42.6	241.7	85.8	117.6	63.7	53.9	0.8
1937	916.7	46.2	434.1	111.8	173.8	81.1	68.1	1.6
1938	586.7	30.1	280.5	66.5	87.9	55.9	64.2	1.6
1939	621.5	20.9	289.5	63.1	120.0	68.6	57.7	1.7
1940	577.5	6.6	266.5	45.2	117.6	90.6	47.7	3.3
1941	401.7	4.2	148.5	55.3	68.4	92.1	30.8	2.4
1942	219.2	1.3	84.1	20.3	29.3	60.2	20.7	3.3
1943	144.6	1.5	77.8	15.7	7.1	30.8	9.8	1.9
1944	219.5	0.4	152.4	19.0	6.2	32.2	6.7	2.6
1945	255.3	1.4	153.1	29.5	20.6	33.7	14.8	2.2
1946	607.3	20.2	300.7	94.8	106.3	37.3	42.5	5.5
1947	914.9	43.7	374.4	158.2	165.5	78.0	87.2	7.9
1948	973.8	89.5	338.6	147.3	210.5	77.4	105.8	4.7
1949	912.6	55.8	405.5	146.0	152.2	35.0	113.5	4.6
1950	911.0	17.6	399.4	146.2	144.1	58.7	138.8	6.2
1951	1,111.7	34.3	386.9	152.6	284.1	85.4	154.5	13.9

Source: Economic Commission for Latin America.

Table VIII

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN BRAZIL
(Thousands of tons)

Years	*Total*	*Rails and accessories*	*Bars, strip, shapes and structural steel*	*Wire and wire products*[a]	*Sheet*	*Tinplate*	*Tubes*[b]	*Other products*[c]
1925	381.2	120.6	65.1	78.0	35.7	25.5	43.3	13.0
1926	409.0	146.0	101.2	56.5	35.0	16.3	40.2	13.8
1927	458.8	115.0	112.2	71.7	60.0	32.3	39.7	27.9
1928	500.1	122.1	121.5	88.9	54.4	33.6	56.2	23.4
1929	488.3	94.8	148.7	83.4	50.7	25.8	55.0	29.9
1930	273.8	60.0	75.8	45.6	28.1	24.2	22.5	17.6
1931	144.4	22.7	32.4	30.5	19.9	23.3	9.4	6.2
1932	155.1	15.8	45.5	29.0	22.0	23.8	13.8	5.2
1933	280.2	59.1	72.9	46.1	42.6	33.0	20.6	5.9
1934	343.9	94.4	101.0	50.3	38.2	30.0	21.8	8.2
1935	349.4	62.1	125.8	53.5	42.7	31.8	28.8	4.7
1936	387.7	62.6	138.1	59.2	48.9	42.9	33.4	2.6
1937	506.5	94.5	173.6	66.5	62.0	56.4	50.5	3.0
1938	357.9	48.2	154.2	45.4	41.8	38.7	27.1	2.5
1939	430.0	82.8	157.2	53.0	52.3	51.0	31.9	1.8
1940	426.3	55.4	172.2	45.6	53.1	66.7	31.7	1.6
1941	399.7	56.4	159.4	47.0	42.2	59.5	29.2	6.0
1942	274.5	19.1	146.7	39.0	16.7	42.4	9.3	1.3
1943	339.6	70.2	151.9	36.0	24.8	42.3	12.8	1.6
1944	492.3	77.7	209.8	54.6	68.1	51.7	27.3	3.1
1945	482.3	103.6	193.8	54.5	51.4	52.2	24.8	2.0
1946	661.6	127.6	273.9	92.9	81.4	40.8	41.5	3.5
1947	773.2	95.2	301.6	129.5	112.9	77.9	52.5	3.6
1948	639.8	89.4	198.0	87.3	134.1	74.0	43.1	13.9
1949	753.1	45.6	262.0	147.1	153.1	66.2	76.8	2.3
1950	874.9	65.6	340.1	164.4	154.2	85.6	65.0	..

Source: Economic Commission for Latin America.

[a] Until 1939, imports only. After 1940 the production of the Companhia Siderúrgica Belgo-Mineira was added.

[b] Until 1946, imports only. After 1947 the production of the Companhia Siderúrgica Belgo-Mineira was added. There was no information on other companies.

[c] Includes special steels and iron and steel in various unspecified forms.

Table IX

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN CHILE
(Thousands of tons)

Years	*Total*	*Rails and accessories*	*Bars, strip, shapes and structural steel*	*Wire and wire products*	*Sheet*	*Tinplate*	*Tubes*	*Other products*
1925	126.1	19.6	36.3	19.9	26.5	6.4	17.4	—
1926	113.0	23.3	27.7	16.7	19.3	8.0	18.0	—
1927	129.1	28.0	42.3	18.8	22.8	5.5	11.7	—
1928	174.8	57.2	40.2	23.7	27.6	6.8	19.3	—
1929	224.5	41.0	81.9	30.8	35.2	8.6	27.0	—
1930	245.6	57.9	78.0	24.2	35.7	9.6	40.2	—
1931	92.3	9.8	34.3	9.9	16.4	4.0	17.9	—
1932	27.6	1.0	9.1	6.1	5.4	2.1	3.9	—
1933	40.4	7.7	12.0	8.2	4.8	2.4	5.0	0.3
1934	61.8	2.2	30.8	11.2	7.6	4.7	4.8	0.5
1935	113.1	10.7	56.0	17.6	12.5	5.8	9.5	1.0
1936	114.2	15.9	52.5	13.8	15.9	7.4	7.2	1.5
1937	128.2	4.0	61.1	18.6	18.8	7.9	15.5	2.3
1938	121.2	18.6	52.9	13.9	15.6	5.8	12.1	2.3
1939	122.6	10.0	48.5	20.3	20.6	9.0	11.7	2.5
1940	135.5	7.3	61.5	19.3	22.6	11.3	11.7	1.8
1941	106.6	5.3	48.9	17.8	14.3	8.4	11.4	0.5
1942	82.6	5.5	43.2	7.7	7.0	9.3	9.0	0.9
1943	89.7	11.4	42.1	8.1	9.1	9.0	8.9	1.1
1944	111.0	10.0	50.9	19.4	14.4	4.6	10.5	1.2
1945	127.4	15.1	62.7	22.1	11.9	7.3	6.8	1.5
1946	134.7	17.8	66.5	19.8	14.9	4.8	10.0	0.9
1947	145.5	24.4	67.8	16.3	15.7	7.9	9.0	4.4
1948	153.9	14.3	67.5	18.4	19.3	11.8	15.1	7.5
1949	192.5	11.9	92.3	21.1	23.2	9.8	26.7	7.5
1950	164.5	6.3	81.2	20.2	19.5	8.6	23.9	4.8
1951	206.2	28.2	100.9	6.9	27.1	13.5	19.3	10.3

Source: Economic Commission for Latin America.

Table X

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN COLOMBIA
(Thousands of tons)

Years	*Total*	*Rails and accessories*	*Bars, strip, shapes and structural steel*	*Wire and wire products*	*Sheet*	*Tinplate*	*Tubes*
1925	50.4	17.6	7.3	12.3	10.1	1.5	1.6
1926	65.8	23.4	13.3	13.7	10.6	3.2	1.6
1927	61.3	12.2	6.9	17.9	17.6	3.8	2.9
1928	89.1	27.0	17.7	16.6	21.2	3.2	3.4
1929	77.6	11.9	20.4	19.0	21.8	1.2	3.3
1930	45.4	15.3	6.7	10.8	9.7	1.5	1.4
1931	27.7	5.6	3.2	10.7	6.3	0.6	1.3
1932	30.0	1.9	7.9	10.1	7.7	1.0	1.4
1933	40.9	3.6	7.5	11.4	7.5	2.3	8.6
1934	53.4	7.3	13.4	14.3	8.8	3.2	6.4
1935	53.6	4.0	12.7	12.7	12.5	2.5	9.2
1936	75.4	5.1	17.3	17.1	17.7	3.4	14.8
1937	90.9	6.0	23.9	16.8	14.9	4.4	24.9
1938	98.6	2.1	19.1	12.4	15.0	2.8	47.2
1939	102.4	2.2	23.6	20.8	18.0	6.0	31.8
1940	80.5	4.5	22.6	14.2	12.5	5.0	21.7
1941	60.9	3.2	23.6	12.4	4.6	4.0	13.1
1942	12.0	0.2	2.9	2.3	1.3	1.2	4.1
1943	35.5	0.5	12.2	6.7	3.8	4.1	8.2
1944	78.8	1.5	33.8	10.0	5.2	1.4	26.9
1945	94.4	0.8	36.4	12.0	9.5	2.6	22.1
1946	120.2	7.8	48.3	17.7	13.7	1.9	30.8
1947	164.0	16.0	57.4	26.7	16.1	4.7	43.1
1948	98.6	6.0	29.6	22.1	10.4	6.5	24.0
1949	109.8	1.9	31.6	24.1	11.2	4.4	36.6
1950[a]	152.2	0.4	55.5	39.8	22.0	5.5	29.0

Source: Economic Commission for Latin America.
[a] Provisional figures, as several minor products have not been included.

Table XI

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN CUBA
(Thousands of tons)

Years	*Total*	*Bars[a], shapes, strip and structural steel*	*Wire and wire products*	*Sheet*	*Tinplate*	*Tubes*	*Other products[b]*
1925	151.1	85.3	17.4	18.2	7.2	11.8	11.2
1926	126.5	76.0	14.3	14.3	4.0	9.7	8.2
1927	141.6	74.1	18.5	19.4	6.5	11.6	11.5
1928	106.6	37.0	19.7	14.2	5.2	22.5	8.0
1929	117.2	43.3	20.0	12.7	7.0	21.7	12.5
1930	69.5	24.9	13.0	9.0	6.2	7.3	9.1
1931	31.4	10.3	8.0	4.1	3.9	3.3	1.8
1932	23.8	6.1	7.7	3.8	3.6	1.7	0.9
1933	27.6	4.8	9.2	3.9	5.0	2.5	2.2
1934	38.4	7.4	11.9	6.8	6.7	2.6	3.0
1935	56.6	15.1	16.0	9.1	7.4	4.9	4.1
1936	71.0	20.7	16.4	10.6	9.9	6.2	7.2
1937	83.0	24.2	19.3	14.0	12.8	9.0	3.7
1938	58.3	16.7	14.0	7.2	9.9	5.8	4.7
1939	69.3	19.8	16.8	8.0	13.5	7.5	3.7
1940	64.7	23.3	11.6	10.1	11.2	6.2	2.3
1941	72.1	19.2	14.7	6.2	19.8	9.2	3.0
1942	30.6	2.9	4.4	4.4	14.9	2.5	1.5
1943	39.2	6.4	5.1	5.2	13.1	2.6	6.8
1944	73.7	26.3	13.4	12.5	11.6	5.0	4.9
1945	85.6	23.3	13.8	14.7	12.7	13.0	8.1
1946	104.7	49.4	12.5	11.8	16.9	7.1	7.0
1947	145.7	52.2	26.1	19.4	17.4	7.8	22.8
1948	120.7	32.6	23.5	18.7	22.1	11.2	12.6
1949	127.5	40.3	25.2	17.9	12.8	22.4	8.9
1950	135.9	47.9	25.4	20.1	20.8	15.9	5.8

Source: Economic Commission for Latin America.

[a] Includes the statistical group "Other Iron and Steel Manufactures" for 1925–27, covering products which in later years were broken down in detail.

[b] Includes rails and railway accessories, special steels and other smaller headings.

Table XII

ESTIMATED STEEL CONSUMPTION BY GROUPS OF PRODUCTS IN MEXICO
(Thousands of tons)

Years	*Total*	*Rails and accessories*	*Bars, strip, shapes and structural steel*	*Wire and wire products*	*Sheet*	*Tinplate*	*Tubes*
1925	165.9	24.7	50.0	21.3	14.1	12.1	43.7
1926	169.1	32.5	54.2	23.2	15.6	15.1	28.5
1927	149.3	36.1	41.5	20.4	14.1	11.4	25.8
1928	161.2	31.3	55.5	21.7	16.6	13.1	23.0
1929	224.7	32.7	70.5	26.7	35.0	19.7	40.1
1930	167.9	31.0	72.6	22.0	8.9	9.4	24.0
1931	128.5	24.4	47.3	13.1	12.1	12.0	19.6
1932	93.3	15.0	34.6	9.9	14.4	9.4	10.0
1933	136.5	21.9	43.3	15.7	23.7	10.9	21.0
1934	228.7	27.3	94.1	20.3	34.2	13.4	39.4
1935	248.4	33.6	104.7	24.1	28.5	11.1	46.4
1936	260.6	37.4	101.4	27.1	34.1	16.6	44.0
1937	367.7	43.3	163.6	30.2	40.6	18.0	72.0
1938	174.5	33.0	72.5	23.0	16.1	11.9	18.0
1939	216.6	31.2	95.4	24.6	29.7	18.2	17.5
1940	222.1	22.7	102.3	28.4	32.0	17.7	19.0
1941	234.6	21.2	103.8	34.4	30.4	19.6	25.6
1942	205.9	26.9	88.7	33.1	21.0	16.7	19.5
1943	245.7	24.2	78.2	36.2	45.1	16.1	35.9
1944	375.1	37.6	153.5	60.7	67.3	15.8	40.2
1945	430.6	33.3	198.3	57.9	80.2	16.5	44.4
1946	538.9	62.5	239.4	69.8	100.4	11.2	55.6
1947	614.2	105.3	257.6	68.1	93.0	21.3	68.9
1948	422.8	59.7	165.6	57.3	88.7	15.3	41.3
1949	506.7	62.5	198.2	64.8	111.1	21.8	48.3
1950	575.0	105.1	205.3	61.4	111.2	23.8	68.1
1951	737.0	158.1	290.9	68.1	127.8	36.2	55.9

Source: Economic Commission for Latin America.

Table XIII

RELATION BETWEEN IRON AND STEEL CONSUMPTION AND THE DEVELOPMENT OF INDUSTRIAL PRODUCTION
(1935–39 = 100)

	Argentina		*Brazil*		*Chile*		*Mexico*	
Years	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)
1925	109.8	—	93.8	49.2	105.2	61.4	65.4	60.7
1926	108.9	—	100.7	53.5	94.3	66.4	66.6	68.9
1927	127.2	..	112.9	59.3	107.7	59.8	58.8	62.3
1928	163.2	..	123.1	77.5	145.8	65.9	63.5	65.4
1929	157.6	..	120.2	73.4	187.3	80.4	88.5	69.3
1930	128.2	..	67.4	71.4	204.9	80.4	66.2	72.9
1931	65.4	..	35.5	72.4	77.0	59.8	50.6	72.8
1932	48.1	..	38.2	69.4	23.0	68.2	36.8	62.9
1933	62.2	..	69.0	75.5	33.7	75.0	53.8	58.2
1934	77.8	..	84.6	79.4	51.6	81.7	90.1	86.9
1935	91.6	83.7	86.0	93.5	94.4	94.2	97.9	84.6
1936	90.7	93.7	95.4	92.5	95.3	93.4	102.8	97.3
1937	137.0	103.2	124.7	100.5	107.0	101.0	144.9	102.0
1938	87.7	107.8	88.1	100.4	101.0	108.6	68.9	105.0
1939	93.0	111.6	105.8	113.1	102.3	102.8	85.5	111.1
1940	86.3	..	104.9	119.7	113.0	115.0	87.5	114.5
1941	60.0	115.9	98.4	130.5	88.9	126.2	92.4	124.6
1942	32.7	..	67.6	137.0	68.9	124.0	81.1	138.6
1943	21.6	123.2	83.6	157.1	74.8	123.4	96.8	140.1
1944	32.8	..	121.2	170.4	92.6	121.9	147.8	147.1
1945	38.1	140.6	118.7	169.4	106.2	136.4	169.7	154.5
1946	90.8	150.8	162.8	180.2	112.4	151.9	212.4	155.3
1947	136.8	182.9	190.3	174.2	121.4	157.3	242.0	151.3
1948	145.6	184.9	157.5	200.4	128.4	164.7	166.6	158.7
1949	136.4	178.1	185.4	206.4	160.6	172.0	197.7	168.3
1950	136.2	181.1	215.3	219.0	137.2	171.5	226.6	192.7

Source: Economic Commission for Latin America.
Column (*A*) represents steel consumption.
Column (*B*) represents industrial production.

Table XIV

RELATION BETWEEN THE CONSUMPTION OF STEEL BARS AND SHAPES AND CEMENT CONSUMPTION
(1935–39 = 100)

	Argentina		*Brazil*		*Chile*		*Colombia*		*Cuba*		*Mexico*	
Years	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)
1925	80.5	43.0	43.5	54.1	67.0	43.6	37.8	—	444.1	254.1	46.5	45.1
1926	90.3	51.0	67.6	65.9	51.1	56.8	68.8	37.3	394.7	213.1	50.4	51.0
1927	105.5	58.2	74.9	80.1	78.0	68.7	35.7	—	384.9	254.1	38.6	54.2
1928	135.1	64.8	81.1	87.6	74.2	65.9	91.6	81.9	194.1	303.3	51.6	67.9
1929	135.8	76.2	99.3	101.6	151.1	123.2	105.6	92.4	227.0	341.5	65.6	76.2
1930	109.6	73.1	50.6	75.9	143.9	131.8	34.7	50.8	128.3	259.6	67.5	72.2
1931	60.0	162.1	21.6	45.3	63.3	42.3	16.6	38.2	52.6	54.6	44.0	49.7
1932	45.1	56.9	30.4	49.8	16.8	38.8	40.9	39.6	32.9	43.7	32.2	42.4
1933	53.4	51.3	48.7	54.8	22.1	43.6	38.8	44.7	26.3	35.5	40.3	53.3
1934	61.8	58.7	67.4	72.5	56.8	63.7	69.4	58.8	39.5	49.2	87.5	82.1
1935	91.1	72.8	84.0	77.3	103.3	95.3	65.7	61.9	78.9	68.3	97.4	77.8
1936	79.3	86.4	92.2	90.7	96.9	79.3	89.5	95.6	108.5	98.4	94.3	85.2
1937	142.5	107.4	115.9	104.7	112.7	99.9	123.7	98.0	125.0	112.0	152.2	103.7
1938	92.1	121.4	103.0	108.2	97.6	116.5	98.9	118.9	85.5	101.1	67.4	112.7
1939	95.0	112.0	104.9	119.1	89.5	109.0	122.2	125.6	102.0	120.2	88.7	120.6
1940	87.5	101.6	115.0	123.1	113.5	127.0	117.0	124.7	121.7	136.6	95.1	142.2
1941	48.7	109.2	106.4	126.6	90.2	124.5	122.2	132.0	98.7	139.3	96.5	157.7
1942	27.6	101.7	97.9	131.6	79.7	121.2	15.0	127.9	13.2	147.5	82.5	165.0
1943	25.5	92.9	101.4	122.4	77.7	122.4	63.1	155.4	32.9	158.5	72.7	186.2
1944	50.0	104.4	140.1	146.9	93.9	126.4	174.9	190.0	138.2	158.5	142.8	201.8
1945	50.2	105.0	129.4	165.7	115.7	146.1	188.4	206.2	121.7	221.3	184.4	267.1
1946	98.7	108.5	182.9	189.6	122.7	186.3	250.0	243.3	256.6	256.8	222.6	301.1
1947	122.9	143.4	201.4	203.1	125.1	191.2	297.1	283.9	273.0	306.0	239.6	311.8
1948	111.1	154.3	112.2	237.3	124.5	172.0	153.2	249.4	171.0	297.8	153.9	305.7
1949	133.1	148.9	174.9	279.5	170.3	157.9	163.6	309.6	210.5	344.3	184.3	352.0
1950	131.1	164.6 [a]	227.1	288.3	149.8	163.4	287.3	363.3	250.0	..	190.9	404.2
1951	127.0	184.0 [a]	..	..	186.2	176.8	..	..	..	..	270.5	..

Source: Economic Commission for Latin America.
[a] Estimated figures.
Column (*A*) represents consumption of bars and shapes.
Column (*B*) represents cement consumption.

Table XV

RELATION BETWEEN IRON AND STEEL IMPORTS AND THE CAPACITY TO IMPORT
(1935–39 = 100)

	Argentina		*Brazil*		*Chile*		*Colombia*		*Cuba*		*Mexico*	
Years	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)
1925	110.6	92.1	114.8	162.7	207.1	164.7	59.9	59.8	223.3	233.3	90.3	161.8
1926	109.6	92.4	118.5	140.5	108.2	166.7	78.2	78.1	187.0	177.8	89.8	178.0
1927	128.1	118.7	133.2	133.1	123.6	157.7	72.8	83.8	209.9	203.7	81.5	172.7
1928	164.3	147.6	142.9	149.4	167.3	176.4	105.8	104.3	158.4	157.4	79.4	162.0
1929	158.7	133.3	138.2	153.8	214.9	167.7	92.2	92.9	173.7	151.8	119.0	150.7
1930	129.2	85.0	74.7	105.0	235.2	116.0	54.1	92.4	103.0	94.4	68.3	95.2
1931	65.9	88.7	37.8	102.1	88.4	88.3	32.9	100.0	45.8	85.2	57.4	78.8
1932	48.5	81.1	37.8	84.3	26.4	34.6	35.6	77.2	34.4	64.8	38.5	50.0
1933	62.6	74.4	71.6	88.8	38.6	44.2	48.6	71.2	40.1	72.2	62.0	55.0
1934	78.4	78.6	89.0	105.0	59.2	73.6	63.6	104.7	57.2	81.5	99.0	88.4
1935	92.3	90.4	89.5	91.7	98.8	79.7	63.7	88.5	84.0	88.9	98.5	110.8
1936	91.2	104.5	97.9	102.1	97.8	87.8	89.5	98.4	105.0	105.6	113.2	102.7
1937	138.0	136.3	131.2	103.5	108.4	127.7	107.9	108.3	122.1	116.7	157.6	116.8
1938	87.6	82.2	82.2	97.6	98.7	105.1	117.2	96.8	85.9	90.7	57.3	82.0
1939	90.9	86.7	99.2	105.1	96.3	99.7	121.7	108.0	103.0	98.1	73.4	87.7
1940	83.3	60.8	87.7	81.4	119.6	101.8	95.6	93.9	95.4	79.6	79.4	81.0
1941	53.7	56.8	75.2	99.1	81.0	116.0	72.5	95.7	106.9	118.5	88.8	69.4
1942	24.7	57.6	36.0	97.6	54.2	126.8	14.2	84.2	45.8	81.5	63.4	71.4
1943	11.2	63.1	54.9	110.9	64.8	103.1	42.2	87.2	57.2	138.9	103.3	92.5
1944	10.5	62.7	98.2	131.6	82.3	110.7	93.6	77.2	108.8	159.2	200.8	87.1
1945	15.8	64.4	95.5	136.1	95.1	103.6	112.1	83.8	126.0	153.7	195.7	101.0
1946	65.8	101.5	130.0	173.1	97.3	103.6	142.8	137.3	154.6	150.0	233.6	107.4
1947	112.1	115.0	143.6	164.2	104.8	108.2	194.8	146.7	215.6	213.0	271.1	121.0
1948	121.0	106.8	71.2	162.7	100.9	123.2	117.0	160.7	179.4	192.6	150.0	136.4
1949	107.3	66.0	74.6	156.8	124.8	108.7	130.4	185.2	188.9	174.1	144.3	..
1950	101.0	99.5	75.9	227.8	106.7	114.5	180.8	233.7	202.3	..	195.8	..
1951	122.2	..	..	..	..	..	..	..	..	..	295.5	..

Source: Economic Commission for Latin America.
Column (*A*) represents iron and steel imports.
Column (*B*) represents the capacity to import.

Chapter II

Influence of locational factors on the iron and steel industry in Latin America

I. Foreword

1. Scope and purpose of this chapter

Although Latin America's iron ore reserves have not yet been fully prospected, it is known that the region is rich in high-grade ores. Reserves prospected so far represent approximately 20% of all known world reserves. But only a small proportion of the region's iron ore is at present mined and, in 1950, represented about 4% of world production.

The relatively slow devolpment of iron ore mining is mainly due to the low iron and steel consumption of the region. This, in turn, is related to the low national income prevailing in most Latin-American countries. Another factor which limits iron and steel production is an almost general scarcity of good coking coals. Most of the steel plants would be compelled to transport their coal for long distances and many of those in existence supplement domestic production by imports. Other possibilities which have been scarcely utilized to date are the use of substitutes for coal or of reduction methods other than the blast furnace.

An additional obstacle to the development of the industry in the region is the general shortage of capital, which is of considerable consequence since the steel industry requires high investments.

This chapter has two main objectives. The first is to determine the influence on the cost structure of the industry of factors which arise from the location of the plants, such as the quality of the raw materials, the distance of raw materials from the plants, wage rates, etc. The second aim is to point out the technical problems which the industry would have to solve both to make better use of available resources and to reduce costs.

Seven Latin-American countries have been selected for this comparative study. They are Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, where steel plants are already in existence, are being built, or where there appear to be resources and possibilities for the operation of a steel plant. In each of these countries, one location for a hypothetical steelworks was selected as an example. Pig iron, steel ingot and finished steel costs were then estimated for each of the hypothetical plants. The selection of the location was made for sites where either a steel industry exists or construction has been under consideration. The compilation of information regarding the factors which build up costs was thus facilitated. The inclusion of a certain site in this study does not imply that an opinion has been formed as to its comparative advantages in relation to other locations in the same country; nor does it imply that the selection of the raw materials cannot be improved by using different combinations.

Since pig-iron production by the classical process of the blast furnace is the most widely used and the method about which most information and cost figures have been published, the present analysis refers exclusively to this process. For each location at least two possibilities will be considered, namely, (*a*) where the industry mines all or part of its raw materials and (*b*) where the industry purchases its raw materials from other sources.[1]

Scale of operation has an important bearing on steel costs and, since it is determined by the size of the market, it also becomes a locational factor in Latin America. To simplify, this whole subject has been divided into two parts, the first of which, contained in the present chapter, analyses the influence of the locational factors except the size of the market and, secondly, Chapter III, which determines the influence of the scale of operation exclusively. The hypothetical plants in the various countries are all of equal size—250,000 tons of finished steel per year. The most favourable selection of raw materials for each location has been determined and, subsequently, production costs and the necessary investments have been estimated. Many prices and other cost factors of minor importance were not investigated in detail, but general assumptions were used. Many of these assumptions are based on conditions prevailing in the United States in 1948, and without too great a margin of error, they are still representative for broad estimates. Because of the necessity to determine the over-all results of these assumptions, and of the desire to obtain a basis for comparison with costs of steel produced in one of the exporting countries, an identical hypothetical plant was located on the Atlantic coast of the United States.

In regard to the second objective, that of finding through analysis the main technical and economic problems facing the steel industries in Latin America, the procedure consisted in investigating the different cost items which appeared abnormally high for each location. The prospects for future research into such cost raising factors were then analysed in the light of the documents presented at Bogotá. Comparisons were facilitated because the design of the imaginary plants is identical, except for differences which might arise due to variations in the composition of iron ore and fuel. Except for differences in raw materials costs, the main variations in costs are those caused by wage rates.

The usual procedure for cost analysis of a steel plant is to separate the different factors into two groups: (*a*) assembly costs, and (*b*) conversion costs. Assembly costs comprise the cost of mining and transporting the essential raw materials to the plant. Conversion costs are those which arise from the transformation of these raw materials into pig iron, steel ingot and steel products.

The principal variations in pig-iron costs produced in different plants are caused by differences in assembly costs. In the present case conversion costs should be

[1] Since the latter is the simpler case, the full set of calculations referring to it will be made first, and afterwards the necessary modifications for an integrated plant will be introduced.

relatively constant except for the prevailing wage rates, since the plants are similarly equipped.

Since wage rates are one of the factors influenced by location, determination of costs in this paper departs from the usual procedure, separating labour from the remaining conversion costs. In this way the study is more flexible, since the addition of the wages to other expenses yields the usual two groups of assembly costs and conversion costs.

2. Description of the hypothetical plants

To summarize, this study refers to steel plants using coke blast furnaces, having an annual capacity of 250,000 tons of finished steel, and purchasing their iron ore, coal and limestone.

In addition to a number of general services, the productive sections of an industry of this type consist of: the blast furnaces and auxiliary equipment (handling of raw materials), coke ovens, by-products plant, transport facilities for liquid pig iron, pig-casting machine, slag handling equipment, and mechanical facilities to treat, size and mix raw materials and fluxes.

The stelmaking shop consists of a mixer (a refractory-lined tank to store liquid pig iron), steel furnaces, ingot moulds (cast iron moulds to cast liquid steel into ingots), plus the necessary equipment to transport the raw materials and the hot metal in different stages, and to handle the scrap. Three types of steelmaking processes have been envisaged; their selection depends on analysis of the iron ore. They are the open-hearth process, a combination of acid converters and open hearth, and the combination of basic converters and an electric steel furnace. The plant must melt and mix with the fresh material, two types of scrap—the scrap produced by the rolling mill itself, which will henceforth be referred to as "circulating scrap", and whatever scrap can be purchased outside to lower steel costs, and which will be called "purchased scrap".

The rolling department consists of a blooming mill to roll the ingots pre-heated in pit furnaces into blooms, slabs or billets, according to size and shape of the final product, followed by the final rolling or finishing of the steel. Incidentally, the scale of operation has a greater bearing on this particular section, as it influences the degree of mechanization of the rolling mills.

Between the various blooming and rolling mills, there are re-heating furnaces to maintain the semi-finished steel at the necessary temperature, cranes and roller tables for its transportation, cold rolling, rectifiers, and shears for the finishing process, and finally, a special shop for the maintenance of the rollers.

The general services of the plant comprise administrative offices, transport within the plant, laboratories, warehouses, general repair shops, electric power facilities, lighting, steam, gas, sanitary services and so on.

3. Description of the industrial process

Iron ore, coke and fluxes, loaded into the upper part of the furnace, constitute the charge. The raw materials (mostly classified by size, within fairly narrow limits) are loaded into the furnace in strictly controlled doses, depending on their analysis. Hot air is injected at high pressure into the lower part of the furnace. It burns part of the coke, raising the temperature sufficiently for the excess of fuel to react with the oxygen content of the ore, reducing it to liquid metal that accumulates in the lower part of the furnace. The hot gases leave the upper part of the blast furnace and, in passing through the layers of iron ore and coke, lose most of their excess temperature, pre-heating the material as they go down. The ore impurities, the ash of the coke and the fluxes make up the slag, which also drops to the bottom and owing to its lower specific gravity floats on the top of the liquid iron. The slag plays an important part in the process, protecting the metal from re-oxidization. The gases when leaving the blast furnace retain a relatively small amount of heating value. Some of them are used to pre-heat the air used in the blast furnace and the remainder are generally mixed with the richer gas from the coke ovens to produce electric power, and for general heating purposes. Any excess of gas is sold. The liquid metal and the slag are extracted at regular intervals. The liquid pig iron is either carried directly to the converters, where these exist, to the mixer for storage, ore to the pig-casting machine. The slag is usually granulated with water and is often used as a raw material for cement manufacture.

The liquid pig iron contains many impurities: carbon, silicon, manganese, phosphorus and sulfur. The reduction of their contents to certain established limits, usually very low, is called steelmaking. The processes used for such refining are based on the fact that these impurities have a greater affinity for air than for iron.[2]

The oxidizing agents used for steelmaking are air, high grade iron ore, oxygen, and oxygen-enriched air. The liquid steel thus obtained has often to be re-carburized, or different alloys added, in the ladles coming from the steel furnaces. Once its chemical composition is satisfactory, it is poured into ingot moulds. Size and shape of the ingots vary in accordance with the products to be rolled and the size of the blooming mill. In order to reduce the section of the steel ingots or semi-manufactured products to final shape they are placed between two moving steel cylinders which are often grooved in order to give the products a definite shape. This process is repeated by using successively smaller sizes of final grooves, or by increasing the pressure between the rolls, until the final section is obtained.

II. Data on selected locations

1. Countries and locations selected as examples

One hypothetical plant is assumed to be located in each of the following countries: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, comprising about 80% of the population of the region and accounting for 90% of its steel consumption.[3]

(a) *Argentina*

The most recent Argentine steel plan envisages the construction of three main plants: (*a*) a large plant in San Nicolás on the Paraná river, using either imported or Sierra Grande ores, (*b*) a small plant based on charcoal blast furnaces in the north, near the Zapla deposits, (*c*) a medium-size plant in the south, using Sierra

[2] With the exception of sulfur which is usually eliminated, in combination with lime, as sulfide of lime.

[3] In this paper, steel consumption will include rolling mill products and also some easily manufactured steel products such as wire, nails, tubes, etc. It does not include steel contained in manufactured goods, such as durable consumer goods, machinery, equipment, etc.

Grande ores and possibly Río Turbio coals supplemented by a binder.

For the purpose of the comparisons in this document, San Nicolás will be the only site considered; it is located between Buenos Aires and Rosario, the two most important steel consuming centres in the country. Cost estimates have been prepared using three different sources of iron ore: (1) Zapla ore of 48% grade, transported by rail; (2) Sierra Grande ore of 57% grade, brought by sea and river; and (3) Brazilian Itabira ore, 65% grade, to be shipped from Victoria. In each of these cases, the coking coal is assumed to be imported.

A fourth possibility, which has not been considered, consists of using iron ore from the Urucúm deposits, near Corumbá in Brazil on the upper reaches of the Paraguay river, or alternatively from a Bolivian deposit on the opposite bank of the same river. Both these possible sources would require the dredging of the upper Paraguay, and possibly part of the Paraná river.

(b) *Brazil*

Among the many possibilities in this country, only the location at Volta Redonda is considered, using iron ore from Lafaieta (65% grade) and coke from a blend of 70% imported and 30% Brazilian coal.

(c) *Chile*

The site at the Bahía San Vicente, where the Huachipato plant is now located, was chosen as the example. Iron ore was assumed to be 60% grade from El Tofo in Chile and coke from a blend of 85% Chilean and 15% imported coal.

(d) *Colombia*

Calculations were made in accordance with the raw material supply and location of the Paz de Río project (Belencito). High phosphorus content ore of 47% grade and coke produced entirely from domestic coal are assumed to be used. The main departure from the existing project consists in the size of the plant and the assumption that flat products will also be produced.

(e) *Mexico*

Among the many existing possibilities, the location and sources of raw material of the Monclova plant were chosen. Iron ore of 60% grade from the Cerro de Mercado and coke produced entirely from Sabinas coal in the state of Coahuila were taken as the raw materials.

(f) *Peru*

The chosen plant was located at Chimbote. It was assumed to use 60% grade ore from Marcona, transported by sea to Chimbote. The fuel would consist of a variety of coke produced from 15% imported asphalt and 85% anthracites from the Santa Valle.

(g) *Venezuela*

Owing to the proximity of the Naricual coal deposits, the hypothetical plant was assumed to exist at the port of Barcelona, using El Pao ore (65% grade). Two fuel possibilities were considered: (*a*) the use of coke made from asphalt or petroleum residues, and (*b*) coke produced from imported coal which could advantageously be transported as a return freight on ships exporting iron ore.

(h) *United States*

An identical plant to those assumed in the Latin-American sites was located at Sparrows Point, Maryland, where the Bethlehem Steel Corporation at present owns a plant using Chilean and Venezuelan ores. The hypothetical plant would use 65% grade iron ore from El Pao in Venezuela and coke from West Virginia coals.

III. General bases for calculations

It has been assumed that at all the locations selected the plant would be able to purchase scrap amounting to between 9% and 11% of the requirements of the steelmaking shop, at a price equivalent to 90% of the pig-iron cost.

Since all the plants were assumed to have an annual capacity of 250,000 tons of finished steel, the optimum capacity for the blast furnace would be about 800 tons of pig iron daily. An additional reason for accepting this capacity is that it does not appear to make excessive demands upon the quality of the coke. Except in those cases where the composition of the iron ore has influenced the steelmaking process, the design and degree of mechanization of all the plants has been assumed to be identical and it has also been assumed that they are equipped with the latest technical improvements justifiable on economic grounds. These assumptions have permitted the use of identical figures for various consumptions expressed in physical units or of unit values.[4]

Thus, uniform costs or prices have been adopted for the items detailed in Table XVI of the statistical annex. Among these general assumptions, the following important items should be mentioned: mining cost of iron ore and limestone (open pit operations in all plants), cost of transporting and pumping cooling water, cost of imported coal f.o.b., prices of ferroalloys and other fluxes, cost of hydro-electric power, transport costs both for the raw materials and for the finished products, equal need and costs for repairs and replacements per unit of steel produced, and lastly, capital charges.

With a view to simplifying calculations and eliminating the need to collect a variety of detailed data on the spot, and at the same time to maintain comparability, different assumptions of a technical nature were also made. Some of these appear in the text, together with the pertinent analysis, others appear in the statistical annex, and thirdly, the simplest are outlined below:

(*a*) It was assumed that productivity of the workers in all these plants was the same as in the United States, although in countries where the steel industry would be new, efficiency could only be reached after several years' operation;

(*b*) The assortment of finished products greatly influences the cost of labour and its efficiency. It is assumed that all the plants would produce the same assortment and equal quantities of the different products;

(*c*) It was assumed that the daily output of the blast furnaces, identical in every case, is independent of the grade of ores considered in this study. This hypothesis is not actually true, but again the small margin of error to which it may give rise can be ignored.

[4] It is evident that this generalization does not take the difference of wage rates from one country to the other into account. However, as the proportion of labour in many raw materials is small, the simplification of the calculations obtained by this method justifies the small margin of error which might arise.

The only raw material which has not been included in the above generalization is the coal of domestic production. Geological conditions, the thickness of the veins and the scale of operation greatly influence its cost. On the other hand, since fuel influences the cost structure considerably, a wrong cost figure for it could greatly affect the results of this analysis. Hence fuel prices prevailing in 1948 were adopted for the existing deposits. In cases where the deposits must still be developed, as would apply for most of the integrated plants, an estimate was made based on expected productivity, taking into account geological conditions, size of the mine, prevailing wage rates and other data.

The basic assumption that most of the factors of secondary importance do not vary significantly from one plant to another, implies that differences in final cost will be due exclusively to a few important factors. They refer mainly to the quality and location of raw materials, wage rates, etc. Accordingly, it becomes important to know: (*a*) iron content of the ore and both carbon content and coking properties of the coal. With this information the quantity of raw materials required per ton of products can be determined; (*b*) quantity and composition of certain impurities contained in ore and coal, to ascertain the steelmaking process, the amount of fluxes and ferroalloys to be employed; (*c*) the distances and means of transport, in order to evaluate the cost of raw materials at plant; and (*d*) the wage rates prevailing in similar activities. Calculations in this paper have been organized as follows:

(*a*) Although costs in an integrated plant[5] will be analysed after completing the study of a plant purchasing its raw materials, an analysis will first be made of the probable cost of mining the various raw materials. Next, it is assumed that the plants will purchase raw materials from other enterprises, at prices estimated in view of the preceding analysis.

(*b*) The raw material costs thus obtained will be used to calculate probable pig-iron costs;[6]

(*c*) The resultant cost of pig iron will be used to estimate the cost of steel ingots;

(*d*) The price of steel ingots so obtained will be used to estimate the cost of finished steel;

(*e*) Combining the data thus obtained, the aggregate position of the conversion process will be analysed and certain conclusions concerning the cost structure of the industry determined;

(*f*) The cost of the raw materials used in the blast furnace will be substituted by the necessary mining and transport costs to present the case of an integrated industry. Finally, an analysis of the variations of cost, if steel consumption increases in Latin America, will be prepared, and a comparison made with costs of imported steel.

IV. Pig-iron costs

Pig-iron costs will first be determined by the assumption that the steel plants have to purchase their iron ore, coal and limestone from outside sources.

1. Assembly costs

Assembly costs have already been defined as the mining of the main raw materials and their transport costs to the blast furnace. Since the proportion of such raw materials required to produce one ton of pig iron is high, ranging from 3 to 5 tons, assembly costs have an important bearing on the final cost of pig iron. The situation concerning the most important raw materials is discussed below.

(a) *Iron ore*

The influence on the cost of iron ore supplies is analysed in Table XVIII. The iron content or grade of the ore, the amounts necessary per ton of pig iron, the distance and the means of transport are shown there. The data on which the estimates of Table XVIII are based, are the following: costs of iron ore and transport rates from Table XVI; total cost of iron ore in the plant from Table XVII. Regarding the amount of ferrous materials necessary for the production of one ton of pig iron, 1,000 kg. has been accepted. Thus, a small margin exists to cover unavoidable losses in the blast furnace.

Railway transport has been the basis for overland freight costs. In some instances, the distances are very short and cost could be reduced by the use of road vehicles, in which case the figures shown in Table XVIII may be exaggerated. Sea transport was estimated on the basis of normal prevailing rates, and it is thus excessive if the steel plant owns the ore ships. Consequently, the cost of ore per ton of pig iron, as shown in Table XVIII, represents the probable maximum.

Attention should be drawn to the very high ore cost at the Argentine blast furnace of San Nicolás if it uses Zapla ore. The high cost is due to the combination of relatively low-grade iron ore, with a long railway haulage. This is the most unfavourable condition which can arise in practice. Calculations are therefore also included based on Sierra Grande ore or imported iron ore from Itabira, Brazil.

(b) *Coal costs*

Table XIX shows the statistics for the coal supply. The origin of the respective fuels are indicated and the proportions for blending in cases where more than one type of coal has been employed. Prices prevailing at the port of origin and transport cost to the plant are also presented, to obtain the cost of fuel at plant. Table XX determines the cost of the blend at each coke plant, the amount of coal necessary, and the resulting costs per ton of pig iron. The high price of Santa Catarina coking coal in Brazil is particularly notable and is explained by difficulties in mining and washing. Through the latter process, two types of fuel are obtained: metallurgical coal for use in the coking plant and steam coal for which other applications must be found. Provision has been made to account for any increase in the price of coking coal, which might arise from losses in the sale of the other fraction.

The advantages for countries which mine their own coking coal become apparent from this table and results from the relatively low cost of coal compared with freight costs. The cheap price for imported coal in Venezuela, as compared with the high value in Argentina, Brazil and Chile, results from the fact that return freights could be utilized.

(c) *Limestone costs*

Table XXI presents the figures for limestone costs, which are based on data contained in Table XVI. Except in Argentina, should Zapla ore be used, and in Chile,

[5] See footnote [2] to Chapter I of Part One.

[6] All prices and values in this chapter, unless otherwise indicated, are at the 1948 value of the dollar.

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limestone is but a small item within total costs. The high figure for Argentina stems from the large tonnages required because of the low grade of the Zapla ore; in Chile the relatively high price is due to the long maritime transport involved. In Venezuela, if asphalt or petroleum residues are used, the amount of limestone would have to be increased to offset the high sulfur content of such fuels.

(d) *Total assembly costs of raw materials*

Table 18 shows the assembly costs per ton of pig iron and the respective percentages corresponding to iron ore, coal and limestone. It permits a comparison of the influence of the different raw materials within the assembly costs of the various plants. Assembly costs at Sparrows Point are high in relation to those prevailing in other steel producing centres of the United States. In addition, as will be seen later, the final costs of steel depend essentially upon the size of the plant, assembly costs and wage rates; a plant with low assembly costs has therefore one advantage in its favour.

Table 18

ASSEMBLY COSTS AND CONTRIBUTING RAW MATERIAL COSTS

Plant	Aggregate assembly costs[a] (dollars)	Raw materials: Iron ore (percentages)	Coal	Limestone
San Nicolás[b]	59.15	51.1	45.6	3.3
San Nicolás[c]	42.74	48.0	50.0	2.0
San Nicolás[d]	38.88	38.0	59.0	3.0
Volta Redonda	37.33	28.0	66.9	5.1
Huachipato	23.05	32.7	60.4	6.9
Belencito	17.62	44.0	49.6	6.4
Monclova	26.74	61.7	35.8	2.5
Chimbote	18.80	53.8	39.6	6.6
Barcelona[e]	21.68	50.5	41.2	8.3
Barcelona[f]	26.40	41.5	54.6	3.9
Sparrows Point	27.14	60.3	35.9	3.8

Source: Economic Commission for Latin America.
[a] Per ton of pig-iron.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt or petroleum residues.
[f] Coke from imported coals.

A glance at this table shows that assembly costs are very high at the San Nicolás plant in Argentina, especially if Zapla ores are used. Combinations of raw materials envisaged for San Nicolás, while still higher than most of the plants in the other countries, would be within reasonable range of the assembly costs at Volta Redonda.

The cost of coal is fairly high at San Nicolás, since only imported fuel has thus been considered here. Argentina has a substantial coal deposit at Río Turbio, which is high volatile C grade and therefore non-coking. Some of the documents presented to the Bogotá meeting described methods used in other countries which have resulted in the utilization for coke of up to 60% of such coals.

At Volta Redonda, the main problem is the cost of coal. Until a better solution is found for the washing problems of Barro Branco coal, relatively high prices of coke will prevail in Brazil. In the present cost estimates, an increase of the percentage of imported coal has been contemplated. Other possibilities for reducing costs, which are being undertaken in the actual plant, are the improvement of transport and handling facilities for imported coal.

An excessive expansion of the coal in the ovens during the coking process places Brazilian coal in a unique position in the region, since the type of high volatile coal which is most available in the region is precisely that required as imports. The replacement of United States' coal at present employed at Volta Redonda by high volatile Colombian coal is a possibility which might reduce costs, in view of the shorter distance involved. Another possible solution, suggested by documents presented at Bogotá might be the washing, through the new method called "phase separation", of the fraction which is at present excluded from metallurgical use. Brazilian coal problems are further complicated by the high sulfur content.

In the case of Chile, it is essential to reduce prices and increase domestic production of coal. The Huachipato plant has conducted considerable research in this direction. Document L.27 refers to economies in blast furnace operations through the elimination of some injurious petrographic compounds and of the coal fraction above 1.35 specific gravity.

In the case of Monclova in Mexico, the factor which principally raises assembly costs is the long haulage distance for iron ore. Prospecting has been conducted recently to locate more favourable ore deposits. This search has met with some success and at present several new deposits are being studied.

Assembly costs at Chimbote are quite satisfactory. It should be noted that the use of anthracite-asphalt coke has been envisaged, although this process is still being investigated. A group of Peruvian industrialists sponsored the research which is described in document L.14. A pilot coking plant is being installed so that the characteristics of the coke may be learnt before details of the full-scale blast furnace are outlined. In the present estimate, a larger percentage of imported asphalt as a binder than that appearing in document L.14 has been considered, thus giving a safety margin should the new process not entirely fulfil expectations.

Table 18 shows that the cost of coal is the principal economic problem related to assembly costs in the steel industry of Venezuela. Various solutions are being considered, of which the possibility of using gas reduction as an alternative to the blast furnace will not be dealt with here, since it falls outside the scope of this chapter. Among other possibilities the following may be mentioned: production of coke from natural asphalt or petroleum residues; improvement of non-coking coals through addition of asphalt or petroleum or, lastly, the use of coke from imported coal.

For a plant located at Barcelona the cost of iron ore would be relatively high. This is because the ore would have to travel along a complicated system of transport with several handlings. It might well be that Barcelona is not the location with the most favourable assembly costs; in this particular case it has tentatively been chosen on account of its proximity to the Naricual coal deposits.

Finally, the abnormally high cost of iron ore at Sparrows Point as shown in Table 18 is due to the great distance from Latin America. In the case of plants operating on the Atlantic seaboard of the United States, this handicap is finally offset, in relation to steel produced in the Pittsburgh area, by advantages in transporting the finished products to the coastal areas.

2. CONVERSION COSTS

Two main factors, influenced by location, have a bearing upon conversion costs of iron and steel. These are:

(*a*) wages, and (*b*) cost of the by-products of the coke plant, gas, etc.

(a) *Labour costs*

Table 19 shows the hourly rates of wages considered as an average of the wages which the respective industries would have paid in 1948. To obtain these data, actual averages of steel plants operating that year in several countries were used. Where no steel plant existed, the wage rates of a similar activity, preferably petroleum refineries, were used.

Table 19

LABOUR COSTS

(1948 dollars)

Plant	Hourly rates	Wages per ton of pig iron
San Nicolás	0.57	0.45
Volta Redonda	0.53	0.41
Huachipato	0.44	0.35
Belencito	0.60	0.47
Monclova	0.49	0.38
Chimbote	0.41	0.32
Barcelona	1.30	1.01
Sparrows Point	1.57	1.22

Source: Economic Commission for Latin America.

Efficiency of labour has been assumed throughout to be equal to that prevailing in 1948 in the United States. In the case of blast furnaces, the wage rates have been multiplied by 0.78, the number of man-hours required for the production of one ton of pig iron in an 800-ton daily blast furnace. Some additional labour is used for maintenance and repairs.

(b) *Costs and credit in the coke plant*

Excluding amortization and the interest on capital, operations in the coke plant involve certain costs and bring some returns from the sale of by-products. The balance of this position is shown in Table XXII. The differences shown in the coke yield for several plants arise from variations in the chemical composition of the coal, and it becomes necessary, therefore, to include them among locational factors. The basis which was used for these calculations is shown in Table XXIII.

It should be noted that at two plants (Chimbote and Barcelona), assumed to be using totally or partially asphalt or petroleum binders, no account has been taken of the value of by-products. In fact, the quality and value of the latter depends on the nature of the petroleum products used and their behaviour at high temperature. It might well be that their value corresponds exclusively to their residual heating power. However, it might also be that aromatic hydrocarbons, of higher value as chemical compounds, are formed due to cracking in the coke ovens under special conditions.

3. COSTS NOT RELATED TO THE LOCATION OF PLANT

In the general assumptions shown in Table XVI, the cost estimates for certain items assumed to be identical at all these plants were given. Among them are the following:

Item	Dollars per ton of pig iron
Cooling water	0.42
Repairs and maintenance	0.50
General and miscellaneous costs	2.65[a]
Returns from sale of blast furnace gas	1.90

[a] These have been slightly increased in the case of Colombia and Venezuela, in order to offset higher wage levels.

In 1948 a blast furnace with the proposed characteristics would have required an investment of $80 per ton of pig iron produced annually in the United States. This investment comprises coke oven, raw material stockyards and their equipment, pig-casting machine, cranes, etc.[7] It has been estimated that in the United States an 8% provision annually is sufficient to cover amortization of these investments and interest on loans.

In Latin America, because of the smaller availability of engineering resources and of the longer transport distances involved, in addition to the necessity for a larger assortment of spare parts, this investment and provision for its service appeared insufficient. The investment figure was increased by 20% to $96 per ton and the provision for their amortization and interest on loans was raised to 9% annually.

4. COST OF PIG IRON

With the data so far obtained, Table XXIV was prepared, comprising all the items which make up the cost of pig iron. To facilitate the analysis, these figures were re-grouped in Table 20 under various major accounting headings, which will be used throughout to analyse the cost structure in the various phases of the industry. These items differentiate between assembly costs, direct and indirect labour costs, and other conversion costs.

The same figures are shown in Table 21, where they are expressed as percentages of total cost.

[7] It does not include investments in mines and transport facilities.

Table 20

PIG-IRON PRODUCTION COSTS

(1948 dollars per ton)

Plant	Assembly costs [a]	Salaries and wages	Other conversion costs	Capital charges	Total
San Nicolás [b]	57.25	1.02	1.72	8.64	68.63
San Nicolás [c]	40.84	1.02	1.93	8.64	52.43
San Nicolás [d]	36.98	1.02	1.88	8.64	48.52
Volta Redonda	35.43	0.94	1.84	8.64	46.85
Huachipato	21.15	0.79	1.67	8.64	32.25
Belencito	15.72	1.07	2.53	8.64	27.96
Monclova	24.84	0.87	1.77	8.64	36.12
Chimbote	16.90	0.73	4.83	8.64	31.10
Barcelona [e]	19.78	2.32	5.97	8.64	36.71
Barcelona [f]	24.50	2.32	1.87	8.64	37.33
Sparrows Point	25.24	2.79	1.46	6.40	35.89

Source: Economic Commission for Latin America.
[a] After deducting blast furnace gas credit.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt or petroleum residues.
[f] Coke from imported coals.

Table 21

PERCENTAGE PIG-IRON PRODUCTION COSTS

Plant	Assembly costs [a]	Salaries and wages	Other conversion costs	Capital charges	Total (dollars)
	(Percentages)				
San Nicolás [b]	83.4	1.5	2.5	12.6	68.63
San Nicolás [c]	78.0	1.9	3.7	16.4	52.43
San Nicolás [d]	76.2	2.1	3.9	17.8	48.52
Volta Redonda	75.6	2.0	3.9	18.5	46.85
Huachipato	65.3	2.5	5.2	27.0	32.25
Belencito	56.3	3.8	9.0	30.9	27.96
Monclova	68.7	2.4	4.9	24.0	36.12
Chimbote	54.5	2.3	15.4	27.8	31.12
Barcelona [e]	53.9	6.3	16.3	23.5	36.71
Barcelona [f]	65.6	6.2	5.0	23.2	37.33
Sparrows Point	70.4	7.8	4.0	17.8	35.89

Source: Economic Commission for Latin America.
[a] After deducting blast furnace gas credit.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt or petroleum residues.
[f] Coke from imported coals.

In Table 21 some striking differences appear between the various plants, to some of which references have already been made. For instance, the high proportion of conversion costs in relation to the total cost of pig iron at the Chimbote plant are caused by the lack of any credit for the sale of by-products from the coke plant. Venezuela shows a high percentage for wages since, as shown in Table 19, the highest Latin-American wage rates exist there. This strongly underlines the advantages to be gained by a development similar to that of the United States industry—higher mechanization and capacity of the plants.

As regards the relationship between capital charges and labour costs, it will be found that the latter are considerably lower. The ratio between wages and capital charges varies between 1 : 6 and 1 :12. This emphasizes the importance of reaching full capacity, even if more manpower than necessary must be employed. The wage rates used in this analysis for the different countries have been made sufficiently high to provide for a margin as an incentive for workers to attain great proficiency. Until this is achieved a certain training period will be necessary.

Considering the problem from another angle, this relationship fully justified the policy adopted by some managements of the recently established Latin-American industries, which are as follows:

(1) All efforts are directed towards raising production to full capacity;

(2) Once that goal has been attained, to ensure that the standards of quality are obtained;

(3) Subsequently improve labour efficiency by encouraging good workers and dismissing the others, if excessive manpower had been initially necessary to accomplish the first condition.

But several Latin-American steel industries have been unable to maintain permanent production up to capacity, in spite of operating for some time. Shortages in transport, in adequate raw material supplies, in adjustment between capacity of the various sections of the plant and the market, or finally, in efficient management, all of them, if they prevent full capacity from being reached, cause a substantial increase in costs, especially in regard to capital charges per unit of production.

V. Steel ingot production costs

As briefly mentioned earlier, liquid pig iron tapped from the blast furnace contains various metalloids in solution: carbon, silicon, phosphorus and sulfur, etc. In the different types of steel, small quantities of these substances remain. The process of reducing the percentage of these substances to specification limits takes place in the steelmaking shop.

With the exception of sulfur, these impurities are extracted by taking advantage of their greater affinity for oxygen. The steelmaking processes may be divided into two principal types: (*a*) converters, in which oxidization of the impurities is effected by air injected through the liquid metal, and (*b*) furnaces, in which oxidization takes place, partly on the surface and partly by adding oxidizing agents, such as iron ore. The latter type of furnace can be heated by gas or petroleum (open hearth furnaces) or by electric current. The sulfur is usually extracted through its reaction to lime, by addition of limestone; the resulting sulfide of lime passes into the slag. The other impurities, once they are removed from the metal by oxidization, also increase the volume of slag. When controlling the progress of steelmaking for each load of metal, attention to the transformation which the slag is undergoing is therefore essential.

Both the impurities contained in the pig iron and the fluxes which have to be used for their elimination determine whether the reaction is acid or basic. According to this, the preferential extraction of one or the other of the metalloids is encouraged.

In addition to the quality of the available ores, which determines the amount and type of the impurities, the requirements of the market are also influential in the steelmaking process and reaction. This is because steel produced by different processes may have limited ranges of application. Lastly, the necessity of re-using the scrap produced in the rolling mills, plus scrap which can be purchased, also influences the type of process.

The abundance of scrap on the market is one of the advantages highly industrialized countries have for producing cheaper steel than in Latin America where scrap is usually scarce. Incidentally, it has been assumed that all the plants would be able to buy enough scrap to cover 10% of their steel ingot production.

On account of its flexibility for the fulfilment of most of the necessary conditions, it was assumed that the process used in the steelmaking departments of these plants would principally be the basic open hearth. In the countries where there is an adequate supply of iron ore, it has also been considered that 20% of the liquid pig iron would be refined by the acid converter (Bessemer) process. The nature of its ore, which makes the use of the basic converter (Thomas) indispensable, causes Colombia to be an exception. Here the scrap from the rolling mill plus the purchased scrap would be smelted and refined in a basic electric furnace.

In short, it has been assumed that basic open hearth furnaces would be installed for refining the total output at San Nicolás and Monclova. A combination of 80% basic open hearth steel and 20% Bessemer is assumed at Volta Redonda, Huachipato, Chimbote, Barcelona and Sparrows Point. Lastly, Belencito is based on a Thomas installation, supplemented by an electric furnace for resmelting the scrap.

1. Pig iron used in the steelmaking departments

Table 22 shows the amount of pig iron which would be required by these three combinations, respectively, in order to produce one ton of steel ingot. It may be observed that the basic open hearth furnace would require 759 kg., the combination of Bessemer and basic open hearth 768 kg., and finally, the Thomas converter 857 kg. of pig iron per ton of ingot.

2. Steelmaking costs

Again a series of general assumptions have been made in order to facilitate the calculation of steelmaking costs and to increase comparability. Some of these assumptions correspond to physical units, while other constitute the aggregate of the values of certain items of a heterogeneous nature. The former are shown in Table XXVI of the statistical appendix, while the latter are expressed in dollars per ton in Table XXV.

Among the more important assumptions, attention should be focused on the following: a unit value of 90% of the cost of pig iron has been assigned to all scrap whether purchased or circulating. Capital charges follow the same criteria in the case of the blast furnaces.

In the open hearth, Bessemer and Thomas processes, which use a minimum of electric power, it has been assumed that power was supplied by the general power plant of the mill and its costs were included under the heading "General and miscellaneous costs". At Belencito, the additional power required for the electric resmelting furnace has been included as a separate item, its costs being approximately equivalent to the rates prevailing in the United States.

Table 23 has been prepared with data taken from Tables XXV and XXVI and shows costs of steel ingot in the various plants. In Table 24 they are shown as percentages of total costs; the structure of these tables follows the same lines adopted for pig iron. The items thus listed are: (*a*) raw materials; (*b*) salaries and wages; (*c*) other conversion costs, and (*d*) capital charges.

Since a fundamental assumption was that all these plants were built along similar lines, the differences shown in Table 23 are mainly determined by: (*a*) fluctuations in costs of raw materials; and (*b*) fluctuations in wages. The influence of the latter is greater than in the case of pig iron, since more labour per ton is used in this department than in the blast furnace.

Variations in other conversion costs and in capital charges are very small and stem from differences in the processes imposed by the composition of the iron ore. In this connexion, at Belencito where costs are slightly higher for these two items, the column "raw materials" was credited with $6.50 per ton obtained from the sale of phosphate slag. Document L.54 refers to the possibility of adding phosphate rock to the blast furnace charge in order to obtain basic converter pig iron. Such a procedure could probably be advantageously used in Argentina, Brazil, Chile and Mexico, in which case a credit for phosphate slag would also appear in the corresponding estimate. Incidentally, some of these countries require phosphorus fertilizers urgently. The fact that there is hardly any trade in steel ingot makes any further analysis of these costs unnecessary.

Table 22

Pig iron required to produce one ton of steel ingot
(kilogrammes)

	100% open hearth	*20% Bessemer, 80% open hearth*		*100% of pig in Thomas converter; scrap in electric furnaces*	
	Open hearth	*Open hearth*	*Bessemer*	*Thomas*	*Electric furnace*
Liquid pig iron	759	615	153	857	—
Circulating scrap	203	171	—	51	153
Purchased scrap	101	102	—	—	101
Bessemer scrap	—	28	—	—	—
Total liquid metal	1,063	915	153	908	254
Minus losses in furnaces	63	55	13	148	14
Total steel ingots	1,000	860	140	760	240
Minus losses in furnaces	48	43	7	38	12
Minus circulating scrap	203	171	28	151	49
Rolled steel products	749	646	105	571	179
Pig iron per ton of finished steel	1,013.4	1,023.6		1,143.7	

Source: Economic Commission for Latin America.

Table 23

STEEL INGOT PRODUCTION COSTS
(1948 dollars per ton)

Plant	Raw materials	Salaries and wages	Miscellaneous conversion costs	Capital charges	Total costs
San Nicolás [a, b]	73.05	2.35	3.37	6.40	85.17
San Nicolás [a, c]	56.32	2.35	3.37	6.40	68.44
San Nicolás [a, d]	52.28	2.35	3.37	6.40	64.40
Volta Redonda [e]	50.97	1.95	3.23	5.94	62.09
Huachipato [e]	35.42	1.62	3.23	5.94	46.21
Belencito [f, g]	26.53	1.50	4.22	6.22	38.47
Monclova [a]	39.50	2.02	3.37	6.40	51.29
Chimbote [e]	34.23	1.51	3.23	5.94	44.91
Barcelona [e, h]	40.05	4.79	2.94	5.94	53.72
Barcelona [e, i]	40.71	4.79	2.94	5.94	54.38
Sparrows Point [e]	39.21	5.79	3.23	4.40	52.63

Source: Economic Commission for Latin America.
[a] 100 per cent open hearth.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] 80% open hearth, 20% Bessemer.
[f] 100% Thomas, electric re-smelting of scrap.
[g] Discounting product of slag sales.
[h] Coke from asphalt or petroleum residues.
[i] Coke from imported coal.

Table 24

PERCENTAGE OF STEEL INGOT PRODUCTION COSTS

Plant	Raw materials	Salaries and wages	Miscellaneous conversion costs	Capital charges	Total costs (dollars)
	(percentages)				
San Nicolás [a, b]	85.7	2.8	4.0	7.5	85.17
San Nicolás [a, c]	82.3	3.4	4.7	9.4	68.44
San Nicolás [a, d]	81.2	3.6	5.3	9.9	64.40
Volta Redonda [e]	82.0	3.2	5.2	9.6	62.99
Huachipato [e]	76.7	3.5	7.0	12.8	46.21
Belencito [f, g]	69.0	3.9	11.0	16.1	38.47
Monclova [a]	76.9	3.9	6.7	12.5	51.29
Chimbote [e]	76.2	3.4	7.2	13.2	44.91
Barcelona [e, h]	74.6	8.9	5.5	11.0	53.72
Barcelona [e, i]	74.9	8.8	5.4	10.9	54.38
Sparrows Point [e]	74.5	11.0	6.1	8.4	52.63

Source: Economic Commission for Latin America.
[a] 100 per cent open hearth.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] 80% open hearth, 20% Bessemer.
[f] 100% Thomas, electric re-smelting of scrap.
[g] Discounting product of slag sales.
[h] Coke from asphalt or petroleum residues.
[i] Coke from imported coal.

VI. Rolling mill costs

1. TYPES OF FINISHED PRODUCTS

In a country where there is only one iron and steel industry, the plant usually has to supply the pig-iron requirements for foundries, cast iron pipe and tube manufacture and often those of liquid steel for steel castings. These three outlets for the industry's products represent only a small proportion of the market. Most of the pig iron together with the scrap are transferred into steel ingots which in turn are rolled into finished steel. Usually the rolling department consists of a blooming mill which transforms the ingots into blooms, slabs or billets followed by various finishing mills, where, in the course of the immediate or subsequent process, the semi-finished material is rolled into finished steel.

The design and output of the rolling department depend fundamentally on the types and quantities of products to be produced. In this chapter, it has been assumed that all the plants will produce an equal assortment of products, selected in such a way as to correspond to the situation which often arises if the plant is the only source of domestic steel in a small market. The limitations on the assortment are imposed by the basic assumption that each section of the plant should have a relatively high utilization factor. Under these circumstances special products for which there is only a limited demand, would continue to be imported.

Table 25

BREAKDOWN OF THE ROLLING MILL PROGRAMME

Product	Percentage of total	Tons per year
Bars and rails		
Heavy rails and shapes	6.5	16,250
Light bars of less than 38 mm. square, with an average weight equivalent to 16 mm. diameter (5/8 in.)	42.5	106,250
Wire bars and heavy wire	17.0	42,500
Bars and rails	66.0	165,000
Flat products		
Plate over 12.7 mm. thickness (1/2 in.)	1.00	2,500
Plate and sheet, and strip for welded tubes up to 100 mm.	18.0	45,000
Sheet for tinplate and galvanization[a]	15.0	37,500
TOTAL	100.0	250,000

Source: Economic Commission for Latin America.
[a] Despite the inclusion of sheet in the programme, and contrary to usual practice in Latin America, investments and costs for tinning and galvanization have not been considered in these papers.

As noted earlier, the tonnages indicated in Table 25 correspond approximately to consumption in a small market, but, in addition to the size limitation, no highly developed steel transforming industry should exist there. It was further assumed that the manufacturing orders for merchant bars would average 200 tons per order, and that the operating factor is about 70%.

2. Rolling costs

As for efficiency, wages, capital charges, raw materials and miscellaneous costs, general assumptions were made which can be met in a new plant after a reasonable period of experience. With these data and based on steel ingot costs as obtained in the preceding section, Table XXVII was prepared.

The resulting figures have, in turn, been grouped together in Tables 26 and 27 along the same lines used in the preceding sections. Table 26 shows the figures as 1948 dollars per ton and Table 27 as a percentage of total cost.

VII. Analysis of combined costs of blast furnace, steelmaking shop and rolling mills

By suitable computation of the data in Table 22, it can be found that, in addition to circulating scrap and purchased scrap, it would be necessary to use the following amounts of pig iron per ton of finished steel for the various steelmaking processes: (*a*) 1,013 kg. for the basic open hearth; (*b*) 1,023 kg. for the combination of 80% basic open hearth and 20% Bessemer, and (*c*) 1,143 kg. for the combination of basic converter and electric re-smelting furnace.

In order to obtain an over-all picture of the cost structure of the steel industry, the classified cost data obtained in the previous section for pig iron, steel ingot and rolled products have been combined and they have been weighted according to their consumption of raw materials; Table 28 shows the results of this calculation. Based on final costs, three groups can be separated; first, Belencito, Chimbote, Huachipato and Monclova, for which costs are lower than at Sparrows Point; secondly, Volta Redenda and Barcelona with figures approximately equivalent to those of Sparrows Point; and finally, San Nicolás, where costs are above those of Sparrows Point. The reason in the case of San Nicolás is the higher raw material costs even under the most favourable possible conditions, that is, using Sierra Grande ore.

Table 26

Finished steel production costs
(1948 dollars per ton)

Plants	*Raw materials*	*Salaries and wages*	*Miscellaneous conversion costs*	*Capital charges*	*Total costs*
San Nicolás [a]	97.72	6.96	4.65	18.81	128.14
San Nicolás [b]	79.36	6.96	4.65	18.81	109.78
San Nicolás [c]	74.92	6.96	4.65	18.81	105.34
Volta Redonda	72.14	6.48	4.65	18.81	102.08
Huachipato	54.78	5.38	4.65	18.81	83.62
Belencito	45.33	7.33	4.65	18.81	76.12
Monclova	60.45	6.00	4.65	18.81	89.91
Chimbote	53.33	5.00	4.65	18.81	81.79
Barcelona [d]	63.75	15.88	4.65	18.81	103.09
Barcelona [e]	64.47	15.88	4.65	18.81	103.81
Sparrows Point	62.48	19.18	4.65	13.94	100.25

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.

Table 27

Percentage of finished steel production costs

Plants	*Raw materials* (percentages)	*Salaries and wages* (percentages)	*Miscellaneous conversion costs* (percentages)	*Capital charges* (percentages)	*Total costs (dollars)*
San Nicolás [a]	76.3	5.4	3.6	14.7	128.14
San Nicolás [b]	72.3	6.3	4.2	17.2	109.78
San Nicolás [c]	71.1	6.6	4.4	17.9	105.34
Volta Redonda	70.6	6.4	4.6	18.4	102.08
Huachipato	65.5	6.5	5.5	22.5	83.62
Belencito	59.6	9.6	6.1	24.7	76.12
Monclova	67.1	6.7	5.2	21.0	89.91
Chimbote	65.2	6.1	5.7	23.0	81.79
Barcelona [d]	61.8	15.4	4.5	18.3	103.09
Barcelona [e]	62.1	15.3	4.5	18.1	103.81
Sparrows Point	62.3	19.2	4.6	13.9	100.25

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.

Table 28

COST STRUCTURE OF IRON AND STEEL PRODUCTION
(pig iron, steel ingot, finished steel)
(1948 dollars per ton of finished steel)

Plant	Raw materials	Wages and salaries	Other costs	Capital charges	Total
San Nicolás[a]	70.04	11.12	10.89	36.09	128.14
San Nicolás[b]	51.48	11.12	11.09	36.09	109.78
San Nicolás[c]	47.08	11.12	11.05	36.09	105.34
Volta Redonda	45.62	10.04	10.84	35.58	102.08
Huachipato	29.03	8.35	10.66	35.58	83.62
Belencito	15.41	10.77	13.12	36.82	76.12
Monclova	33.31	9.57	10.93	36.10	89.91
Chimbote	24.55	7.76	13.90	35.58	81.79
Barcelona[d]	28.31	24.47	14.68	35.58	103.09
Barcelona[e]	33.23	24.51	10.49	35.58	103.81
Sparrows Point	33.68	29.75	10.45	26.37	100.25

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.

Table 29

PERCENTAGE COST STRUCTURE OF IRON AND STEEL PRODUCTION
(pig iron, steel ingot, finished steel)

Plant	Raw materials	Wages and salaries	Other costs	Capital charges	Total
	(percentages)				(dollars)
San Nicolás[a]	54.6	8.7	8.5	28.2	128.14
San Nicolás[b]	46.9	10.1	10.1	32.9	109.78
San Nicolás[c]	44.7	10.6	10.5	34.2	105.34
Volta Redonda	44.7	9.8	10.6	34.9	102.08
Huachipato	34.7	10.0	12.7	42.6	83.62
Belencito	20.2	14.1	17.2	48.5	76.12
Monclova	37.0	10.6	12.2	40.2	89.91
Chimbote	30.0	9.5	17.0	43.5	81.79
Barcelona[d]	27.5	23.7	14.2	34.6	103.09
Barcelona[e]	32.0	23.6	10.1	34.3	103.81
Sparrows Point	33.6	29.7	10.4	26.3	100.25

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.

VIII. Cost of finished steel in integrated plants

1. General considerations

In this section it is assumed that the seven plants are integrated and individually mine all the iron ore, coal and limestone they require. This does not always correspond to reality in the region, since some plants, such as Huachipato, are buying iron ore and coal from undertakings which already produced such materials before they were established.

Raw materials that remain to be purchased, such as imported coal, are accounted for separately. Similarly an account is open for materials such as purchased scrap, since use of the latter cannot be omitted from the manufacturing programme. Investments necessary for initial mining operations increase the capital charges correspondingly, and wages and other expenses must be added to the respective items. Summarizing, the analysis begins by breaking down the over-all pig-iron assembly costs into the main primary factors and distributing them within the corresponding accounts. For this analysis, it is necessary to formulate several additional general assumptions, which are included in Tables XXVIII and XXIX. It also becomes essential to isolate some expenses such as transport costs, purchased scrap, imported fuel or ore, etc.

In Table 30 this breakdown of raw material costs has been made. The outstanding point is the importance of transport costs in some of the examples. For instance, in Argentina, when Zapla ore is used, it is almost $27 per ton of finished steel, as compared with about $14 at Monclova and $11 at Volta Redonda. Since transport costs have been estimated at $17 per ton at Sparrows Point, San Nicolás is the only plant which appears to be in a really unfavourable position as regards assembly costs.

2. Distribution of finished steel costs at an integrated plant

Dollar values for the different types of expenses are shown in Table 31, while in Table 32 they appear as percentages of total costs. It may be noted that wages, miscellaneous costs and capital charges have increased slightly as compared with the figures in the preceding section, due to the addition of some amounts previously included under assembly, or raw material, costs. The new items, such as cost of transport and imported fuel or ore, are particularly heavy at San Nicolás, Volta Redonda and Barcelona (in the latter case, if imported blast furnace coke is used).

Table 30

DISTRIBUTION OF RAW MATERIAL COSTS BY ITEMS

(1948 dollars per ton of finished steel)

Plant	*Wages and salaries*	*Miscellaneous costs*	*Capital charges*	*Transport*	*Imported fuel and ore*	*Purchased scrap and ferroalloys*	*Total raw material*
San Nicolás[a]	2.36	2.15	1.42	26.65	27.36	10.10	70.04
San Nicolás[b]	1.58	1.44	0.95	17.63	21.65	8.23	51.48
San Nicolás[c]	1.85	1.69	1.11	11.42	23.28	7.73	47.08
Volta Redonda	3.87	3.22	2.52	10.62	18.00	7.39	45.62
Huachipato	5.57	4.17	4.18	5.25	4.38	5.48	29.03
Belencito	7.12	5.33	4.14	3.53	—	4.02	15.47[d]
Monclova	5.23	3.94	3.92	13.97	—	6.25	33.31
Chimbote	3.16	2.55	2.60	7.84	3.09	5.31	24.55
Barcelona[e]	3.48	2.21	2.39	14.12	—	6.11	28.31
Barcelona[f]	1.90	1.16	0.96	8.24	14.77	6.20	33.23
Sparrows Point	4.21	2.69	3.59	17.30	—	5.89	33.68

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Credit of $8.67 being the value of Thomas slag per ton of finished steel. ($6.50 ingot steel.)
[e] Blast furnaces using coke made from asphalt or petroleum residues.
[f] Blast furnaces using coke from imported coal.

Table 31

DISTRIBUTION OF FINISHED STEEL COSTS AT INTEGRATED PLANTS

(1948 dollars per ton)

Plant	*Imported fuel and ore*	*Purchased scrap*[a]	*Transport*	*Wages and salaries*	*Miscellaneous costs*	*Capital charges*	*Credits*	*Total costs*
San Nicolás[b]	27.34	11.21	26.61	13.48	13.90	37.52	−1.92	128.14
San Nicolás[c]	25.17	9.25	17.63	11.31	12.14	36.20	−1.92	109.78
San Nicolás[d]	23.00	8.20	11.28	12.97	14.57	37.22	−1.92	105.34
Volta Redonda	17.58	8.29	10.37	13.91	15.78	38.10	−1.95	102.08
Huachipato	4.28	6.03	5.13	13.91	16.46	39.76	−1.95	83.62
Belencito	—	5.26	3.07	17.87	19.78	40.98	−10.84	76.12
Monclova	—	6.57	13.81	14.80	16.64	40.01	−1.92	89.91
Chimbote	3.02	5.76	7.65	10.92	18.21	38.18	−1.95	81.79
Barcelona[e]	—	6.63	13.79	27.99	18.66	37.97	−1.95	103.09
Barcelona[f]	14.42	6.83	8.05	26.41	13.51	36.54	−1.95	103.81
Sparrows Point	—	6.54	16.89	33.97	14.84	29.96	−1.95	100.25

Source: Economic Commission for Latin America.
[a] Plus ferroalloys.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt and petroleum residues.
[f] Coke from imported coal.

Table 32

PERCENTAGE DISTRIBUTION OF FINISHED STEEL COSTS AT INTEGRATED PLANTS

Plant	*Imported fuel and ore*	*Purchased scrap*[a]	*Transport*	*Wages and salaries*	*Miscellaneous costs*	*Capital charges*	*Credits*	*Total costs (Dollars)*
San Nicolás[b]	21.3	8.7	20.8	10.5	10.9	29.4	−1.5	128.14
San Nicolás[c]	22.9	8.4	16.1	10.3	11.1	33.0	−1.8	109.78
San Nicolás[d]	21.8	7.8	10.7	12.3	13.8	35.4	−1.8	105.34
Volta Redonda	17.2	8.1	10.2	13.6	15.5	37.3	−1.9	102.08
Huachipato	5.1	7.2	6.1	16.6	19.7	47.6	−2.3	83.62
Belencito	—	6.9	4.0	23.5	26.0	53.8	−14.2	76.12
Monclova	—	7.3	15.4	16.5	18.5	44.4	−2.1	89.91
Chimbote	3.7	7.0	9.3	13.4	22.3	46.7	−2.4	81.79
Barcelona[e]	—	6.4	13.4	27.2	18.1	36.8	−1.9	103.09
Barcelona[f]	13.9	6.6	7.8	25.4	13.0	35.2	−1.9	103.81
Sparrows Point	—	6.5	16.8	33.9	14.8	29.9	−1.9	100.25

Source: Economic Commission for Latin America.
[a] Plus ferroalloys.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt and petroleum residues.
[f] Coke from imported coal.

3. Influence of wage rates and capital charges

An analysis of the data of Table 31 demonstrates that several plants show higher estimated costs than Sparrows Point. The breakdown of the assembly costs permits a more precise analysis of the causes of these abnormalities; in the case of Argentina, Brazil and Venezuela it is the high cost of raw materials and transport.

Consideration of labour costs will show that almost all Latin-American plants are favoured by low wage rates. The extreme case is that of Peru, where the difference between these rates and those of the United States is as much as $23, or 27% of the estimated cost of Peruvian finished steel. The wage rates considered, as repeatedly underlined, are somewhat high, and have thus been chosen to constitute in themselves an incentive for a proper selection of the labour force.

It is logical to assume that, as economic development of these countries progresses, wage rates will have to be increased. Such an evolution would reduce the present advantage for the plants in the region. But it may be assumed that a limit for such wage rate increases might be reached when they obtain the same values as those prevailing in the United States.

Table 33 shows the Latin-American steel costs in the selected plants if wages were equal to those of the United States. Excluding Venezuela, the increases vary from 20% in Argentina to 28% in Peru. Venezuela, because of higher wages, shows a slight increase between 6% and 7%.

On the other hand, it may also be assumed that when economic development in Latin America reaches a stage where wage rates are equal to those of the United States, such evolution would be accompanied by technological progress, more advanced mechanical industries and a higher rate of capital formation. Thus capital charges equal to those prevailing in the United States could also reasonably be anticipated. This possibility has been taken into account in column C of Table 33, which shows the percentage by which the estimated total cost would decline as a result of such an improvement in Latin-American economic conditions.

Table 33

Estimated finished steel costs assuming charges similar to the United States

Plant	Total estimated cost (dollars)	Increases in costs to equal United States' wages (percentages)	Reduction in costs brought about by equivalent capital charges[a] (percentages)	Results (dollars)
	(A)	(B)	(C)	(D)
San Nicolás[b]	128.14	18.5	− 5.8	144.34
San Nicolás[c]	109.78	19.3	− 6.5	123.83
San Nicolás[d]	105.34	20.0	− 7.0	119.03
Volta Redonda	102.08	19.7	− 8.0	114.02
Huachipato	83.62	23.9	−11.8	93.73
Belencito	76.12	21.0	−14.6	81.30
Monclova	89.91	21.3	−11.3	98.90
Chimbote	81.79	28.1	−10.0	93.32
Barcelona[e]	103.09	5.8	− 7.8	101.06
Barcelona[f]	103.81	7.3	− 6.3	104.79
Sparrows Point	100.25	—	—	100.25

Source: Economic Commission for Latin America.
[a] Equal engineering costs and rates of interest.
[b] Zapla ore.
[c] Itabira ore.
[d] Sierra Grande ore.
[e] Coke from asphalt and petroleum residues.
[f] Coke from imported coal.

Table 33 also shows the result of the combined action of these two factors—increase in wage rates and decrease in capital charges—to equal in every case conditions prevailing in the United States. In such examples, which might be considered as the extremes, the cost figures move into close proximity to Sparrows Point data. In the best cases Brazil would still be 14% and Argentina 20% above Sparrows Point costs. On the other hand, costs at Belencito would be 20% lower as a result of the extremely favourable assembly costs. The high costs in Brazil are entirely due to the high price of its coal. (See document L.2.)

In order to facilitate final comparisons and conclusions, Table 34 has been prepared. Three sets of figures containing the main conclusions reached in this paper are presented as indices, the base being Sparrows Point.

Table 34

Comparative costs at selected plants
(Sparrows Point = 100)

Plant	Assembly costs per tons of pig iron	Cost of finished steel under conditions assumed for Latin America	Cost of finished steel with wages and capital charges equal to those in the United States
	(A)	(B)	(C)
San Nicolás[a]	218	128	144
San Nicolás[b]	158	110	123
San Nicolás[c]	143	105	119
Volta Redonda	138	102	114
Huachipato	85	84	94
Belencito	65	76	82
Monclova	99	90	100
Chimbote	69	82	93
Barcelona[d]	80	103	101
Barcelona[e]	97	104	105
Sparrows Point (dollars)	27.14	100.25	100.25

Source: Economic Commission for Latin America.
[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.

Since the hypothetical plant located at Sparrows Point[8] and producing 250,000 tons of a wide assortment of small tonnages of different steels cannot be taken as representative either of costs or of conditions prevailing in the United States, the figures shown in Table 34 have only limited validity and merely show the respective locational advantages.

A study of column A of Table 34 shows that, except in Brazil and Argentina, the sites selected in Latin America have lower assembly costs than those of Sparrows Point in the United States.[9] The high figures for Argentina would probably be reduced by using a substantial percentage of Río Turbio coal; those for Brazil by a greater recovery of metallurgical coal from the Barro Branco run-of-mine fuel. Lower figures would perhaps appear in both countries, if all, or a substantial part, of their imported coal is purchased in Colombia, instead of in the United States.

[8] Sparrows Point has higher assembly costs than the plants in the main steel-producing centres of the United States. But as the steel used on the coast or for export would have to carry still higher transport costs within the United States than the difference in assembly costs, the Sparrows Point plant appears more favourably located for serving export markets.

[9] Assuming that Sparrows Point uses 100% ore from El Pao, Venezuela.

The study of the indices given in column B shows that the influence of conversion costs tends to modify the relative differences arising in assembly costs. (See Table 34.) Costs at Huachipato, Belencito, Monclova and Chimbote are below those of Sparrows Point, while Barcelona, Volta Redonda and San Nicolás are only slightly higher. This result is due to the fact that all the plants show low wage rates.

Column C of Table 34 shows that if, instead of comparing the influence of actual factors, it is assumed that wages and capital charges are equal to those of the United States, then only the plants at Volta Redonda and San Nicolás show an adverse result. Again this difference would be smaller than the Sparrows Point costs, increased by transport expenses for finished steel. Those Latin-American plants, such as Volta Redonda and San Nicolás, where assembly costs are even above the already high figures for Sparrows Point, would still be in a position to compete for their domestic markets. High-grade ore, in most cases with sufficient reserves for several centuries, and lower wage rates offset some of the difficulties which arise from the lack of knowledge of coking coal reserves and of methods for coking the high volatile fuels which are abundant in the region.

This does not justify a general endorsement of establishing an industry in cases where rich ores are available and the plant could be located close to regional markets. The volume of annual production, or the size of plant, influences production costs very considerably. Large-scale operations become even more advantageous because an industry producing for a broad market may further reduce costs through specialization. This is so in the United States, but in Latin America markets are small and spread over vast areas. The following chapter deals with this aspect of the problem, analysing the influence of the size of operation on costs and investment for steelworks assumed to be in the same locations as those studied in this chapter.

IX. Statistical annex

Table XVI

GENERAL BASES FOR THE CALCULATIONS
(values in 1948 dollars per ton)

1.	Cost of open pit mining of iron ore, per metric ton, at loading station of mine	2.26
2.	Cost of open pit mining of limestone, per metric ton, at loading station of mine	2.26
3.	Cost of cooling water	0.42 [a]
4.	Cost of coking coal. Pocahontas. c.i.f. Norfolk, Virginia	8.94
5.	Cost of ferroalloys for 100% open hearth production	2.17 [b]
	Cost of ferroalloys for 80% open hearth and 20% acid Bessemer	1.92 [b]
	Cost of ferroalloys for 100% basic Bessemer (Thomas)	1.40 [b]
6.	Lime and refractories (ingot steel)	1.10 [b]
	Lime and refractories, Belencito (Thomas ingot steel)	1.60 [b]
7.	Refractories and spare parts (finished steel)	2.00 [c]
8.	kWh (hydro-electric power)	1.20 [c]
9.	*Unit cost of transport for raw materials in bulk*	
	Railway transport	0.00848 dollars/ton. kilometre
	Inland waterway transport	0.00399 dollars/ton mile
	Maritime transport [d] (normal rate)	0.002341 dollars/ton. nautical mile
	Maritime transport [e] (low rate)	0.000944 dollars/ton. nautical mile
	Trans-shipment [f]	1.20 dollars/ton
	Panama Canal charges	1.25 dollars/ton
10.	Maintenance materials (ingot steel)	0.50 [b]
	Maintenance materials Belencito (Thomas ingot steel)	0.85 [b]
11.	Services and overhead (ingot steel) 100% open hearth	0.45 [b]
	80% open hearth and 20% Bessemer	0.57 [b]
	100% basic Bessemer (Thomas)	1.05 [b]
12.	Materials, services, maintenance and overhead (finished steel)	1.45 [c]

Capital charges

Countries	*Pig iron*	*Finished steel*
Latin-American countries	96 dollars	209 dollars
United States	80 "	174.30 "

[a] Cost per ton of pig iron.
[b] Cost per ton of crude steel.
[c] Cost per ton of finished steel.
[d] Normal rates.
[e] Reduced rates, not used in this study.
[f] One loading and one unloading operation.

Table XVII

COST OF IRON ORE, DELIVERED TO 250,000-TON PLANTS
(1948 dollars per ton)

Location	Mining costs	Transport costs: Sea	Inland water-way	Land	Trans-shipment	Total [a]
San Nicolás, Zapla ore	2.26	—	—	11.03	1.20	14.49
San Nicolás, Itabira ore	2.26	3.85	—	4.85	2.40	13.36 [b]
San Nicolás, Sierra Grande ore	2.26	2.24	—	1.53	2.40	8.43 [c]
Volta Redonda	2.26	—	—	3.34	1.20	6.80
Huachipato	2.26	1.06	—	—	1.20	4.52
Belencito	2.26	—	—	0.19	1.20	3.65
Monclova	2.26	—	—	6.42	1.20	9.88
Chimbote	2.26	1.05	—	0.34	2.40	6.05
Barcelona	2.26	1.45 [d]	0.51 [e]	0.49	2.40	7.11
Sparrows Point	2.26	4.97 [d]	0.51 [e]	0.49	2.40	10.63

Source: Economic Commission for Latin America.

[a] To transport and other costs, a sum of $2.26 per ton has been added to represent mining costs. This is the price paid by Compañía de Acero del Pacífico, Huachipato, based on 1948 dollars.

[b] Does not include profit for the company owning the Itabira deposit in Brazil.

[c] Includes cost of railway transport to Puerto Madryn (180 km.) and maritime freight at the usual rate, from Puerto Madryn to San Nicolás (955 nautical miles).

[d] Corresponds to inland waterway and maritime transport. Normal tariffs of direct transport were used, along the Orinoco river and seaways, to the steel plant.

[e] Covers debt service, corresponding to the dredging of the Orinoco river and cost of maintenance of the waterway for a yearly transport of 5 million tons of ore. According to the *Journal of Metals and Mining Engineering*, February 1950, the cost of dredging the Orinoco can be estimated at $18 million. Assuming interest at 3% and an amortization rate of 5%, as well as maintenance costs of $1.1 million annually, a total cost of $2.5 million per year would be obtained. Estimating the average annual extraction to be 5 million tons, the average cost per ton exported would be $0.51.

Table XVIII

COST OF IRON ORE PER TON OF PIG IRON PRODUCED

Plant	Deposit location	Iron content (per cent)	Ore per ton of pig iron (kilogrammes)	Cost of ton of ore (1948 dollars)	Cost of ore per ton of pig iron (1948 dollars)
San Nicolás	Zapla	48	2,085	14.49	30.20
San Nicolás	Itabira	65	1,540	13.36	20.57
San Nicolás	Sierra Grande	57	1,755	8.43	14.80
Volta Redonda	Lafaietta	65	1,540	6.80	10.47
Huachipato	El Tofo	60	1,670	4.52	7.55
Belencito	Paz de Río	47	2,120	3.65	7.74
Monclova	Durango	60	1,670	9.88	16.50
Chimbote	Marcona	60	1,670	6.05	10.10
Barcelona	El Pao	65	1,540	7.11	10.95
Sparrows Point	El Pao	65	1,540	10.63	16.37

Source: Economic Commission for Latin America.

Table XIX

COST OF COKING FUELS DELIVERED TO PLANT
(1948 dollars per ton)

Location	Source of fuel	Percentage	Cost of mine	Transport, etc.	Total
San Nicolás, Zapla ore	Imported	100	..	..	20.00
San Nicolás, Itabira ore	Imported	100	..	..	20.00
San Nicolás, Sierra Grande ore	Imported	100	..	..	20.00
Volta Redonda	Imported	70	8.94	14.01	22.95
	Domestic	30	16[a]	6.42	22.42
Huachipato	Imported	15	8.94	12.68	21.62
	Domestic	85	8.19	0.36	8.55
Belencito	Domestic	100	6.02	0.10	6.12
Monclova	Domestic	100	6.80	0.85	7.65
Chimbote	Imported (asphalt)	15	13.20	7.62	20.82
	Domestic	85	4.50	0.85	5.35
Barcelona	Imported	100	8.94	4.54	13.48
	Domestic (asphalt)	100	2.26	3.32	5.58
Sparrows Point	Domestic	100	..	..	9.10

Source: Economic Commission for Latin America.

[a] The original calculation was $20.50, but it was reduced at the suggestion of the representatives of Volta Redonda to the real figure of $16.

Table XX

COST OF COAL DELIVERED TO PLANT

(in 1948 dollars per ton of pig iron)

Location[a]	Cost of blend per ton (dollars)	Coal per ton of pig iron (tons)	Cost of coal per ton of pig iron (dollars)
San Nicolás, Zapla ore	20.00	1,350	27.00
San Nicolás, Itabira ore	20.00	1,070	21.40
San Nicolás, Sierra Grande ore	20.00	1,150	23.00
Volta Redonda	22.79	1,095	24.96
Huachipato	10.54	1,320	13.91
Belencito	6.12	1,420	8.75
Monclova	7.65	1,250	9.56
Chimbote	7.68	970	7.45
Barcelona	5.58	1,600	8.93
Barcelona	13.48	1,070	14.42
Sparrows Point	9.10	1,070	9.74

Source: Economic Commission for Latin America.

[a] For percentage composition of fuel see Table XIX.

Table XXI

LIMESTONE COSTS

(1948 dollars per ton)

Location	Transport costs (dollars)	Limestone costs (dollars)	Limestone per ton of pig iron (kilogrammes)	Limestone per ton of pig iron (dollars)
San Nicolás, Zapla ore	1.60	3.86	505	1.95
San Nicolás, Itabira ore	1.60	3.86	200	0.77
San Nicolás, Sierra Grande ore	1.60	3.86	200	1.08
Volta Redonda	4.54	6.80	280	1.90
Huachipato	3.41	5.67	280	1.59
Belencito	0.00	2.26	500	1.13
Monclova	0.09	2.35	290	0.68
Chimbote	2.22	4.48	280	1.25
Barcelona[a]	2.90	5.16	350	1.80
Barcelona[b]	2.90	5.16	200	1.03
Sparrows Point	2.90	5.16	200	1.03
Average (Venezuela from imported coal only) = $1.74				

Source: Economic Commission for Latin America.

[a] Coke from asphalt or petroleum residues.

[b] Coke from imported coal.

Table XXII

COSTS OF COKING OPERATIONS

	Dollars
The *Mineral Yearbook* gives the cost of production of metallurgical coke in the United States in coke-ovens for 1948.	
Gross cost per ton of coke	18.58
Cost of coking coal per metric ton of coke	12.77
Coking cost per ton of coke	5.81
which includes capital charges of	2.27
Coking cost per ton of coke	3.54
Therefore, the approximate coking cost per ton of coking coal, would be	2.48
and the credit for by-products would represent	3.09

Table XXIII

COKING PLANT COSTS AND CREDITS

(1948 dollars per ton)

	Costs of coking coal	Credit for coal by-products	Net cost or credit for coal	Coal consumed per ton of pig iron	Coking coal per ton of pig iron
San Nicolás, Zapla ore	2.48	3.09	−0.61	1,350	−0.86
San Nicolás, Itabira ore	2.48	3.09	−0.61	1,070	−0.65
San Nicolás, Sierra Grande ore	2.48	3.09	−0.61	1,150	−0.70
Volta Redonda	2.48	3.09	−0.61	1,095	−0.67
Huachipato	2.48	3.09	−0.61	1,320	−0.81
Belencito	2.48	3.09	−0.61	1,430	−0.88
Monclova	2.48	3.09	−0.61	1,250	−0.76
Chimbote	2.48	..	+2.48	970	+2.40
Barcelona[a]	2.48	..	+2.48	1,270	+3.15
Barcelona[b]	2.48	3.09	−0.61	1,070	−0.65
Sparrows Point	2.10	3.09	−0.99	1,070	−1.06

Source: Economic Commission for Latin America.

(+) Costs.

(−) Credits.

[a] Coke from asphalt or petroleum residues.

[b] Coke from imported coal.

Table XXIV

PIG-IRON COSTS AT 250,000-TON PLANTS

(1948 dollars per ton)

Item	San Nicolás										
	Zapla	*Itabira*	*Sierra Grande*	*Volta Redonda*	*Huachipato*	*Belencito*	*Monclova*	*Chimbote*	*Barcelona* [a]	*Barcelona* [b]	*Sparrows Point*
Iron ore	30.20	20.57	14.80	10.47	7.55	7.74	16.50	10.10	10.95	10.95	16.37
Coking coal	27.00	21.40	23.00	24.96	13.99	8.75	9.56	7.45	8.93	14.42	9.74
Limestone	1.95	0.77	1.08	1.90	1.59	1.13	0.68	1.25	1.80	1.03	1.03
Assembly costs	59.15	42.74	38.88	37.33	23.13	17.62	26.74	18.80	21.68	26.40	27.14
Less credit for blast furnace gas	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90
Assembly costs less credit	57.25	40.84	36.98	35.43	21.15	15.72	24.84	16.90	19.78	24.50	25.24
Direct wages	0.45	0.45	0.45	0.41	0.35	0.47	0.38	0.32	1.56	1.56	1.22
Indirect wages and salaries	0.57	0.57	0.57	0.53	0.44	0.60	0.49	0.41	2.00	2.00	1.57
Total wages and salaries	1.02	1.02	1.02	0.94	0.79	1.07	0.87	0.73	3.56	3.56	2.79
Cooling water	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Net coking costs	—	—	—	—	—	—	—	+2.40	+3.15	—	—
Less net coking credits	−0.86	−0.65	−0.70	−0.67	−0.81	−0.38	−0.76	—	—	−0.65	−1.06
Repairs and overhead	2.16	2.16	2.16	2.09	2.06	2.49	2.11	2.01	2.40	2.10	2.10
Total, other transformation costs	1.72	1.93	1.88	1.84	1.67	2.53	1.77	4.83	5.97	1.87	1.46
Direct costs	59.99	43.79	39.88	38.21	23.61	19.32	27.48	22.46	29.31	29.93	29.49
Capital charges	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	6.40
TOTAL COSTS	68.63	52.43	48.52	46.85	32.25	27.96	36.12	31.10	37.95	38.57	35.89

Source: Economic Commission for Latin America.

[a] Coke produced with asphalt or petroleum residues.
[b] Coke produced from imported coal.

Table XXV

STEEL INGOT COSTS AT 250,000-TON PLANTS

(1948 dollars per ton)

Item	San Nicolás										
	Zapla	*Itabira*	*Sierra Grande*	*Volta Redonda*	*Huachipato*	*Belencito*	*Monclova*	*Chimbote*	*Barcelona* [a]	*Barcelona* [b]	*Sparrows Point*
Liquid pig iron	52.10	39.80	36.83	35.98	24.77	23.96	27.42	23.90	28.19	28.67	27.56
Circulating scrap	12.54	9.58	8.87	8.65	5.78	5.13	6.61	5.57	6.57	6.69	6.43
Purchased scrap	6.24	4.77	4.41	4.42	2.95	2.54	3.30	2.84	3.37	3.43	3.30
Ferroalloys	2.17	2.17	2.17	1.92	1.92	1.40	2.17	1.92	1.92	1.92	1.92
Less credit for Thomas slag	—	—	—	—	—	−6.50	—	—	—	—	—
Total, ferrous material cost	73.05	56.32	52.28	50.97	35.42	26.53	39.50	34.23	40.05	40.71	39.21
Direct wages	2.00	2.00	2.00	1.60	1.33	0.90	1.72	1.24	3.93	3.93	4.74
Indirect wages	0.35	0.35	0.35	0.35	0.29	0.60	0.30	0.27	0.86	0.86	1.05
Total wages	2.35	2.35	2.35	1.95	1.62	1.50	2.02	1.51	4.79	4.79	5.79
Fuel oil	1.32	1.32	1.32	1.06	1.06	—	1.32	1.06	0.77	0.77	1.06
Limestone and refractories	1.10	1.10	1.10	1.10	1.10	1.60	1.10	1.10	1.10	1.10	1.10
Purchased electric energy	[c]	[c]	[c]	[c]	[c]	1.05[d]	[c]	[c]	[c]	[c]	[c]
Maintenance materials	0.50	0.50	0.50	0.50	0.50	0.85	0.50	0.50	0.50	0.50	0.50
Overhead, materials and services	0.45	0.45	0.45	0.57	0.57	0.72	0.45	0.57	0.57	0.57	0.57
Total, fixed production expenses	3.37	3.37	3.37	3.23	3.23	4.22	3.37	3.23	2.94	2.94	3.23
Total direct costs	78.77	62.04	58.00	56.15	40.27	32.25	44.89	38.97	47.78	48.44	48.23
Capital charges	6.40	6.40	6.40	5.94	5.94	6.22	6.40	5.94	5.94	5.94	4.40
TOTAL COSTS	85.17	68.44	64.40	62.09	46.21	38.47	51.29	44.91	53.72	54.38	52.63

Source: Economic Commission for Latin America.

Note: See Table XXVI. Basic assumptions used in the comparative calculation of crude steel costs.

[a] Coke from asphalt or petroleum residues.
[b] Coke from imported coal.
[c] Assumed to be produced in the plant, included in "General and miscellaneous costs".
[d] 700 kWh per ton of re-melted scrap; 210 kWh per ton of ingot steel at $0.005 the kWh.

Table XXVI

BASIC ASSUMPTIONS USED IN THE COMPARATIVE CALCULATION OF STEEL INGOT COSTS

Item	*Unit*	*100% open hearth*	*80% open hearth and 20% acid Bessemer*	*100% basic Bessemer. Scrap re-melted in electric furnace*
Liquid pig iron per ton of steel ingot	Kg.	759	768	857
Circulation scrap	Kg.	203	199	205
Purchased scrap (at 90% of pig iron price)	Kg.	101	102	101
Ferroalloys per ton of steel ingot	Dollars	2.17	1.92	1.40
Fuel oil	Kg.	110	88	—
Limestone and refractories	Dollars	1.10	1.10	1.60
Direct wages	Hours	3.5	3.02	1.50
Miscellaneous wages and expenses estimated in working hours	Hours	0.30	0.37	0.67
Repairs and maintenance corresponding to labour	Hours	0.32	0.30	0.32
Purchased electric power	Dollars	..[a]	..[a]	1.05[b]
Maintenance materials	Dollars	0.50	0.50	0.85
Materials and services under the item "General and miscellaneous costs"	Dollars	0.45	0.57	1.05
Capital charges in United States 8%; in Latin America 9% on United States capital investment increased by 20% to cover transportation and other costs. This capital is estimated for Latin-American plants, per ton of annual capacity at	Dollars	73.30	66.00	69.60

Source: Economic Commission for Latin America.

[a] Assumed to be produced in the plant, included in "General and miscellaneous costs".

[b] 700 kWh per ton of re-melted scrap; 210 kWh per ton of ingot steel at $0.005 the kWh.

Table XXVII

FINISHED STEEL COSTS AT 250,000-TON PLANTS

(1948 dollars per ton)

Item	*Zapla*	*San Nicolás: Itabira*	*San Nicolás: Sierra Grande*	*Volta Redonda*	*Huachipato*	*Belencito*	*Monclova*	*Chimbote*	*Barcelona*[a]	*Barcelona*[b]	*Sparrows Point*
Steel ingot	113.56	91.25	85.87	82.79	61.61	51.29	68.39	59.88	71.63	72.51	70.17
Fuel blast furnace gas	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Less scrap credit	−16.72	−12.77	−11.83	−11.53	−7.71	−6.84	−8.82	−7.43	−8.76	−8.92	−8.57
Raw materials per ton	97.72	79.36	74.92	72.14	54.78	45.33	60.45	53.33	63.75	64.47	62.48
Rolling wages (10.18 man-hour)	5.80	5.80	5.80	5.40	4.48	6.11	5.00	4.17	13.23	13.23	15.98
Maintenance and overhead wages (20%)	1.16	1.16	1.16	1.08	0.90	1.22	1.00	0.83	2.65	2.65	3.20
Total wages	6.96	6.96	6.96	6.48	5.38	7.33	6.00	5.00	15.88	15.88	19.18
Refractories and spare parts	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Maintenance materials for services and overhead	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Electric power	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Total materials and services	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Total direct costs	109.33	90.97	86.53	83.27	64.81	57.31	71.10	62.98	84.28	85.00	86.31
Capital charges	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	13.94
TOTAL COST	128.14	109.78	105.34	102.08	83.62	76.12	89.91	81.79	103.09	103.81	100.25

Source: Economic Commission for Latin America.

[a] Coke from asphalt or petroleum residues.

[b] Coke from imported coal.

Table XXVIII

BREAKDOWN OF IRON ORE, COAL AND LIMESTONE COSTS
(1948 dollars per ton)

Item	*San Nicolás (Zapla)*		*Volta Redonda*		*Huachipato*		*Belencito*		*Monclova*		*Chimbote*		*Barcelona*[a]		*Barcelona*[b]		*Sparrows Point*	
	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)	(*A*)	(*B*)
Iron ore																		
Wages	0.90	1.88	0.90	1.39	0.90	1.50	1.00	2.12	0.90	1.50	0.90	1.50	0.85	1.31	0.85	1.31	0.85	1.31
Miscellaneous	0.82	1.71	0.82	1.26	0.82	1.37	0.86	1.82	0.82	1.37	0.82	1.37	0.75	1.00	0.65	1.00	0.65	1.00
Capital charges[c]	0.54	1.13	0.54	0.83	0.54	0.90	0.40	0.85	0.54	0.90	0.54	0.90	0.76	1.17	0.76	1.17	0.76	1.17
Local transport	12.23	25.48	4.54	6.99	2.26	3.77	1.39	2.94	7.62	12.73	3.79	6.33	4.85	7.47	4.85	7.47	8.37	12.89
TOTAL	14.49	30.20	6.80	10.47	4.52	7.55	3.65	7.74	9.88	16.50	6.05	10.10	7.11	10.95	7.11	10.95	10.63	16.37
***Fuels* (domestic)**																		
Wages	..	..	9.60	3.16	3.29	3.69	2.53	3.61	2.73	3.41	1.62	1.34	0.86	1.38	..	..	2.10	2.24
Miscellaneous	..	..	6.40	2.10	2.20	2.47	1.69	2.41	1.82	2.27	1.08	0.89	0.58	0.93	..	..	1.40	1.49
Capital charges	..	..	4.50	1.48	2.70	3.03	1.80	2.57	2.25	2.81	1.80	1.49	0.80	1.28	..	..	2.40	2.56
Transport	..	..	6.42	2.11	0.36	0.40	0.10	0.14	0.85	1.06	0.85	0.70	3.32	5.31	..	..	3.20	3.41
Imported fuel	..	27.00	..	14.94	..	4.28	..	..	..	..	..	3.02	..	..	..	13.48	..	..
TOTAL	..	27.00	26.92	23.79	8.55	13.87	6.12	8.73	7.65	9.56	5.35	7.44	5.56	8.90	13.48	14.37	9.10	9.70
Limestone																		
Wages	0.90	0.45	0.90	0.25	0.90	0.25	1.00	0.50	0.90	0.26	0.90	0.25	0.85	0.30	0.85	0.17	0.85	0.17
Miscellaneous	0.82	0.41	0.82	0.23	0.82	0.23	0.86	0.43	0.82	0.24	0.82	0.23	0.65	0.23	0.65	0.13	0.65	0.13
Capital charges	0.54	0.27	0.54	0.15	0.54	0.15	0.40	0.20	0.54	0.16	0.54	0.15	0.76	0.27	0.76	0.15	0.76	0.15
Transport	1.60	0.82	4.54	1.27	3.41	0.96	..	..	0.09	0.02	2.22	0.62	2.90	1.01	2.90	0.58	2.90	0.58
TOTAL	3.86	1.95	6.80	1.90	5.67	1.59	2.26	1.13	2.35	0.68	4.48	1.25	5.16	1.81	5.16	1.03	5.16	1.03

Source: Economic Commission for Latin America.

[a] Coke from asphalt or petroleum residues.

[b] Coke from imported coal.

[c] Investment 6 dollars/ton/year.

Column (*A*) represents iron ore.

Column (*B*) represents pig iron.

Table XXIX

DISTRIBUTION OF RAW MATERIAL ASSEMBLY COSTS
(1948 dollars per ton)

	San Nicolás, with ore from: Zapla	San Nicolás, with ore from: Itabira	San Nicolás, with ore from: Sierra Grande	Volta Redonda	Huachipato	Belencito	Monclova	Chimbote	Barcelona[a]	Barcelona[b]	Sparrows Point
Wages											
Iron ore	1.88	..	1.58	1.39	1.50	2.12	1.50	1.50	1.65	1.65	1.65
Coal	..	..	..	2.14	3.69	3.61	3.41	1.34	1.38	..	2.25
Limestone	0.45	0.18	0.25	0.25	0.25	0.50	0.26	0.25	0.37	0.21	0.21
	2.33	0.18	1.83	3.78	5.44	6.23	5.17	3.09	3.40	1.86	4.11
Miscellaneous											
Iron ore	1.71	..	1.44	1.26	1.37	1.82	1.37	1.37	1.00	1.00	1.00
Coal	..	..	..	1.65	2.47	2.41	2.28	0.89	0.93	—	1.50
Limestone	0.41	0.16	0.23	0.23	0.23	0.43	0.24	0.23	0.23	0.13	0.13
	2.12	0.16	1.67	3.14	4.07	4.66	3.89	2.49	2.16	1.13	2.63
Capital charges											
Iron ore	1.13	..	0.95	0.83	0.90	0.85	0.90	0.90	0.83	0.83	0.83
Coal	..	..	..	1.48	3.03	2.57	2.81	1.49	1.31	..	2.57
Limestone	0.27	0.11	0.15	0.15	0.15	0.20	0.16	0.15	0.19	0.11	0.11
	1.40	0.11	1.10	2.46	4.08	3.62	3.87	2.54	2.33	0.94	3.51
Transportation											
Iron ore	25.48	17.10	10.83	6.99	3.77	2.95	12.73	6.33	7.47	7.47	12.89
Coal	..	..	..	2.11	0.40	0.14	1.06	0.70	5.31	..	3.42
Limestone	0.82	0.32	0.45	1.27	0.96	..	0.02	0.62	1.01	0.58	0.58
	26.30	17.42	11.28	10.37	5.13	3.09	13.81	7.65	13.79	8.05	16.89
Fuel											
Imported coal	27.00	24.87	23.00	17.58	4.28	..	..	3.02	..	14.42	..
	59.15	42.74	38.88	37.33	23.01	17.60	26.74	18.80	21.68	26.40	27.14
TOTAL											
Iron ore	30.20	20.57	14.80	10.47	7.55	7.74	16.50	10.10	10.95	10.95	16.37
Coal	27.00	21.40	23.00	24.96	13.87	8.73	9.56	7.45	8.93	14.42	9.74
Limestone	1.95	0.77	1.08	1.90	1.59	1.13	0.68	1.25	1.80	1.03	1.03
	59.15	42.74	38.88	37.33	23.01	17.60	26.74	18.80	21.68	26.40	27.14

Source: Economic Commission for Latin America.

[a] Coke from asphalt or petroleum residues.
[b] Coke from imported coal.

Chapter III

Influence of the size of the market on the iron and steel industry in Latin America

I. Foreword

Chapter II of Part Two analysed the influence on cost and investment structure of all factors related to geography, raw materials, and wage rates. In this chapter, considerations are added concerning the size of the markets, which, by governing the size of plants, exerts considerable influence on the cost and investment pattern. To examine the situation and possibilities of the industry in the region, Chapters II and III should be considered jointly.

To determine the influence of locational factors, it was assumed in Chapter II that, at the given sites in each of the seven Latin-American countries, plants with an annual output of 250,000 tons of finished steel were operating. It was further assumed that a similar plant existed at Sparrows Point. This provided a basis for comparison with the industry outside the region.[1]

Information was obtained covering almost all important data for each country and site, while general assumptions were used for less important figures. These assumptions may, with minor changes, be taken as generally valid; they improve comparability between the various solutions, and, at the worst, introduce only a slight margin of error. An exception is transport, a factor with an important bearing on aggregate costs. The figures to evaluate transport costs more or less correspond to the average of those in the United States in 1948. In most cases, where plants already exist at the selected sites, current transport rates were available, but preference was given to uniform assumptions to cover sites where no industries exist at present. It may be assumed that the present figures will change once such an industry is installed, with its heavy demand for transport. Moreover, many of the current rates are scarcely related to costs but are affected by subsidies and by many other considerations.

The values indicated in both these papers have been converted into dollars at 1948 value. The exchange rates used for countries with multiple systems were those for steel import payments in 1948. While facilitating comparison with the output of more industrialized countries, this has done much to simplify calculations.

Finally, the process analyzed in the papers contemplates coke blast furnaces for iron ore reduction,[2] basic open hearth or a combination of 20% Bessemer and 80% basic open hearth for steelmaking, or Thomas converters in the case of Colombia. Rolling mills are of the conventional type. In every case it has been assumed that the same assortment of products would be produced, broken down as in Table 25 in Chapter II.

The resulting figures were thus grouped to permit considerable flexibility in analysis, as for example:

(*a*) Assembly costs, which represent the aggregate cost for mining and purchase and transport of raw materials to the plant, are usually higher in Latin America than in industrialized countries.[3] This is due to the great distances involved and the relative shortage of coking coals. Such assembly costs were compared with those for Sparrows Point in the United States, on the assumption that iron ore from Venezuela would be used there. As a result, for that location, costs are higher than is usually the case in the United States. Consequently, some Latin-American assembly costs, which compare favourably with those of Sparrows Point, may in fact be high when compared with those for the principal iron and steel centres of the United States and Europe.

Nevertheless, if the transport costs for the finished products to the coast are added to assembly costs of the industry in the main centres of the United States, then Sparrows Point appears in a more favourable position as regards exports to Latin America. Similarly, the addition to assembly costs, both in Europe and Latin America, of the respective transport charges to regional markets generally result in advantages for Latin-American plants.

(*b*) Wage rates, which are lower in Latin America, have an important bearing on the cost of finished steel (See Table 25.) It may be observed in this table that almost all the Latin-American labour costs are more favourable than those for Sparrows Point. It is inconceivable that a small unit with an annual capacity of 250,000 tons would actually operate in the United States; by producing a complex assortment of steel products, it would lack the advantages of large-scale operation and specialization. Therefore, the data in Table 25 are unrealistic, except for assessing the comparative position of Latin America when its markets have developed sufficiently to permit large-scale steelworks, similar to those in the United States.

(*c*) It is probable that such development will inevitably lead to higher wage rates in Latin America, so that one of its present advantages would disappear. But the shortage of capital now prevailing in the region would also disappear. Column D of Table 33 illustrates a case in which these two factors become equal to the rates prevailing in the United States. Results differ considerably, but in general the values would tend to approach those of Sparrows Point.

The final conclusions of Chapter II show that, from purely locational factors, differences of only a small percentage arise between the cost of steel for the various sites. These differences are much smaller than those caused by changes in the plant size, as noted later. The

[1] The sites selected for these hypothetical plants correspond to locations for which most information was available in each country; this does not imply an opinion concerning their comparative advantages over any others.

[2] Even in Peru, where a 53,000-ton iron and steel plant is being built at Chimbote, based on Tysland-Hole electric furnaces.

[3] Belenccito, in Colombia, is a notable exception to this almost general rule.

comparability of the results of both cases is assumed by using, as far as possible, the same data and methods of calculation.

II. Influence of the size of the plant on production costs

The main influence which the size of the plant exerts on production costs, in plants producing the same assortment of steel products, is due to variations in two different factors: (*a*) the greater productivity of labour as the scale of operations increases, and (*b*) the lower investment required per unit of output in larger plants.[4] In order to permit an analysis of the influence of plant size on costs, with locational factors remaining constant, Tables 35, 36 and 37 have been compiled showing costs corresponding to different stages of production in plants of 50,000, 250,000, 500,000 and one million tons a year respectively.[5]

Table 35

PIG-IRON PRODUCTION COSTS IN PLANTS OF DIFFERENT SIZES LOCATED AT SPARROWS POINT
(1948 dollars per ton)

Item	*Annual production capacity* 50,000	250,000	500,000	1,000,000
Iron ore	17.93[a]	16.37[b]	16.37[b]	10.90[c]
Coal	10.71[d]	9.74	9.74	9.74
Limestone	1.08[e]	1.03	1.03	0.92
Assembly costs	29.72	27.14	27.14	21.56
Credit for blast furnace gas	−1.90	−1.90	−1.90	−1.90
Assembly costs *minus* credit	27.82	25.24	25.24	19.66
Direct wages	6.75	1.22	0.68	0.63
Indirect wages and salaries	5.40	1.57	0.87	0.80
Total salaries and wages	12.15	2.79	1.55	1.43
Cooling water	0.46	0.42	0.40	0.36
Repairs and general expenses	5.90	2.10	1.72	1.48
Minus net credits from the coke plant	−1.17[d]	−1.06	−1.06	−1.06
Total for conversion costs	5.19	1.46	1.06	0.78
Direct cost	45.16	29.49	27.85	21.87
Capital charges	8.16	7.00	5.80	5.76
TOTAL COST	53.32	36.49	33.65	27.63

Source: Economic Commission for Latin America.
[a] Freight for El Pao ore, Venezuela, at the normal rate, without dredging the Orinoco river.
[b] Freight for El Pao ore, Venezuela, at the normal rate, with the Orinoco river dredged.
[c] Freight for El Pao ore, Venezuela, at a low rate and with the Orinoco river dredged.
[d] Estimated cost 10% higher than that for the 250,000-ton plant.
[e] Limestone cost estimated 5% higher than for the 250,000-ton plant.

Sparrows Point has been selected as the site for this example. However, because of the substantial wage levels in relation to Latin America, the influence of size on the wage costs is somewhat exaggerated in comparison with the usual position in the region. The opposite is the case with the influence on capital charges.

Table 35 shows that pig-iron costs in a plant with an annual capacity of a million tons are 50% lower than those of a small plant producing 50,000 tons of finished steel a year. Conversely, it may be observed that the 250,000-ton steelworks, selected as an example for the installations in Chapter II, approaches the point on the curve where the influence of the size of operation on costs begins to decline. In fact, doubling output to 500,000 tons reduces total costs by 8%, while raising it four times to a million tons reduces them by 24%. Two-thirds of the second reduction, or 15% of the total cost, are due to economies through using larger ships and better ports, as justified by a greater annual traffic.

Wage costs per ton fall by almost 50% when passing from the 250,000-ton plant to that of a million tons, although this reduction only represents 4% of total costs. On the other hand, the difference in labour costs between a 250,000-ton plant and one with an annual capacity of 50,000 tons a year is about 400%, and represents 25% of the total cost of the smaller plant.

Table 36

STEEL INGOT PRODUCTION COSTS IN PLANTS OF DIFFERENT SIZES LOCATED AT SPARROWS POINT
(1948 dollars per ton)

Item	*Annual production capacity* 50,000	250,000	500,000	1,000,000
Liquid pig iron (768 kg.)	41.00	28.02	25.95	21.20
Circulating scrap (199 kg.)	9.55	6.54	6.03	4.95
Purchased scrap (102 kg.)	4.90	3.35	3.09	2.54
Ferroalloys	2.30	1.92	1.90	1.90
Total cost, ferrous material	57.75	39.83	36.97	30.59
Direct wages	8.45	4.74	3.20	2.67
Indirect wages	1.85	1.05	0.95	0.84
Total wages	10.30	5.79	4.15	3.51
Fuel oil (88 kg.)	1.30	1.06	1.02	0.85
Lime and refractories	1.40	1.10	1.10	1.00
Maintenance materials	0.54	0.50	0.45	0.40
Overhead materials and services	0.70	0.57	0.55	0.50
Total fixed manufacturing costs	3.94	3.23	3.12	2.75
Total direct cost	71.99	48.85	44.24	36.85
Capital charges	5.00	4.40	3.18	3.17
TOTAL COST	76.99	53.25	47.42	40.02

Source: Economic Commission for Latin America.

The cost per ton of steel ingot produced in a plant of a million tons a year is 48% lower than that for a plant with an annual production of 50,000 tons. The difference is thus very slightly lower than that shown for pig iron, where the difference is 50%. For the 250,000-ton plant, steel ingot costs show the same tendency as pig-iron costs in relation to the 50,000-ton steelworks, the influence of size of operations beginning to decline.

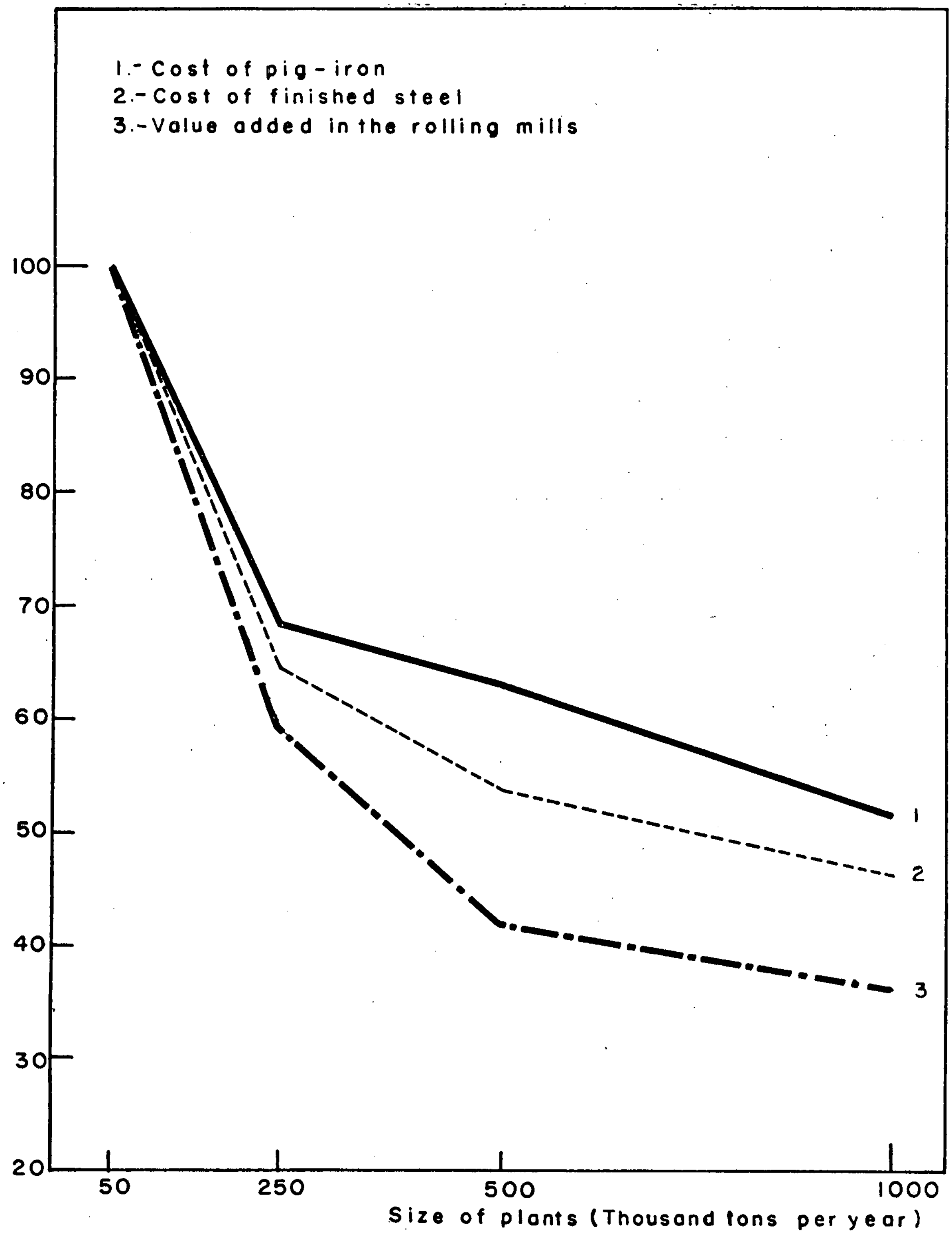
In the rolling mill, the influence of the size of operations on wages is considerably greater than in the preceding steps, because of the various degrees of mechanization appropriate to the different sizes. In fact, finished steel costs in a plant producing a million tons a year, are 54% lower than in a 50,000-ton plant. In turn, doubling the 250,000-ton plant produces a cost reduction of

[4] A third factor may be added here, the greater facilities for specialization which exist in a broader market. Similarly, although there is no numerical expression for it, with many products, such as sheet, for instance, the quality produced by modern plants cannot be achieved with the use of small-scale equipment.

[5] These plants are assumed to have been designed expressly for their respective sizes. This does not correspond exactly to the facts in Latin America, where, owing to the rapid rise in demand, expansions are usually considered in advance to make provision for additional investment.

Chart XIII

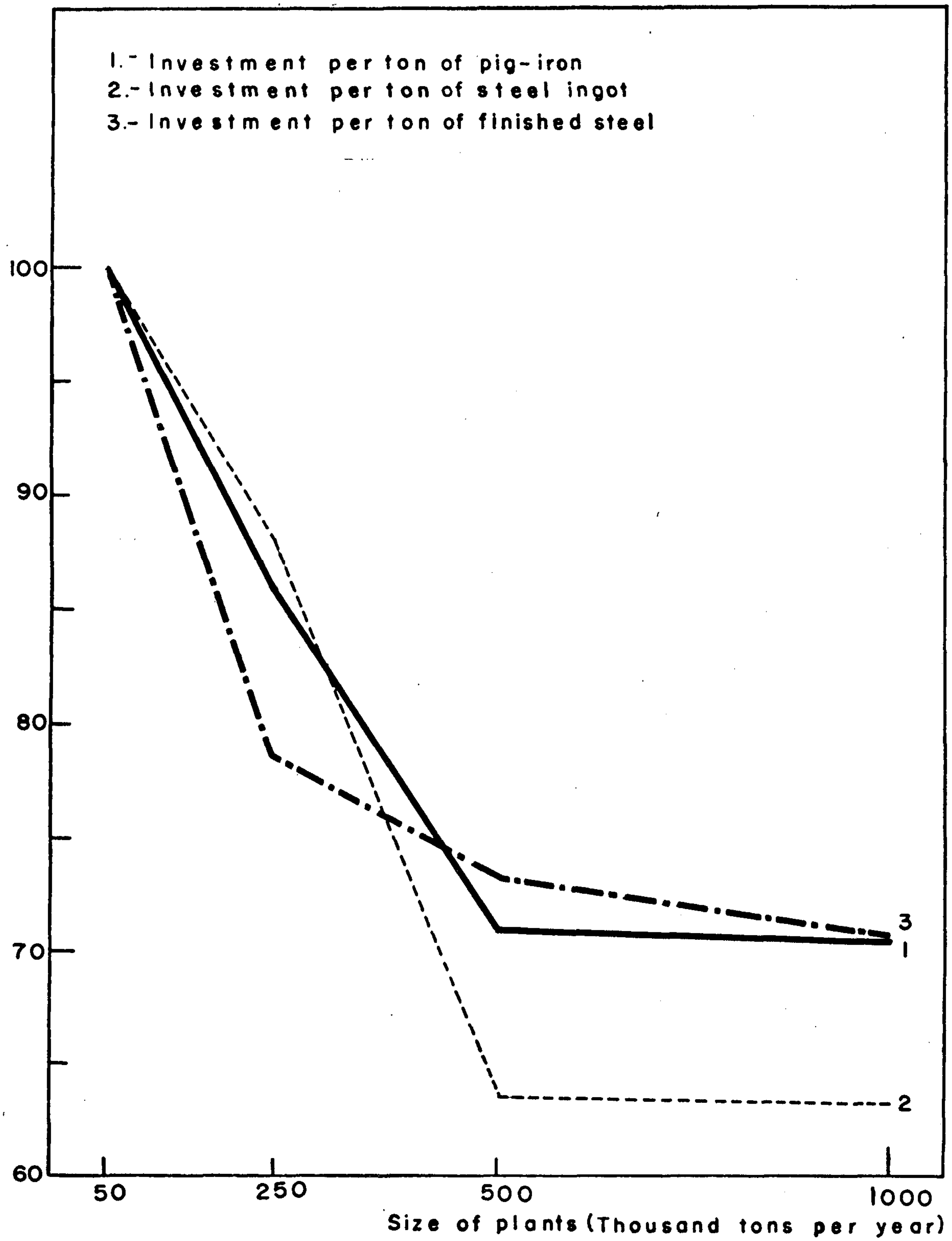
INFLUENCE OF SIZE OF PLANT ON PRODUCTION COSTS PER TON
index: 50,000-ton plant = 100.



Source: Economic Commission for Latin America.

Chart XIV

INFLUENCE OF SIZE OF PLANT ON ANNUAL INVESTMENTS PER TON
index: 50,000-ton plant=100.



Source: Economic Commission for Latin America.

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Table 37

FINISHED STEEL PRODUCTION COSTS IN PLANTS OF DIFFERENT SIZES LOCATED AT SPARROWS POINT
(1948 dollars per ton)

Item	*Annual production capacity*			
	50,000	*250,000*	*500,000*	*1,000,000*
Steel ingots (1,333 kg.)	102.65	71.00	63.23	53.36
Fuel, blast-furnace gas	0.88	0.88	0.88	0.88
Credits for circulating scrap	−12.73	−8.72	−8.04	−6.60
Total raw materials per ton	90.80	63.16	56.07	47.64
Rolling mill wages	28.10	15.98	7.85	5.59
Maintenance wages and general expenses	9.70	3.20	2.18	1.98
Total wages	37.80	19.80	10.03	7.07
Refractories and replacements	4.00	2.00	2.00	2.00
Overhead maintenance materials and services	2.90	1.45	1.45	1.45
Electric power	2.40	1.20	1.20	1.20
Total materials and services	9.30	4.65	4.65	4.65
Total direct cost	137.90	86.99	70.75	59.36
Capital charges	17.76	13.94	13.04	12.56
TOTAL COST	155.66	100.93	83.79	71.92

Source: Economic Commission for Latin America.

17%, compared with an 11% difference at the steelmaking shop and 8% at the blast furnace.

The results shown in Tables 35 and 37 have been converted into indices in Chart XIII, taking the data for the 50,000-ton plant as the base. The chart shows costs: (*a*) per ton of pig iron in the four plants; (*b*) of finished steel; (*c*) of the value added per ton of steel in the rolling mill. In accordance with the preceding analysis, the curve corresponding to the steelmaking plant would be so close to that for pig iron that, to avoid confusion, it has been omitted. Chart XIII shows that the influence of the size of operation is lowest at the blast furnace and highest at the rolling mill.

This fact is important in order to examine possibilities for inter-Latin-American trade.[6] Indeed, a country having a large market and high assembly costs can expect only a relatively small reduction in pig-iron costs as a result of expanding its blast furnaces. On the other hand, for a country having low assembly costs and a small market, it might be beneficial to suppress rolling operations, which would be very costly, and to exchange pig iron for finished steel. If the situation as regards some special products is examined, such as tubes, railway tires, etc., instead of taking an assortment of steel products such as that considered in this paper, it is very likely that fruitful combinations could be found.

Chart XIV shows similar indices concerning investments. It is apparent that the investment required for the blast furnace remains almost constant beyond an output of approximately 500,000 tons. This is because calculations have been based on maximum units of 1,400 tons a day, and the addition of others if necessary. The indices for value added at the rolling mill are anomalous, as they appear with an abnormally low concentration of investment in the 250,000-ton plant. This is because the rolling of flat products in a plant for 500,000 tons a year (which would have to roll 185,000 tons of tinplate and sheet), has been planned on the basis of a semi-continuous mill. Such units are much more expensive and are not justifiable for small tonnages; but they produce a cheaper and better quality material in greater quantities than the hand-operated mills considered in the smaller plants. This should also be taken into account when studying possible combinations for intra-regional trade.

[6] No possibility of planning industries to supply more than one country has been considered in this chapter.

III. The size of the markets

The plants for the seven sites are considered in the present analysis as supplying the entire domestic market. To estimate requirements, 1947 consumption was usually taken—a year of high demand for iron and steel in Latin America. The figure was reduced by 20%, since it was considered that no matter how varied the production of a given plant might be, the country would still have to import certain special products, the manufacture of which could not be justified on economic grounds. Since 1947 consumption figures have been exceeded in many of the countries, the estimate so obtained is low and would therefore tend to give very conservative cost and investment figures for Latin America.

Nevertheless, the above general rule was not followed in some cases. First, consumption figures for 1951-52 were used for Chile, because of their increase over those for 1947 as a result of the new production of the Huachipato plant; secondly, in the cases of Colombia, Peru and Venezuela, there is no integrated industry and it may be assumed that an increase in consumption would result from the installation of such an industry. This would raise consumption to figures which could be estimated with the aid of the correlations in Chapter I of Part Two. Such estimates were based on two different market sizes in each country: (*a*) one on 1947 consumption figures; and (*b*) one corresponding to a possible expansion in consumption following the installation of the industry. The respective figures for Colombia are 105,000 and 250,000 tons per year;[7] for Peru, 50,000 and 150,000 tons; for Venezuela 200,000 and 300,000 tons.

Table 38

ANNUAL CAPACITIES OF PLANTS
(Thousands of tons annually)

Plant	*Pig iron*	*Steel ingot*[a]	*Finished stee*
San Nicolás	862	1,135	850
Volta Redonda	735	955	716
Huachipato	236	307	230
Belencito	120	140[b]	105
	286	333	250
Monclova	436	573	430
Chimbote	51	67	50
	154	200	150
Barcelona	205	267	200
	308	400	300
Sparrows Point	1,024	1,333	1,000

Source: conomic Commission for Latin America.

[a] Steel ingot demand has been calculated as an average of 1.333 tons per ton of finished steel.

[b] Includes scrap re-smelted in the electric furnace.

Pig iron and steel ingot outputs required for the estimated consumption of finished steel are shown in Table 38.

[7] The 105,000-ton plant represents the Belencito project and does not include flat products, so that it differs from the assortment of steel products used for all other plants.

According to Table 38, only in Argentine, Brazil and Mexico have the 1947 consumption figures been maintained and, being too low at present, tend to illustrate unfavourable costs. Actually, this is misleading, since more than one steel works has been installed or is being planned in these three countries. The respective tonnages considered here, therefore, are really more favourable than those of existing plants. But consumption is rising in these three countries and Volta Redonda, for example, contemplates increasing output to one million tons.

IV. Use of special ships and return cargoes

A further difference between the basic assumptions used here and those in Chapter II is that, in the present case, provision has been made for every possibility of reducing transport costs, especially maritime freight. It has been assumed that, where economically justified by the scale of operations, specially built ships and ports would be used. Where this procedure cannot be justified, return cargoes would be employed where there is regular trade.

The comments on Table 35 pointed out that some of the variations in assembly costs for different sizes of plants located at Sparrows Point arose from reductions of transport costs by the above methods. It is obvious that some cost reductions are also feasible in plants with a capacity of 250,000 tons a year, such as those used to illustrate the influence of locational factors. Table 39 shows finished steel costs; the adjustment has been made by including, for comparative purposes, the costs obtained in Chapter II using normal transport rates.

The plants benefiting most from these possibilities are, in order of precedence, Volta Redonda, Sparrows Point and Barcelona, while only very small economies are possible for Monclova and Belencito. Reduction of costs at Sparrows Point is particularly important, this location having been specifically selected to compare costs in Latin America with those of the steel-exporting countries.

Table 39

COSTS OF FINISHED STEEL IN 250,000-TON PLANTS WITH AND WITHOUT THE USE OF SPECIAL MEANS OF TRANSPORT FOR RAW MATERIALS

Plant	Costs at normal rates	Costs at special rates using return loads	Difference
	(dollars)		(percentage)
San Nicolás	105.32	102.47	2.7
Volta Redonda	102.08	95.74	6.2
Huachipato	83.62	81.14	3.0
Belencito	76.12	75.59	0.8
Monclova	89.91	89.91	. .
Chimbote	81.79	80.20	2.2
Barcelona	103.81	98.78	5.0
Sparrows Point	100.25	94.67	5.6

Source: Economic Commission for Latin America.

V. Costs of pig iron, steel ingot and finished steel in plants appropriate to Latin-American markets

The tables in the statistical annex to this chapter detail production costs corresponding to the three stages of steel production, for plants appropriate to the size of the markets and located in the usual sites. The information contained therein is summarized in Tables 40, 41 and 42, and which also show costs corresponding to 250,000-ton plants.[8]

[8] The figures in Table 39 have been used for this comparison.

Table 40

COST STRUCTURE FOR PIG IRON IN PLANTS APPROPRIATE IN SIZE TO MARKETS[a]

Plant and annual capacity of blast furnaces (thousands of tons)	Assembly costs[b]	Salaries and wages	Other expenses	Capital charges	Totals	250,000-ton plant with low freight rates
	(percentages)				(dollars)	
San Nicolás[c] 862	78.1	1.4	2.5	18.0	42.97	45.76
Volta Redonda 735	75.0	1.7	3.2	20.1	38.97	41.46
Huachipato 236	60.0	2.8	5.8	31.4	30.30	30.08
Belencito 120	47.7	6.0	10.9	35.4	30.26	27.49
Belencito 286	52.2	3.9	9.2	34.4	27.49	27.49
Monclova 436	69.9	1.5	4.3	24.3	34.09	35.93
Chimbote 51	38.8	9.5	22.6	29.1	37.83	29.70
Chimbote 154	46.2	4.1	17.2	32.5	31.85	29.70
Barcelona 205	56.6	8.4	6.2	28.8	34.08	32.95
Barcelona 308	60.0	6.5	5.6	27.9	32.19	32.95
Sparrows Point 1,024	71.2	5.2	2.8	20.8	27.63	31.02

Source: Economic Commission for Latin America.

[a] Costs are expressed in dollars per ton and the four cost items as percentages of them.
[b] Deducting the credit for blast furnace gas.
[c] Using Sierra Grande ore and imported coal.

Table 41

COST STRUCTURE FOR STEEL INGOT IN PLANTS APPROPRIATE IN SIZE TO MARKETS[a]

Plant and capacity of the steel mill (thousands of tons)	Raw materials	Salaries and wages	Sundry expenses	Capital charges	Total cost	250,000-ton plant	250,000-ton plant with low freight rate
	(percentages)				(dollars)		
San Nicolás[b]							
1,135	69.1	4.9	7.2	18.8	56.66	64.40	61.74
Volta Redonda							
955	67.3	4.8	7.8	20.1	51.35	62.09	56.12
Huachipato							
307	54.5	5.1	10.3	30.1	44.24	46.21	43.96
Belencito[c]							
140	36.5	7.0	19.5	37.0	43.52	38.47	38.01
333	39.1	6.3	16.8	37.0	38.01	38.47	38.01
Monclova							
573	61.5	5.1	9.6	23.8	47.76	51.29	51.26
Chimbote							
67	44.2	7.9	19.7	28.2	53.93	44.91	43.46
200	46.2	7.5	16.0	30.3	47.26	44.91	43.46
Barcelona[d]							
267	51.2	13.3	9.4	26.1	51.57	54.38	49.82
400	53.2	12.0	9.5	25.3	48.31	54.38	49.82
Sparrows Point							
1,333	61.1	11.5	8.4	19.0	40.12	52.63	47.57

Source: Economic Commission for Latin America.

[a] Costs are expressed in dollars per ton and the four cost items as percentages of them.
[b] Using Sierra Grande ore and imported coal.
[c] Discounting Thomas slag.
[d] Using coke from imported coal.

Table 42

COST STRUCTURE FOR FINISHED STEEL IN PLANTS APPROPRIATE IN SIZE TO MARKETS[a]
(pig iron—steel ingot—finished steel)

Plant and annual capacity of finished steel (thousands of tons)	Raw materials	Salaries and wages	Other expenses	Capital charges	Costs of appropriate size plants	Cost in 250,000-ton plant	250,000-ton plant with low freight rates
	(percentages)				(dollars)		
San Nicolás[b]							
850	46.5	7.4	11.0	34.1	91.66	105.34	102.47
Volta Redonda							
716	44.1	7.4	12.4	36.1	85.41	102.08	95.74
Huachipato							
230	31.2	10.5	13.0	45.3	82.44	83.62	81.14
Belencito[c]							
105	19.1	13.7	19.6	47.6	76.56	—	—
250	18.0	14.0	17.4	50.2	75.98	76.12	75.59
Monclova							
430	38.2	8.2	13.0	39.9	83.10	89.91	89.91
Chimbote							
50	23.1	15.3	18.4	43.2	102.22	—	—
150	25.0	11.7	16.4	46.9	88.29	81.79	80.20
Barcelona[d]							
200	26.1	25.5	10.4	38.0	106.60	—	—
300	29.0	22.3	11.5	37.2	93.65	103.81	98.78
Sparrows Point							
1,000	37.4	18.4	12.7	31.5	71.92	100.25	94.67

Source: Economic Commission for Latin America.

[a] Costs are expressed in dollars per ton and the four cost items as percentages of them.
[b] Using Sierra Grande ore and imported coal.
[c] Discounting Thomas slag.
[d] Using coke from imported coal.

It is probably a mere coincidence that the locations showing the highest assembly costs in Chapter II—Argentina and Brazil—are favoured in the present cost calculations because of the greater size of their markets. Conversely, those sites where assembly costs are lower correspond to countries with smaller markets: Chile, Colombia and Peru. As a result, in Latin America as a whole, consideration of the scale of operation tends to reduce the differences between costs.

As explained earlier, two solutions are presented for Venezuela. The first is a 200,000-ton plant, based on the 1947 market, and the second a 300,000-ton plant corresponding to potential demand and estimated according to the analysis in Chapter I of this part. While the cost of finished steel in the first amounts to $107 per ton, it is only $94 in the second. These figures, somewhat higher than those for the other sites, are due to prevailing wage rates. It is interesting to note that the considerable influence of the size of plant, in this case, is mainly due to the high level of wages.

Finally, costs at Sparrows Point (which did not differ substantially from those referring to the other plants in Chapter II) are very much lower as a result of the large size assigned to the plant.

Table 43 shows the average costs for the eight locations, including Sparrows Point, both when capacity equals 250,000 tons and when it is appropriate to the size of the markets.

Table 43

COMPARISONS BETWEEN AVERAGE COSTS: LATIN AMERICA AND SPARROWS POINT

(percentages and 1948 dollars per ton)

	Pig iron	*Steel ingot*	*Finished steel*
A. *250,000-ton a year plants using reduced freight rates*			
Average costs in the seven plants (dollars)	34.77	49.70	89.12
Differences between extreme costs in relation to average (percentage)	53	48	30
Differences of average with respect to Sparrows Point costs (percentage)	+12	+5	−6
B. *Plants appropriate to the size of the markets in Latin America*[a]			
Average costs in the seven plants[b] (dollars)	33.91	47.54	86.74
Differences between extreme costs in relation to average (percentage)	46	39	21
Differences between average and Sparrows Point costs (percentage)	+23	+19	+20

Source: Economic Commission for Latin America.

[a] Selecting the larger plants in those cases where plants of two sizes have been studied for one location.

[b] Arithmetical average. If weighted averages are used, results are slightly more favourable.

The influence of the scale of operations has drawn cost figures closer together. The spread between the maximum in relation to the average has fallen by 5% to 8% of the total cost. Differences between the Latin-American average and the cost at Sparrows Point have increased considerably, to the disadvantage of Latin-American plants: 11% for pig iron; 14% for steel ingot and 26% in finished steel. These percentage variations reflect the different influence of size on the three steps of steel production.

The grouping of plants by sizes, as shown in Table 44, brings out the importance of the scale of operations more clearly.

Table 44

DIFFERENCES BETWEEN PRODUCTION COSTS FOR FINISHED STEEL IN PLANTS, ACCORDING TO SIZE

Location	*Annual capacity (thousands of tons)*	*Costs per ton* — *In plants adjusted to size* (dollars)	*Costs per ton* — *In 250,000-ton plants* (dollars)	*Percentage difference*
	(A)	(B)	(C)	(D)
Chimbote	50	102.22	80.20	+28
Chimbote	150	88.29	80.20	+10
Barcelona	200	106.60	98.78	+ 8
Huachipato	230	82.44	81.14	+ 2
Belencito[a]	250	75.98	75.59	..
Barcelona	300	93.65	98.78	− 5
Monclova	430	83.10	89.91	− 8
Volta Redonda	716	85.41	95.74	−11
San Nicolás	850	91.66	102.47	−11
Sparrows Point	1,000	71.92	94.67	−24

Source: Economic Commission for Latin America.

[a] The 105,000-ton plant being built at Belencito has not been included, since, unlike the others, flat products will not be produced there. The plant is of special design with no blooming mill and the steel ingots will have to be small.

Variations as regards costs of 250,000-ton plants range from a 28% increase in the 50,000-ton plant to a reduction of 24% in the one-million-ton plant.

VI. Utilization of resources

Table 45 shows the utilization of labour in man-hours per ton, as well as value added by the industry. These figures are useful to ascertain whether a steel industry should be created in a country, or a larger volume imported. As stated in Chapter II, the table is based on the assumption that labour in the Latin-American plants has reached a similar efficiency as in the United States. Naturally this will only occur after some years of operation, if there has been no previous iron and steelmaking experience.

Table 45 shows the substantial influence exerted by the size of the plant on productivity. The million-ton plant at Sparrows Point requires, per ton of steel, less than half the manpower needed by the 250,000-ton plant at Belencito. The projected 50,000-ton plant at Chimbote requires, per ton, more than double the manpower of the 250,000-ton plant. There is thus a ratio of almost 5 to 1 between the extremes. The influence of the scale of operations on productivity is large enough to compensate for the reduction in the cost, and results in increases of value added to the raw materials in the larger plants. These increases, however, are lower than that of total production per man-year, because in the larger plants a greater volume of raw materials is also transformed per worker.

While the value added per man is approximately doubled when passing from a 50,000-ton to a one-million-ton plant, value of production per man increases more than threefold. The two plants analysed for Barcelona, Venezuela, show somewhat higher figures for total production and value added than would correspond to their position within the order of size.

Finally, the sharp jump as regards labour requirements between the 850,000-ton and the one-million-ton plants is due to the assumption that a continuous wide strip mill would be used for flat products in the latter case.

Table 45

UTILIZATION OF LABOUR IN THE IRON AND STEEL INDUSTRY
(man-hours, tons and 1948 dollars)

Plant	Capacity (thousands of tons)	Man-hours per ton	Steel produced per man (tons)	Value of production per man-year (dollars)	Value added to raw materials per man-year [a] (dollars)
Chimbote	50	38.3	63	6,430	4,950
Chimbote	150	25.7	93	8,220	6,160
Barcelona	200	20.7	116	12,366	9,137
Huachipato	230	19.7	122	10,057	6,918
Belencito	250	17.7	136	10,320	8,450
Barcelona	300	16.0	150	14,048	9,952
Monclova	430	13.9	172	14,293	8,832
Volta Redonda	716	12.1	211	18,021	10,073
San Nicolás	850	12.0	213	19,523	10,443
Sparrows Point	1,000	8.5	300	21,576	9,189

Source: Economic Commission for Latin America.

[a] The figures are based on the hypothesis that raw materials are purchased from independent companies. Where the mines are directly owned, value added per worker falls on an average by 14%.

Table 45 also indicates that the primary iron and steel industry yields a considerable output per man employed: between $6,430 and $21,576 a year. In addition the value added to raw materials is high; between $4,950 and $10,443. In other words, labour intensity is rather low in the industry. Alternatively, capital intensity is high, as may be seen from Table 46.

The investment per ton of annual output declines with the increased size of the plant, but affects productivity in a lesser degree.

As mentioned in the notes to Table 46, value of production and that added to raw materials are being compared here with a figure termed "production cost" which does not include profits or provision for taxes and other items, which usually make up the selling price. The only exception is interest on the investment. The coefficients obtained in this paper are therefore somewhat smaller than usual.

In order to obtain a figure representing the average selling price in some export markets for the products assigned to the Latin-American plants, the so-called "composite finished steel price" was selected.[9] In 1948 the average value of that weighted price was $86.20 per ton, placed in Pittsburgh.

To this sum, steel transport costs from Pittsburgh to the markets in Latin America should be added, while transport costs from the selected regional plants to their respective markets should be deducted. According to available data, the difference between freight rates from the Atlantic seaboard of the United States minus the cost of local trasport, amounted in 1948 to: $10 per ton for Venezuela, $12 for Colombia and Mexico, $14 for Brazil and Peru, $15 for Chile and $19 for Argentina. Supplementary transport costs between United States' iron and steel producing centres and the Atlantic seaboard may be estimated at some $10 per ton.

On the basis of these figures, output and value added per year for each $100 invested are shown in Table 47, which, to facilitate comparison, also reproduces figures based on hypothetical costs.

[9] Compiled for many years in the annual edition of *Metal Statistics*, published by American Metal Market, New York.

Table 46

UTILIZATION OF INVESTMENT IN THE IRON AND STEEL INDUSTRY

Plant	Capacity (thousands of tons)	Investment per ton-year (dollars)	Tons of steel (per 100 dollars invested)	Annual output [a] (per 100 dollars invested)	Value added to raw materials [a b] (per 100 dollars invested)
Chimbote	50	491	0.203	20.75	15.96
Chimbote	150	469	0.213	18.81	14.12
Barcelona	200	451	0.222	23.67	17.49
Huachipato	230	415	0.241	19.86	13.66
Belencito	250	422	0.237	18.00	14.70
Barcelona	300	386	0.259	24.26	17.21
Monclova	430	368	0.272	22.60	13.97
Volta Redonda	716	343	0.292	24.93	13.94
San Nicolás	850	355	0.282	25.84	12.02
Sparrows Point [c]	1,000	283	0.353	25.38	15.89

Source: Economic Commission for Latin America.

[a] These columns compare capital with production cost. Such cost consists of the operating costs, including repairs and amortization, plus 4% a year on investments. Therefore, the value added and the value of production do not refer to selling prices, which is the usual way of expressing these relationships.

[b] In compiling this table, it has been assumed that the plants would acquire their raw materials from third parties. If mines are directly owned, as is the case in an integrated plant, value added per $100 invested improves on the average by 4% to 5%, because of relatively smaller investments in the mines.

[c] The lower investment at Sparrows Point is partly due to the assumption that transportation, combined with lesser facilities as regards mechanical workshops, increase equipment costs by 20% in Latin America, as compared with those for a similar plant in the United States.

Table 47

Comparison of output value and value added to raw materials [a]
(dollars per $100 invested)

Plant	Capacity (thousands of tons)	Dollars per ton based on estimated costs		Dollars per ton based on possible selling prices	
		Annual output	Value added to raw materials	Annual output	Value added to raw materials
Chimbote	50	20.75	15.96	22.37	17.57
Chimbote	150	18.81	14.12	23.47	18.68
Barcelona	200	23.67	17.49	23.57	17.59
Huachipato	230	19.86	13.66	26.79	20.60
Belencito	250	18.00	14.70	25.64	22.34
Barcelona	300	24.26	17.21	27.50	20.43
Monclova	430	22.60	13.97	29.43	20.79
Volta Redonda	716	24.93	13.94	32.17	21.15
San Nicolás	850	25.84	12.02	32.48	20.46
Sparrows Point	1,000	25.38	15.89	33.95	19.41

Source: Economic Commission for Latin America.

[a] Selling prices have been estimated, adding to the average "composite finished steel" price in Pittsburgh in the base year, transport costs from Pittsburgh to the Latin-American markets, and subtracting transport costs from Latin-American plants to their respective markets.

The average value of total production per $100 of investment in the seven Latin-American countries was —on cost basis—$22.04, rising to $28.21 if based on the selling price. Considering value added to raw materials, the corresponding averages are $14.25 and $20.64. The last figure means that the output-capital ratio in this industry would have been about 4.8 units of capital to one of value added in manufacture.

This relationship improves still further to about 4.5 in the case of integrated plants, since in this instance the plant also owns and works the mineral deposits.

These figures indicate that the capital intensity of steelmaking is very substantial. Therefore, before deciding to construct a new plant, careful study of its advantages and disadvantages appears to be indicated. The alternative might be to develop other industries earning foreign exchange and to base steel supplies upon increased imports. However, the indirect and direct advantages inherent in the establishment of steel transforming industries in Latin America should also be borne in mind when reaching a decision, since the primary industry might be necessary to ensure a more regular supply of steel products. Foreign currency resources are notoriously scarce in most of the Latin-American countries. Table 48 shows those items in the cost of steel which correspond to foreign currency disbursements.

Table 48

Foreign currency payments per ton of finished steel

Plant	Imported fuel[a]	Wages and salaries[a]	Ferro-alloys[a]	Sundry expenses[a]	Capital charges[a]	Total payments in foreign currency[b]	Percentage of cost at the plant
	(dollars)						
San Nicolás	23.28	0.34	1.27	3.63	23.47	51.99	57
Volta Redonda	12.84	0.31	1.04	3.47	23.14	40.80	48
Huachipato	3.07	0.43	1.28	3.55	27.97	36.30	44
Belencito (250,000)	..	0.52	0.93	4.33	28.47	34.25	45
Belencito (105,000)	..	0.52	1.12	4.97	27.33	33.94	44
Monclova	..	0.34	1.31	3.78	24.89	30.32	44
Chimbote (50,000)	3.11	0.78	1.53	6.20	33.15	44.77	44
Chimbote (150,000)	3.11	0.47	1.15	4.84	31.56	41.13	47
Barcelona (200,000)	12.20	1.37	1.40	3.66	30.43	49.06	46
Barcelona (300,000)	12.20	1.04	1.15	3.56	26.12	44.07	47

Source: Economic Commission for Latin America.

[a] Percentages of foreign currency: 100, 5, 50, 33, 75 respectively.

[b] At 1948 costs.

Considerable saving in foreign currency arises in all cases as a result of iron and steel production in Latin America. Payments in foreign exchange amount to 46% of the average costs, considering only the most favourable plants in those countries in which more than one solution has been included. The percentage of foreign exchange saving shown in Table 48 is, of course, lower than in reality, since the average prices which the region pays for imports exceed the estimated costs for the United States by some $24 per ton. If this figure is used as a basis, the savings in foreign exchange would correspond to 64% of the purchase price in domestic markets.

VII. Steel costs compared with delivered cost of imported steel

It was concluded from Table 43 that steel produced at Sparrows Point, in a one-million-ton plant, would be 20% cheaper placed at the plant than the average of seven Latin-American plants. It is therefore interesting to compare the costs of domestically produced steel with the costs at which steel imported from the United States might be delivered to the markets of the region.

In connexion with Table 47, such terms as "composite finished steel" and "transport cost differentials" have been explained. The latter represents, in reality, the advantage in transport costs which Latin-American steel plants possess because of the short distances to their respective markets. Its addition to costs or prices in the respective production centres in exporting countries,[10] permits direct comparison with the figures obtained throughout these studies. The selection of 1948 figures for the United States' selling price is due to the use of dollars at 1948 values throughout these papers.

Delivered costs and prices for imported steel and shown in Table 49. It is evident that this delivered price in different Latin-American locations requires two conditions to be valid: (*a*) that the selling price for export steel should be the same as that prevailing in the United States' market, which is not always the case, and (*b*) that there should be no additional profits, premiums or surcharges.

Latin-American production costs are based on the assumption that the plants are working at full capacity and that fully skilled labour is available. In countries with no previous experience of the iron and steel industry, these norms could be achieved only several years after the plant had entered operation.

[10] The terms "delivered cost of imported steel" and "delivered price of imported steel", which have been applied to this addition, for the sake of simplicity, are therefore arbitrary, as the corresponding figures do not represent real selling prices or costs.

Table 49

STEEL PRODUCTION COSTS COMPARED WITH IMPORTED STEEL COSTS

Plant	*Capacity (thousands of tons)*	*Cost per ton*	*Delivered cost of Sparrows Point steel*[a]	*Delivered selling price of Pittsburgh steel in 1948*[b]
		(dollars)		
Chimbote	50	102	86	110
Chimbote	150	90	86	110
Barcelona	200	107	82	106
Huachipato	230	82	87	111
Belencito	250	76	84	108
Barcelona	300	94	82	106
Monclova	430	83	84	108
Volta Redonda	716	85	86	110
San Nicolás	850	92	91	115
Sparrows Point	1,000	72	—	—

Source: Economic Commission for Latin America.

[a] Cost at Sparrows Point, plus transport cost differentials (see Table 47).

[b] Composite finished steel price in Pittsburgh in 1948 plus transport cost differentials. Freight costs from Pittsburgh to United States port have been estimated at $10 per ton.

Table 49 shows that:

(i) Production costs from Barcelona at 200,000 tons annually would slightly exceed the delivered sales price of steel from the United States placed on the Venezuelan market.

(ii) Costs at the larger plant of 300,000 tons would be $12 cheaper than the delivered selling price of imported steel, and would exceed delivered cost by some 15%.

(iii) Cost at the two plants in Peru will lie between the delivered cost and the delivered selling price of imported steel amounting to 16% over the 50,000-ton plant and 5% higher in the case of the 150,000-ton plant.

(iv) In all the other steelworks which have been considered, except Barcelona's 200,000 and 300,000 ton plants, cost in Latin America would be almost the same or below the delivered cost of imported steel. Colombia is in the most favourable position, with an advantage of 10% below delivered cost.

VIII. Statistical annex

Table XXX

PIG IRON COSTS IN PLANTS APPROPRIATE TO SIZE OF THE MARKETS
(1948 dollars per ton)

Plant	*San Nicolás*	*Volta Redonda*	*Huachipato*	*Belencito*[c]		*Monclova*	*Chimbote*		*Barcelona*		*Sparrows Point*
Annual capacity[a]	*850*[b]	*716*	*230*	*105*	*250*	*430*	*50*	*150*	*200*	*300*	*1,000*
Iron ore	11.39	9.55	6.50	6.46	6.46	15.50	8.06	8.06	8.70	8.70	10.90
Coal	23.00	19.68	12.60	8.75	8.75	9.56	7.44	7.44	11.91	11.91	9.74
Limestone	1.08	1.90	0.97	1.13	1.13	0.68	1.09	1.09	0.60	0.60	0.92
Credit for blast furnace gas	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90	−1.90
Total assembly costs	33.57	29.23	18.17	14.44	14.44	23.84	14.69	14.69	19.31	19.31	19.66
Direct wages	0.26	0.29	0.37	0.80	0.47	0.23	1.59	0.58	1.26	0.92	0.63
Indirect wages and salaries	0.33	0.37	0.47	1.02	0.60	0.29	2.02	0.74	1.60	1.17	0.80
Total wages and salaries	0.59	0.66	0.84	1.82	1.07	0.52	3.61	1.32	2.86	2.09	1.43
Cooling water	0.37	0.38	0.43	0.57	0.42	0.44	0.94	0.42	0.45	0.42	0.36
Additional coking cost							+2.40	+2.40			
Coking plant credits	−0.86	−0.67	−0.81	−0.88	−0.38	−0.76			−0.65	−0.65	−1.06
Repairs and overheads	1.56	1.54	2.13	3.60	2.49	1.77	5.21	2.67	2.30	2.02	1.48
Total miscellaneous conversion costs	1.07	1.25	1.75	3.29	2.53	1.45	8.55	5.49	2.10	1.79	0.78
Direct cost	35.23	31.14	20.76	19.55	18.04	25.81	26.85	21.50	24.27	23.19	21.87
Capital charges	7.74	7.83	9.54	10.71	9.45	8.28	10.98	10.35	9.81	9.00	5.76
TOTAL COST	42.97	38.97	30.30	30.26	27.49	34.09	37.83	31.85	34.08	32.19	27.63

Source: Economic Commission for Latin America.

[a] In thousands of tons.

[b] Using Sierra Grande ore.

[c] The 250,000-ton plant rolling the complete assortment of products; the 105,000-ton plant rolling bars and light rails, shapes and structures.

Table XXXI

STEEL INGOT COSTS IN PLANTS APPROPRIATE TO SIZE OF THE MARKETS
(1948 dollars per ton)

Plant	*San Nicolás*	*Volta Redonda*	*Huachipato*	*Belencito*[c]		*Monclova*	*Chimbote*		*Barcelona*		*Sparrows Point*
Annual capacity[a]	*850*[b]	*716*	*230*	*105*	*250*	*430*	*50*	*150*	*200*	*300*	*1,000*
Liquid pig iron	32.61	29.93	23.27	25.93	23.56	25.87	29.05	24.46	26.17	24.72	21.20
Circulating scrap	7.85	6.98	5.43	5.58	5.07	6.23	6.78	5.70	6.10	5.77	4.95
Purchased scrap	3.91	3.58	2.78	2.75	2.50	3.10	3.47	2.92	3.13	2.96	2.54
Ferroalloys	1.90	1.55	1.92	1.68	1.40	1.95	2.30	1.92	2.11	1.92	1.90
Credit for Thomas slag				−6.50	−6.50						
Total ferrous material cost	46.27	42.04	33.40	29.44	26.03	37.15	41.60	35.00	37.51	35.37	30.59
Direct wages	2.00	1.60	1.33	0.90	0.90	1.72	1.24	1.24	3.93	3.45	2.67
Indirect wages and salaries	0.35	0.36	0.29	0.60	0.60	0.30	0.27	0.27	0.87	0.76	0.84
Total wages and salaries	2.35	1.96	1.62	1.50	1.50	2.02	1.51	1.51	4.80	4.21	3.51
Fuel oil	1.32	1.06	1.06			1.32	1.27	1.17	1.06	1.06	0.85
Limestone and refractories	1.00	1.00	1.10	1.95	1.45	1.10	1.43	1.10	1.10	1.10	1.00
Maintenance materials	0.50	0.50	0.50	1.10	0.80	0.50	0.64	0.50	0.50	0.50	0.40
Miscellaneous materials, services and overheads	0.45	0.50	0.57	1.35	0.97	0.57	0.73	0.57	0.57	0.57	0.50
Purchased electric power				1.26	1.00						
Total fixed conversion costs	3.27	3.06	3.23	5.66	4.22	3.49	4.07	3.34	3.23	3.23	2.75
Direct costs	51.89	47.06	38.25	36.59	31.75	42.66	47.18	39.85	45.54	42.81	36.85
Capital charges	4.77	4.29	5.99	6.93	6.26	5.10	6.75	6.40	6.03	5.50	3.17
TOTAL COST	56.66	51.35	44.24	43.52	38.01	47.76	53.93	46.25	51.57	48.31	40.02

Source: Economic Commission for Latin America.
[a] In thousands of tons.
[b] Using Sierra Grande ore.
[c] The 250,000-ton plant rolling the complete assortment of products; the 105,000-ton plant rolling bars and light rails, shapes and structures.

Table XXXII

FINISHED STEEL COSTS IN PLANTS APPROPRIATE TO SIZE OF THE MARKETS
(1948 dollars per ton)

Plant	*San Nicolás*	*Volta Redonda*	*Huachipato*	*Belencito*[c]		*Monclova*	*Chimbote*		*Barcelona*		*Sparrows Point*
Annual capacity[a]	*850*[b]	*716*	*230*	*105*	*250*	*430*	*50*	*150*	*200*	*300*	*1,000*
Steel ingots (1,333 kg.)	75.55	68.47	58.99	58.03	51.07	63.61	71.91	61.67	68.76	64.41	53.36
Fuel, blast furnace gas	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Credit for circulating scrap	−10.47	−9.31	−7.24	−7.44	−6.76	−8.31	−9.04	−7.60	−8.13	−7.69	−6.60
Total raw materials	65.96	60.04	52.63	51.47	45.19	56.18	63.75	54.95	61.51	57.60	47.64
Rolling mill wages	2.28	2.33	4.69	4.43	6.11	2.82	7.34	5.62	14.95	10.92	5.59
Wages for maintenance and overhead	0.75	0.72	0.94	2.00	1.22	0.78	2.54	0.12	2.99	2.21	1.98
Total wages and salaries	3.03	3.05	5.63	6.43	7.33	3.60	9.88	5.74	17.94	13.13	7.07
Refractories and spare parts	2.00	2.00	2.00	1.60	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Supplies for maintenance and overhead	1.45	1.45	1.45	1.16	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Electric power	2.12	1.77	1.20	0.96	1.20	1.87	1.20	1.20	1.20	1.20	1.20
Total supplies and services	5.57	5.22	4.65	3.72	4.65	5.32	4.65	4.65	4.65	4.65	4.65
Direct cost	74.56	68.31	62.91	61.62	57.17	65.10	78.28	65.34	84.10	75.38	59.36
Capital charges	17.10	17.10	19.53	14.94	18.81	18.00	23.94	22.95	22.50	18.27	12.56
TOTAL COST	91.66	85.41	82.44	76.56	75.98	83.10	102.22	88.29	106.60	93.65	71.92

Source: Economic Commission for Latin America.
[a] In thousands of tons.
[b] Using Sierra Grande ore.
[c] The 250,000-ton plant rolling the complete assortment of products; the 105,000-ton plant rolling bars and light rails, shapes and structures.

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PART ONE

Chapter I

Introduction

Iron and steel is the first industry to be studied on a systematic basis by the Economic Commission for Latin America.[1] The reasons for this choice are threefold: (*a*) the importance of iron and steel industry for the economic development of Latin America; (*b*) the interest in this industry shown by a number of Latin-American Governments during the last half century, and (*c*) the frequency of discussions regarding the advantage or disadvantage of installing such an industry in specific countries.

To avoid extending the scope of this study unduly, the analysis has been restricted to seven countries of the region, where either an integrated[2] steel industry already exists or there are known to be good prospects for the establishment of such an industry. These countries are Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela.

The work undertaken was directed towards four main objectives:

(*a*) Analysis of the evolution of consumption and supply of iron and steel products;[3]

(*b*) Study of the hypothetical costs of steel production at selected sites in Latin-American countries. These are compared with production costs in industrialized countries and with hypothetical sales prices of imported steel as delivered to Latin-American markets;

(*c*) Approximate estimates of the investment required to establish integrated steel plants, appropriate to the size of the respective markets and at the locations mentioned above;

(*d*) Technical problems hindering the development of the steel industry in the region.

I. Preliminary results of the study

For the analysis of the points covered by paragraph (*a*) above, official statistics of the different countries have been used. For paragraphs (*b*), (*c*) and (*d*), research was necessary into the relative importance of various domestic factors, for example availability of raw materials, their grades and locations, wage rates, sizes of markets, etc.

Some problems face all seven countries, other questions apply only to several of them, while there are certain difficulties which refer exclusively to one specific country. Despite the fact that several problems are of a definite economic character—for example production costs and the financing of steel companies—all of them are to some extent related to technical factors, owing to the influence of the steelmaking process upon the structure of costs. The main conclusion of the preliminary study may be summarized in the following paragraphs.

1. Economic problems

(*a*) The analysis of steel consumption in Argentina, Brazil, Chile, Colombia, Cuba and Mexico shows that during most of the past 25 years, almost all of these countries were unable to obtain the steel which they required. Instead, they secured only such amounts as their capacity to import would permit them to buy on the world market, supplemented, in some cases, by domestic steel production. The majority of the countries whose markets were studied show deficits in their supply of steel products.

(*b*) The size of the plant has the most important bearing on costs. If the scale of operation is small, the costs and the investment per unit of production are high while productivity is low.

(*c*) In general, the consumption rates of even those Latin-American countries which use most steel (Argentina and Brazil) are still too small to justify the installation of modern specialized plants capable of profiting from all the improvements which increase productivity.

(*d*) Regarding production costs, a detailed analysis of the influence of the most important factors affecting Latin America's steel industry was prepared. Hypothetical steelworks of equal size were therefore assumed to exist. Their costs were compared with plants of the same capacity but located at Sparrows Point on the eastern coast of the United States. The results of such hypothetical comparisons have generally been favourable for Latin America. In reality, steel plants in the industrialized countries, and especially in the United States, have far greater capacities. Their costs, therefore, are lower than those calculated for the Latin-American plants. Nevertheless, these differences are generally offset by freight charges for steel from the foreign producer to Latin-American markets.

(*e*) The exceptions are Peru and Venezuela, with hypothetical plants having an annual capacity of 150,000 and 300,000 tons respectively. The disadvantages of these countries can probably be eliminated and steel costs reduced if additional production of pig iron destined for export is envisaged. Moreover, Peruvian and Venezuelan production costs are lower than the delivered price of imported steel in the respective markets.

(*f*) In all cases analysed—even for those which would result in high costs—domestic output of steel in Latin

[1] The study on *Labour Productivity of the Cotton Textile Industry in Five Latin-American Countries* (E/CN.12/219, United Nations Publication, Sales No.: 1951.II.G.2), undertaken previously, refers to special aspects of this industry only.

[2] A steel plant which produces at least some of the required raw materials, and manufactures pig iron, steel ingots and steel products, is entitled "integrated" in this study.

[3] Throughout this study, and for all documents of the Meeting of Experts, the expression "steel products" refers to products of the rolling mill and of some primary transforming industries, such as those producing tubes, wire, nails, screws and bolts. It excludes, therefore, the steel contained in manufactured goods, equipment, etc.

America would mean a substantial saving of foreign exchange per unit of steel manufactured.

(*g*) Steel production is a heavy industry and requires substantial investment. The capital intensity is such that in the initial stages four or five units of investment are required to obtain one unit of production.[4] This ratio generally prevails whether the plant mines its own raw materials or purchases them.

(*h*) The fact that the steel industry has a relatively low output-capital ratio has been used as an argument against the establishment of steel industries in Latin America. However, it must be recalled that iron and steel production are activities which are basic to many other transforming industries, in which the output-capital ratio is much higher. The problem must thus be viewed from all angles. Moreover, the establishment of the steel industry in Latin America has generally sprung from the need to substitute domestic production for imports, in order to allow a higher rate of increase in income than in the rate of growth of the capacity to import. It is thus possible that, in order to achieve certain import substitutions, investments have to be made with a lower output-capital ratio than average investments prevailing in the economy.

2. Fuel problems

(*a*) In most Latin-American countries, with perhaps the sole exception of Colombia, known coal reserves are scarce;

(*b*) Few of the proven deposits contain good coking coals;

(*c*) Several good coking coals in Latin America are difficult to wash, because the ashes they contain are finely disseminated. This represents an increase in the cost of washing, or, alternatively, higher freight charges and greater operating costs for the blast furnace.

(*d*) Little knowledge is available of Latin-American raw materials which can be used for blending to improve the coking property of coals, or as substitutes for coke. Their properties and possible applications have not been sufficiently investigated.

(*e*) The distances for coal transport to steelworks in the region—including imported coal—are generally excessive and lead to high pig-iron costs. The influence of this factor varies substantially from case to case.

(*f*) The bad quality of the coke which can be manufactured with known raw materials without an undue increase in fuel costs, has caused restrictions to the height of the blast furnaces at some plants, which in turn reduces their productivity.

(*g*) Some of the coals, blending materials, or substitutes for coal known in Latin America have such a high sulfur content that they have been discarded altogether or have raised operating costs of the blast furnace substantially.

[4] These figures are the result of hypothetical calculations based on conditions prevailing in 1948. Since then, world events caused a considerable increase in steel prices, which was not followed to the same degree by a rise in prices for capital goods. If the output-capital ratio is calculated for any period after 1950, the figures will be lower than those presented here. It is possible that once the new steel plants which are being constructed in many countries enter operations, the relative position of prices for steel products and capital goods will return to the situation in 1948. The data given here have not therefore been modified, but it should be emphasized that they probably depict the most unfavourable situation for financing the steel industry.

3. Iron ore problems

Problems arising from the quality or availability of iron ores are less important than those caused by fuels. Latin America in general is rich in high-grade ore, and is at present a substantial exporter. Nevertheless, the following difficulties may be mentioned in this connexion.

(*a*) In several countries, steel plants must use iron ores with a phosphorus content which does not precisely correspond to the most favourable limits of steel refining processes. The phosphorus content is too high for the basic open-hearth process (which is used for the production of 95% of the steel in the United States) and too low for the basic converted process (Thomas), widely employed in Europe.

(*b*) Somewhat unusual percentages of certain impurities appear in the case of two countries, arsenic in Mexico and titanium in Chile.

(*c*) Latin-American integrated plants can be supplied with only a very restricted range of different iron ores, thus eliminating the solution of blending various ores which is frequently used in more industrialized countries, and obliging greater caution to be exercised in studying the design and operations of steel works. These, in addition, must produce a wider assortment of different steel qualities to cover as much as possible of the domestic steel requirements.

4. Transport problems

The production of one ton of steel requires four to six tons of raw materials, depending upon the grade of the minerals and coal. Transport of raw materials therefore represents an important share of aggregate production costs, and, together with the transport of end products to the market, determines the best economic site for the plant. In some countries—especially Brazil, Colombia and Mexico—distances are great, transport difficult, and consumer centres are relatively scattered. In Brazil and Mexico there is more than one large steel plant. This reduces the scale of operation for each plant below the figures for the over-all market and contributes to higher production costs. Even so, such dispersion does not entirely eliminate the problems linked with the transport of raw materials and finished products.

In Latin America, therefore, a particular technical problem exists, that of finding iron and steelmaking processes which allow improvements in productivity for small-scale operations. Such processes could certainly be applied to specific sites in the aforementioned countries. In addition, they would permit the establishment of small steel industries in other countries of the region which have not been included in this survey, since steel produced with classical processes in these countries would be excessively costly owing to the limited size of their markets.

5. Problems connected with the uses of steel

In countries where steel transforming industries are under-developed, most of the metal is used by the building industry. The principal quality requirements which such steel has to satisfy are resistance and ductility, while chemical composition is of little importance. The requests made by some consumers that such building materials should conform to narrow variations of chemical composition unnecessarily increase production costs and are prejudicial to all consumers. They may also result in unnecessarily high investment in the plants required to meet such demands.

In view of the rapid growth of steel production in Latin America during recent years, there would appear to be every advantage in establishing standards and specifications for steels as soon as possible. When preparing these standards, consideration should be given to the use to which the steel will be applied, to existing raw materials and facilities, and to the avoidance of unnecessary increases in production costs.

II. The Meeting of Experts on the Iron and Steel Industry in Latin America

After the United Nations Technical Assistance Administration (TAA) and the Government of Colombia had considered the results of the preliminary studies by ECLA, they offered to co-operate in the first meeting of experts on the iron and steel industry in Latin America, which was held at Bogotá in October 1952. The meeting was convened under the joint auspices of ECLA and TAA while the Government of Colombia acted as host and generously provided for its material success.

The meeting was formally opened on 13 October by His Excellency the Acting President of Colombia, Dr. Roberto Urdaneta Arbeláez, who welcomed the participants to Colombia. He underlined the importance of a steel industry to economic development and the bearing of such industries upon an improvement in over-all standards of living.

Mr. Bruno Leuschner of the ECLA secretariat, Executive Director of the meeting, expressed the gratitude of the Secretary-General of the United Nations, the Director-General of the Technical Assistance Administration and the Executive Secretary of the Economic Commission for Latin America. He explained the background for the meeting and that the work was directed towards seeking means to overcome the principal obstacles to the establishment of iron and steel industries in Latin America and towards determining whether such industries were economically justifiable.

One hundred and seventeen experts participated at the meeting[5] and 83 background documents were contributed.[6] The participants and the authors of the papers represented 19 different countries and among them were some of the best known experts on iron and steel in the world today.

At the opening session, Dr. Roberto Jaramillo Ferro, Managing Director of the Paz de Río Iron and Steel Company, was elected Chairman. Seven vice-presidents were elected, one from each of the Latin-American countries which participated at the meeting.[7] Mr. Bruno Leuschner acted as Executive Director to the Meeting and Dr. Mariano Ospina Hernández as Secretary General.

[5] See Appendix I to this chapter, "Contributors and Participants".

[6] See Appendix II, "Documents and Technical Papers presented at the Meeting". (See also Volume II.)

[7] Argentina: Ing. Augusto Legrand; Brazil: Ing. Eduardo Pyles Lozano; Chile: Ing. Danilo Vucetich; Colombia: Dr. Joaquín Prieto Isaza; Mexico: Ing. Alfredo González Ballesteros; Peru: Ing. Alfonso Ballón; Venezuela: Ing. Argenis Gamboa.

The substantive matters considered at the meeting are summarized in Chapters III, IV and V of this report, and include:

(*a*) *Fuel problems*: washing of coal; improvement of coking properties of poorly coking coals; substitutes for metallurgical coke;

(*b*) *Iron ore reduction problems*: economic conclusions on the use of various fuels in blast furnaces, on charcoal blast furnaces and on reduction of iron ore by processes other than the blast furnace;

(*c*) *Steelmaking and finishing*: comparative costs of different steelmaking processes; alternative processes both for steelmaking and for finishing steel with special reference to small-scale operations; range of application of steel made by different processes; steel specifications;

(*d*) *Economic problems*: a special section of the meeting was devoted to the study of the working papers on economic themes presented by the Economic Commission for Latin America.[8]

The dates on which the various items of the substantive matter were discussed appear in the agenda.[9] All discussions took place at plenary meetings. Only three problems which had not been included in the programme of substantive matters were presented by non-Latin-American experts at committee meetings.[10]

Some Latin-American experts remained at Bogotá for the entire meeting. Since they were primarily technicians in managerial positions in their respective industries, they had an over-all knowledge of the problems of the steel industry in their countries. The majority of other participants had specialized knowledge on specific problems, and their attendance was thus primarily planned for the discussions of their particular specialty. The presence of the "general" experts throughout the meetings gave continuity to the debates, especially by focusing attention on the analysis of specific Latin-American problems. In addition many specialists attended meetings where problems outside their own field were discussed. During almost the entire meeting, therefore, there were present, in addition to experts for specific items on the agenda, a further group of technicians of high standing in other spheres. A series of interesting discussions thus arose, since experts of the latter type often intervened. They drew on their experience to make suggestions for research and to detail solutions achieved in other technical branches of the industry which bore some relation to the problems under discussion.

As a result, the meeting encouraged an exchange of experience and knowledge, both between participants from the Latin-American countries, and between them and experts from other regions.

The conclusion was almost unanimous that this type of meeting had proved of great benefit to all those pres-

[8] See Part Two: "Factors influencing iron and steel consumption in Latin America" (Chapter I); "Influence of locational factors on the iron and steel industry in Latin America" (Chapter II); "Influence of the size of the market upon Latin America's steel industry" (Chapter III).

[9] See Appendix III, Agenda of the Meeting.

[10] M. Raymond Cheradame (France): "Analysis of Coal Washing Methods Based on the Coefficient of Imperfection"; Prof. Robert Durrer (Switzerland): "Notes on the Future Evolution of Iron Production"; and Prof. B. Kalling (Sweden): "New Process for the Desulfurization of Liquid Pig Iron Based on the Use of Lime" (See Volume II).

ent. ECLA and TAA had submitted to the meeting a series of specific questions related to the common objective of finding processes which would permit lower costs for steel production in the region. Within this framework, the knowledge of the specialists resulted in many valuable suggestions. Their contribution, in addition to definite suggestions for the solution of some Latin-American problems, acted as an inspiration for further research towards greater progress in steelmaking in general.

The meeting was also successful if judged by the number of participants and papers presented. To a great extent this was due to the wholehearted assistance of universities, research centres, professional associations and many private steelworks. Through consultation with the major professional associations, names of representative equipment-manufacturing firms and consulting engineers were obtained. Their co-operation was subsequently requested and in many cases obtained, some of them contributing with working papers, some through the actual participation of their officials and others with both. It should be noted that this group of participants provided some of the best working material.

The Empresa Siderúrgica Nacional de Paz de Río of Colombia contributed a series of papers prepared either by its own staff or by the firms supplying it with equipment and technical advice. This company also gave substantial material help to the success of the meeting, to which must be added the facilities provided by the Government of Colombia.

The agenda did not include every problem of interest to the Latin-American steel industry for two main reasons. Firstly, the time factor made it advisable to present a reduced number of papers to ensure that all of them should receive as much attention as possible. Secondly, it was hoped to obtain a maximum number of divergent opinions on each topic, which in turn obliged the elimination of some agenda items which were considered insufficiently covered by the working papers obtained.

In view of the composition and organization of the Bogotá meeting, the basic objective was not to reach specific agreements or recommendations. Rather, the primary purpose was to discuss the different problems thoroughly by covering as many aspects as possible. The meeting was closed by its Chairman, Dr. Roberto Jaramillo Ferro, on 31 October.

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3. REPRESENTATIVES OF THE UNITED NATIONS AND SPECIALIZED AGENCIES

International Labour Organisation	Jean-Pierre DESPRÉS
Economic Commission for Europe	H. W. A. WARING
Economic Commission for Latin America	Bruno LEUSCHNER, representing the Executive Secretary
Technical Assistance Administration	Raymond ETCHATS, representing the Director-General

4. SECRETARIAT

LEUSCHNER, Bruno	Executive Director of the meeting and Chief, Industry and Mining Division, ECLA
STAKHOVITCH, Alexander	Industry and Mining Division, ECLA
VUSKOVIC, Pedro	Industry and Mining Division, ECLA
YANES, Hugo	Industry and Mining Division, ECLA

Appendix II

DOCUMENTS AND TECHNICAL PAPERS PRESENTED AT THE MEETING

*Symbol** ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Author*	*Title*
L.1	Raymond CHERADAME, France	Considerations on Coal Washing in Europe and its Possible Application to Latin-American Coals.
L.2	Thomas FRASER, United States	Problems in the Preparation of Metallurgical Coal in Latin America.
L.3	Jacques TURPIN, France	Modern Techniques and Installations for the Mechanical Treatment of Coal by the PIC Company.
L.4	John GRIFFEN, United States	The Tromp Heavy Media Coal Washing Process.
L.5	Alvaro de Paiva ABREU, Brazil	Notes on the Production of Metallurgical Coal in Brazil.
L.6	Alfredo GONZÁLEZ, Chile	Description of Chilean Coals Used in the Steel Industry.
L.7	Joaquín PRIETO I., J. A. LÓPEZ T., B. ALVARADO and V. SUÁREZ HOYOS, Colombia	Problems Related to Colombian Coal Used for Steelmaking.
L.8	Salvador CORTÉS OBREGÓN, Mexico	The Coal Used in the Mexican Iron and Steel Industry.
L.9	Walter VOGEL, Chile	New Processes for Extracting Primary Ash from Coal.
L.10	Kurt BAUM, Federal Republic of Germany	The Washing of Peruvian Anthracite Fines.
L.11	Raymond CHERADAME, France	Utilization of High-volatile French and Saar Coals for the Production of Metallurgical Coke. Application of the Conclusions to Latin-American Coals.
L.12	John D. PRICE, United States	The Blending of Western Coals for the Production of Metallurgical Coke.
L.13	John D. PRICE, United States	Low-temperature Char as a Substitute for Low-volatile Coal in the Production of Metallurgical Coke.
L.14	Kurt BAUM, Federal Republic of Germany	The Manufacture of Metallurgical Smelting Carbon from Non-coking Coals.
L.15	A. R. POWELL, United States	Improving Coking Qualities of Coal by Addition of Various Materials.
L.16	A. R. POWELL, United States	Correlation of Small-scale Carbonizing Tests with Commercial Coke-oven Results.
L.17	A. R. POWELL, United States	Argentine Asphaltites as Blending Materials for Poorly Coking Coals.
L.18	M. D. CURRAN, United States	The Utilization of Petroleum Pitches and Asphalts for the Production of Metallurgical Coke.
L.19	J. A. PRIETO I., J. A. LÓPEZ T., B. ALVARADO and V. SUÁREZ HOYOS, Colombia	Coking Properties of the Coal for the Steel Industry in Colombia.
L.20	Salvador CORTÉS OBREGÓN, Mexico	Production of Metallurgical Coke in Mexico.
L.21	Américo ALBALA, Chile	Metallurgical Coke from Chilean Coals.
L.23	Alberto VARGAS MARTÍNEZ, Colombia, and Thomas FRASER, United States	Development of the Cauca Valley Coals.
L.24	Kurt BAUM, Federal Republic of Germany	Manufacture of Metallurgical Coke from Peruvian Anthracite.
L.25	Sidney MEWHIRTER, United States	The Cerrejón Coal Mining Project.
L.26	John D. PRICE, United States	Coal Washery Performance as Related to Blast Furnace Costs.
L.27	Walter VOGEL, Chile	The Influence of Ash Content on the Hardness of Cokes Made from High-volatile Coals.
L.31	Louis ENSCH, Brazil	Pig Iron Production in Blast Furnaces Using Charcoal.
L.32	Danilo VUCETICH, Chile	Operation of the Charcoal Blast Furnace at Corral Using Mixtures of Metallurgical Coke and Charcoal.
L.33	Francisco J. PINTO DE SOUZA, Brazil	The Sintering Plant at Monlevade.
L.36	Georg BULLE, Federal Republic of Germany	Notes on the Production of Pig Iron.
L.37	Hermann WALDE, Federal Republic of Germany	Progress in the Manufacture of Pig Iron and Ferro-alloys with the Low-shaft Electric Furnace.
L.38	H. S. NEWHALL, United States	Making of Steel in Electric Furnaces.
L.39	Friedrich JOHANNSEN, Federal Republic of Germany	The Krupp Renn Process.
L.40	Marc ALLARD, France	International Research on the Low-shaft Blast Furnace.
L.42	Knud E. JENSEN, Denmark	The Basset Process for the Production of Pig Iron in Rotary Kilns.

* Any gaps in the numeration are due either to the fact that the corresponding documents were not received by the Secretariat, or to modifications in the order of the Agenda.

Chapters I, II and III of Part Two of this volume were originally issued as documents L.86, L.87 and L.91.

*Symbol** ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Author*	*Title*
L.44	Russell C. BUEHL, United States	Production of Sponge Iron in a Rotary Kiln at Temperatures Below the Fusion Point of the Material.
L.45	Robert DURRER, Switzerland	Considerations on the Development of the Production of Iron.
L.46	Bo KALLING, Sweden	The Rotary Kiln Processes for Sponge Iron, Developed at the Avesta Iron and Steel Works and the Domnarfvet Iron and Steel Works. Sweden.
L.47	J. STÅLHED, Sweden	Production of Sponge Iron According to the Wiberg-Söderfors Method.
L.48	Alfonso BALLÓN, Peru	The Electric Reduction Furnace.
L.49	M. SEM, Norway	Electric Smelting of Pig Iron.
L.51	Edouard DECHERF, France	Manufacture of Thomas (Basic Converter) Steel at Paz de Río, Colombia.
L.52	Wm. A. HAVEN, United States	Selection of Steelmaking Processes and of Locations for Integrated Iron and Steel Works.
L.53	Charles F. RAMSEYER, United States	Comparative Investment Costs for Different Steelmaking Processes.
L.54	Società ILVA, Italy	Use of Phosphorus Ores for the Production of Pig Iron for Transforming into Steel by the Thomas Process.
L.55	Georg BULLE, Federal Republic of Germany.	Steel Production in Latin America.
L.56	Ernst KREBS, Federal Republic of Germany	The Balance of Materials and the Economic Comparison of the Different Steelmaking Processes.
L.57	R. L. JUNG, France	Considerations Concerning the Choice of Electrical Equipment for the Iron and Steel Plants of Paz de Río (Colombia) and Chimbote (Peru).
L.58	Gabriel PÉRIN, France	The Problem of Energy in Steel Plants.
L.59	A. GONZÁLEZ BALLESTEROS and Narciso MORALES, Mexico	The Duplex Steelmaking Process at Monterrey.
L.60	HÉCTOR CANGUILHEM, Chile	The Acid Bessemer Process in Huachipato (Chile).
L.61	A. MERCIER, France	Details of a Steel Plant for a Non-steel-producing Country.
L.62	Patrick E. CAVANAGH, Canada	Approximate Comparative Production Costs and Investment Requirements of the Standard Blast Furnace, Electric Smelting Furnace, Sponge Iron Furnace and Tunnel Kiln Sponge Iron Furnace.
L.63	Edouard DECHERF, France	Construction of the Thomas Steel Plant at Paz de Río and Production Costs of Thomas Steel.
L.64	G. R. FITTERER, United States	Economics of the Modern Acid Open Hearth Practice.
L.65	W. O. PHILBROOK, United States	The Acid Bessemer Process.
L.66	T. Y. WILSON, United States	Continuous Casting of Steel by the Rossi-Junghans Process.
L.67	Patrick E. CAVANAGH, Canada	Direct Reduction Yields—Variable Density Steels. (Reprint from *The Iron Age,* 24-31, January 1952).
L.68	Jacques SÉJOURNET, France	Notes on the Ugine-Séjournet Extrusion Process.
L.69	Bo KALLING, Sweden	Desulfurization of Pig Iron with Pulverized Lime in Rotary Kilns.
L.70	G. WESTON and R. L. RICHARDS, United Kingdom	Standardization in Relation to Control in Steel Production.
L.71	Jean PALMÉ, France	Thomas Steel Rails in France.
L.72	G. R. FITTERER, United States	Acid Open Hearth Products and Their Specifications.
L.73	P. COHEUR, Belgium	Thomas Steel with Low Nitrogen and Phosphorus Contents.
L.74	A. LANARI, Brazil	Brief Account of Iron and Steel Producing Processes Used in Brazil.
L.75	Francis W. BOULGER, United States	Some Effects of Minor Elements on the Characteristics of Plain-carbon Steels.
L.76	G. WESTON and G. R. BOLSOVER, United Kingdom	The Control of Composition During Steelmaking.
L.77	William C. BUELL, Jr., United States	Basic Open Hearth Steelmaking Practice in the United States of America.
L.78	Federico FRICK, Chile.	Notes on Specifications of Steel for Different Uses.
L.79	Marc ALLARD, France	Perrin Process for Converter Steelmaking.
L.80	Oscar HERRERA SILVA, Chile	Specifications of the Products Made by the Compañía de Acero del Pacífico, Huachipato, Chile.
L.81	International Labour Office	Some Aspects of Labour Problems in the Iron and Steel Industry.
L.82	Roberto JARAMILLO F., Joaquín PRIETO I., and Jaime RUDAS	Foundry Iron by Recarburization of Steel Scrap.
L.83	Marcelo ARAMBURU, Mexico	Consumption of Iron and Steel Products in Mexico.
L.84	Pablo M. SADA, Mexico	Some Notes on the Organization of Monclova Steel Works.
L.86	ECLA SECRETARIAT	Factors Influencing Iron and Steel Consumption in Latin America.

*Symbol** ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Author*	*Title*
L.87	ECLA SECRETARIAT	Influence of Locational Factors on the Iron and Steel Industry in Latin America.
L.88	ECLA SECRETARIAT	Structure of the Steel Transforming Industry in Latin America.
L.91	ECLA SECRETARIAT	Influence of the Size of the Market on the Iron and Steel Industry in Latin America.

Appendix III

AGENDA OF THE MEETING

First Meeting: 13 October 1952–4 p.m.

1. Inaugural Address by His Excellency the Acting President of the Republic of Colombia.
2. Address by the Executive Director of the Meeting of Experts on the Iron and Steel Industry in Latin America.

Second Meeting: 14 October–11 a.m.

1. Introductory Statement by the Executive Director.
2. Election of Chairman.
3. Election of Officers.
4. Discussion of Method of Procedure.

Third Meeting: 14 October–3 p.m. Item I.A.1. FUELS *Reduction of coal impurities*

Discussion of the following papers:

Symbol ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Title*	*Author*
L.1	Considerations on Coal Washing in Europe and its Possible Application to Latin-American Coals	R. Cheradame
L.2	Problems in the Preparation of Metallurgical Coal in Latin America	T. Fraser
L.3	Modern Techniques and Installations for the Mechanical Treatment of Coal by the PIC Company	J. Turpin
Fourth Meeting: 15 October–9 a.m. Item I.A.1. FUELS *Reduction of coal impurities* (continuation)		
L.4	The Tromp Heavy Media Coal Washing Process	J. Griffen, presented by R. C. Woodhead
L.8	The Coal Used in the Mexican Iron and Steel Industry	Salvador Cortés Obregón
L.6	Description of Chilean Coals Used in the Steel Industry	A. González, presented by B. Leuschner
L.7	Problems Related to Colombian Coal Used for Steelmaking	Joaquín Prieto I., J. A. López, T., B. Alvarado and V. Suárez Hoyos, presented by J. Prieto
Fifth Meeting: 15 October–3 p.m. Item I.A.1. FUELS *Reduction of coal impurities* (conclusion)		
L.10	The Washing of Peruvian Anthracite Fines	K. Baum
L.5	Notes on the Production of Metallurgical Coal in Brazil	A. de Paiva Abreu
L.9	New Processes for Extracting Primary Ash from Coal	W. Vogel
Sixth Meeting: 16 October–9 a.m. Item I.A.2. FUELS *Production of coke from poorly coking coal and substitute fuels*		
L.11	Utilization of High-volatile French and Saar Coals for the Production of Metallurgical Coke. Application of the Conclusions to Latin-American Coals	R. Cheradame
L.12	The Blending of Western Coals for the Production of Metallurgical Coke	J. D. Price
L.13	Low-temperature Char as a Substitute for Low-volatile Coal in the Production of Metallurgical Coke	J. D. Price
L.14	The Manufacture of Metallurgical Smelting Carbon from Non-coking Coals	K. Baum
Seventh Meeting: 16 October–3 p.m. Item I.A.2. FUELS *Production of coke from poorly coking coal and substitute fuels* (continuation)		
L.15	Improving Coking Qualities of Coal by Addition of Various Materials	A. R. Powell

Symbol ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Title*	*Author*
L.16	Correlation of Small-scale Carbonizing Tests with Commercial Coke-oven Results	A. R. Powell
L.17	Argentine Asphaltites as Blending Materials for Poorly Coking Coals	A. R. Powell
L.18	The Utilization of Petroleum Pitches and Asphalts for the Production of Metallurgical Coke	M. D. Curran, presented by J. Sturgeon

Eighth Meeting: 17 October–9 a.m. Item I.A.2. FUELS *Production of coke from poorly coking coal and substitute fuels* (conclusion)

L.19	Coking Properties of the Coal for the Steel Industry in Colombia	J. A. Prieto I., J. A. López T., B. Alvarado and V. Suárez Hoyos, presented by J. A. Prieto
L.20	Production of Metallurgical Coke in Mexico	Salvador Cortés Obregón
L.21	Metallurgical Coke from Chilean Coals	A. Albala
L.24	Manufacture of Metallurgical Coke from Peruvian Anthracite	K. Baum

Ninth Meeting: 17 October–3 p.m. Item I.B.1. IRON ORE REDUCTION *Economics of the blast furnace*

L.26	Coal Washery Performance as Related to Blast Furnace Costs	J. D. Price
L.27	The Influence of Ash Content on the Hardness of Coke made from High-volatile Coals	W. Vogel, presented by B. Leuschner
L.23	Development of the Cauca Valley Coals	A. Vargas M. and T. Fraser, presented by A. Vargas M.
L.25	The Cerrejón Coal Mining Project	S. Mewhirter, presented by A. Vargas M.

Tenth Meeting: 21 October–9 a.m. Item I.B.2. IRON ORE REDUCTION *The charcoal blast furnace*

L.31	Pig Iron Production in Blast Furnaces Using Charcoal	Louis Ensch, presented A. Lanari
L.32	Operation of the Charcoal Blast Furnace at Corral Using Mixtures of Metallurgical Coke and Charcoal	D. Vucetich
L.33	The Sintering Plant of Monlevade	F. J. Pinto de Souza, presented by B. Leuschner

Eleventh Meeting: 21 October–3 p.m. Item I.B.3. IRON ORE REDUCTION *Methods of reducing ores otherwise than in blast furnaces*

L.37	Progress in the Manufacture of Pig Iron and Ferro-alloys with the Low-shaft Electric Furnace	H. Walde
L.48	The Electric Reduction Furnace	A. Ballón
L.49	Electric Smelting of Pig Iron	M. Sem
L.38	Making of Steel in Electric Furnaces	H. S. Newhall

Twelfth Meeting: 22 October–9 a.m. Item I.B.3. IRON ORE REDUCTION *Methods of reducing ores otherwise than in blast furnaces* (continuation)

L.45	Considerations on the Development of the Production of Iron	R. Durrer
L.36	Notes on the Production of Pig Iron	G. Bulle
L.40	International Research on the Low-shaft Blast Furnace	M. Allard
L.39	The Krupp-Renn Process	F. Johannsen

Thirteenth Meeting: 22 October–3 p.m. Item I.B.3. IRON ORE REDUCTION *Methods of reducing ores otherwise than in blast furnaces* (conclusion)

L.47	Production of Sponge Iron According to the Wiberg-Söderfors Method	J. Stålhed, presented by B. Kalling
L.42	The Basset Process for the Production of Pig Iron in Rotary Kilns	K. E. Jensen, presented by A. Mercier
L.46	The Rotary Kiln Processes for Sponge Iron, Developed at the Avesta Iron and Steel Works and the Domnarfvet Iron and Steel Works, Sweden	B. Kalling
L.44	Production of Sponge Iron in a Rotary Kiln at Temperatures Below the Fusion Point of the Material	R. C. Buehl

Fourteenth Meeting: 23 October–9 a.m. Item I.C.1. STEEL MAKING AND FINISHING *Comparison of Economics of different processes of steelmaking*

L.65	The Acid Bessemer Process	W. O. Philbrook
L.77	Basic Open Hearth Steelmaking Practice in the United States of America	William C. Buell, Jr.

Symbol ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Title*	*Author*
L.64	Economics of the Modern Acid Open Hearth Practice	G. R. Fitterer
L.51	Manufacture of Thomas (Basic Converter) Steel at Paz de Río, Colombia	E. Decherf

Fifteenth Meeting: 23 October–3 p.m. Item I.C.1. STEEL MAKING AND FINISHING *Comparison of economics of different processes of steelmaking* (continuation)

L.72	Acid Open Hearth Products and Their Specifications	G. R. Fitterer
L.54	Use of Phosphorus Ores for the Production of Pig Iron for Transforming into Steel by the Thomas Process	Società Ilva, presented by M. Allard
L.79	Perrin Process for Converter Steelmaking	M. Allard
L.73	Thomas Steel with Low Nitrogen and Phosphorus Contents	P. Coheur

Sixteenth Meeting: 24 October–9 a.m. Item I.C.1. STEEL MAKING AND FINISHING *Comparison of economics of different processes of steelmaking* (continuation)

L.55	Steel Production in Latin America	G. Bulle
L.56	The Balance of Materials and the Economic Comparison of the Different Steelmaking Processes	E. Krebs
L.53	Comparative Investment Costs for Different Steelmaking Processes	C. F. Ramseyer
L.61	Details of a Steel Plant for a Non-steel-producing Country	A. Mercier

Seventeenth Meeting: 24 October–3 p.m. GENERAL SUBJECTS AND COMMEMORATION OF UNITED NATIONS DAY

L.62	Approximate Comparative Production Costs and Investment Requirements of the Standard Blast Furnace, Electric Smelting Furnace, Sponge Iron Furnace and Tunnel Kiln Sponge Iron Furnace	P. E. Cavanagh
L.69	Desulfurization of Pig Iron with Pulverized Lime in Rotary Kilns	Bo Kalling
L.84	Some Notes on the Organization of Monclova Steel Works	P. M. Sada

Address in commemoration of United Nations Day by Mr. Juan Uribe Holguín, Minister of Foreign Affairs, Colombia

Acknowledgment on behalf of the Secretary-General of the United Nations by Mr. Raymond Etchats, Permanent Representative of the Technical Assistance Board in Colombia

L.74	Brief Account of Iron and Steel Producing Processes Used in Brazil	A. Lanari

Eighteenth Meeting: 28 October–9 a.m. Item I.C.1. STEEL MAKING AND FINISHING *Comparison of economics of different processes of steelmaking* (conclusion)

L.52	Selection of Steelmaking Processes and of Locations for Integrated Iron and Steel Works	Wm. A. Haven, presented by Mr. Buell
L.59	The Duplex Steelmaking Process at Monterrey	A. González B. and N. Morales, presented by A. González
L.60	The Acid Bessemer Process in Huachipato (Chile)	H. Canguilhem
L.57	Considerations Concerning the Choice of Electrical Equipment for the Iron and Steel Plants of Paz de Río (Colombia) and Chimbote (Peru)	R. L. Jung

Nineteenth Meeting: 26 October–9 a.m. Item I.C.2. STEEL MAKING AND FINISHING *Alternative methods to the rolling mill for finishing steel*

L.66	Continuous Casting of Steel by the Rossi-Junghans Process	T. Y. Wilson, presented by R. C. Buehl
L.67	Direct Reduction Yields–Variable Density Steels (Reprint from *The Iron Age*)	P. E. Cavanagh
L.68	Notes on the Ugine-Séjournet Extrusion Process	J. Séjournet, presented by P. L. Schereschewsky
L.81	Some Aspects of Labour Problems in the Iron and Steel Industry	International Labour Office, presented by J.-P. Després.

Twentieth Meeting: 26 October–3 p.m. Item I.C.3 STEEL MAKING AND FINISHING *Range of application of steels made by different processes*

L.75	Some Effects of Minor Elements on the Characteristics of Plain-carbon Steels	F. W. Boulger
L.70	Standardization in Relation to Control in Steel Production	G. Weston and R. L. Richards, presented by F. Saniter

Symbol ST/TAA/CONF.4/L. ST/ECLA/CONF.1/L.	*Title*	*Author*
L.76	The Control of Composition During Steelmaking	G. Weston and G. R. Bolsover, presented by F. Saniter
L.80	Specifications of the Products Made by the Compañía de Acero del Pacífico (Huachipato, Chile)	O. Herrera Silva, presented by H. Canguilhem
L.78	Notes on Specifications of Steel for Different Uses	F. Frick, presented by B. Leuschner

Twenty-first Meeting: 29 October—3 p.m. Item I.C.3. STEEL MAKING AND FINISHING *Range of application of steels made by different processes* (conclusion)

L.71	Thomas Steel Rails in France	J. Palmé
L.58	The Problem of Energy in Steel Plants	G. Périn
L.63	Construction of the Thomas Steel Plant at Paz de Río and Production Costs of Thomas Steel	E. Decherf
L.82	Foundry Iron by Recarburization of Steel Scrap	R. Jaramillo F., J. A. Prieto I., and Jaime Rudas, presented by J. A. Prieto
L.83	Consumption of Iron and Steel Products in Mexico	M. Aramburu

Twenty-second Meeting: 30 October—9 a.m. Item II.B. ECONOMIC PROBLEMS

L.87	Influence of Locational Factors on the Iron and Steel Industry in Latin America	ECLA Secretariat, presented by B. Leuschner and H. Yanes

Twenty-third Meeting: 30 October—3 p.m. Item II.B. ECONOMIC PROBLEMS (continued)

L.87	Influence of Locational Factors on the Iron and Steel Industry in Latin America (continuation)	
L.91	Influence of the Size of the Market on the Iron and Steel Industry in Latin America	ECLA Secretariat, presented by B. Leuschner and H. Yanes

Twenty-fourth Meeting: 31 October—9 a.m. Item II.A. FACTORS DETERMINING THE CONSUMPTION OF IRON AND STEEL IN LATIN AMERICA

L.86	Factors Influencing Iron and Steel Consumption in Latin America	ECLA Secretariat, presented by P. Vuskovic

Twenty-fifth Meeting: 31 October—3 p.m. Item II.C. TRANSFORMING INDUSTRY

L.88	Structure of the Steel Transforming Industry in Latin America	ECLA Secretariat, presented by A. Stakhovitch

Closing of the Meeting

1. Closing Address by the Chairman, Mr. Roberto Jaramillo Ferro, Paz de Río, Colombia.
2. Words of Acknowledgment by Mr. P. L. Schereschewsky, Chambre syndicale de la sidérurgie française, France.
3. Words of Acknowledgment by Mr. F. Saniter, the United Steel Companies Ltd., United Kingdom.
4. Farewell Address by Mr. R. C. Buehl, United States Department of the Interior, Bureau of Mines, United States.
5. Farewell Address by General E. de Macedo Soares e Silva, Companhia Aços Espeçiais Itabira, Brazil.
6. Closing Address by the Executive Director, Mr. B. Leuschner, ECLA Secretariat.

Chapter II

Specific problems of seven selected Latin-American countries

There is much which Latin-American countries can derive from the papers and discussions at the meeting of experts on the Iron and Steel Industry in Latin America. To avoid a detailed examination of the abundant material, it was decided to extract some of the more interesting subjects related to problems which occur with relative frequency in the region.

This analysis has been divided into two main parts. The first refers to some economic factors and the cost structure of the industry, without considering the specific questions confronting the different countries. The second deals with the particular problems of some countries or their existing plants, and presents a review of the information and discussions contributed by the meeting in connexion with these particular cases.

I. General considerations

There appears to be a close link between the consumption of steel products and economic development. Chapter I of Part Two[1] analyses the factors influencing iron and steel consumption in six countries of the region. The conclusion is that the majority of them have not been able to obtain the steel tonnages which they required during most of the past 25 years, but rather only the quantity which their capacity to import has permitted.

A knowledge of the size of the market is essential before deciding on the installation of a new steel industry, because the scale of operations substantially influences steel costs. It has been common practice in Latin America to base market studies on data for the immediately preceding years. This procedure tends to underestimate the market in cases where unsatisfied demand existed because of limitations in the capacity to import. The consequence of such erroneous estimates may be either the abandonment of the project, due to high production costs resulting from the small size of the plant, or the installation of units so small that they will again result in high steel costs and cause plant expansion to be necessary in the immediate future.

Chapter I of Part Two presents a methodology which allows a definite judgment of the size of the potential market of the Latin-American countries to be formed, relating it with readily available economic data, for example, national income, imports of capital goods, consumption of cement, etc. If the results indicate that the availability of steel products is below estimated potential demand, efforts to increase the supply become justified.

In Chapter II of Part Two, hypothetical steel production costs have been calculated for one plant located in each of the following seven countries: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. Except in Venezuela, the locations chosen correspond to sites where either steelworks are operating or construction is contemplated. This selection has simplified research. The fact that plants have been hypothetically placed in their respective locations does not imply that the advantages of the site chosen are superior to others which might exist in the country. The analysis covers plants of equal size and over-all design—250,000 tons of finished steel per year—and, in addition, all of them are assumed to have an equal degree of mechanization. The figures have been expressed either in values at 1948 dollar prices or in physical units. Following the same procedure, and with a minimum of significant data, it is easy to calculate for comparative purposes the hypothetical costs corresponding to any other site or project. In addition, the respective annexes explain in detail the methodology which has been followed.

The appreciable number of differing cases enables some preliminary comparisons to be made between certain factors which influence costs. Among those of major importance may be mentioned the composition of raw materials, the mileage from their source to the projected plant, the distance of the plant from local markets, wage rates, and so forth.

The capacity of a steelworks has an exceptional influence upon production costs. It is undoubtedly the one individual factor with the largest bearing on cost formation. Thus, in Chapter III of Part Two, hypothetical costs of other plants located in the same sites have been tabulated. Their capacity has been adjusted to the dimensions of the respective market in this paper, which also justifies the choice of size in each particular case. For three countries — Colombia, Peru and Venezuela — two plants of different size have been considered. The resulting 11 steel works (including Sparrows Point) provide capacities which vary between 50,000 and 1 million tons per year.

If identical plants as such were built in the seven Latin-American countries and on the Atlantic seaboard of the United States, the former group would on the average show lower production costs. This comparison, naturally enough, is not realistic because the plants at present existing in the United States have larger capacities and are more specialized. They therefore produce at even lower costs than the largest plants which can be justified by markets in Latin America. But the difference between current freight charges from North America to the region and from Latin-American steelworks to domestic markets should be added to the cost in the United States. This addition represents a margin of protection permitting the costs of many Latin-American plants to be lower on the domestic market than the "delivered cost" of steel from the United States.[2]

[1] Chapters I, II and III of Part Two were previously numbered documents L.86, L.87 and L.91.

[2] In order to provide a uniform basis of comparison throughout this analysis, reference will be made to an arbitrary figure which will be called the "delivered cost" of imported steel. It corresponds to the hypothetical cost of production of a million-ton per year plant, located at Sparrows Point, Maryland, plus the transport cost differentials of finished steel from this plant, and from imaginary Latin-American plants, to the markets of the region. The justification for this choice, and its comparison with average United States, European or Japanese steel costs and prices, appear in Chapter V.

A STUDY OF
THE IRON AND STEEL INDUSTRY
IN LATIN AMERICA

Volume I

Report on the meeting of the Expert Working Group held at Bogotá

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The above general conclusion does not apply in the particular cases of Peru and Venezuela. For the other countries it is applicable only in so far as the general assumptions of the calculation are fulfilled. In fact, it can be established that for each location there exists a minimum or critical size of plant, below which costs would be higher than the delivered cost of imported steel. The size of operation at this limit depends upon the quality of raw materials, haulage distance, wage rates, etc. In general, steelworks with lower assembly costs[3] and wage rates, are in a more favourable position to face competition, that is, the minimum size will be smaller.

Among the examples selected, two plants are close to the coast and have relatively low assembly costs and wage rates: those in Chile and Peru. The first has been scheduled for a production of 230,000 tons and the second for 150,000 tons per year. The latter appears with a higher hypothetical cost than the delivered price of imported steel; the Chilean plant produces at lower costs.[4] It can, therefore, be assumed that for Latin-American steel plants located close to the seaboard, and with reasonably low assembly costs, the "critical" size of the plant fluctuates around 200,000 tons of finished steel per year.

The bearing of certain cost factors on the value of this limit can be appreciated in the case of the 300,000-ton plant, hypothetically sited at Barcelona, Venezuela. The wage rate is about three times that prevailing in Peru and Chile and, combined with lower transport costs from the United States, the critical size of the plant in Venezuela is above 300,000 tons per year.[5]

Conversely, the critical size of a steelworks may be lower in some exceptional cases. This occurs, for instance, where substantial inland freight costs must be added to the normal maritime freight charges for imported steel. Such internal haulage costs increase the margin of protection above the figures represented by maritime transport. Situations of this type seem to exist in various steel consuming centres in Argentina, Brazil, Colombia and Mexico.

A specific example of this situation is the plant in Colombia at Belencito. Assembly costs are very low, since the site of the raw materials makes it one of the most favourable locations in the world. Moreover, one of the main consumption centres, Bogotá, is so situated that the transport costs for steel imports form substantial protection. As a result of the combined action of these two factors, the critical size of the plant falls under 100,000 tons of steel annually.

In addition, the approximate value of the required investment at 1948 prices is shown. Such needs are high. They vary between $491 per ton annually in the 50,000-ton plant at Chimbote, to $355 in the 850,000-ton plant which has been assumed to exist at San Nicolás.

These data show that steel production is an activity where capital intensity is high, and, since capital is a scarce production factor in Latin America, careful study is required before the decision to establish a new industry is taken.

[3] Mining cost of raw materials plus haulage costs to the plant.
[4] See Table 9.
[5] If the sales price for North American steel is taken into account, the balance alters in favour of Venezuela.

Capital is not the only scarce factor for the region. In many countries, the availability of foreign exchange to pay for imports represents a similar or even a worse problem. The findings are that the hypothetical plants under consideration would cause an average foreign exchange saving of 67% as compared with the delivered price of imported steel in the markets of the region. A special mention in the case of Argentina seems justified, since here the calculations are based on the supposition that 100% of the coking coal will be imported. Nevertheless, the saving in foreign exchange would be 55% of the delivered price of imported steel. Similar results are apparent for Peru, where even the high cost plant with a capacity of 50,000 tons a year would save 60% of the foreign exchange outlay.

The present analysis began by quoting the market research of Chapter I of Part Two which indicates that in Latin America a shortage of steel frequently exists in relation to potential demand. Such deficiencies generally result from limitations in the capacity to import. As shown in Chapter III of Part Two, however, domestic production, even on a very small scale, could well save at least 50% of the foreign exchange necessary to cover the delivered cost of imported steel.

On the other hand, it may be deduced from the same document that production under a certain capacity will result in a cost increase above the delivered cost of imported steel. Under favourable conditions, the limit of the capacity lies around 200,000 tons annually. Ignoring non-economic motives for erecting a steel plant, which may be of considerable importance in some cases, the decision as to whether it is advantageous to install a steel plant in a country with a smaller potential market than 200,000 tons annually, should therefore depend on the relative importance of conserving foreign exchange.

The aforementioned data and conclusions refer exclusively to steel plants based on classical production processes, including the reduction of the mineral by coke blast furnaces, the method used to produce almost all the current world output of pig iron. No consideration has yet been given here to the many methods of iron ore reduction other than the blast furnace. Among these, the following are the most important: electric blast furnaces, low-shaft furnaces, and the numerous so-called direct reduction methods, which produce in some instances a substitute for scrap and in others some variety of pig iron with special characteristics. At the technical sessions of the Bogotá meeting, considerable importance was attached to these methods since, in general, they need smaller investments and use a larger proportion of manpower, apart from not requiring coke which is, with a few exceptions, scarce in Latin America. At first sight, therefore, such other methods appear to be better adjusted for an adequate utilization of the production factors existing in the region, especially in the case of smaller countries. Further, the influence of the scale of operation is not as great as in plants where classical processes are employed.[6]

Two facts must be emphasized in relation to these alternative methods. First, their use does not eliminate

[6] The cost analyses tabulated in the technical papers have been prepared either on the basis of values or of physical units, but always in comparison with data corresponding to a classical plant. In this way, they can be linked to the rest of the analysis.

the need for steelmaking and rolling facilities and it is precisely the final stages of steel production which are most affected by variations in the scale of operation. Secondly, during the course of the discussions, doubts were expressed as to the suitability of installing such methods in countries with little capital, especially since few of these alternative processes have been tested on a commercial scale elsewhere.

The data gathered for these studies appear to indicate another fact. In countries such as Brazil and Mexico, consumption begins to grow with a much greater impetus with the initiation of domestic production of flat products. The possibility that this may constitute a more general rule seems to be corroborated by the fact that 60% of the steel used by the steel transforming industries in Mexico consists of flat products. Huachipato in Chile has included the making of flat products since it entered operation and the influence on the market has been remarkable.

A detailed analysis of markets in those countries contemplating a new steel industry would be useful to clarify the relationship between steel consumption and domestic production of flat products. To that effect, an analysis of the possibilities of growth in the steel transforming industry would have to be prepared in each case. Such a study has not fallen within the scope of this work.

II. The situation in the respective countries

1. Argentina

Argentina has the highest per capita consumption of primary steel products in Latin America, 57 kg. in 1947-49.[7] If Argentina's steel consumption is compared with the national income, the steel consumption per $100 of national income is lower than that of Chile, Brazil and Mexico. On the other hand, the comparison prepared in Chapter I of Part Two with various indicators of economic growth shows that steel consumption has been reduced for several years by limitations in the capacity to import.

Argentina's iron and steel plan envisages, as a first step, the annual production of from 700,000 to 750,000 tons. This figure is slightly lower than the actual consumption during recent years.

There have been many discussions as to whether the installation of an integrated steel industry in Argentina is justified. The adverse opinions have been based less on the disadvantage of investing large sums of capital and more on the assumption that a country devoid of coking coals would produce expensive steel.[8]

The figures in Chapter III of Part Two show that a plant with a capacity of 850,000 tons at San Nicolás would have almost identical delivered costs for finished steel and for imported steel,[9] even if all the coal for coke production were imported. According to these calculations, the San Nicolás plant would save 55% of the foreign exchange required to cover delivered price of imported steel.

As has been noted, the cost analysis was based on the assumption of coking coal imports. The only major coal formation yet to be found in Argentina, at Río Turbio in Patagonia, contains a highly bituminous non-coking variety. Although this fuel may be as expensive as imported coal at Río de La Plata ports, Argentina's main interest lies in economizing foreign exchange. Some papers presented at the Bogotá meeting may serve as a guide for research into the possibilities of producing metallurgical coke from this coal. Among such documents, L.9, L.10 and L.14 refer to a new coal cleaning process called "phase separation".[10] According to paper L.14, metallurgical coke is at present being produced from black lignites in Yugoslavia.

Document L.11 refers to methods employed in France to produce good coke from highly bituminous Lorraine coals. Several processes for coke production on a commercial scale, using up to 60% of such coals, are described.

Documents L.12, L.13, L.15 and L.17 describe various processes to improve the coking properties of unsatisfactory coals. There are for example, blends with low volatile coals; chars (low temperature coke) made of non-coking coals; asphaltites; asphalts and petroleum residues. All these appear among the methods which have been studied or applied in other countries. Research into such processes would be justified in relation to Río Turbio coal.

Finally, document L.18 refers to coke produced exclusively from asphalts or petroleum residues, a system employed in Argentina at the zinc refinery of Comodoro Rivadavia. These several alternatives justify the assumption that it will be possible to utilize a substantial proportion of Río Turbio coal at the San Nicolás plant.

If some imports are unavoidable, part of the coal might be purchased from Cerrejón in Colombia, an alternative which would result in lower freight charges. Conversely, the metallurgical centre envisaged for the south of the country near the Sierra Grande deposits as well as the relative proximity of the Río Turbio formation, of the Comodoro Rivadavia oil fields and of the sub-Andean asphaltites (if substantial deposits are still available) all justify a much closer investigation of the use of Río Turbio coal. In this zone, Argentine coal would be appreciably cheaper than imported fuel.

In relation to new metallurgical processes, two methods were discussed at Bogotá which could be applied to Argentina. They refer to the most common impurities contained in iron ore and fuels, namely phosphorus and sulfur. With regard to phosphorus, the European and United States' experts insisted upon the advantage of enriching the air of the basic converter (Thomas) with oxygen. This would be used (*a*) to obtain converter steels of greater purity, equivalent, according the latest research, to those made by the basic open hearth process; (*b*) to reduce investment and production costs of the plant; and (*c*) to provide means for re-smelting scrap

[7] In terms of finished products.

[8] Fortunately, the discovery of the rich iron ore deposit of Sierra Grande will eliminate the necessity of also importing iron ore, or, as an alternative, will avoid the long railway haulage necessary to transport ore from Zapla to the steelmaking centres.

[9] A comparison of the data regarding the size of plant shown here, and those of the Five Year Plan show that the latter only contemplates the production of 500,000 tons in San Nicolás, whereas the former is based on a capacity of 850,000. The conclusions are not affected in this particular case, since the steel plant contemplated in the Plan has a certain degree of specialization which reduces costs.

[10] This consists in grinding the coal finely in the presence of water and a small percentage of oil. The oil binds the coal particles together, whereas the ashes remain in suspension in the water. Subsequently centrifugal force separates the water from the coal oil pulp.

in the converter, at least in the proportion to which this material is at present being used in Latin America in open hearth furnaces.

As regards sulfur, which may become a problem in Argentina if petroleum derivatives or asphaltites are used for making coke, a new process was discussed. Professor Kalling, of Sweden, explained a new method of extracting sulfur from the liquid pig iron, by using lime in a closed deposit which is rotated at considerable speed. This deposit receives the taps directly from the blast furnace. The process is at present being utilized on a commercial scale at one steelworks in Sweden and is to be installed at several others. Even if the sulfur content of the coke were normal, such a process deserves study. It is particularly applicable to countries where fuel is expensive or scarce, since the possible operation of blast furnaces with an acid reaction would permit the use of lower temperatures and result in substantial coke economies.

2. Brazil

Brazil has the largest steel industry in Latin America. Production of finished steel in 1951 was 700,000 tons and projects are under way to increase it to 1.5 million tons or even more by 1955. Despite these substantial totals, per capita consumption is relatively low, smaller than in Argentina, Chile or Mexico.

Brazil has a long metallurgical tradition, since the rich ores of the state of Minas Gerais have been exploited for many years. Numerous charcoal blast furnaces are in operation, with capacities varying between 10 and 200 tons a day. (The latter is probably the largest blast furnace of its type in the world.) Since the 1920's, steel based on charcoal pig iron has also been produced. Volta Redonda has been operating since 1946, as the only integrated plant using coke blast furnaces; it mainly produces flat products, rails and heavy sections. Among the projects for new industries, or expansion of existing works, the plans for the Volta Redonda plant should be mentioned. In 1951, this plant produced 342,000 tons of finished steel with one blast furnace of 1,000 tons per day capacity. As the initial step in its expansion, a second blast furnace is being installed which it is hoped will provide an aggregate annual capacity of a million tons of steel ingots.

The Companhia Siderúrgica Nacional, owner of Volta Redonda, was mainly organized with government capital. In addition, there is also strong official influence in the Companhia Aços Espeçiais Itabira, which is gradually raising its capacity to a production of about 60,000-70,000 tons of special steels per year. The remaining output, mainly bars, light sections and tubes, is furnished by private enterprises. Of these, Companhia Belgo-Mineira is the most important. Belgo-Mineira, as well as many other firms of the private sector of the industry, is planning expansions which will jointly yield a considerable tonnage. In addition to existing steelworks, the erection of several new plants with individual capacities ranging from 200,000 to 500,000 tons per year has been contemplated.

In view of the considerable growth of consumption over recent years, it is probable that all these new facilities will find a ready market. Furthermore, in view of the specialization at Volta Redonda, over-all production seems fairly well balanced.

Of all the projects which have been mentioned, for the moment, only Volta Redonda will really take advantage of cost reduction through large-scale operations. The smaller plants will inevitably result as higher cost producers, but transport advantages and the manufacture of special products will add to their profitability.

The largest coking coal formation known in Brazil is at Barro Branco. It presents many mining and washing difficulties. Documents L.2 and L.5 explain in detail how these problems have been faced to date. The ash content of hand-picked coal ranges from 32 to 34%, and is reduced by washing to 15 or 16%. As a by-product, a medium quality coal is obtained with an ash content of 27 to 28%. The cleaner coal is used for metallurgical purposes and the dirtier fraction for boilers and furnaces.

Documents L.9 and L.14 which refer to coal cleaning through phase separation, may be applied to both fractions of Barro Branco coal. The possibilities of reducing costs of coal transportation, and blast furnace operation, through better washing of the cleaner fraction, should be investigated. Studies on the dirtier part of the coal should aim at increasing the proportion of the total which can be economically employed in the blast furnace.

Barro Branco coal has special sulfur problems, which are probably unique in the world. In the veins, the sulfur content is around 14%. Hand picking during extraction reduces it to 7.7%, and it drops to about 1.5 in the washed coal (which still retains 16% ash). The sulfur appears in the coal mainly in the form of pyrites and these are contained in the higher specific gravity fractions. If the phase separation method cannot eliminate the sulfur to the desired extent, the desulfurization method suggested by Professor Kalling might be considered.

It should also be borne in mind that Barro Branco coal is highly expansive and is a good binder during carbonization. Volta Redonda is at present using blends containing 30 to 37% of Brazilian coal, the remainder being imported high and medium volatile coals. This selection was necessary to prevent damage to coke ovens which might arise through excessive expansion of the coal. Document L.25 states that the Cerrejón coals in Colombia are high volatile fuels which in all probability are suitable for these blends. The use of Cerrejón coals would also reduce the distance from source to plant.

An analysis of problems of the Brazilian steel industry must include a mention of charcoal blast furnaces. This industry takes advantage of the high grade ores and natural forests of the state of Minas Gerais. The ores consist of different types of oxides with varying phosphorus contents and also differing physical properties and reactivity. These two reasons explain why many of the smaller plants practise selective mining of the ores, although it reduces productivity. It occurs mainly at those plants which have no open hearth furnaces but only Bessemer converters.

On the other hand, almost all the indigenous trees in the forests of Minas Gerais, as well as several varieties of recently planted eucalyptus, contain such a high proportion of phosphorus that the average content of the charcoal reaches 0.06%. Since all this phosphorus enters the pig iron, in addition to that contained in the ores, the difficulties increase.

Both in charcoal blast furnaces and in those using coke where phosphorus content might be high, it would seem justified to investigate the possibility of making basic converter (Thomas) steel using oxygen enrichment, as mentioned in the case of Argentina. Another solution would be to dephosphorize the steel through the use of special slags, such as those which are described in document L.79.

Brazil is richly endowed with iron ore deposits and even if selective mining continues there are adequate reserves for many generations. But the elimination of difficulties due to ores mined with improper selection would solve not only a problem related to current steel costs, but also that of the conservation of resources. Document L.33 describes the sinterization of iron ores for use in the Monlevade charcoal blast furnaces. If this method is employed jointly with processes for eliminating phosphorus, the solution can be found to many Brazilian steelmaking problems.

3. Chile

The influence of the creation of the Huachipato plant on Chilean steel consumption has been truly remarkable. If this fact is weighed jointly with the findings in Chapter I of Part Two, namely that Chile has long faced a scarcity of steel, it is easy to understand the difficulties of forecasting what the potential market will be in any given situation. It may be said, however, that when the present expansion of the Huachipato plant is completed, the capacity will probably cover the size of the market for several years and occasionally permit the export of small tonnages.

The main fuel problem for Chile is the need to import low volatile coals to improve the coking properties of domestic fuel. Chilean coal does not present complicated washing problems. But document L.27 discusses the petrographic composition of Chilean coal and analyses the effects of some of the constituents on the coking properties. If the conclusions of this document are accepted, it becomes necessary to separate the coal into three fractions, as in Brazil, for which operation there is no equipment in Chile.

The author of document L.27 states that the exclusion of certain petrographic elements through grinding and selective screening, followed by washing to eliminate fractions of higher specific gravity than 1.35, substantially reduce the requirements for adding imported coal of low volatile content before coking.

The substantial tonnages of imported coal, which the Chilean plant is at present using in its blends, are due to limitations in the country's mining capacity. According to tests, the minimum percentage of imported low volatile coal to produce good coke has been between 15 and 20%. On the other hand, documents L.13 and L.15 refer to the substitution of low volatile coal by chars in the coking blends. Both papers agree that the maximum favourable addition of char corresponds to 15% and that once this proportion is reached the gains resulting from the use of char diminish fairly rapidly. In addition, paper L.13 states that the influence of char in improving the coking properties of the coal is somewhat smaller than that of selected low volatile coal. The small gap which separates the optimum percentage of low volatile coals used at Huachipato from the 15% which constitutes the maximum acceptable addition of char, raises hopes that if the quality of the domestic coal is simultaneously improved through the suggestions made in paper L.27, imports of coal for coke improvement may eventually be entirely eliminated.

If such experiments do not prove fully successful, it should be recalled that, according to document L.2, low volatile coals are available in the Cauca Valley in Colombia. The substitution of Colombian for United States' coal would decrease the transport distance.

Chile faces two different metallurgical problems. Ores currently used at Huachipato are mined at El Tofo and have a phosphorus content which is slightly higher than is convenient for the open hearth process. This phosphorus, however, is lost during the refining process. Document L.54 presents information regarding a similar problem in Italy, where phosphoric ores (apatites) are added to the charge of the blast furnace, in order to produce a pig iron rich in phosphorus which can be used for the basic converter process.

Apatite reserves exist in Chile and the general scarcity of phosphorus in the soil and of phosphoric fertilizers seems to justify a study of this method. The resulting phosphoric slag would represent a by-product of the steel plant, thus reducing its costs. In the course of the discussions it was also mentioned that European countries, particularly Sweden, usually phosphorize the pig iron through addition of slags to the blast furnace.

Basic converter steels have a smaller range of application than basic open hearth steels at present produced in Chile. To ensure that steels from phosphorized pig iron should have similar ranges of application, it would be necessary to enrich the air of the basic converter with oxygen.

Another problem confronting the Chilean steelworks is the somewhat excessive titanium content of the iron ore. The Chilean technicians attending the meeting studied this problem in committees outside the regular sessions at Bogotá, with the co-operation of several metallurgists from outside the region.

4. Colombia

Although steel consumption has risen considerably in Colombia, its correlation with indicators such as national income, cement consumption and capital goods' imports (see Chapter I of Part Two) suggests the existence of a potential unsatisfied demand around 50 to 60% of the steel imports during recent years. The plant under construction at Belencito, smaller in capacity than Colombia's present consumption, thus appears to be too small. The possible negative influence on future production costs will partly be offset by rich natural resources which are well situated in relation to the plant. As a result Belencito may well show figures for assembly costs which are among the lowest in the world.

The initial plan for the steelworks excludes the manufacture of flat products for which there is a minimum market of some 50,000 tons annually. In agreement with the general conclusions in section I of this chapter, it would probably be advantageous to add production of flat products as soon as possible. Should the plant be enlarged to cover flats or a greater tonnage of bars, consideration should be given to oxygen injection in the converter to provide both lower costs and steels with a wider range of application.

Colombia has no fuel problems. It possesses the largest known coal reserves in the region, of widely varying chemical compositions and coking properties. The coke for Belencito will be manufactured from medium volatile coal which produces good coke without any blending and is mined less than 30 km. from the steelworks.

In the conclusions referring to other countries, reference has been made to the possibility of coal exports from Colombia and in fact real assistance could be given in this way to the steel industries of most other Latin-American countries. For instance an exhaustive study of the metallurgical coals which might be exported from deposits near the coast should be carried out, to determine the grades suitable for Volta Redonda, San Nicolás, Huachipato, the proposed Venezuelan plant and possibly for the Pacific seaboard in Mexico also. At a later stage further research should be made of the other vast reserves to develop the mines which could supply the required types of fuel, preferably from the sources close to the sea.

5. Mexico

Among the Latin-American countries whose markets were considered, Mexico shows the most rapid rate of increase in steel consumption during recent years. Of the various correlations used to approximate the potential demand, only cement consumption indicates the possible existence of a steel shortage. While technological changes may have contributed to reduce the consumption ratio of steel to cement, it appears that if any unsatisfied steel demand exists in Mexico, it is not substantial. The increase in steel consumption was accompanied both by greater imports and by a rise in domestic output. The former have therefore not grown fast enough to satisfy the increasing demand. Mexico's steel industry should, therefore, basically aim at reducing imports and at meeting the normal rise in consumption.

In past years, development of the steel industry has been greatly influenced by two factors. First, internal transport difficulties which have increased owing to the proximity of the two integrated steel mills. Secondly, there is an almost chronic shortage of coking coal and coke itself. The combination of these two factors has resulted in the two integrated plants working below full capacity and has given rise to a scrap smelting and rerolling industry, based on imports of scrap from the United States. In addition, a series of small steelworks which mainly smelt and roll domestic scrap are located in different parts of the country.

Each of the existing integrated steel plants has a capacity of nearly 200,000 tons of crude steel. If they are profitable, in spite of their reduced size, it is probably because they specialize in different products in such a way that their rolling mills correspond jointly to a larger capacity plant. In addition, for different reasons both show lower investment costs than those calculated in Part Two.[11]

Mexico is rich in iron ore deposits and has coal formations many of which are coking coals or coals suitable for coking through one of the special methods surveyed. Under such conditions the possibility is studied of overcoming transport difficulties and the overloading of the railway system which at present serves the integrated plants through the creation of new steel-making centres in other zones. The data contained in Chapter III of Part Two can act as a guide to the relative merits of such decentralization. They supply a methodology to determine possible cost reductions which would result from an expansion of the existing industry and, conversely, cost increases resulting from the installation of several small plants, the annual capacity of which would be well below the optimum limit.

As far as fuel is concerned, the coking coals from the Sabinas formation are among the few in Latin America which can be coked directly without blending. They contain a susbtantial ash content, approximately 32% as mined, and are subsequently washed to bring them down to some 15 to 16%. The resulting coke, therefore, contains about 20% ash. This figure is high, especially for a country where the transport system is overloaded. In contrast, Mexican iron ores are of a very high grade and it is therefore necessary for the coke to contain a certain ash content to ensure the required slag production. In addition, laboratory tests prove that Sabinas coals develop high expansion pressures during the carbonization process, to such an extent that according to experience elsewhere with similar coals they should destroy the oven walls. Since there has never been an accident of this type in Mexico, the theory has been advanced that the high ash content absorbs the excessive pressure.

All factors considered, it would be interesting for the Mexican industry to investigate the advantages of using the Kalling desulfurization method and of operating their blast furnaces with an acid reaction thus reducing coal consumption. A prerequisite for this purpose would be coal delivered with less ash, for which the washing methods suggested in documents L.9 and L.10 should be investigated.

With reference to new projects elsewhere in Mexico, document L.24 describes a process being developed in Peru to manufacture metallurgical coke from anthracite. Perhaps a similar process could be applied to Sonora anthracites, if it were decided to establish a new metallurgical centre in that area.

In Mexico, as in Chile, the addition of apatite to the ores of the Cerro de Mercado should be considered. It would allow the use of phosphorus slag as a fertilizer. The basic converter blowing of the steel might cause inconveniences regarding quality; however, this problem could probably be solved through oxygen enrichment. Before any investment is made in this direction, new specifications for this special type of Thomas steel should be studied and accepted.

The Banco de México is at present studying the establishment of small metallurgical centres in different parts of the country. One plan is to substitute the blast furnace by some other ore reduction process, in the hope of finding a method better adapted to domestic raw materials and less sensitive to smaller capacity operations. Papers referring to nine of these proposed methods were presented at the meeting, many of them containing data on their cost structure, either in values or in physical units. The assembled information therefore facilitates the study of the comparative advantages of these processes, as well as their contrast with the classic blast furnace.

Information regarding a Mexican plant to produce 12,000 tons a year of sponge iron, as a substitute for scrap, was of considerable interest to the meeting. This

[11] See also document L.84, which gives some details regarding the Monclova plant of Altos Hornos de México, S.A.

process uses the tunnel kiln, as developed in Canada, and results have been such that the annual capacity of the plant is being trebled. It is believed that this is the first plant in the world to employ this process; it is also the first one in Latin America to produce steel on a commercial scale by a process different from the blast furnace.

6. Peru

The project for a 53,000-ton steel plant, to be installed at Chimbote and using electric ore reduction furnaces, originated during the Second World War. The electric reduction system was chosen because the steel plant constitutes an integral element of the river Santa hydroelectric project. The original intention was to use a relatively small percentage of the total power and, given the flexibility of this type of reduction furnace, it was hoped that it could use surplus power whereby the unit cost of electric current would be very low.

For a series of reasons the construction of the hydroelectric plant has been delayed in such a way that the first unit to enter operation will roughly represent the aggregate requirements of the steel plant. As a result, power will not be as cheap as originally envisaged. On the other hand, there is a very good possibility of exporting pig iron to Argentina, taking advantage of regular return freights for wheat imports. Thus, a project is being studied to erect an orthodox blast furnace in Peru with a capacity of 180,000 tons. Some 53,000 tons of steel would be produced for domestic consumption and the remaining pig iron would be available for export.

If the method for estimating potential markets presented in Chapter I of Part Two is applied to Peru, the conclusion may be drawn that a plant of 150,000 tons annual capacity of rolled steel would be required.[12]

These data indicate that once the new plant enters production, a sharp rise in the market will result. To satisfy this larger domestic demand, enlargements will be necessary. It is thus indispensable to make an early start on the second step of the existing enlarged project, namely the installation of another blast furnace of the same capacity close to the iron ore deposits, in order to produce pig iron for export. In this way, cargo space could be fully utilized in both directions, northbound ships carrying ore and southbound ones fuel. In view of the time-lag to develop coal mining, an exact evaluation of the potential steel market appears to be justified.

The possibility of producing good metallurgical coke with Santa Valley anthracite is at present being investigated. For this purpose, a minimum proportion of petroleum derivatives should be added to the coal, since Peru's fuel oil output provides no excess production of asphalts beyond supplies for road building plans. The process being studied is new and is explained in documents L.10 and L.24. A pilot plant is being built in Peru at a cost of about $250,000. During the discussions at Bogotá, no doubts were expressed regarding the possibility of producing coke under this system. However, in agreement with the Peruvian technicians, it was deemed essential to conduct full scale tests of the new coke before designing an appropriate blast furnace. Many characteristics of the new fuel are unknown and there are no means to ascertain them except by direct experimentation.

Therefore, until these tests are complete, no choice can be made between the possible solutions, the 50,000-ton electric furnace plant, the anthracite coke blast furnace or a combination of the two. In the first case the steel furnaces would probably be electric also. Should a coke blast furnace be used, the quality of the ore would suggest acid converters, but oxygen enrichment should be considered to permit the finished steel to meet a wide range of application. This would reduce the amount of nitrogen dissolved in Bessemer steel.

7. Venezuela

In many ways Venezuela occupies a unique position in Latin America. With regard to steel and the installation of a steelworks, the salient features in comparison with the other six Latin-American countries are as follows: (*a*) no definite project exists for the construction of a steel plant; (*b*) wage rates are very high and represent a peak in Latin America; (*c*) Venezuela has no foreign exchange problems.

Points (*b*) and (*c*) will certainly be valid as long as a high level of industrial activity prevails in the world and no restrictions on the international trade in petroleum appear. This analysis refers exclusively to the present situation, since possible variations in world economic activities cannot be taken into account here.

In order to simplify the analysis, steel consumption in Venezuela may be divided into two almost equal groups: (*a*) the petroleum industry, which consumes about 250,000 tons of steel annually, primarily tubes, plates for the working platforms in Lake Maracaibo, structures, bars, etc.; and (*b*) the rest of the economy, which consumes an additional 250,000 tons a year. The latter, with an assortment similar to that found in most Latin-American countries, contains a high percentage of steel for the building industry. To these tonnages, it is necessary to add much steel contained in durable consumer goods, capital goods, etc., which is outside the scope of the present study.

Consumption is concentrated in three main areas close to the coast. The region around Lake Maracaibo accounts for most of the steel consumption of the petroleum industry. A smaller proportion of this industry's aggregate requirements is used at the Oriente oil fields, in the states of Monagas and Anzoátegui. Finally, the cities of Caracas and La Guaira and the surrounding zone consume most of the steel outside the petroleum sector.

Venezuela does not face the serious exchange problems which limit the capacity to import elsewhere. Nevertheless, if the standard correlation is applied to Venezuela, there is an unsatisfied demand in the non-petroleum consumption sector which may total some 60,000 tons.[13]

Among the natural resources available for steel production in Venezuela the following should be noted:

(*a*) There are very large reserves of the highest grade ore, mainly hematites, which are situated to the south and east of the Orinoco close to its junction with the Caroni river. Two deposits have been granted as concessions to large steel companies from the United States. Ports, mining facilities, ships and eventually the

[12] As an example of the additional consumption to increase the demand, more barbed wire for the Sierra zone would encourage a substantial increase in the sheep population.

[13] These findings were the reason for the inclusion of two plants for Venezuela: one of 200,000 and one of 300,000 tons.

dredging of the Orinoco are being organized. The ore which Venezuela might need for domestic steel production could be obtained from these sources through a system similar to that utilized in Chile for ores from El Tofo.

(*b*) Some coal deposits now being exploited on a small scale are located close to Barcelona on the Atlantic coast, between La Guaira and the mouth of the Orinoco. Naricual is the largest of them and although they are reputed to be non-coking, they may be interesting since they are situated between the iron ore deposits and the steel markets and further, because of their vicinity to the asphalt deposits and to the petroleum fields where the heaviest Venezuelan oil is found. Both these substances may be used as a binder to improve the coking properties of coal, as explained in documents L.11, L.14, L.15, L.17 and L.18. It might be possible, therefore, to base perhaps 80% of the fuel supply of a Venezuelan steel plant on this coal.

An interesting alternative arises from information presented by the Colombian participants, namely that the Boyacá formation continues in all its width up to the Venezuelan border. It may be thus anticipated that the seam continues into Venezuela to the south-west of Lake Maracaibo from the city of Cúcuta in Colombia. Research into this formation by Venezuela would seem especially justified if it is recalled that the direct coking coal to be used at Belencito belongs to this formation, and that it also includes a substantial variety of other coals.

(*c*) Regarding hydro-electric resources, preliminary studies are complete for a large power plant at the confluence of the Caroni and Orinoco rivers, with a potential supply of one million kWh. It is evident that this project will not materialize if other uses for the power, in addition to the possible consumption of the steelworks, are not developed. Some of the discussions held and documents presented at the meeting may prove useful as a means of evaluating the comparative advantages of coke and power, based on individual relative prices. As a first approximation, it was stated that an electric reduction furnace should only be considered where the price per kWh. is equivalent or smaller than one-fifth or one-sixth of the price of one kg. of coke.

(*d*) Venezuela obtains from both of its main petroleum districts substantial supplies of natural and petroleum gas, the majority of which is at present lost. Consideration has been given to the installation of a small plant using this natural gas for some system of direct reduction. Another method to which reference was made during the meeting, would be to design a special blast furnace into which petroleum gas would be injected above the air tuyeres. The theory is that this gas should perform most of the heating of raw materials, in the same manner as electric power in the electric reduction furnace. It should also assist in the indirect reduction of the ore in the upper part of the blast furnace. No blast furnace of this type is at present known to be operating on a commercial scale, but if it could be constructed, a substantial economy in coke would be effected. The best possible location for a steel industry using such gas would be near the Orinoco, in the vicinity of the iron ore deposits and a little more than 100 km. from the eastern oil fields.

(*e*) As a possible substitute for coal in coke production, or as a binder to improve the quality of the coke, asphalt is available in several substantial lakes on the left bank of the Orinoco. In this area, there are also petroleum fields producing very high density crudes, whose prices in world markets are lower than those for normal oils. Document L.18 describes an oven being used in Argentina to make metallurgical coke (for the zinc industry) which employs petroleum residues as raw material. During the discussion of this document, the Venezuelan participants stated that exploitation of the asphalt lake is very difficult on account of the viscosity of the material at prevailing temperatures. Furthermore, in utilizing heavy crude petroleum, they estimated that if carbonization costs are added to export prices for the crudes, the cost of the resulting coke would be higher than that of a coke manufactured from imported coals.

The possible utilization of natural asphalt, which would offer many advantages, depends only on the development of a suitable method for its extraction. During the discussion of carbonization problems, it was stated that coke ovens are available with either vertical or horizontal retorts which permit the manufacture of coke from coal, from petroleum residues, or from blends of both in any desired proportion.

Another technical problem arising from petroleum derivatives as a raw material for metallurgical fuel is their high sulfur content. In the previous sections, reference was made to a new desulfurizing process, using lime. Perhaps this process could solve the sulfur problem arising from asphalt and petroleum products. Since coal and petroleum products can supplement or substitute each other in the manufacture of metallurgical coke, every advantage can be gained from intensive research in co-operation with the petroleum industry. Initially, the countries which might benefit most from such research would appear to be Argentina and Venezuela.

(*f*) In addition to natural resources, and as an added advantage for steel production, mention should also be made of the empty cargo space in ships returning from the United States to Venezuela after delivering iron ore exports. It might be feasible to use the empty cargo space for transporting coking coal to Venezuela at low freight rates. This factor would, of course, influence the location of any projected steelworks.

Although, for reasons to be outlined later, the classical blast furnace process received little attention in the different studies undertaken in Venezuela for the solution of the steel problem, some aspects will be examined here. This process was the only one used for investigating cost structures. Of the two possible types of fuel which were studied for Venezuela, only the use of imported coal will be examined here, since the output of coke based on petroleum depends upon research which is still incomplete.

In Chapter II of Part Two, the price of imported coal delivered to plant in Venezuela was estimated at $13.48 per metric ton, of which 0.60 cents represent handling in the country. If domestic fuel is used instead of imported coal, to equal the above price its cost for coal washed at the mine could be around $10 per ton. This implies that only some $6 per ton could be devoted to wages if the price for imported coal is not to be exceeded.[14]

If the wage rate of $1.30 per hour, used throughout Chapter II of Part Two for Venezuela, is applied to the

[14] The difference, compared with the price of imported coal, was covered by transport, handling, etc.

mining operation, it becomes evident that coal can be obtained at this price only if the mine is sufficiently mechanized to permit an output per man per day, of $8 \times 1.30 : 6 = 1.73$ tons. These production figures are obtained with ease in the United States, but Latin-American mines usually present difficult geological conditions and are less mechanized. In Mexico, the production per man per day is around 0.9 tons; in Chile 0.6, while Brazil shows even lower figures.

The narrow margin of labour costs appears hard to meet and suggests that, when a Venezuelan coal deposit is being investigated for the production of coking coal, the study should include mining facilities and obstacles as well as the mineral properties. It is only thus that an adequate evaluation can be made of the comparative advantages of domestic coal production, of foreign exchange economies, of employment of domestic manpower and of regular supplies as measured against a possible price increase in raw materials.

In Chapters II and III of Part Two, a hypothetical plant located at Sparrows Point on the Atlantic seaboard of the United States was used as the basis for comparison with plants hypothetically situated in Latin America. From Table 42 it may be seen that assembly costs including scrap, would amount at Barcelona to $27.6 per ton of steel compared with $26.9 at Sparrows Point.[15] Therefore, if the basic assumptions used in this paper are sustained, a plant in Venezuela appears to show almost exactly the same assembly costs as at Sparrows Point.

On the other hand, Venezuela enjoys the benefits of lower transport costs to the domestic market. The value of this advantage has been estimated as being equivalent to $10 per ton, this amount constituting a margin of protection for the Venezuelan industry. But the advantages of mass production and the possibilities for specialization in the United States should be borne in mind, since they result in higher labour productivity and lower investment costs at steelworks with a large capacity.

At the beginning of this chapter, reference was made to an arbitrary basis of comparison entitled "delivered steel costs". Since selling prices in the United States during the base year 1948 were considerably higher than hypothetical production costs at Sparrows Point, the comparison of Latin-American costs with delivered costs of imported steel therefore involves a safety margin.[16]

Table 1 shows that costs would be slightly higher at even the largest size plants—which exceed the capacity of the Venezuelan market—than the delivered cost of imported steel. In other words the disadvantages in Venezuela from wages and capital charges in plants of such a size are too large to be offset by the lower differential in transport costs.

If, instead of basing the comparison on delivered costs, it is founded upon the selling price in the United States in 1948, plus the transport cost differential, the situation is modified substantially. In this case, profits in the United States are included and raise the possible margin of difference above Barcelona output costs from $10 to $34. This increase provides protection for even a small plant producing 200,000 tons annually, but it eliminates the safety margin.

Table 1

COST DIFFERENTIALS IN PLANTS OF VARIOUS CAPACITIES AT BARCELONA IN RELATION TO PRODUCTION COSTS OF A MILLION-TON PLANT AT SPARROWS POINT

(In 1948 dollars per ton of steel produced)

Plant capacity at Barcelona (thousand tons annually)	*Wages at Barcelona*[a]	*Capital charges at Barcelona*[b]	*Increase over Sparrows Point costs*		
			Wages[c]	*Capital charges*[c]	*Total*
50	49.79	44.20	36.49	21.50	57.99
150	33.41	42.20	20.11	19.50	39.61
200	26.91	40.60	13.61	17.90	31.51
230	23.01	37.40	9.71	14.70	24.41
300	20.80	34.70	7.50	12.00	19.50
430	18.07	33.20	4.77	10.60	15.37
716	15.73	30.80	2.43	8.10	10.53
850	15.60	31.90	1.70	9.20	10.90

Source: Economic Commission for Latin America.

[a] Obtained by multiplying the man-hours per ton in Table 45 by the Venezuelan wage rates.

[b] Obtained by applying a total of 9% for interest and amortization to the investment figures per ton annually in Table 46.

[c] Difference between columns [a] and [b] minus the respective costs of a million-ton plant at Sparrows Point.

Returning to Table 1, it may be seen that while cost differences arising from capital charges in the smaller plant only duplicate the figures of the larger one, the cost differentials due to wages vary twenty-fold. An analysis of the data shows that the rolling mill is responsible for most of the variations in productivity and in labour costs.

In view of the high Venezuelan wage level, alternative processes to the rolling mill should be carefully considered for this country. Documents L.66 and L.68 refer to equipment and methods of this type already being used on an industrial scale in the United States, France, and the United Kingdom. For the present there seem to be two difficulties. First, they are not yet sufficiently developed to permit their establishment in a country where mechanical resources are inadequate. Secondly there are still many limitations to the type and weight of the shapes which they can produce.

Unorthodox methods for iron ore reduction have, in general, the disadvantage for Venezuela that they require more labour per ton of production than the classical processes. If installed in Venezuela, they would produce at even higher costs than those tabulated in Table 1. A possible exception to this general rule might arise from the process described in document L.67. This is still under study and the inventor stated at Bogotá that its development would take one more year, prior to which no new information could be disclosed.

There are two other alternatives for Venezuela which should also be explored. The first consists of producing pig iron for export on a large scale. This could eventually be used to cover part of the shortage of ferrous material which is developing in Europe, especially in Italy. If such a plan became a reality, the cost of pig iron for Venezuela's industry could be considerably reduced. The second alternative, also aiming at the creation of a broader market, would be to add a large scale industry for the piping required by the petroleum companies to the steelworks proposed for Venezuela. Part of the Latin-American market could then be supplied from this output.

[15] Sparrows Point with Venezuelan ore; Barcelona with United States' coal. Plants adjusted to size of markets.

[16] This margin seems indispensable, because, under certain circumstances, steel industries of exporting countries might face a situation whereby it would be more advantageous for them to export at cost price, than to reduce production or to close down.

Chapter III

Technical findings relating to metallurgical fuels

I. Foreword

According to available information, Latin America has always been considered a region rich in high-grade, fine quality iron ores, but is generally poor in coal reserves, particularly those suitable for producing good metallurgical coke.[1] In drawing up the agenda for the Bogotá meeting the study of coal and coking problems was thus emphasized.

The relative scarcity of coking coal has been reflected in the existing and projected iron and steel industries of Latin America. Very serious thought had to be given to the selection of locations for steelworks, because long haulages of fuel have an important bearing on assembly costs. Chapter II of Part Two analyses the influence of transport on assembly costs in selected examples of plant sites in seven Latin-American countries.

Table 2 shows the fuel haulage required per ton of finished steel. Loading and unloading operations, transfers, inland waterway and sea transport have all been converted to the number of ton-kilometres at which a ton of coal could be transported by rail at equivalent cost. The table also shows the source of the coal in percentages.

Table 2

SOURCE OF COAL REQUIRED TO PRODUCE ONE TON OF STEEL AND TRANSPORT INVOLVED

Plant	Source of coal: Domestic (Per cent)	Source of coal: Imported (Per cent)	Transport (railway ton-kilometre equivalents)
(H) San Nicolás, Argentina	—	100	2,185
(E) Volta Redonda, Brazil	30	70	1,599
(E) Huachipato, Chile	85	15	352
(H) Belencito, Colombia	100	—	39
(E) Monclova, Mexico	100	—	126
(H) Chimbote, Peru	85[a]	15[b]	219
(H) Barcelona, Venezuela	—	100	586

Source: Economic Commission for Latin America.
(E) Existing plant.
(H) Hypothetical plant.
[a] Santa valley anthracite.
[b] Asphaltic pitch.

Except in Colombia, transport to all plants is excessive when compared with the distances in Belgium, Luxemburg, the United Kingdom, the north of France, the Ruhr Basin, Pennsylvania, etc. Moreover, in only two of the seven Latin-American countries was it possible to base the supply entirely upon domestic coal, although the region encounters great difficulties in obtaining foreign exchange.

There were thus two concrete economic objectives at the Bogotá meeting in connexion with fuel problems: (*a*) to provide information to enable an existing or projected Latin-American industry to reduce its fuel transport costs; and (*b*) to direct studies and research towards replacement of imported fuels by domestic or other Latin-American fuels. To serve these purposes, a number of widely-differing solutions may be adopted. They range from better coal washing, to prevent unnecessary haulage of inert matter, to total or partial replacement of coal by other fuels. Through blends the coking properties of coals can be substantially improved, thus permitting the use of some coals which are at present rarely employed, if at all, for metallurgical purposes on account of their poor coking properties.

During the meeting the contributions of Latin-American participants were mainly confined to descriptions of fuel resources and the coking properties of some coals from the region. Experts from other countries, however, usually explained the methods adopted and the research being conducted in their respective countries. Frequently these were related to specific conditions in Latin America or to coals similar to those found in the region.

One of the exceptions to the preceding general rule is document L.2, presented by Mr. Thomas Fraser of the United States Bureau of Mines. In the course of several technical assistance missions to the region, he has probably become one of the persons best acquainted with Latin-American coal problems.

II. General summary of findings

1. Coal reserves in Latin America

According to document L.2, European geologists, who first explored the coal reserves of the region, classified coals according to their geological age and relegated those of Asia and the Western Hemisphere to an inferior category. More intensive study of these formations has shown considerable variations in the coals and that their characteristics range from lignites to anthracites, depending upon the extent to which local tectonic action has influenced the rate of carbonization. The wide extent of coal-bearing formations in the Andes removes all doubt as to the presence of substantial reserves throughout the region. The broad variety of coals found in the few areas so far investigated indicates that sufficient coking coal can be found in Latin America to supply the modest requirements of the iron and steel industries at present planned.

Latin-American experts presented a number of papers at the meeting describing deposits and mining methods. In other cases information on the washing or washabil-

[1] *World Iron Ore Resources and their Utilization* (ST/ECA/6, United Nations Publication, Sales No. :1950.II.D.3), makes the following statement on this subject: "Latin America is particularly deficient in coal resources; Mexico alone is known to have good coking coal. Some coals of Chile and Colombia are apparently of coking quality, though of relatively poor grade; Brazilian coal is even poorer. The coking quality of Peruvian coal may have been established recently. Elsewhere, Latin America appears to be totally devoid of coking quality coals. Large-scale utilization of Latin-American iron ores for the production of pig iron and steel must therefore depend on large-scale imports of coking coal or, alternatively, on techniques that do not require any form of coal for reducing iron ore."

ity of the region's coals was submitted.[2] With the exception of Colombia, this information was almost exclusively limited to coals for use in the respective iron and steel industries. In the case of Colombia, reference was made to coals which could be exported for the same purpose to other Latin-American countries. Although some of these papers referred to more than one item on the agenda, only those sections relating to coal formations will be discussed at this stage, leaving coking and washing to be examined later.

Document L.5 mentions some 20 million tons of coking coals in the state of Paraná, Brazil. This coal is not being used owing to its high sulfur content, which being in organic form cannot be eliminated.[3] The Santa Catarina area supplies all the metallurgical coal mined in Brazil from Barro Branco. This deposit consists of narrow seams, separated by rock intrusions of varying thickness and is therefore expensive to work. The hand-picked coal averages a content of 32 to 34% ash and almost 8% sulfur. Although the ash is reduced through washing to 15 to 16% and sulfur to 1.5%, the elimination of these impurities increases costs. Reserves of this type of coal are estimated at 500 million tons. In view of their exceptional coking properties, they can be used as a blending material to improve poorer fuels. This is the explanation, despite the difficult features of the deposit and the washing problems, of Mr. Fraser's statement in document L.2:

> "Notwithstanding all these technical difficulties, the phenomenally strong coking quality of this coal, its adequate reserves, and its strategic location with respect to the tremendous deposits of exceptionally high-grade iron ore of Brazil, may well place the Barro Branco coal among the most important coking coal reserves of the world in decades to come."

Document L.6 describes the metallurgical coal of the Gulf of Arauco in Chile. This fuel has a low sulfur and ash content and is easy to wash. It has two disadvantages: firstly, its coking power is weak and requires the addition of 15 to 20% of low volatile coal (which has not yet been found in Chile); secondly, these are submarine mines so that operating costs are fairly high. The mine face is at present from 4 to 6 km. off the coast. Aggregate reserves have been very conservatively estimated at some 260 million tons, of which 55% is composed of coking coals and the remainder cannot be used as such. There are also extensive coal deposits of poorer quality in Chile, ranging from sub-bituminous to lignites,[4] which are unsuitable for use in the iron and steel industry. These latter reserves, according to some estimates, raise the total to nearly 4,000 million tons.

Document L.8 refers to the coal found in Mexico. It describes deposits of the Sabinas and Saltillito formations in Coahuila, which at present supply the entire consumption of the Monterrey and Monclova plants. Reserves are estimated at between 1,250 and 2,000 million tons, almost all of which is good coking coal. The ash content of run-of-mine coal ranges between 22 and 32%, and is washed to 15 or 16%. The sulfur content is low, ranging from 1.1 to 1.3%. This coal produces excellent coke without blending. Reference is made to the Oaxaca deposit, situated some 350 km. south of Mexico city, and relatively close to iron ore deposits. Coal reserves of varying volatile matter content are here estimated at some 100 million tons, some of which appear to have good coking properties. This fuel has a high content of finely dispersed ash, which poses serious problems for the conventional washing processes.[5] Finally, this document describes deposits of anthracite coals in the state of Sonora, which are estimated to contain not less than 22 million tons with about 10% of ash. Since there are also high-grade iron ores in this State, consideration has been given to the establishment of a new steelmaking centre to use these anthracites for the blast furnace, either directly in lumps or pressed into briquettes.[6]

Document L.7 estimates Colombia's total coal reserves at 40,000 million tons, of which 1,900 million have been found within a radius of 40 km. from the steel plant at Belencito. Owing to differences in tectonic action in various parts of this formation, coals are found with widely varying properties. They range from highly bituminous non-coking coals to low and medium volatile coals with strong coking characteristics which could be used as blending materials. A mine with a reserve of some 200 million tons of directly coking coal has been opened close to the iron ore deposits at Paz de Río. This fuel is easily washed to obtain a coal with 8 to 9% ash, with sulfur under 1% and with 85% recovery. Because of its geographical location and high transport costs, this fuel can only be used in Colombia for the moment. In the Cúcuta area, these formations appear to extend into the state of Zulia in Venezuela. The seams contain a large variety of coals and it would not be surprising if Venezuela could also find good coking coal deposits in that zone.

Document L.24 describes Colombian coals from the Cauca Valley, in the area close to Cali, with reserves estimated at some 400 million tons of recoverable coal. This fuel normally has a fairly high ash content, and would require washing. The seams contain widely varying types of coal with different quantities of volatile matter. Incidentally, the samples from some mines correspond closely to the famous Pocahontas No. 3 vein in the United States, while others are sub-bituminous non-coking coals.

It was revealed during the discussions that Colombia is taking steps to develop the mining and preparation of these coals for export. Chile's iron and steel industry might be a purchaser of fuel of the high-coking type. Similarly if Mexico should build an iron and steel centre to the southwest of the Federal District, based on Oaxaca coals, a market might be established there for some varieties of coal from the Cauca Valley.

Document L.25 describes Colombian coals from Cerrejón, in the Guajiras peninsula on the Caribbean sea. These are high bituminous non-coking coals with both a low ash content (from 2 to 6%) and a very low sulfur content. Reserves are estimated at some 36 million tons. Brazil might gain by substituting Cerrejón coal for up to

[2] These papers were: L.5, Brazil; L.6, Chile; L.7, Paz de Río zone, Colombia; L.8, Mexico; L.10, Washing of Santa anthracites, Peru; L.23, Cauca Valley, Colombia; L.25, Cerrejón, Colombia.

[3] The reference to desulfurization made later in this paper entirely modifies this situation, so that this coal might perhaps be added to the potential reserves for steelmaking.

[4] According to the classification of the American Society for Testing Materials.

[5] It is likely that the method of washing coal by phase separation described in document L.9 could be used successfully here, perhaps in combination with the manufacture of coke briquettes using the Convertol process outlined in document L.24.

[6] The Convertol system, referred to in document L.24, could perhaps also be used successfully in this case.

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50% of its current imports, thus reducing the distance from mine to plant. Similarly, if Venezuela cannot find coking coals, some of its requirements could be covered by this Colombian coal, coking of which might be achieved through blending.

Descriptions of coal reserves in Argentina, Peru and Venezuela were not presented to the meeting of experts. In Argentina, reserves were discovered and have recently entered operation at Río Turbio in the south. They are supposed to contain coal which is difficult to coke, although the results of research have not yet been made public. In Peru there are probably not less than 2,000 million tons of anthracites of varying grades; reference to the coking properties and other uses are outlined in documents L.10 and L.14. Finally, Venezuela has proven reserves at Uaricual, in the Lake Maracaibo area, and abundant seams, probably connected with the Boyacá reserves in Colombia, which have not been studied in any great detail.

On the basis of this information it appears that Latin America's coal reserves are by no means negligible. Colombia is undoubtedly the most richly endowed country in this sense and could well supply several Latin-American countries with the appropriate coals for their blends. Needless to say, the various suggestions mentioned here must be submitted to the essential test of research which alone can determine the real possibilities. (The potential objectives, should all the tests prove successful, would be those indicated in Table 3.)

Table 3

POSSIBLE COMPOSITION OF FUEL SUPPLIES PERMITTING THE GREATEST USE OF REGIONAL FUELS AND CONSEQUENT MILAGES

Plant	Possible composition (per cent)		Transport: According to Table 2	Transport: According to possible composition
(H) San Nicolás, Argentina	Cerrejón, Colombia	40	2,185	1,940
	Pocahontas, U.S.A.	60		
(E) Volta Redonda, Brazil	Domestic sources	30[a]	1,599	1,300
	Cerrejón, Colombia	70		
(E) Huachipato, Chile	Domestic sources	85[b]	352	258
	Cauca, Colombia	15		
(H) Belencito, Colombia	Domestic sources	100	39	39
(E) Monclova, Mexico	Domestic sources	100	126	126
(H) Chimbote, Peru	Domestic sources	85[c]	219	219
	Venezuela	15[d]		
(H) Barcelona, Venezuela	Domestic sources	100[e]	586	632
(H) Barcelona, Venezuela	Domestic sources	30[d]	586	419
	Cerrejón, Colombia	70		
		Average	729	614

Source: Economic Commission for Latin America.
(E) Existing plant.
(H) Hypothetical plant.
[a] Barro Branco.
[b] Gulf of Arauco.
[c] Santa valley anthracite.
[d] Asphaltic pitch.
[e] Zulia.

In addition to reductions in the transport shown in Table 3, fulfilment of this possible composition of fuel would ensure a more reliable supply and would increase intra-regional trade by some $12 million in terms of 1948 prices.

2. Coal washing

This part of the meeting reviewed present or planned coal washing practices in the iron and steel industries of the region, discussion being mainly based on information provided by Latin-American participants. Some experts from outside the region, in general those connected with engineering firms which construct or design washing apparatus, described equipment, almost all of which is already in industrial operation, and referred to its possible application to Latin-American coals. There were two exceptions to this general rule. First, a description was given in document L.1 of the mathematical formula known as the "coefficient of imperfection" which is used in France to select the type of machine best suited for washing coals which present difficult problems of separating various fractions of different specific gravities and ash contents. Secondly, documents L.9 and L.10 refer to a new washing process known as phase-separation.

The discovery of the so-called "coefficient of imperfection" was first announced at the Congress on Coal Preparation at Paris in 1950. Subsequent studies and practical corroboration have confirmed the theory's validity. It consists, briefly, in discovering that each washing process can be characterized by a certain coefficient related to the deviation of the particles and independent of the type of coal or the density adopted for the separation.[7] From the average results which formed the basis for establishing the coefficients for each type of apparatus, calculations can be made which are of undoubted industrial value. On the one hand the sizes which provide the maximum yield can be determined and on the other the yields in each of the various possible processes can be compared in relation to the washing cost.

These calculations were evolved in Europe in view of the general fuel shortage, which obliges seams to be mined that would not be worked in countries with a better supply. It is thus essential to clean coals whether or not they are simple to wash and the separation is not confined to two fractions alone (coal and tailings) but to two or more coal fractions with different ash contents in addition to tailings.

The dispersion of the ash determines the ease with which the coal can be washed. In some cases, seams consist of two clearly different fractions, one of combustible matter with very little ash and the other with a

[7] The lower the deviation of the coal particles which pass to the ash fraction, the higher the yield; inversely, the lower the deviation of particles rich in ash which fall within the coal fraction, the cleaner the product.

high ash content and little coal. Such coals are easy to wash and comprise those generally mined in the United States, Germany and the United Kingdom. "Integral" washers can be used for them advantageously since they treat run-of-mine coal, that is, without separating the various sizes and thus yield only coal and tailings.

In other coals, the ash is finely and unevenly dispersed, so that there is a whole range of intermediate products between clean coal and tailings. In these cases, in order to obtain a suitable fuel, it is necessary: (*a*) to separate two or more fractions having different ash contents (and therefore different specific gravities), and seek suitable applications for each fraction, or (*b*) to crush the larger fragments with excessive ash to sizes in which a reasonable proportion of acceptable coal particles appear. A combination of these two processes is a common feature in Europe. In Latin America, Brazil furnishes a typical example, since coal is separated into metallurgical fuel, steam fuel and tailings (see documents L.2 and L.5).

Only the metallurgical coals found in Chile, Colombia and Peru are easy to wash and can be separated efficiently into two fractions. Those in Argentina, Brazil and, to a smaller degree, Mexico, are difficult to clean. Therefore, to use the limited coking coal resources of the region to the maximum, it is often necessary to resort to complicated washing methods, including a substantial amount of crushing and search for other uses for the low-calorie coal.

Document L.27 analyses the influence of coke ash constituents on the blast furnace costs and yield. The theory, supported by operational statistics for the Huachipato blast furnace, demonstrates that the small quantity of ash which appears in coal fractions with a specific gravity over 1.35 reduces the coking quality of the coal. Similar petrographic studies—if extended to other metallurgical coals in Latin America—might well prove the advantage of extracting certain of the ash components. It may thus be indispensable that even coals classified as easy to wash should be separated into more than two fractions.

Documents L.1 and L.3 establish that there is more precise separation of the fractions when coals over 8-10 mm. are washed by heavy media apparatus. Document L.4 describes one of the latest designs which can be adapted for producing two or three fractions.

For grains between 0.5 and 10 mm., documents L.1 and L.3 recommend jigs with filter beds as the best solution. If separation at high density should be required, then a feldspar bed is recommended (specific gravity 2.7). For separation at lower densities ceramic cubes (specific gravity 2.2) are sufficient. For grains under 0.5 mm. either froth flotation or cyclones can be used up to specific gravities of 1.75.

Two different trends in the treatment of fines appear to exist in Europe. The first is apparent in the United Kingdom and the Netherlands and consists of finding ways to float ever-larger grains. The second, predominating in France and Germany, is a tendency to improve mechanical washing in order to achieve efficient separation with ever-finer grains.

Documents L.9 and L.10 refer to a new coal preparation process entitled "phase separation". It consists of grinding the coal finely in water and some 3 to 4% of oil. The oil adheres to the clean coal surfaces, thus forming a pulp, while the water tends to disintegrate the ashes (usually clays) and to detach them from the coal. Centrifugal force separates water—with the ash in suspension —from the oil-coal pulp, humidity being reduced to 8%. If it is intended to coke the clean coal, the oil can be so selected as to improve the coking properties.

Document L.2 describes Latin-American coal formations, washing capacity and processes best suited to some of the metallurgical coals. It underlines the sulfur problem of Brazilian Barro Branco coal, which is probably unique in the word. The hand-picked coal has a very high sulfur content (8%) and about 32% ash. Washing of the coal to 15 or 16% ash fortunately reduces the sulfur, mainly consisting of pyrites, to about 1.5%. As regards the sulfur, attention should be directed to the new desulfurization process for liquid pig iron which is described elsewhere. If the economics of this new process are satisfactory, many of the limitations imposed by the sulfur content on the adaptability of fuels to the blast furnace may be eliminated. As will be seen later, petroleum derivatives which are excellent binding materials often have an excessive sulfur content. The new method may therefore be highly favourable for Latin America, permitting a greater use of petroleum derivatives as binding elements without later complications in the slag.

3. Suitability of coals for producing good metallurgical coke

Document L.11 states that despite all the research on the subject the process by which coal is transformed into coke is yet unknown. There is still no definite answer to this question in spite of all the work accomplished by many research workers. Numerous indices and measurements of arbitrarily selected factors have been compiled, but they have proved insufficient for a comprehensive explanation. Meanwhile it is impossible to state why a coal or a blend swells, or why a coke cracks. Much less can there be any *a priori* conclusion as to whether or not a coal or a blend will produce a satisfactory coke.

Experience is the only formula to ascertain the type of coke which can be produced by a given coal or blend. Before reaching a decision on the establishment of a steelworks or of the requisite coking plant, much information concerning the properties of the resulting coke must be obtained. The most important are its hardness, physical resistance to pressure and friction and, in many cakes, the facility with which the coke reacts with iron ore.

Many indices and measurements for coals have been established with the object of anticipating their behaviour in the blast furnace. They are based on experience and may pre-determine the results to be expected from treating similar coals.

Document L.11 describes experiments in this respect carried out in France. It also draws attention to the exceptionally high-grade ores in some Latin-American countries, especially in comparison with average French ores, which justify lower standards for coke quality. Document L.16 analyses similar research in the United States using a small 200 kg. test oven, and refers to the correlation of the data obtained from such experimental ovens with those from large-scale operations.

Documents L.7, L.19 and L.21 outline the research into coking coals in Colombia and Chile, the process described in document L.16 having been used for this purpose. Discussion of these papers referred to the conditions which a good sample must fulfil. The doubt arose as to whether the samples of Naricual coal previously tested in Venezuela met these conditions; conclusions on the lack of coking properties of fuel from this source thus appeared doubtful and a further series of tests is required.

The difficulties of correlating the indices and measurements in different countries were very apparent at the meeting. For instance, it was evident that the French participants encountered problems in interpreting the results of measurements using the Gieseler plastometer, which is almost unknown in their country.

Document L.27 may be considered as beginning to clarify the mechanics of coking and the factors which influence the process. It provides data on the petrographic analyses made with Chilean coals and describes the unfavourable influence on coking properties of some of the components, such as fusinite and carbonaceous schist, which in turn contain the greater part of the ash. Many experiments at Huachipato have proved that a reduction of the ash content, and of the above-mentioned petrographic components, substantially improve the coking properties of Chilean coal.

A method based on similar principles and described in document L.11, is the Sovaco-Burstlein process which consists of grinding and later screening the coal to eliminate certain petrographic fractions. The remainder is crushed to appropriate sizes.

Turning from theory and preliminary research to actual practice, document L.12 states that if difficulties are encountered in obtaining the correct blending materials to improve the quality of coke produced from different coals, the following modifications to the process may be attempted: (*a*) washing the coal, (*b*) changing the size of the grain, (*c*) altering carbonization temperature or (*d*) changing loading methods and the bulk density of the charge. Document L.16 adds to this list the acceleration of heating of the charge in the oven as particularly beneficial for poorly coking coals with high volatile content and rich in oxygen. For such coals, document L.11 describes the process used at Thionville in France, where 67% of low coking high volatile coal from Lorraine is used. Results in this case improve when crushing to 7-15 mm. is effected at the precise moment the coal is used, in order to reduce oxidization.

4. Coking of coal and coal blends

Very few metallurgical coke plants produce coke from a single type of coal without resorting to blends. Document L. 12 points out that only 10.5% of the 86 important coking plants operating in the United States during 1949 were using only one grade of coal; of these plants 5.8% were using high volatile coal, while the remainder employed medium volatile grades. Document L.15 defines the purpose of such blends. The required properties are usually strength and grain size, although in a few cases the blends are made to reduce the content of certain unsuitable components of the coal (see also document L.12). The outstanding phases which take place during the coking process are swelling and fluidity. The first, when excessive, may endanger the oven walls, while the second largely determines the strength and size of the coke.

Low and medium volatile coals are broadly considered as suitable for coking, with high volatile coals at the other end of the scale. Despite this general rule, high volatile coals are often blended with others to improve fluidity. In some cases, sufficient compression within the oven may offset certain deficiencies in fluidity.

It is not surprising, therefore, that in Latin America only Mexico and Colombia are able to use a single type of coal, while all the other countries use blends. The necessity for blending creates a serious problem since the coals for this purpose must be imported.

The great variety of coals in Colombia may justify the hope that Latin-American steel industries can substitute fuel from this source for imports from other regions, once mining and transport facilities in Colombia are developed.

At present the following coals are being blended. In Brazil, where Barro Branco coal is too expansive, high volatile coals are added. Chilean high volatile coal is blended with low volatile imported fuel of good coking properties in order to produce a harder coke. In Peru, the addition of asphalt or petroleum derivatives to anthracites is planned. The extent to and the form in which Argentina's Río Turbio coals will be used has not yet been made public. But the composition of this coal (high volatile and rich in oxygen) suggests the following additions: (*a*) a low volatile good coking coal with the possible addition of char made of Río Turbio coal; (*b*) an asphaltic product with or without the addition of another coal.

5. Improvements in coking by adding anthracite, coke breeze or char

According to document L.16, the addition of around 5% anthracite fines or coke breeze (below 0.4 mm.) hinders the shrinkage of the hot coke during the contraction stage in the oven. Coke of larger dimensions can thus be obtained if the coal has good coking properties. The same addition can produce a satisfactory coke from poorly coking high voltatile coals, given sufficient fluidity. According to this paper, coke granules in larger sizes, such as 5 mm., are always harmful.

In France, on the authority of document L. 11, very good coke is being made by the Carling method, using a large proportion of poorly coking Lorraine coal, mixed with good coking coal (Ruhr or Pas de Calais). Alternatively, document L.12 states that the addition of coke or anthracite breeze to high volatile coals similar to those of Latin America has not given good results in the western United States. Sawdust has also been used to reduce contraction, with results similar to those obtained when using anthractite or coke dust.

According to documents L.12 and L.15, some high volatile coking coals with high fluidity, found in the western United States, produce, through the addition of 15 to 20% of low temperature coke (char), a much stronger and larger coke. Document L.12 compares the beneficial action of char and low volatile coals, providing charts in which the effect of these additions on the properties of the resulting coke are shown. It is thus possible to determine which are the respective amounts necessary to obtain certain results.

It is assumed that the action of char—which is entirely devoid of fluidity—consists in providing surfaces for the plastic adherence of the coal. This enables a strong weld to be effected in contrast to what occurs when coke or anthracite breeze are used. In the later stages of the process, the char hampers contraction, thus contributing to the formation of a larger coke.

In papers L.11 and L.14, it is explained that the chars are also used as blending elements with other components, such as Lorraine coals and the black lignites of Yugoslavia. The manufacture of coke from the latter involves a complicated procedure, to be discussed later. Up to 60% of Lorraine high volatile poorly coking coals are blended with 25% of high volatile good coking coal of great fluidity and 15% of fine char (of which between 45 and 75% is below 0.5 mm.). The resulting product, though inferior to other blends used in France, has given good results in the blast furnaces.

Document L.13 provides a brief history and description of the progress achieved during half a century of research into char production for blending purposes. The statement that char does not have to be made of the same coal used as a basis for the manufacture of coke aroused much interest. It seems that high volatile non-coking coals give better results in producing semi-coke because they lack adherence during the plastic period of the heating process.

This statement is of interest to Chile, where imports of low volatile coals might be reduced or even eliminated by adding to its non-coking coals up to 15% of char, preferably produced from non-coking high volatile coals. The latter fuels constitute one of the veins in Chilean deposits and have to be mined simultaneously.[8] Similarly, if research should prove that Río Turbio coals have unfavourable coking properties, Argentina could always blend improved grades of imported coals with not more than 15% of Río Turbio char, after suitably washing the coal. This possibility might be extended to other high volatile poorly coking coals, such as Colombia's Cerrejón coal. It is almost certain, judging from French experience with inferior coals, that a blend of about 60% of such Cerrejón coal, with 15% of char from the same source, plus 25% of some coal with greater fluidity from another source, could be used.

Finally, document L.12 also mentions the good results obtained in the western United States by adding up to 20% of petroleum coke breeze which contains 8% residual volatile matter. The resultant coke is slightly less porous than that produced from straight coal, but it gains considerably in size and strength, while improvements are evident with even very small additions of petroleum coke.

6. Use of pitch, asphalts and petroleum derivatives

Document L.12 presents some of the results obtained in the west of the United States by adding coal tars and pitches to the coke blend. Size, strength and stability of the coke increase until the addition of these binders reaches a certain limit, ranging between 10 and 15%.

Document L.15 and the discussions at the meeting confirm that the coke plant itself seldom produces more than 2 to 3% of suitable coal pitches and tars, therefore this method of improving coke has very limited applications in Latin America. The effect of these coal tar or petroleum products increases fluidity during the plastic phase. Lack of fluidity is the main obstacle to producing good quality coke with high oxygen content coals. This theory agrees with document L.12 in that the beneficial effect of these semi-solid additions culminates at around 15% and declines rapidly thereafter.

Document L.17 describes a number of tests with blends of 70% Chilean high volatile coking coals and 30% Argentine asphaltite. By thus increasing the fluidity of the Chilean coal, the coking properties of the blend are clearly improved.

A second series of experiments with asphaltite blends was conducted with strongly coking North American coals. In every case a larger coke was obtained, taking the form of blocks having a fairly hard structure, and appeared to be well fused during coking. In one of these tests, low volatile coal was used which had a high carbonization pressure, but the addition of asphaltite reduced this pressure to a point where there was little danger of damage to the coke ovens. Once again the product improved in quality compared with coke produced from unblended coal.

The use of coal briquettes formed with binders derived from coal or petroleum is described in documents L.14 and L.24. These briquettes can either be carbonized directly to produce coke or transformed into char which is fully carbonized at a later stage. The two coals referred to in these two documents both fall into an extreme section of the classification, from the point of view of volatile matter and of geological age. Document L.14 deals with brown and black Yugoslav lignites, blended with tar or petroleum pitch. Document L.24 refers to a blend of Peruvian meta-anthracites with the same binders. The processes usually entail the washing of the coal by means of the phase separation system, the briquetting of the blend and its subsequent carbonization. Special ovens with retorts where hot gas circulates to raise heating of the charge are described. The oil used in phase separation to assist in binding the briquettes may be transformed in the oven into aromatic hydrocarbons of enhanced value. The briquettes form a hard coke, of uniform size, fine grain and a satisfactory porosity if judged by the relationship between the size of the pore and the thickness of the dividing walls. Document L.24 mentions that this process has been successfully employed in Yugoslavia to produce lignite briquettes to be transformed into metallurgical coke. The same process is being developed in Peru for meta-anthracites; the coke briquettes obtained in the laboratory are of satisfactory appearance, although their suitability for the blast furnace is not yet known. For this reason a plant on a semi-commercial scale is under construction at Chimbote, where enough briquettes to conduct full-scale blast furnace tests can be produced. In the manufacture of briquettes by this process it is usual to employ between 3 and 4% of petroleum residues or oils for the phase separation washing of the coal. Aromatic hydrocarbons from tar, asphalt or petroleum residues are then added as a binder. During carbonization some 4% of the oily matter, mainly hydrocarbons, are recovered and may be re-used. Aggregate consumption of oils and fresh binders is therefore only about 8%.

Document L.18 describes the manufacture of metallurgical coke from petroleum derivatives as practised in Argentina for zinc smelting based on petroleum residues. Between 23 and 25% of the petroleum is converted into good metallurgical coke while the remainder is recuperated either as liquid or gaseous fuel by-products.

During the discussions it was noted (*a*) that blends of coal with certain petroleum derivatives produce good

[8] They are at present used as steam coals.

cokes in almost any proportion; (*b*) that there is no danger of liquid fractions leaking off vertical coking ovens as long as the proportion of petroleum derivatives remains below 30%. Where higher percentages of petroleum derivatives are employed, the use of horizontal ovens, as described in paper L.18, would be advantageous. Equipment is thus available which can be adapted to any solution; (*c*) that these conclusions provide a broad field for regional co-operation between the petroleum and iron and steel industries in the field of economical coke output.

Within a relatively short period it is probable that industrial centres will grow up around Latin-American iron and steel plants. They will require fuel and the by-products of a steelworks based on petroleum derivatives would thus find useful applications. The possibilities of basing coke output partially on petroleum derivatives should not therefore be rejected without careful study. Many local factors must be considered in each case, among which transport plays an important role.

Since petroleum output and refining in Latin America are generally far distant from coal mines, the opportunity arises to reduce assembly costs and to improve coke quality by basing the supply of the coke plant on both fuels. For instance, in Argentina the possibility of utilizing Río Turbio coals for coke would be worth examining in the light of the following possibilities: (*a*) blends with char; (*b*) blends with asphaltites which are found at the foot of the Andes; and (*c*) blends with petroleum residues from Comodoro Rivadavia. Since the Sierra Grande ore deposits are relatively close to Río Turbio, it should be feasible to establish an iron and steel industry with low assembly costs in southern Argentina, always providing that experiments with raw materials for coke are successful. Something similar might be attempted in Venezuela, which has high volatile non-coking coal beds at Naricual. The addition of petroleum residues, heavy crude oil and asphalts from the abundant available resources might well lead to the production of satisfactory metallurgical coke with low assembly costs.

7. Use of natural gas in blast furnaces

Venezuela, with its great wealth of iron ore and relatively large market for steel products, poses an interesting question in regard to the supply of fuel for a steelworks. In addition to the previous solution, consideration could be given to a blast furnace of the classical type, using coke as fuel and as reducing agent, but supplemented by the injection of petroleum or natural gas under pressure. The gas might be regulated to perform the bulk of the heating and the indirect reduction. A blast furnace of this type could operate at a coke rate customary in electric reduction furnaces which would be between that considered economical in a classical blast furnace and that obtained from an electric furnace where most of the calorific energy is provided by electricity. This possibility merits investigation, since no coking coal deposits have yet been found in Venezuela, whereas large quantities of natural gas from the petroleum wells are being wasted only 100 km. from the iron ore deposits.

8. Influence of quality of metallurgical fuel upon blast furnace operating costs

Documents L.26 and L.27 study the effect of the ash content of coke upon the operating costs of the blast furnace.

Document L.26 starts from the hypothesis that the composition of all the coal and ash is uniform. It analyses the effect on cost per ton of pig iron of the following factors, which have opposite effects: on the one hand, the additional cost of reducing the ash content of the coke through better washing of the coal and, on the other, the reduction in operating costs of the blast furnace, due to the use of cleaner coke.

Document L.27 refers to the special case of Chilean coking coals and its conclusions might apply to other Latin-American coals. The author establishes first that the combustible matter and the ash are not of uniform composition and that certain fractions of these coals and ashes contain components adversely affecting the quality of the coke. A comparison of the cost involved in extracting these elements is presented, with the economy in blast furnace operating costs which might ensue from using the resultant better quality coke.

Document L.26 describes the more general case and the calculations applied to a hypothetical example which should be used for each plant and for each blend of coal before deciding upon a policy regarding the ash content to be tolerated in the coal. Reasoning is advanced and formulae are proposed for establishing the degree to which a lower ash content in the coke results in its cost increase. On the other hand factors are listed which influence the operating cost of the blast furnace and vary with the purity of the coke. The degree to which these costs decrease in relation to a progressively lower ash content in the coke is established, and three fundamental reasons for this reduction are underlined: (*a*) coke consumption per ton of pig iron is reduced in view of the greater content of combustible matter in the coke itself; (*b*) limestone consumption is reduced; (*c*) daily output of the blast furnace increases without a disproportionate rise in operating costs. This is because a blast furnace can receive a uniform amount of coke daily, no matter what its ash content.

The algebraic addition of the two groups of resulting figures shows the over-all economic effect of coal washing, as compared with operating costs of the blast furnace for different degrees of coke purity. If this addition is expressed graphically it resembles a parabola, with the apex at the point marking the most favourable ash content in the coke. Once this is known, it is easy to determine the ash percentage which can be tolerated in the coal.

Document L.27 begins by determining the pernicious effects of certain petrographic components and ash fractions. It first establishes that by screening the grains below 1.5 mm., many of the harmful petrographic elements can be eliminated. Reference is then made to some of the fractions of intermediate density which should be eliminated because they contain an excessive amount of a certain type of ash, adverse petrographic elements, and sulfur. Apparently the effect of the two former elements consists in impeding perfect impregnation and welding of the surface of the coal particles with the binding bitumens. Using statistics for tests made at the Huachipato plant in Chile, a correlation is established between the ash content of the coke and its quality expressed in strength and size. This relationship, in turn, is transformed into a coefficient which expresses the equivalent between the decrease of the ash content in the coke and the proportion of low volatile imported coal which must be added in order to compensate the adverse effects of the ash and to produce coke of a certain quality. Document L.27 then analyses the cost increase of the remaining coking coal, after separation of the harmful fractions. Such an increase, even in the extreme case where the fractions eliminated from the coke have no commercial value at all, is compared with the substantial economies which would result in blast furnace operation. The document ends by establishing that the reduction in ash and sulfur within the proposed degree, would not create any difficulty of insufficient slag for the blast furnace.

Chapter IV

Technical Findings Relating to Iron and Steel Metallurgy[1]

I. Foreword

The Bogotá meeting provided the opportunity for a fertile exchange of ideas and experiences. North American and European participants gave information both on the results of experiments at operating steelworks and the varied research with new processes which is now being carried out.

The Latin-American participants drew attention to their first efforts aimed at developing iron and steel production as a basis for industrialization, an indispensable factor for social and human progress. They underlined the technical problems which stem from the nature of their raw materials and prevailing economic conditions, both by reason of the transport difficulties and of the varied needs of transforming industries from the standpoint of quantity and quality. The fact that Latin-American countries cannot now equip their iron and steel industries with domestic capital goods was similarly emphasized. To provide most of the new equipment, Latin America must resort to imports which are covered by foreign exchange. If advantage is to be taken of the most recent technical progress, such expenditure may involve very substantial sums for much of the mass production equipment.

These factors make it essential for Latin-American countries to stagger their equipment purchases as much as possible, adapting them to a general plan that can be developed in successive stages. Thus, they are often unable at present to reap the benefits of the appreciable drop in costs, which has occurred in other countries through the introduction of mass production methods. As a result, Latin-American countries are interested in any modern process which is suitable for their raw materials and would provide low costs through the introduction of technical innovations. Broadly speaking, the opportunities for experiment in Latin America are limited. Before taking a decision, therefore, the countries of the region must resort to established iron and steel producers for assistance in studying the results obtained in steelworks or pilot plants outside Latin America.

It is certainly true that the new problems thus raised will arouse the attention of the more developed countries, leading to research into new fields, and with results which should prove beneficial on an international scale.

II. General summary of findings

1. Reduction of iron ores

The first problem for any potential iron and steel producer, particularly in view of the general shortage of scrap iron for re-smelting, is to obtain iron from the different available ores. This is the fundamental task of an iron and steel industry, even when the product obtained is associated with other useless or harmful elements, such as carbon, sulfur or phosphorus, and thus requires subsequent refining. Professor Robert Durrer made an outstanding analysis of this process (document L.45), to which frequent reference is made here. He recalls that the present process for the mass production of iron from ores—the blast furnace, with all its latest improvements—is no more than the logical outcome of a routine, experimentally acquired as a result of the fortuitous discovery of iron production by methods such as the Catalan Hearth. Professor Durrer notes that the Chinese had undoubtedly progressed further in analysing the problem since many centuries ago they had already reduced iron oxide by using coal and had adopted a system of reduction in externally heated containers, thus splitting up the operation more efficiently than the blast furnace. The Höganäs process and the tunnel-kiln (Ontario-Cavanagh) are simple variations of this process. Because a systematic analysis of this type was not continued and because the results obtained by the blast furnace proved economically profitable, this latter method, involving a complex series of different operations, has prevailed until today. Many consider that it might have been better to invest directly in blast furnace research rather than in dispersed experiments of many kinds. But the study of methods such as electric reduction, Krupp-Renn, Wiberg-Söderfors, Avesta-Domnarfvet and Basset (which actually involve a breakdown of the blast furnace process into some of its components) have served perhaps unwittingly, but most usefully, to increase knowledge in this field.

Despite progress in research, experts are far from solving the complexity of these operations and have not yet determined the reciprocal influences of the different factors at play between the mouth and the tap-hole of the blast furnace, a piece of equipment which simultaneously performs the following operations:

Drying and possibly elimination of the volatile portion of the load;

Partial indirect reduction of the oxides by gases;

Direct reduction by contact with coal;

Fusion of the iron and the gangue;

Desulfurization; and, lastly,

Production of molten iron at an adequate temperature.

Analytic controls of the materials and of the gases at different heights, controls of temperature by thermocouples, likewise at different heights, and the study of pressures, also at different stages, have all been completed, but no really satisfactory results were obtained. New and recent methods of research, such as the use of isotopes, may perhaps increase knowledge to some extent, particularly in the case of sulfur. But the fact remains that it is still impossible to split up blast furnace operations into their primary elements. It is thus considered that any new method involving some of the reactions occurring in the blast furnace should be care-

[1] For the preparation of this chapter, the Secretariat received very valuable assistance from M. Marc Allard, Deputy Director of the Institut de recherches de la sidérurgie at Saint Germain-en-Laye, France.

fully observed, since it may provide a new element for the study of the blast furnace itself. This is the reason for the consideration of all these methods, bearing in mind that one of the essential principles, emphasized during the meeting, is that good quality mineral coal (or even charcoal) is a valuable material of considerable use in reducing iron ore. Such fuel should thus not be employed merely for the production of heat by combustion (as is partly the case in blast furnaces). This principle is valid in most Latin-American countries and also in many other parts of the world, particularly Europe.

2. Steel making

At present, since scrap is in short supply and intermediary products, such as sponge iron, have not yet been developed on a practical basis, it may be assumed that the different techniques for steel making are all essentially based on the use of liquid pig iron. The main refining problems arise from the sulfur and phosphorus content.

If it is too costly to remove sulfur in the blast furnace by appropriate preparation of the slag, there are other satisfactory desulfurization processes such as those utilizing soda or lime (Kalling process). Moreover, every basic steel furnace can be used for desulfurization.

It is practically impossible to avoid the incorporation in the pig iron furnaces of almost all the phosphorus contained in the charge. At present, moreover, no really practical method of dephosphorization is known other than the use of basic slag, generally in steel furnaces. It appears, however, that ores of low phosphorus content are becoming increasingly rare. Hence, the methods for steel refining with basic slags have been highly developed in the course of the past few years, leaving acid processes well behind. These latter, however, are probably applicable in certain Latin-American countries, where ores with a low phosphorus content exist.

Broadly speaking, the refining processes can be divided into three main categories:

The basic or acid open hearth furnace;

The basic or acid converter; and

The basic or acid electric furnace.

However, a factor to be emphasized is the marked interest shown during the meeting for converter research studies, and particularly for basic (Thomas) converters. This interest, in view of recent experiments, stems fundamentally from the use of oxygen-enriched air, which seems to permit the elimination of difficulties generally acknowledged in the Bessemer and Thomas processes, namely;

The excessively high nitrogen content of the steel;

The impossibility of re-smelting large quantities of scrap; and

The need for a minimum phosphorus content in the ore for the basic process.

This renewed interest in converter methods, particularly for basic ores, has even been observed in the United States. The cost of the dephosphorization operation (document L.77) in the large basic open hearths is by no means negligible, especially when the phosphorus content is somewhat high.

Thus, after a successful start with converter processes (Bessemer and Thomas) in the nineteenth century, followed by their eclipse in favour of open hearth furnaces for mass production, there is now a tendency to return to the earlier methods. This trend is apparent throughout the whole world. In fact it is not uncommon in industry that technical innovations or economic improvements, in this case cheap oxygen, enable a return to processes which were formerly popular but which were temporarily replaced while awaiting technical improvements. In handling liquid pig iron, the converter process is attractively simple. Similarly, there may be a return to the open hearth smelting furnaces (Martin or electric) if new processes for the extraction of iron from ore, producing solid scrap (sponge iron, for instance) are used on an industrial scale.

Another tendency during the meeting involved some opposition to the extension of the Duplex processes. It probably arose as a result of actual achievements or hopes based on the use of new processes, in particular those using oxygen. This would include, for instance, desilication of the pig iron before it is placed in the furnace, followed by decarbonization. In addition, the more usual Duplex—the Bessemer converter and open hearth furnace—is costly, both to install and to operate. It requires both Bessemer and open hearth steel producing facilities and involves iron losses in both procedures. Methods based on single steel producing facilities thus appear to be far more attractive.

3. The shaping of steel

Since the main purpose of the meeting was to consider the production of pig iron and crude steel, less attention was given to the transformation of the metal into rolled products. However, the more interesting data assembled on this subject are summarized below.

Rolling techniques for steel finishing are well known and their choice depends on the purpose in view. Rolling mills which embody the latest improvements and provide the lowest costs are unfortunately too large for the medium or small capacity plants required to supply Latin-American markets.

Maximum economies in manpower must thus be effected, because wage levels in under-industrialized countries tend to rise once a plant is installed, and because skilled rolling-mill labour is aways difficult to find.

Logically, optimum yield should involve the use of favourable local conditions for certain products and the specialization of individual steelworks to produce one specific article at a low cost price. Such principles, however, can be applied only when transport facilities are adequate to allow unrestricted trade between countries or within a given country. In this connexion, the suitability of employing sea and inland water transport to a greater extent should be emphasized.

The majority of Latin-American plants attempt to produce a range of products which are necessary for the development of basic industries.

Rolling mills are essentially dependent upon first the steel tonnages available to them and secondly the range of products which it is proposed to manufacture and their annual output.

A basic difference exists between heavy products manufactured directly from hot ingots, thus economizing many calories, and lighter products which are rolled on small mills requiring intermediary reheating for the semi-finished products. A new mill should ideally be equipped to produce both heavy products and semi-finished items which can be re-rolled. Later, if the plant is enlarged, a greater degree of finishing may be envisaged, including vertical concentrations and even the output of finished goods which would reduce unnecessary transport.

Reference will be made to the advantages offered by the converter process to rolling mills of medium size plants. This method permits quasi-continuous operations and therefore provides rolling mills with a regular supply of hot ingots. It compares well with the excessive bulk of material and lack of continuity from open hearth operations.

Interesting data on all these subjects were submitted to the meeting in documents L.53, L.61 and L.74, as well as in the reports regarding the plants being erected at Paz de Río and at Chimbote.

Document L.66 provides up-to-date information relating to continuous steel casting by the Rossi-Junghans method. It would appear that this very interesting experiment cannot yet be considered for industrial operation. Hourly output of steel by this method is limited and precise data on costs are still lacking. However, this process should be studied carefully, particularly in connexion with plants equipped with electric steel furnaces of the tilting type which allow small quantities of steel to be poured.

Document L.67, explained by its author, Mr. Cavanagh, outlines a unique process involving the use of a tunnel-kiln for the direct manufacture—starting from iron powder—of ferrous products of variable density. This method offers interesting prospects for producing special steels, but not for mass production as yet. The process might be envisaged for plants where the nature of the raw material allows economic use of the tunnel-kiln reducing system.

Lastly, document L.68 describes the new Ugine-Séjournet extrusion process. In the same manner as the tunnel-kiln method mentioned above—although it is intended for a different field—this process can be adapted to the manufacture of high quality steel products by extrusion rather than by rolling. It has the advantage of lending itself economically, with small capital investments, to the shaping of reduced metal tonnages and is therefore of interest to small capacity mills.

III. Detailed examination of iron ore reduction processes

1. The standard blast furnace and the low-shaft furnace

The classical blast furnace, with its offshoots such as the charcoal blast furnace and the oxygen enriched low-shaft furnace, together with the electric furnace, have been the only methods so far used by integrated plants with an annual output of some 100,000 tons or more. These methods will be examined below.

Other reduction methods may be of genuine interest because they use raw materials with unusual characteristics or produce steels for special uses; in other cases they may ensure supplementary production of metal for a given mill. These alternative methods will likewise be considered below.

The classical blast furnace appears to provide the best solution for the reduction of ores, if good coking coals are available. Where iron ore is being exported, it might be more profitable to exchange it for coking coal and to use the classical technique in preference to insufficiently tested solutions.

Except in special cases, it may be said that 800 tons per day is about the lowest capacity which may be adopted at present for new coke blast furnaces operating under conditions prevailing in Latin America. It calls for a plant with an annual ingot production of 300,000-400,000 tons in the first stage, to be followed by an expansion programme to raise output to 600,000-800,000 tons.

Such plans can only be envisaged at a few sites in Latin America because coke supplies are inadequate and initial investment is excessive for a plant of this size. Consequently, while maintaining the blast furnace principle, it is necessary to study the following points individually or simultaneously:

(*a*) Modifications in the blast furnace to allow the use of a fuel manufactured from non-coking or poorly-coking coal;

(*b*) Preparation of the raw materials for the blast furnace charge in order to adapt them to low value fuels; and

(*c*) New techniques for the production of fuels to replace coke in the blast furnace using raw materials which up to the present have been considered as non-coking.

These questions may now be considered in the light of the available data.

(*a*) Since it is mainly the large size of the blast furnace which necessitates the use of metallurgical coke, it is natural that small furnaces should be used when the quality of the fuel differs widely from that of coke. Thus, equipment with a daily production capacity of over 150-200 tons can hardly be used for charcoal. When conditions justify charcoal as a fuel (documents L.31, L.32, L.74) it would be advisable to group the manpower servicing the furnaces in such a way that they may attend to several units simultaneously.

Attention should likewise be drawn to the low-shaft furnace which may be adapted to fuels other than ordinary coke (documents L.36, L.40, L.45). However, since these are in fact standard furnaces divided in the middle, top gases of an extremely high temperature are obtained unless special precautionary measures are taken. One such measure is to enrich the blast with oxygen, thus concentrating the high temperature zone in the lower part of the furnace and allowing the gas to escape at a suitable temperature. Indirect reduction by carbon monoxide seems to be less complete in the low-shaft apparatus than in the conventional blast furnace. This would lower the rate of utilization of carbon for the reduction of the ores within the furnace and this inconvenience might be accepted, since it would represent the price paid for using low-grade fuel. The excess energy would finally be recovered in the form of a richer blast furnace gas. In addition better use could be found for the escaping gases than mere heating; for instance, they could be transformed by synthesis in chemical plants, since their composition would be very different from that of the gas obtained from the ordinary blast furnace.

However, the technique of the low-shaft furnace is still in its infant stage. The only recognized feature is that low-shaft furnaces can operate satisfactorily with fine ore and coke of about one inch size, according to trials made at Oberhausen in Germany. It is generally admitted that the low-shaft furnace could satisfactorily use char, a material unsuitable for the classical blast furnace. It is also believed that anthracite fines could be used, since they have already been used in furnaces for the manufacture of pig iron, although admittedly with poor results. Some Latin-American countries would be able to benefit from these opportunities, especially those possessing coal which may be transformed into char or anthracite coal. It will soon be possible to test these fuels in an experimental low-shaft furnace built by the Comité international du bas fourneau at Liège (see document L.40). It is even hoped to experiment with fuels which differ even more widely from coke. The German firm of Klöckner-Humboldt has also experimented in this field and advocates the utilization of low-grade coals agglomerated with fine ores. (See document L.36.) At Liège, in addition, experiments were made with a hot-air cupola and very poor quality coal with a 35% ash content. The Liège low-shaft furnace programme is also scheduled to carry out systematic research into the use of very low-grade fuels and fine ores. (See document L.40.)

It would be unwise at present to base an industry on low-shaft furnaces of this type, particularly because they involve the construction of an oxygen plant. Although this technique has raised such interesting possibilities, it would perhaps be wiser to wait for the results of the first experiments at Liège before any decision is taken.

The importance for Latin America of the research connected with pilot plants in the more highly industrialized countries should be stressed here. Membership of the Comité international du bas fourneau is open to all Latin-American countries.

It should be emphasized that before constructing new blast furnaces or low-shaft furnaces it would be prudent to study the method of adapting high blast pressures. Many steelworks in the United States and in Europe show an interest in this technique. The reduction processes are facilitated and the volume reduced so that the speed of the gases lowers the amount of dust and simultaneously permits production increases.

(*b*) Throughout the world the preparation of the blast furnace charge, that is the crushing, enriching and agglomeration of fines, has been carefully studied and appreciable progress made. In Latin America enrichment is generally unnecessary because high grade ores are available.

A striking example of success in preparation is that of the sinterization process adopted in Brazil to enable the products to be used in charcoal blast furnaces. (See document L.33.) By this means, optimum technical conditions for the use of the charcoal blast furnace appear to have been attained, resulting in maximum fuel economies. Accurate knowledge has thus been obtained of consumption limits in the use of charcoal.

In the same way as the operation of the blast furnace can be simplified and fuel economies effected through the utilization of pre-digested charges, the low-shaft furnace can be fed with agglomerates of fuel and fine ores. Previous coking of the agglomerates in the form of briquettes can also be envisaged. This simultaneously increases their hardness, avoids the furnace acting as a dryer and eliminator of volatiles, and may actually cause a partial reduction of the ore. It is evident that the shorter the furnace, that is to say, the shorter the time available for the passage of the charge, the greater is the need to introduce materials which can easily and rapidly react. The intimate contact between the materials to be reduced and the reducing agent in these briquettes can only favour the reaction. There is no need to enter into additional details regarding the advantages and facilities of the preparation of the blast furnace charges, particularly as regards the passage of gases.

(*c*) The different experiments made in order to manufacture coke substitutes were detailed in the first part of the meeting's report. It should be sufficient to note here that in many cases the adoption of low temperature char, which differs appreciably from ordinary coke, may be acceptable if the low-shaft furnace is used. Crushing of the low-grade coke is thus avoided since the charge is lower.

Frequently and justifiably, attention is drawn (document L.45) to the useless ballast in the blast furnace, consisting of the substantial volume of nitrogen blown in with the oxygen. But this is not as detrimental as may appear at first sight, since it has been noted that indirect reduction is less active with oxygen-enriched air and the temperature of the escaping gases at the top of a normal blast furnace is low. This latter fact implies that the nitrogen ballast carries litte heat to he furnace outlet. The poor quality of the gas escaping at the outlet, due to a high nitrogen content, is perhaps a hindrance; but, although these gases are too poor to be carried any distance, they can nevertheless be used for different purposes at the steelworks itself. (See document L.58.) It should be recalled that the thermic yield of the blast furnace improves with the reductibility of the ores. The richness of the ore is not the only factor to be considered. (See document L.52.) Thus, properly prepared sinters, Brazilian *canga* and the Lorraine *minette,* are particularly well adapted for use in blast furnaces. Moreover, the basic charge, particularly with the use of self-fluxing ores, requires less cooling of the blast furnace and so improves the thermic yield.

If the choice remains open, it may be thus more advantageous to treat the hard silicous ores, which are difficult to reduce, in electric furnaces, provided the cost of power is adequately low.

It should also be recalled that the low-shaft furnace is an interesting attempt to separate the different factors acting in the blast furnace, since in fact only the lower part of the blast furnace is retained. Moreover, since the apparatus is small, experiments should be less expensive than in a blast furnace and high pressure may be more easily applied as well as the use of oxygen. Experiments with the re-circulation of gases and with the injection of gaseous hydrocarbons at different levels into the blast furnace might also be attempted; nor would it be unrealistic to consider the eventual application of ultrasounds, with a view to accelerating the reactions. The behaviour of sulfur might likewise be studied and the available data completed with experiments designed to relieve the blast furnace of its desulfurization functions.

Research in connexion with blast furnaces can also be performed by the use of the motion picture, as already carried out for example by the United States Steel Corporation.

Preface

At its Fourth Session, held in Mexico, the Economic Commission for Latin America adopted a resolution (E/CN.12/279) (10 (IV)) calling for studies on the steel industry and other industries in Latin America, and authorizing the Executive Secretary to call meetings of "industrial experts to examine, on their personal responsibility, the conclusions and recommendations contained in each study before submitting them to the Commission".

The secretariat accordingly proceeded with studies of the steel industry. The United Nations Technical Assistance Administration, which had taken a deep interest in the problem, agreed to co-sponsor, with the Commission, the meeting of an Expert Working Group on Iron and Steel Industry in Latin America. The Government of Colombia generously offered to act as host to the meeting, which was held in Bogotá from 12 October to 2 November 1952.

The purpose of the meeting was to provide experts in the steel industries in Latin America with an opportunity to discuss their problems with each other and with experts from the industrial countries of North America and Europe. These experts were selected after careful deliberation and consultation, and were asked to prepare working papers in accordance with outlines drawn up by the secretariat. This procedure was adopted to ensure that efforts were concentrated on specific aspects of the main problems involved in the production of steel in Latin America. Basic knowledge was sought on various new or experimental processes, both in relation to utilization of available coal reserves and to steelmaking itself. The size of individual Latin-American markets, the scarcity of capital, the characteristics of the raw materials as well as special conditions existing in the various countries which are about to introduce or develop steelmaking facilities, are the main reasons why classic solutions are not always the most adequate for steelmaking in Latin America. The aim, therefore, was to provide papers which would open up new avenues of thought and allow Latin-American technicians to take advantage of the most recent research work performed in industrialized countries.

Volume I of this report contains the findings of the meeting and the secretariat studies. These studies have been carefully revised since their original presentation at Bogotá and at the Commission's Fifth Session. This volume also contains the full list of participants, the agendas and the working papers listed according to their original numeration.

Volume II contains the working papers presented by the experts, together with the summarized discussions of these papers.

The secretariat studies in Volume I were the first of their kind to be undertaken by the Commission, and are being followed by similar studies for other industries, also to be followed by meetings of experts to discuss the findings. The immediate programme includes studies of the pulp and paper industry, the steel industry and of the iron and steel transforming industries.

Finally, the attention of steel specialists should be drawn to the economic advantages connected with the rational utilization of slag. Recent experiments have shown the possibility of extracting alumina from slags with an adequate content for commercial recovery.

2. The electric furnace

Until recently, operation of the electric reduction furnace was mainly limited to the Scandinavian countries but this process should be of considerable interest to many Latin-American countries where there is a shortage of coking coal but also vast hydro-electric resources. These furnaces are now operating successfully and it may be expected that, like their forerunners, the blast furnaces, they may shortly profit from certain improvements in detail, while retaining the full value of existing installations.[2]

Such furnaces fulfil only some of the normal functions of the blast furnace and in a different manner. They effect direct reduction of the iron oxides by contact with reducing coal, there being practically no indirect reduction. Heat is indirectly provided by electricity and not directly by coke as in the case of blast furnaces. The hearth is low and the escaping gas does not contain a nitrogen ballast, but has a high carbon monoxide content and a high temperature. A given charge in an electric furnace gives off seven times less gass than a blast furnace. But in the blast furnace about 25% of the low-grade gas is employed directly in the apparatus itself, being used in the cowpers; the calorific power of the gas in the electric furnace is two and a half to three times higher than that of the blast furnace and its temperature four times higher. On balance it will be noted that for one ton of pig iron, all things being equal, 1.7 times more calories escape from the blast furnace than from the electric furnace. This figure is far less impressive than the preceding volume's ratio might indicate. (For the utilization of blast-furnace gas, see document L.58.)

Broadly speaking, for ores with a 55 to 60% iron content, carbon consumption in electric furnaces is half what it would be in a blast furnace, plus some 2,700 kWh. per ton of pig iron. Here, likewise, adequate preparation of the furnace charge (drying, distillation, etc.) may allow a substantial reduction in the consumption of electric power. As in the case of blast furnaces, it may be possible to eliminate the desulfurization operation in the electric furnace to reduce the amount of limestone in the charge, and consequently the quantity of slag, simultaneously reducing power consumption. For that purpose, desulfurization must then be performed on the liquid pig iron outside the furnace.

The most attractive feature of the electric furnace is that, instead of high-grade carbon (coke or charcoal), low-grade coal and possibly even lignite can be used (document L.37). The electric furnace also has the advantage of being able to use fine ores, since the problem of the porosity of the charge does not arise as in the case of the blast furnace. On the other hand, the unit capacity of the electric furnace is far below that of the blast furnace; it has risen from 100-150 tons daily and at present 200-ton furnaces are being built. It is soon hoped to reach units of 300-400 tons.

[2] Documents L.37, L.38, L.45, L.48 and L.49 provide valuable data on electric furnaces. Document L.82 covers a different subject which is not dealt with in this report, namely synthetic pig iron produced from scrap.

In each instance it would be wise to study all the data pertaining to the problem and in particular to compare the relative prices of electric power and coke. A preliminary estimate, which is generally accepted, indicates that if a kilogram of coke costs five to six times the price of one kWh., the use of an electric furnace is feasible. It is all the more practicable if, as indicated above, the ores to be treated are unsuitable for the blast furnace.

It appears, however, according to the documents presented at the meeting, that different raw materials, either ore or fuels, may behave differently in the electric furnace and therefore require special installations adapted to their characteristics. Before taking any decision, it would be wise to carry out experiments at existing plants, using the raw materials envisaged in each case. It should be remembered that slag, as well as pig iron, leaves the electric furnace in a liquid form, so that in certain instances its valorization can be envisaged, as with blast furnaces.

3. Other reduction processes

The Krupp-Renn process (document L.39), as compared with the blast furnace, reduces the iron directly without desulfurization, and without reduction of the manganese which is transferred into the slag. Partial fusion only is allowed to take place, in other words it is interrupted at the stage when it reaches the lower part of the blast furnace. The mixed products, that is the slag and the pig iron, are cooled and thereafter collected in a solid state, which requires separation by crushing and magnetic sorting. The ferrous product thus obtained is in lenticular form and is subsequently re-smelted. About 80% of the phosphorus from the ore passes into these lenses.

This process follows a technique which is no longer in the experimental stage, although its application is still limited. It also enables practically all the iron to be extracted without the addition of limestone from ores with a high silica content and with limited possibilities for enrichment. These ores cannot be treated in the blast furnace because of the excessive coke tonnages which would be required. On the other hand, this process does not appear suitable for basic ores. Coal with a high ash content can be used in place of blast furnace coke, but it should be observed that only fixed carbon is active in the reduction. High volatile coal is therefore unsatisfactory for this process. It is estimated that for each ton of lenses made from a 60% ore, coke breeze consumption would be 500-600 kg. or its equivalent in fixed carbon, while 75-100 kg. of pulverized coal would have to be used for heating. The above data indicate that the applicability of the Krupp-Renn process for Latin America is probably limited.

The Basset process (document L.42) as compared with the blast furnace, shows unique features. It produces liquid pig iron without silicon and a solid basic slag, while the desulfurization operation is fully performed. In some ways it represents the lower part of a blast furnace working with an extremely high lime-silicon ratio. Reduction is accomplished, as in the Krupp-Renn process, by mixing carbonaceous fuel with the iron ore.

The solid slag is in fact a Portland cement clinker and thereby renders the process economical although the fuel consumption is substantial. In addition to the reducing carbon, heat is provided by burning coal, oil or gas. The temperature of the escaping gas is very high, so that some recovery of heat could perhaps be effected. One condition seems essential, namely, that the raw materials have a sufficiently low alumina content to ensure that the clinker contains no more than about 6% of alumina.

It might be worthwhile to study this process and improve on it, since it could well provide a satisfactory solution for treating certain fine, rich ores found in Latin America. Moreover, the two industries with which it is associated—iron and cement—are developing simultaneously in areas which are being industrialized.

The different methods for sponge iron production which were discussed at the meeting are as follows:

The Wiberg-Söderfors process (document L.47), which during the past few years has been used in the manufacture of heat-resistant steels required for ventilators used to circulate hot gases. As compared with the blast furnace it only fulfils the task of reducing the ore in a hearth by means of reducing gases. The nitrogen ballast is avoided by producing the gas in a carburettor fed with water and coke and heated by electricity. The proportion of hydrogen and carbon monoxide must be very carefully regulated. This process calls for either a 65% ore broken into pieces of 25-80 mm., or a good 65 to 67% sinter. These ores should be resistant to crushing, for instance the El Pao ore would be unsuitable.

The phosphorus in the ore passes into the sponge. Desulfurization does not take place, but by consuming 60 kg. of dolomite per ton of sponge the sulfur content of the fuel could be neutralized.

For a ton of 81% sponge iron, it is estimated that 225 kg. of coke and 1,140 kWh. would be consumed. The use of natural gases would allow a reduction in coke consumption. The resulting sponges so far have been used only as high-grade scrap. Production units are turning out 20-30 tons daily but this cannot be increased because of problems connected with the sections of the gaseous flow pipes. The estimated cost of a plant producing 20,000 tons annually is $800,000.

The above data indicate the limitations inherent in the use of this process and before any decision is taken, the available raw materials should be used for experiment with existing equipment.

The Avesta-Domnarfvet process (document L.46) does not use electric current as did the old Avesta process; it consumes 500-550 kg. coke breeze per ton of 90-95% sponge iron, starting from an ore of about 60% iron content.

The process relies on direct reduction by contact and, therefore, fulfils only one of the functions of a blast furnace. No desulfurization takes place; this must consequently be carried out in an auxiliary furnace, consuming an average of 20 kg. of coke breeze, 30 kg. of limestone and 100 kWh. per ton of sponge.

One of the advantages of the process is that it can make use of anthracite fines and low volatile coal. The ore must be broken up in pieces of less than 25 mm., but if it is too fine, a previous pelletization is preferable. The process has not yet been introduced on an industrial scale. The equipment should be quite cheap but the size of the rotary kilns appears to be necessarily limited, so that a production of more than 15-20 tons daily per unit is not possible. This process is of undoubted interest to certain Latin-American countries, but it might be wise, before any decision is taken, to await the results of a plant operating commercially. Such a plant would allow experiments to be made with the raw materials whose use interests those countries possessing rich ore fines and low volatile coal or anthracite.

The United States Bureau of Mines process (document L.44) which also uses a rotary kiln, seems to have been used more for purposes of studying the ores than for industrial operation. As in the preceding case, it performs only one of the tasks of the blast furnace, though, with the addition of dolomite, desulfurization may also be carried out. This process consumes about 500 kg. of coke breeze per ton of metal produced from a 60% ore, but in addition it requires gas for heating purposes. The technique appears to have been fully investigated and is ready for use; its application is nevertheless limited to ores of a certain composition which can be enriched, at least to a certain extent, the separation of the silica taking place after the sponge iron has beeen manufactured. Difficulties arise in connexion with certain types of ores. The cost of a two-furnace installation producing 100 tons of sponge iron daily is estimated at $700,000.

The Ontario-Cavanagh (tunnel-kiln) process is a variation of the Höganäs process. It would appear to be suitable for limited production, particularly if tunnel-kilns are already installed. This process is particularly indicated for the production of iron powder, and might be successfully used with certain rich and small size ores of Latin America. However, it seems to require a fairly high-grade carbon. Daily production of a complete installation is estimated at 30 tons.

Data on comparative costs of the various reduction processes, which would have to be reviewed for adaptation to conditions prevailing in the respective countries, are indicated in document L.62.

Other methods of extracting iron from ore are constantly being studied. As most of them are still in the laboratory or experimental stage, no useful purpose is served by mentioning them. It should be pointed out, however, that if satisfactory means of direct gaseous reduction could be found for fine, rich ores, avoiding the use of high-grade coal, such a solution would be enthusiastically received by the Latin-American countries where these ores are found.

The results obtained by the Wiberg-Söderfors method are undoubtedly of interest. The studies made in this connexion, concerned principally with optimum proportions of hydrogen and carbon monoxide to be used, might serve as a basis for the possible use of hydrogenated reducing gases in low-shaft furnaces.

An important statement on desulfurization of pig iron was made to the meeting by Professor Kalling. As emphasized above, there is a growing tendency to separate the functions of the blast furnace. The normal desulfurization function in the furnace, requiring basic liquid slag, all too frequently increases the weight of the charge excessively, through the addition of considerable quantities of limestone. The increase in the amount of slag similarly increases coke consumption. Therefore, in many steel mills, desulfurization is performed outside the furnace with sodium carbonate. But this process is expensive; on the other hand, large-scale desulfurization by the simple addition of lime and pulverized carbon seems fairly cheap. This is what Professor Kalling accomplished by using a rotary kiln sealed hermetically, and made to stand a fairly rapid gyratory movement. The results obtained are undoubtedly excellent and the process can eventually be used for all sulfurous, liquid pig irons, either produced by a blast furnace, a low-shaft furnace or an electric furnace.

Studies on desulfurization by limestone have also been carried out recently in Great Britain where interesting results appear to have been obtained.

IV. Detailed examination of steelmaking processes

During the discussions it was pointed out that, in view of the relative scarcity of scrap, steelmaking in Latin America is mainly based on the refining of pig iron. It is not proposed to repeat the details of well known production processes which in any case were carefully and fully outlined at the meeting:

Basic open hearth furnace (document L.77);

Acid open hearth furnace (documents L.64 and L.72);

Basic Bessemer converter (documents L.51 and L.63);

Acid Bessemer converter (document L.65); and

Basic or acid electric furnace (documents L.38, L.52, L.53, L.55 and L.56)

The latter four documents, in fact, are concerned with possible combinations of steelmaking processes in relation to Latin-American needs.

Documents L.73 and L.79 deal essentially with the substantial improvements made in Thomas steel techniques, while document L.71 describes an example of the manufacture of a high quality Thomas product (rails). Documents L.54, L.59 and L.60 examine individual cases which have occurred in three existing Latin-American steel mills.

1. Basic open hearth furnace

The basic open hearth furnace has been considerably developed during the past few years. With a view to reducing the cost of the process, the size has been substantially increased, so that the installation requires very powerful and expensive handling apparatus. Rich fuel, if possible gas or petroleum, must also be available. The increase in the phosphorus content of the ore, and consequently of the pig iron, prolongs the refining process. In using the duplex process (Acid Bessemer and basic open hearth) the steel acquires a high nitrogen content.

The "ore process" enables direct utilization of ore which provides part of the necessary amount of oxygen, so that up to 10% of the steel can be obtained from ore thus directly reduced. The use of very large furnaces does not appear to be justified in Latin America, but units from 80 to 150 tons and more would be suitable and the use of the ore process would be advantageous.

2. Basic electric furnace

The basic electric furnace, thanks to the judicious use of the ore and of the oxygen, has for some years been utilized in the same way as the open hearth furnace for refining pig iron. It may provide an excellent solution in regions where electricity is cheap, or where rich fuel is in short supply and expensive.

3. Acid open hearth and electric furnaces

The acid open hearth furnace and acid electric furnace are limited in use to the manufacture of special products. They require raw materials containing no sulfur and no phosphorus, and therefore cannot be used unless good quality scrap and hematite pig iron are available. The scrap can be provided in a liquid state by some other apparatus such as the basic converter. In this case, however, instead of envisaging a duplex system consisting of a converter and of an acid open hearth furnace, and since a high quality product is desired, it would probably be better to employ the Ugine-Perrin treatment, with an aluminous slag (document L.79), used directly on the products of a basic apparatus such as an open hearth, electric furnace or converter.

4. Converter processes

Lastly, the converter processes, basic or acid, interested the Latin-American participants generally, in view of their flexibility, of the moderate scale of production which they allow and which are well adapted to the requirements of Latin-American steel mills, and also of the low installation costs which they involve.

In this connexion, it should be emphasized that the extensive auxiliary services for a Thomas (basic Bessemer) convertor often causes unnecessary concern. Dolomite requirements are smaller by weight, for instance, than those of an open hearth furnace of the same capacity. Brick presses and bottom-making machines are unnecessary, while excellent results have been obtained with rammed linings, especially for small converters of less than 20 tons. Lime furnaces are still essential, but both the open hearth or electric furnace must also frequently be fed with lime. Moreover, it is probable that the use of oxygen would facilitate the utilization of crushed limestone instead of lime. Slag-crushing is not essential, uncrushed slag having a good market value.

It is certain, however, that the acid Bessemer converter has lower installation and operation costs than the basic Bessemer, but it requires non-phosphoric pig iron.

In mills having several blast furnaces, the low phosphorus ore can be reserved for one of the furnaces, and a part of the production can thus be treated directly by the acid Bessemer process, the higher phosphorus pig iron being refined in a basic furnace (or converter) with or without a duplex process.

5. Treatment of medium phosphorus ores

As regards the problem of phosphorus, various other solutions might be envisaged. Blowing with an oxygen-enriched blast at present enables pig iron with a low phosphorus content (more than 0.15%) to be treated in a basic converter, which may be modified if necessary.[3]

Another means of avoiding the duplex process was proposed for low phosphorus steel (document L.79).

[3] Thus the converter process used at Linz (Austria) involves the use of a full bottom converter, pressure oxygen being injected at the top. At the Huckingen mills (Germany) a slightly different solution has now been adopted (document L.55). Other experts suggest the use of tilting furnaces with blast tuyeres, which would be a cross between converters and open hearth furnaces.

This consists of mixing the steel with a Perrin dephosphorizing synthetic slag. The process would appear to be applicable only to rimmed steels and the cost of smelting the slag has not been given; but this suggestion should be borne in mind.

If the pig iron already has a fairly high phosphorus content, for instance, of 1.3%, and if ordinary steel is to be manufactured, it might be worthwhile to re-load the blast furnace with a part of the re-circulated Thomas slag in order to obtain a phosphorus content of 1.7 to 1.8% in the pig iron. This operation is not expensive if the normal charge of the blast furnace includes limestone, which in this case would be replaced by the lime in the slag. Broadly speaking, it may be assumed that 100 kg. of Thomas slag supplies as much lime as 100 kg. of limestone, and requires only 20 extra kg. of coke, while 10 kg. of iron and 3-4 kg. of manganese can be recovered, making the operation remunerative.

Another solution (see document L.54) consists in adding natural phosphates to the charge, particularly when these phosphates contain iron. This may lower their commercial value for other purposes, but increases it for their use in a blast furnace. In this case, and if these phosphates are cheap, it might be worthwhile to raise the phosphorus content of a charge which may contain as little as 0.5 or 0.6% to the minimum required for Thomas blowing (1.7 to 1.8%). The slag thus obtained is useful as a fertilizer and the value of the phosphorus contained in the phosphates is thus increased.

If a normal Thomas pig iron is thus available without recourse to oxygen, and if it is desired to produce special steels, then it is possible: (*a*) to add to the steelmaking facilities the limited equipment which would be necessary for refining the steel through the addition of aluminous Perrin slag, thus producing high-grade killed steels; or (*b*) to add an open hearth furnace or an electric furnace, which would thus permit re-smelting of the scrap.

6. Use of oxygen

The most logical and flexible solution to the above problem consists in adding an oxygen plant which enables any pig iron[4] to be converted. This also facilitates re-smelting of the scrap and prevents the presence of nitrogen and phosphorus in the steel (document L.73), in fact, it would give the converter the same possibilities as an open hearth furnace.

[4] By enriching the air blown into the converter by 32-35%, pig iron with less than 0.2% phosphorus content can be refined in a Thomas converter.

Research (see document L.79) aimed at reducing losses in metal and making the best use of the converters has increased the value of these methods.[5]

Similarly, the latest developments of the basic Thomas process are also in part applicable to the acid Bessemer. Reference should be made to a duplex combination which may lead to interesting developments. This is the duplex Bessemer-Thomas[6] process, to be used in conjunction with oxygen blowing for pig iron with a low phosphorus content. The pig iron is first blown with the addition of oxygen in the economic acid converter until it is decarbonized completely, which enables scrap to be added, and likewise ensures the final temperature required for pouring. The intermediate product obtained is then passed into a basic converter placed nearby, which plays the same part as a normal Thomas converter using a second basic slag (possibly sodic), if the Thomas operation is to be carried out with two slags. Since the metal remains in the basic converter for only a very short time, the wear and tear of the operation is very limited. Dephosphorization is also carried out with oxygen-enriched blast. The dephosphorizing slag may be prepared beforehand.

Such a process is very economic, since the two types of equipment—acid or basic converters—hardly differ except in the nature of the linings and would moreover be extremely flexible. If required, and according to the nature of the blast furnace charge, the following processes could be utilized: acid Bessemer, or basic Bessemer, or the above-mentioned combination of acid and basic Bessemer.

As a result of the possibilities offered by the use of oxygen, a new and very important field of work is thus provided for steelmaking with converters. In setting out installation projects, however, it would be desirable to study the amount of oxygen consumption primarily envisaged, as well as the day-to-day distribution of this consumption and the supplementary stocks required. The cost of a cubic metre of oxygen may vary according to the size of the installation and the regularity of the flow. Whenever possible it is advisable to increase the oxygen requirements of the steel mill by adding further uses for oxygen. For instance, a low-shaft furnace may possibly fill the role of a supplementary oxygen consumer in the future.

[5] It should be observed that, contrary to recent opinion, the enrichment in oxygen of the blast in the basic converters does not seem to be particularly harmful to the lining.

[6] Indicated by the Institut de recherches de la sidérurgie, France.

Chapter V

Technical findings relating to the qualities and specifications for steel products

I. Foreword

The term "steel" covers a wide range of iron products, the main composition of which is the iron element accompanied by small proportions of a series of others. Such elements provide different properties as regards tensile strength, elasticity, suitability for hot or cold working, resistance to temperature changes or corrosion, shock resistance and so on. Not all steels are appropriate for a given purpose, but, conversely, a widely varying range of steel types are suitable for many given uses.

In order to establish the properties of a given product, steel standards and specifications are used to avoid the necessity for direct contact between the consumer and steel manufacturer. Potential variations in steel composition and properties are such that it is essential to have a reasonable degree of uniformity between the quality of steel produced in different plants. Such specifications are in no way intended to serve as a guide for inexperienced consumers, but those who use steel must verify to what extent materials can be adapted to their specific needs.

Specifications in highly industrialized countries normally set fairly narrow limits for impurities in steel. This is because the mass production industries consuming steel benefit considerably if less variations in composition reduce the differences in the properties of similar types of steel. Variations in steel properties are, on the other hand, less vital if the metal is transformed on a smaller scale. Within certain limits, therefore, there would be some justification for the Latin-American steel industry to allow slightly broader tolerances for impurities in the steel to be used within the region.

Some of the properties and compositions of finished steels arise from the nature of the raw materials, while others depend on the method selected for refining the steel, or on the heat treatment and mechanical process employed during the final production stages. The pernicious effects of discrepancies in the accuracy with which most of these procedures are applied can be offset by means of special treatments. These treatments, however, as well as efforts aimed at attaining a content of certain components within very narrow limits, usually increase steel production costs.

The agenda of the Bogotá meeting thus included a study of the requirements of the Latin-American market and the possibilities of meeting such needs through existing or projected industries. During the course of the discussions, the view was expressed that, since respective national markets have many common characteristics, studies for the adoption of standard steel specifications in the seven countries concerned would be appropriate. Similarly, it was proposed that such standards should be adopted for the rest of Latin America.

Six documents on this subject were presented to the meeting, two of them by Latin-American authors. Of these, document L.80 describes the specifications and limits established at a plant in Latin America to control the proportions of the various components during production. The second (document L.78) is a detailed comparison of specifications accepted in a number of Latin-American countries and in more industrialized countries. Among the others, document L.70 deals with the control of quality during steel production processes, while L.76 explains the reasons for adopting different standards for various types of specifications in two highly industrialized countries, the United Kingdom and the United States. A further paper (document L.75) refers to the influence of certain chemical components, which appear in small proportions, upon steel characteristics. Finally, document L.71 discusses a special problem, the manufacture of steel rails by the Thomas process in France, a subject which is of interest to Latin America in view of the high phosphorus content of several ore deposits.

II. General classification of specifications and their usage

The conclusion may be drawn from these studies, in particular from document L.76, that the following criteria are normally employed in establishing standard specifications: (*a*) mechanical properties, (*b*) chemical composition, (*c*) response to heat treatment.

The control of one or more of the conditions laid down in the specifications is essential to ensure that the steel will conform to a given standard. For a steel sold on the basis of mechanical properties, for instance, it is necessary to control the chemical composition during the refining process. This alone can provide the data to ascertain whether the finished steel will comply with the requirements for its mechanical properties.

Based on these factors, three broad groups of specifications exist: (*a*) those determining mechanical properties only; (*b*) those specifying chemical composition only; and (*c*) those specifying both mechanical properties and chemical composition.

Various other factors are included in each group, but these three main sub-divisions constitute the most important classification. One such factor, which must not be omitted, is the relationship between specifications prepared according to the above criteria and the method of steel refining employed. For many applications, steel produced by a certain method is prescribed, or alternatively, there are two or more different specifications, depending on the refining process employed. The reason is that, with the present development of techniques, the different steel manufacturing processes cause the inclusion of relatively constant proportions of minor impurities. The mention of the process, therefore, automatically sets certain limits to the content of these impurities.

1. SPECIFICATIONS BASED ON MECHANICAL PROPERTIES

This sub-division is confined to carbon steels produced by hot rolling and, in a very small degree, to those which are cold rolled. It is under these specifications that most tonnages are produced and sold. The prescribed mechanical tests have been specially designed to reproduce the conditions to which the steel will later be subjected.

All these specifications include tensile and ductility tests. To meet the combination of minimum tensile strength and a certain ductility, the steel manufacturer must control the carbon content. The minimum determines the tensile strength and the maximum, the ductility. It is also necessary to control the manganese, the other alloys, and the final temperature in the rolling mill.

Steel included in the high-tensile group is seldom specified on the basis of mechanical properties alone, since at least three methods exist for raising tensile strength, each of which provides a different steel. They are, first, a simple raising of the carbon content, secondly, an increase of the content of alloying elements, and thirdly, cold rolling.

2. SPECIFICATIONS BASED ON CHEMICAL COMPOSITION

In contrast to the previous sub-division, which is used almost exclusively for structural work, this group mainly comprises steel intended for secondary transformation. As regards these specifications, there is a difference between practice in the United States on the one hand and Europe on the other, which arises from the size of the respective markets. In fact, the purchase of steel on the basis of chemical composition alone necessitates a relatively accurate knowledge of the content of the various elements if the mechanical properties of the product are to be predicted. This applies particularly to carbon content. The permissible limits are generally narrower than those which can economically be obtained in the steel mill from heat to heat. For instance, if a steel with an 0.3 carbon content has been ordered, the consumer must be certain that it will not vary beyond 0.27 and 0.32. Otherwise tensile strength or ductility will be affected. This range is almost equivalent to the expectations of the variation from heat to heat. Because of the heterogeneous nature of steel, it is inevitable that a heat will occasionally fall outside these limits.

A study of practice in the United States shows that this disadvantage is overcome through a series of specifications with continuous carbon contents. A heat which is outside the fixed limits for one specification may thus fall within those of another. This system leads to a considerable number of specifications, and is only feasible where there is a very large market, as in the United States.

In the United Kingdom, the use of chemical specifications alone for carbon steel is confined to the output of sheet, strip and wire, particularly when these products are cold rolled. The standards establish fairly broad limits for carbon content, probably because in Great Britain cold rolling is mainly carried out by independent companies which fix individual specifications for their contracts. In any case, it is always possible to influence the mechanical properties of steels, for which specifications have been based on the chemical composition alone, by varying the heat treatment during the subsequent manufacturing process.

These considerations apply to steels for use in cases where mechanical strength is the main requirement. But there is also a wide demand for steels in which the most important property is ductility, such as those for stamping and deep drawing. No mechanical testing method has yet been developed for determining the capacity of a steel for processes other than the simplest cold forming operations. The chemical composition of steel is probably the most important single factor, and, generally speaking, the more drastic the deformation process, the lower must be the carbon content. A close control of the chemical composition is therefore essential and explains the large number of specifications for very low carbon steels which require strict control during refining processes.

3. SPECIFICATIONS BASED ON BOTH MECHANICAL PROPERTIES AND CHEMICAL COMPOSITION

In highly industrialized countries the specifications based on mechanical properties combined with limits for impurities cover a large proportion of all steel produced. It is probably greater than the proportion covered by specifications based on mechanical properties alone.

For many years considerable discussion has centred on the essential limits for impurities such as phosphorus and sulfur. Whatever criterion is adopted, an occasional heat which is outside the set limits will always, in practice, occur. This can often be accepted by purchasers when allowance is made for the manganese content and the heat treatment to which the steel is to be subjected. This is, however, no argument for a gradual widening of the acceptable limits.

As regards impurities, the problem of slag inclusions should also be considered. It is rarely mentioned in norms, except perhaps in some general statement to the effect that the steel should be clean. Steels for welding purposes fall within this type of specification. According to document L.78, such steels should be defined by their mechanical properties, limits also being set for the content of carbon, silicon and degrees of purity as regards phosphorus and sulfur. According to document L.75, the purity of the electrode has more influence on the welding strength than that of the pieces to be joined, since the composition of the metal of the "bead" is more important than that of the individual pieces; most of the metal for this bead comes from the electrode.

III. Bases for standardization and specifications

It is probable that over 70% of the steel used in the region is destined for direct use in railways or construction work, while only a relatively small proportion is intended for subsequent elaboration in transforming industries. Specifications based on mechanical properties are obviously sufficient for the first group, with the possible exception of welding steels.

For the steels used by industries, attention must be drawn to the information in document L.76, and in particular to the method on which A.S.T.M.[1] specifications are based. They lead to an excessive number of steel sub-divisions, many of which can have no application on smaller markets, even in the United Kingdom for example.

[1] The American Society for Testing Materials.

On the other hand, raw materials in many Latin-American countries do not facilitate economic steel production in open hearth furnaces. This process, however, is the most widely used in the United States and it is the basis for most of the standards. Such raw materials are, nevertheless, suitable for the production of almost equivalent steels with the use of other methods, such as the converter with oxygen enrichment. These raw materials can also be used for other types of steels with somewhat more limited applications—Bessemer and ordinary Thomas steels for instance—but it is a matter of controversy whether these steels are adaptable to certain uses which impose severe conditions on the material. An example, dealing with the efficient use of Thomas steel rails in France, is described in document L.71. During the Bogotá meeting it was stated that in the United Kingdom preference was for many years given to rails of Bessemer steel. They provided excellent results, but are now disappearing because of the scarcity of ore suitable for this process.

Because of a combination of factors, such as the small size of markets, the structure of steel transforming industries, and the characteristics of indigenous raw materials, Latin-American countries would do well to establish their own standards for the qualities and types of steel they produce. At Bogotá, this was the opinion of many participants both from the region and from the more highly industrialized countries. There would thus appear to be some justification for a meeting to study and propose specifications for adoption by all Latin-American countries, and to consider the specific conditions described above. Such a meeting should be attended by the Governments concerned and organizations representative of iron and steel producers and consumers. An excellent basis for discussion at this future meeting would be the material contributed in documents L.75, L.76, L.78 and L.80, in addition to the records of the debates at the Bogotá meeting.

Chapter VI

Economic factors affecting the consumption level and production costs of iron and steel

I. Foreword

The economic discussions which took place at the Bogotá meeting were essentially devoted to three subjects, on which papers had been prepared by the Secretariat of the Economic Commission for Latin America, namely:

(*a*) The evolution over the last 25 years of steel consumption in the principal Latin-American countries, and factors which have influenced it (Chapter I, Part Two);

(*b*) The role played by steel producing and transforming industries in the economies of Latin-American countries;[1] and

(*c*) The influence of locational factors, including size of markets, on the economics of steel production in certain Latin-American countries and sites (Chapters II and III, Part Two).

In addition to these Secretariat papers, the technical documents submitted by the experts include several which show cost and investment figures for plants using various methods for producing metallurgical fuel, for iron ore reduction and for steelmaking.[2]

The studies presented to the Bogotá meeting represent only a beginning to the systematic examination of these economic problems.[3] In particular, the calculations made of steel production costs in Latin America, which were presented by the Secretariat and are incorporated in this report, are essentially hypothetical. Their main object is to contribute to the *a priori* investigation of the influence of certain factors upon the production costs and investment requirements of the industry.

For methodological reasons and for illustrative purposes cost estimates were made for hypothetical plants assumed to be situated in different locations throughout the region. The estimates were based on known data concerning the availability of resources and raw materials, haulage distances to the hypothetical plants, wages and other information. The remaining cost elements were supplemented by general assumptions, mostly based on conditions prevailing in the United States during the reference year (1948) and sometimes adjusted to special local conditions.

Among the general assumptions, special mention should be made of the efficiency and productivity of labour. The data given is for plants assumed to have been in operation long enough to have reached an efficiency equal to that of identical plants in industrialized countries. Except for this aspect, cost figures and estimates were selected on the high side, so that the results tend to show greater costs than may generally be expected to prevail in plants actually existing in those locations.

The choice of the locations does not imply a judgment as to the comparative advantages of the various possible sites in a given country and the example chosen does not necessarily correspond to the most advantageous location in each country. To avoid an excessive enlargement of this study, only one steel producing process was considered, the conventional coke blast furnace with its steel and rolling mills. In several passages of this report it is recommended that other processes should also be considered and that such research should be carried out before any final decision is reached upon the advisability of establishing an iron and steel industry in a particular country and at a given location, or of continuing to import steel.

For comparative purposes with the industry in more industrialized countries, a series of similar cost computations was established for a hypothetical plant located on the Atlantic seaboard of the United States. A number of tables also show the sales price of steel products on the United States' domestic market, plus freight charges to the different Latin-American markets. Since the above-mentioned comparisons do not include some of the expenses connected with imports such as cost of financing, insurance, etc., these data show less favourable figures for Latin-American industries than actual conditions might imply. This conservative approach appeared all the more justified because the comparisons were generally favourable to the Latin-American industry.

Finally, as will be shown below, in view of the lack of the full employment of steel production resources, comparative costs are by no means the only relevant consideration for an economic study of the industry in Latin America.

The cost comparisons and other figures do not allow the formation of an opinion upon the advisability or otherwise of establishing a steel industry in a given country or at a given location. Nor was it intended to arrive at such a result. The object was simply to offer a method of investigation which could shed some light on many aspects that are still largely unknown and to indicate by this rapid method what factors should be studied in the cases to be examined. Before yielding fully reliable conclusions, the analysis should be substantially amplified, in particular as far as those locations, processes, and hypotheses selected are concerned. The figures given here may well be a useful stimulant to such detailed analyses.

[1] Some data on this subject were presented to the meeting in an unpublished document (L.88). In accordance with resolution 57(V), sub-paragraph 2(*d*), adopted at the Fifth Session of the Commission, a study of the development of the iron and steel and related transforming industries is being carried out.

[2] Documents L.27, L.42, L.53, L.56 and L.69 are outstanding in this connexion.

[3] Mention should be made, however, of an interesting analysis of some aspects of steelmaking in Latin America included in *World Iron Ore Resources and their Utilization, op. cit.*

Before entering upon the problem of costs, some considerations on the demand for steel in Latin America and related subjects are made available here.

II. Steel consumption and national income

The close link between the economic development of a region and its steel consumption is well known.

A great deal of steel is indispensable for the development of industry, agriculture, transport and building. Steel is used either directly, in the form of finished products from steel mills, or indirectly, in the form of capital goods. Economic development, with its consequent improvement in living standards and in the level or real savings, causes a greater demand for steel, which is an indispensable component of almost all capital and durable consumer goods and of certain non-durables. Moreover, as national income increases, the share which can be saved and invested also normally increases. Inasmuch as capital goods contain more steel per dollar of value than consumer goods, aggregate steel consumption increases more rapidly than national income.[4]

Chart II, which shows per capita steel consumption plotted against per capita national income for a series of Latin-American countries, demonstrates the strong positive correlation between them (correlation coefficient equal to 0.898). (See Chapter I of Part Two.)

The more than proportionate increase in steel consumption which takes place as national income increases is, on the whole, borne out by the figures of Table 4, which show the number of kilogrammes of crude steel consumed per $100 of national income in a series of lands, with widely varying income levels. Only three Latin-American countries—Brazil, Chile and Mexico—consumed more than 20 kg. of crude steel per $100 of national income and for Brazil and Mexico this occurred only recently when they had developed domestic steel production. For the more developed countries, conversely, the corresponding consumption ratio varied between 30 and 60 kg. (see Table 4). It should be noted, however, that the figures in Table 4 represent consumption of primary iron and steel products only,[5] and that the real consumption in under-developed countries is much higher since they also import considerable steel tonnages in the form of manufactured products. The steel content of such finished goods is ignored in statistics covering production and imports of steel products throughout this volume.

Obviously, the level of national income is by no means the only important factor affecting the tonnage of steel consumed in a country. For a given level of national income, the degree of industrialization is an essential factor. A comparison between sections A and B of Table 4 illustrates this fact clearly.

[4] This is true at least until the country concerned has been saturated with "heavy" capital goods such as railroad equipment, passenger cars, equipment for heavy industry, etc. Thereafter, with a more intensive development of aeroplanes, precision equipment, electrical machinery, etc., a relative decrease in steel requirements may result. This trend is apparent in the figures for Australia, Belgium, the United Kingdom and the United States, in Table 4.

[5] See Chapter I, footnote [3].

Table 4

RELATION BETWEEN STEEL CONSUMPTION AND NATIONAL INCOME

Countries	*Years*	*Per capita national income (1949 dollars)*	*Per capita steel consumption (kg. of crude steel equivalent)*	*Steel consumption per $100 of national income (kg.)*
A. *Latin America*				
Argentina	1947–49	404	77	19
Bolivia	1947–49	55	5	9
Brazil	1939	90	15	17
Brazil	1950	112	24	21
Chile	1940	170	38	22
Chile	1951	190	50	26
Colombia	1947–49	132	16	12
Cuba	1947–49	296	37	13
Ecuador	1947–49	40	8	20
Guatemala	1947–49	77	8	10
Mexico	1939	95	14	15
Mexico	1950	121	28	23
Peru	1947–49	100	10	10
Uruguay	1947–49	331	38	11
Venezuela	1947–49	322	62	19
B. *Other countries*				
Australia	1946	640	207	32
Austria	1947–48	146	58	40
Belgium-Luxembourg	1947–48	625	234	37
Czechoslovakia	1947–48	320	180	56
France	1947–48	462	166	37
India and Pakistan	1946	50	4	7
Italy	1947–48	212	47	23
Poland	1947–48	242	70	29
Sweden	1947–48	770	292	38
Union of South Africa	1949	264	110	42
United Kingdom	1947–48	730	252	35
United States	1949	1,453	443	30
Western Germany	1950	350	205	59

Sources: (i) *European Steel Trends in the Setting of the World Market* (Geneva, 1949), Economic Commission for Europe.
(ii) *National and per capita Incomes in Twenty Countries* (New York, 1949), United Nations.
(iii) *Economic Survey of Europe in 1949* (Geneva, 1950), Economic Commission for Europe.
(iv) Monthly *Bulletins of Statistics* of the United Nations.
(v) National statistics.

The relative importance of steel transforming industries increases rapidly with the growth of industrialization. Although accurate statistics of steel consumption by steel transforming industries are not available for Latin America, it is known that the consumption of such industries alone accounts for 30 to 40% of the aggregate consumption of all ferrous products in Mexico. The relation is similar for Argentina. But the corresponding proportion for highly industrialized countries stands at 75% or more.[6]

III. The demand, availability and shortage of steel in Latin America

Chapter I of Part Two includes a detailed examination of the evolution of the consumption of steel products in six Latin-American countries: Argentina, Brazil, Chile, Colombia, Cuba and Mexico. It contains an analysis of the influence of such factors as national income, capacity to import, imports of investment goods, building activity and consumption of cement which can be assumed to be linked with the demand and supply of steel, and for which quantitative information is available. Fairly definite conclusions emerge from a consideration of this paper.

Even at the present relatively low levels of economic development, current steel consumption in Latin-American countries is significantly lower than their requirements, the main limiting factor being the shortage of foreign exchange. Developments easing this restriction, including the creation of domestic sources of steel, tend to increase consumption substantially.

These conclusions are supported by the following facts:

1. The countries considered show a remarkably close correlation, over the last 25 years, between their steel imports and their aggregate capacity to import. During this period there have been outstanding economic changes, and some countries have achieved a degree of economic development which has increased the demand for steel. On an average of 1925-51, steel imports have fluctuated somewhat more than total imports. The reason is to be found in the inelastic character of the other imports.[7] Because of the general stagnation, or occasional decline in the capacity to import of many Latin-American countries since 1925, there has been a shortage in steel availabilities which has only begun to be filled by those countries which have developed domestic steel production.

2. Chart II shows clearly the higher steel consumption in those countires with a domestic source of steel.[8] Almost all countries whose steel consumption exceeds the levels shown by the regression line between steel consumption and national income possess a domestic industry to supplement imports.[9] Venezuela is an exception since it is practically the only country in Latin America with no balance-of-payments problems. Mexico, Brazil and Chile have undertaken the domestic production of steel and it is interesting to note that their consumption increased by 60, 32 and 100%, respectively, during the decade between 1939-40 and 1950-51. During this interval, the per capita national income of these countries increased only moderately; 22, 12 and 27% respectively.

To avoid being limited to one indicator alone, namely per capita national income, an analysis has also been made of the relation between steel consumption on the one hand and imports of capital goods and cement consumption on the other—the two latter being closely related to the level of investments as well as to national income. A high multiple correlation coefficient (0.925) has been observed and a regression formula calculated, to which the different levels of the above quantities in selected Latin-American countries can best be adjusted.[10] From this formula a theoretical value of steel consumption for every combination of levels, imports of capital goods and cement consumption and of national income can be derived.

Table 5 shows these theoretical consumption levels, together with the actual steel consumption for the same years. An additional column, expressed in percentages of the calculated levels, shows the departure from them of actual consumption. It will be observed again that the positive deviations correspond to the countries which have developed domestic steel production facilities; they are also greater in the postwar years when these facilities became more important.

Table 5

THEORETICAL AND ACTUAL STEEL CONSUMPTION IN SELECTED LATIN-AMERICAN COUNTRIES

Countries	*Years*	*Theoretical steel consumption* (*kg. of crude steel equivalent per capita*)	*Actual steel consumption* (*kg. of crude steel equivalent per capita*)	*Percentage difference*
Argentina	1947–49	64	77	+20
Bolivia	1947–49	9	5	−44
Brazil	1939	13	15	+15
Brazil	1950	18	24	+33
Chile	1951	38	50	+32
Colombia	1947–49	23	16	−30
Cuba	1947–49	42	37	−12
Ecuador	1947–49	9	8	−11
Guatemala	1947–49	12	8	−33
Mexico	1939	14	14	—
Mexico	1950	21	28	+33
Peru	1947–49	16	10	−38
Uruguay	1947–49	54	38	−30
Venezuela	1947–49	67	62	− 7

Source: Economic Commission for Latin America and sources for Table 4. See also Table 14.

3. Although it is difficult to compare potential demand for a commodity with its actual consumption, in certain cases the evidence of a steel shortage in Latin America can be shown. Thus, notwithstanding the considerable rise in steel output in Brazil during recent years, a rationing system for the products of Volta Redonda is still in force. Given the limited capacity to import of the Latin-American countries, increasing or newly arising demand for certain types of steel linked, for instance,

[6] See Table 2 of *European Steel Exports and Steel Demand in Non-European Countries*, Economic Commission for Europe (E/ECE/163, E/ECE/Steel/75), Geneva, 1953.

[7] In the case of Chile, for instance, it appears that iron and steel imports have a higher elasticity in relation to total imports than imports of foodstuffs, textiles, chemicals and fuel. Among the main groups of imports, only capital goods have a higher elasticity than iron and steel.

[8] See Chapter I of Part Two.

[9] This is also true of non-Latin American countries such as Austria, Italy, Poland and the Union of South Africa, where levels of per capita national income are similar to those of Latin-American countries and for which data on steel consumption have been given in Table 4.

[10] For details see Chapter I of Part Two.

EXPLANATION OF SYMBOLS

The following symbols have been used throughout this volume:

Two dots (. .) indicate that data are not available or are not separately reported.

A dash (—) indicates that the amount is nil or negligible.

A minus sign (−200) indicates a deficit or a decrease.

A full stop is used for decimals.

A comma distinguishes thousands and millions.

Use of a hyphen (-) between dates representing years, e.g., 1947-49, signifies the full period, including the beginning and end years.

Minor discrepancies in totals and percentages are due to rounding.

References to tons in every case represent metric tons.

References to dollars, unless otherwise specified, signify United States dollars.

with industrialization, must be met at the expense of imports of other steel products which are less urgent. Imports of rails and accessories, for example, have been adversely affected in many cases as indicated in Table 6. As a result, this has led to inadequate railway maintenance standards.

Table 6

DECLINE OF THE SHARE OF RAILS AND ACCESSORIES IN LATIN-AMERICAN STEEL

(Percentage of total apparent steel consumption represented by rails and accessories)

Country	1925–29	1945–49
Argentina	15.5	5.7
Brazil	26.7	14.1
Chile	22.0	11.5
Colombia	26.3	5.5
Mexico	17.9	12.8

Source: Economic Commission for Latin America.

4. Finally, throughout the last 25 years, the consumption of steel has tended to decrease in Latin America, both in the aggregate and for specific products when compared with the evolution of a series of other indicators of economic growth normally connected with steel consumption. A detailed study of these trends will be found in Chapter I of Part Two.

There is thus little doubt that steel continues to be in short supply for Latin America. Steel consumption in most Latin-American countries would, other things being equal, increase and develop considerably faster if production facilities were created or amplified.[11]

Thus, Latin America's prospects for steel are governed by the following factors:

(*a*) A steel shortage at present exists in most countries of the region;

(*b*) Population is increasing rapidly at an average of 2.25% annually;

(*c*) Real per capita national income increases at a rate of about 3% annually. It has also been shown that, as a result of the higher proportion of investment, the demand for steel generally increases more rapidly than national income;

(*d*) The present trend towards industrialization in most countries may be expected to continue and industrialization represents additional steel consumption.

It is thus clear that, unless a major depression occurs, Latin America's steel demand in future years will be considerably higher than current consumption levels. The satisfaction of this demand is indispensable to the industrial development of the region.

Essential supplies of steel for Latin America are derived from imports or domestic production, but the unfavourable development of the capacity to import precludes any substantial increase in steel imports for many countries. In contrast, most Latin-American countries, and among them all the major steel consumers, possess at least some of the essential resources for steel production. In fact Latin America contains about 20% of the world iron ores reserves which can be exploited economically. It is the region with the highest per capita resources of iron ore: 37 tons of metallic iron per capita as against a world average of 11 tons.

[11] Already Latin-American per capita steel consumption has increased by one quarter—from 21.6 kg. in terms of crude steel to 27.2—between 1945-48 and 1949-51 (and by one half between 1945-48 and 1951). These rates of increase are exceptional, but a regular yearly increase of 6% in total consumption in all under-developed countries has been considered as a realistic, although high, assumption in a recent study of the Economic Commission for Europe.

IV. Economic characteristics of steel production

1. THE CLASSICAL STEELMAKING PROCESS

Before discussing the respective advantages of domestic steel production in Latin America as against imports, attention should be drawn to certain characteristics of steel production which have a considerable bearing upon costs.

First, steelmaking is a heavy industry, that is, the weight of raw materials in relation to the cost of the product is considerable. Frequently some five to six tons of raw materials, such as two to three tons of iron ore, about two tons of coal and more than one ton of other materials (scrap, fluxes, fuel oil, etc.), are required to produce one ton of finished steel, at present worth about $120. At the existing Latin-American plants, or at the sites which have been considered in this study, the ton-kilometres of transport[12] required to assemble these materials may vary between 800 and 5,000 for ore and coal alone. As a result, raw material transport costs represent an exceptionally high proportion of aggregate steel costs. The ratio in Latin America varies between 5 and 10% for plants which are particularly favourably placed for raw materials, and 15 to 20% for others.

Secondly, an immediate consequence is the strong influence of plant location on steel costs. The distance over which raw materials must be carried, and even more important, the means of transport, whether rail, road, inland waterway or sea, greatly influence costs. The study on the costs of steel production in certain Latin-American locations (Chapter II, Part Two), shows that total transport costs per ton of finished products vary from $3 to $27. To this should be added the cost of transporting finished steel to the consumer.

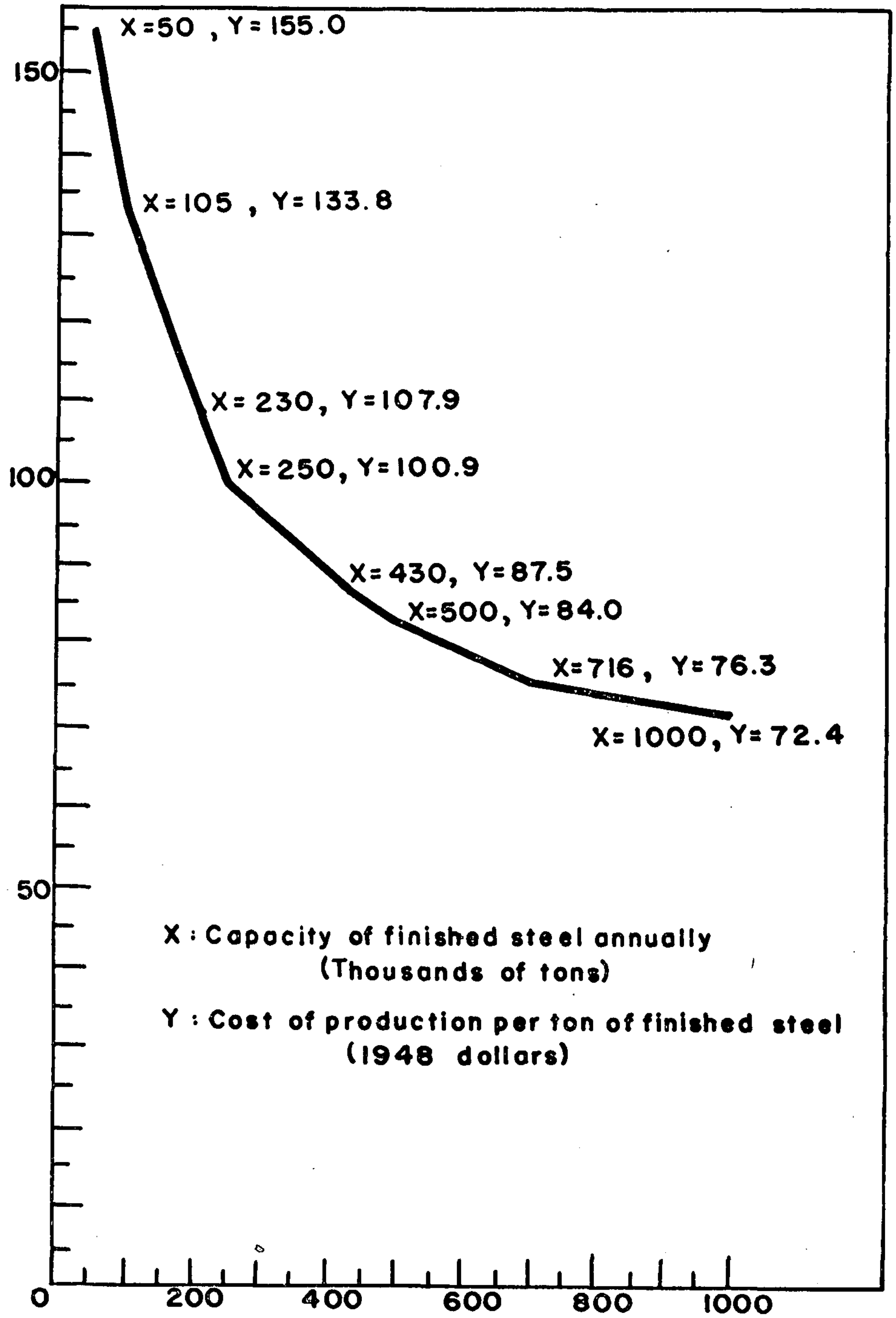
Thirdly, although comparisons of capital investment for different industries are difficult to make, the capital which must be invested per unit of output, in order to add a certain value for steelmaking, is substantially higher than for other industries. (See Table 12.)

Finally, investment costs in steel mills are very strongly affected by the size of the production unit. Rolling operations are particularly influenced by size, since they can be accomplished by a variety of methods. Some utilize relatively rudimentary equipment and a considerable amount of labour whereas others are highly mechanized, use less labour and require very complex equipment. Some modern equipment, such as the continuous wide strip mill, can only be used economically for an output of the order of one million tons a year. The saving in aggregate production costs brought about by more complex and more productive equipment depends on the relative costs of capital, labour and raw materials. As an example, Chart I shows the variations

[12] In equivalents of railway ton-kilometres.

Chart I

RELATION OF SIZE OF PLANT TO PRODUCTION COST OF FINISHED STEEL IN SPARROWS POINT CONDITIONS
(natural scale)



Source: Economic Commission for Latin America.

in the total costs of producing one ton of a given assortment of finished steel at Sparrows Point, in hypothetical plants ranging from 50,000 to one million tons of annual capacity. It will be noted that costs are reduced by more than one half between the smallest and largest plants.

Economies of scale are particularly important in rolling operations; they depend on the type of finished product made, while recent impressive progress in methods of producing flat products (plate, sheet, strip, tinplate, etc.) cause the effect of size to be more pronounced for these items than for bars and sections.

The advantage of building production units as large as the market would allow, combined with the relatively high investment per ton, tends to make investments required for the creation of steel industries very high. Investment costs for a modern plant may easily total hundreds of millions of dollars.

2. ALTERNATIVE PROCESSES FOR STEEL PRODUCTION

The technical section of this report includes a thorough examination of alternative processes, either available or being developed, for the production of iron and steel. They are mainly concerned with iron ore reduction by means other than the blast furnace, and in a lesser degree, with steel making by means other than the usual furnaces, blooming and rolling mills.

These alternative methods are especially appropriate for the use of certain raw materials or of hydro-electric power and other natural resources as well as for the production of specific end-products. They lead to considerable variations in the costs of finished steel, and still more so in the levels of the output-capital ratio. According to document L.62, production costs for pig iron may vary in the four reduction methods considered,[13] from $28 to $45 per ton, whereas investment per ton-year produced may vary from $25 to $100.[14] According to document L.56, production costs of ingot steel have a margin of variation of 20% when the production process varies. Document L.53 shows that investment in the steelmaking shop may vary, according to process, between $20 and $46 a ton.[15] Although similar figures are not available for rolling operations, the utilization of such methods as continuous casting of billets, or extrusion of finished shapes, may bring about considerable variations in production costs and in investments per ton, particularly for relatively small operations.

Some of the alternatives to classical steelmaking and iron ore reduction methods, such as low-shaft furnaces, direct reduction methods, utilization of oxygen in steelmaking and continuous casting and extrusion, require less capital investment although they may reduce the productivity of labour. They therefore seem *a priori* better adapted to small-scale operations in under-developed countries than the classical processes.

The detailed discussions on economic problems at the Bogotá meeting were mainly devoted to the classical processes. This preference results from greater knowledge of these methods, and the existing publications covering costs and investments in their various stages. Cost and investment estimates have, however, also been presented for some of the alternative methods, usually as comparisons with a standard plant of a given size. Since data for the classical process are available for seven Latin-American countries, figures referring to the other processes may thus be related to conditions prevailing in the region.

If the markets of a given country are strongly decentralized, and transport facilities limited (as in the case of Brazil and Mexico), the advantage of installing more than one production centre should be examined. In such a case, the small size of some of the local markets might cause one of the alternative methods to be more desirable.

Situations may arise in which haulage costs to certain areas become so high as to upset the usual pattern of comparative advantages. One instance is explained in document L.82, which describes a small plant recarburizing steel scrap into pig iron, which operated profitably for years near Bogotá. It might well be that in such extreme cases, a small and therefore normally unprofitable plant using a non-classical process could become an incentive to the economic development of an isolated zone. In order to determine the possible advantages for such an industry, a market study of the area is indispensable. The methodology followed in Chapter I, Part II may be helpful in this connexion.

From the discussions dealing with those problems, it became evident that alternative processes, as well as the corresponding costs and investment, must receive a detailed examination before final judgment is passed on the advisability of installing a steel industry in a new country or area.

V. Economic factors relating to steel production at certain Latin-American locations

1. SCARCITY OF RESOURCES AND THE BALANCE OF PAYMENTS

The relative economic advantages of steel production in Latin America, as compared with steel imports, are discussed below.

The analysis will be outlined essentially from the point of view of the interests of the country or community. In fact, such factors as multiple exchange rates, quantitative restrictions, subsidies, taxes, etc., tend to make a generalized examination of the advantages accruing to the individual producer or importer extremely difficult.

Whether steel production in a given location is more advantageous to a country than the importation of steel, depends largely upon the resources required for domestic steel production. Steel output might, or might not, involve the utilization of resources which could otherwise be used for increasing production of exportable commodities for which there is a market abroad, or for the substitution of other imports.

In the former case, relative costs of production and import of steel are extremely relevant. In the latter case, additional criteria must be taken into account. In fact the latter situation occurs in many Latin-American countries.

First, unused resources exist, and steel production could add to the aggregate income of the country without detracting from the potential production of commodities earning foreign exchange.

Secondly, inelastic world demand for many commodities exported by the area is such that a greater volume of exports would not substantially add to foreign exchange earnings.

In contrast to many industrialized countries, productive resources are not fully utilized in many Latin-American countries. For the majority, there is a substantial excess of manpower. Although unemployment is often hidden both in rural and urban districts, there can be little doubt that a large reserve of unused labour exists throughout the region. In so far as raw materials are concerned, as already mentioned, considerable reserves of iron ore exist. In many cases the iron ore reserves could not be exploited because of heavy costs involved in shipping this relatively cheap material to purchasers abroad. This applies to an even greater extent to other resources such as limestone, hydro-electric power or natural gas. On the other hand the majority of Latin-American countries obtain much of their foreign

[13] Blast furnace, electric smelting furnace, sponge iron furnace and tunnel kiln.

[14] Under conditions prevailing in Canada during 1948.

[15] United States conditions, 1952, 250,000-ton plant.

exchange from selling a very limited number of commodities representing an important share of the aggregate world supply. Since world demand for such products is inelastic, the total potential export earnings, and consequently the capacity to import, are limited and cannot be substantially raised by using resources which might alternatively be used for steelmaking. It should be noted on the other hand that capital is almost always scarce in Latin America. This problem will be examined separately below.

Although, as a result of the above facts, comparative costs of production and of imports are by no means the only factors to be considered in an analysis of the economic advantages for steel production in Latin America. The Secretariat has deemed it useful to present some absolute and comparable figures reflecting costs of producing steel, for different locations and scales of operation. The problem of the utilization of resources which are not scarce and the balance-of-payment effect of steel production are analysed hereunder.

2. Steel production costs in Latin America and the United States

(a) *Method, assumptions and examples*

The method followed by the Economic Commission for Latin America is explained in Chapters II and III of Part Two, which should be considered jointly. It consists of a detailed examination of the different cost components of steel production in its different stages, of pig iron, crude and finished steel. To calculate steel production costs in several Latin-American countries, and at one North American site, the following factors must be considered: (*a*) cost, quality and location of raw materials; (*b*) costs of labour and capital; (*c*) size of the market and (*d*) process used.

A certain number of general assumptions were necessary in order to ensure the comparability of cost calculations as between the various locations. The most important are enumerated below:

1. It was assumed that the steelworks are identical in size at the various sites and thus the influence of raw material and labour prices on production costs of plants producing 250,000 tons of finished products per year is determined thereafter. All steelworks were taken as functioning at 100% capacity.

2. For a given means of transport, transport costs per ton-kilometre were assumed to be equal.[16] Transport tariffs which are influenced strongly by open and hidden subsidies have been ignored, since they are often determined by non-economic factors. Allowance has been made in Chapter III, Part Two to some extent for the influence of return freights, etc.

3. Productivity of labour was assumed to be equal at all the sites. This may not be the case for a newly established industry until the end of a certain "breaking in" period of several years, however. The experience of recently established steel industries in Latin America indicates that this hypothesis is not unrealistic.

4. In view of the extensive mechanization of open-pit mining, extraction costs of iron ore and limestone were assumed to be equal at all locations.

5. It was assumed that coke is produced, as far as possible, from domestic coals and blending materials. Coal costs have been estimated on the basis of the thickness of the veins, other geological conditions and mining productivity in each country. The cost of imported coals and blending materials is that of the international market in 1948.

6. A supply of scrap, equal to 10% of crude steel production and worth 90% of the price of pig iron, has been assumed throughout.

7. The cost of steelmaking equipment was considered as equal in all Latin-American locations and 20% higher than in the United States.

8. Interest and amortization were assumed to be equal to 9% of the total cost of the equipment in Latin America and to 8% in the United States. No allowance was made for taxes or profits.

9. Certain minor cost elements were assumed to be equal in terms of either dollars or physical units. For others, reasonable variations have taken local conditions into account.

10. The variety of finished steel products manufactured by all the plants were assumed to be identical in percentage distribution and to be typical of the demand for standard products of a Latin-American country. The quality of steel was assumed equal throughout. (See Chapter II of Part Two.)

11. All prices used refer to the average for 1948.

12. The adoption of these assumptions allowed costs to be calculated directly in dollars for all items except labour. Exchange rates were necessary only when converting wages at the different sites into a common currency. Since the final aim of the study is to illustrate the comparative advantages of producing steel locally, the exchange rates correspond to those used for steel imports in 1948.

Locations of the hypothetical plants for which cost analyses have been made include each of the seven Latin-American countries selected for this study. Most of these sites represent the location either of existing plants or of projected steelworks. Where the site is that of an existing plant, the hypothetical productive unit is usually different in size from that in existence. For this reason, in addition to the hypothesis enumerated above, costs will differ from those actually prevailing in the existing plants.

The only difference between the steelworks of equal size is that linked with the type of process used, which depends upon the qualities of locally available ores. The following processes have been considered: (*a*) open-hearth furnaces; (*b*) a combination of 80% basic open hearth capacity with 20% acid Bessemer capacity; and (*c*) a combination of Thomas converters with electric furnaces.

Generally, cost calculations were based on the maximum utilization of domestic raw materials in every country. However, in many cases, imports of coking coal, covering either part or total requirements, had to be assumed.

At a further stage (Chapter III of Part Two), plants of different sizes are considered. Their size was estimated on the basis of apparent steel consumption during 1947. A reduction of some 20% was made to allow for the fact that no matter how diversified a single plant, it cannot produce the whole assortment of finished steel

[16] Estimates of the actual cost of transporting bulk raw materials in the United States have been used.

Table 7

RAW MATERIALS, PROCESSES AND CAPACITIES SELECTED FOR COST ANALYSIS OF LATIN-AMERICAN STEELMAKING LOCATIONS

Plant	*Source of iron ore*	*Source of coking coal*	*Steelmaking process*	*Annual capacity of finished steel (thousands of tons)*
San Nicolás, Argentina	(i) Zapla, Argentina (ii) Itabira, Brazil (iii) Sierra Grande, Argentina	United Kingdom or Union of South Africa	Basic[a] open hearth	850
Volta Redonda, Brazil	Lafaieta, Brazil	United States 70% Santa Caterina 30%	Basic[b] open hearth and acid Bessemer	716
Huachipato, Chile	El Tofo, Chile	Gulf of Arauco 85% United States 15%	Basic[b] open hearth and acid Bessemer	230
Belencito, Colombia	Paz de Río, Colombia	Paz de Río, Colombia	Basic Bessemer (Thomas) electric furnace for scrap smelting	105 250[c]
Monclova, Mexico	Cerro de Mercado, Mexico	Durango, Mexico	Basic open hearth	430
Chimbote, Peru	Marcona, Peru	Santa (Peru) anthracite 85% Venezuelan asphalt 15%	Basic[b] open hearth and acid Bessemer	50 150[c]
Barcelona, Venezuela	El Pao, Venezuela	(i) Domestic petroleum or asphalt residues (ii) United States (West Virginia)	Basic[b] open hearth and acid Bessemer	200 300[c]
Sparrows Point, United States	El Pao, Venezuela	United States	Basic[b] open hearth and acid Bessemer	1,000

Source: Economic Commission for Latin America.
[a] Using Sierra Grande ores.
[b] Basic open hearth 80%, acid Bessemer 20%.
[c] For explanation of alternative capacities in the cases of Colombia, Peru and Venezuela, see above chapter.

products required by any given country. If it is recalled that Latin America's steel consumption since 1947 always rose each year and that it would increase beyond the present level if domestic production were established, the use of these hypotheses tends to provide cost estimates which are on the high side. On the other hand in the case of Argentina, Brazil and Mexico, a factor which offsets this unfavourable effect is the existing tendency towards the decentralization of steel output.

For Colombia, Peru and Venezuela which had no domestic steel sources in 1947, cost and investment estimates for larger plants than those corresponding to 1947 consumption figures have also been prepared. (See Table 7.) The corresponding capacities have been chosen on the basis of the conclusions of Chapter I, Part Two, namely, the level to which short-term consumption might be expected to rise, assuming that domestic output is developed.[17]

The locations selected and the productive capacities are summarized in Table 7. It should be noted that, for Argentina, three different sources of iron ore were considered; domestic Zapla and Sierra Grande ores, and imported Itabira Brazilian ores. The resulting cost variations are considerable. In analysing the influence of size upon costs, only the use of Sierra Grande ore has been contemplated.

(b) *Results of the analysis of examples selected*

The method permits a full quantitative analysis of the influence upon comparative production costs of the main factors affecting them.

[17] These capacities correspond approximately to 80% of the potential apparent consumption, obtained from the relation between steel consumption on the one hand, and national income, imports of capital goods and cement consumption, on the other, in the four countries with a domestic steel industry.

(i) *Assembly costs of raw materials.* Thus the influence of the available raw materials can be seen from the respective assembly costs of such materials for pig-iron production. These assembly costs represent an important factor in steel costs, because of their considerable bulk and also because coal and iron ore deposits are seldom found near each other. Assembly costs depend upon the quality of the raw materials, the outlay for mining them and costs of haulage to the plant. All these factors, to-

Table 8

HYPOTHETICAL ASSEMBLY COSTS FOR SELECTED LATIN-AMERICAN LOCATIONS

(250,000-ton plants)

Plant	*Assembly costs* — *Dollars per ton of pig iron (1948 dollars)*	*Assembly costs* — *Index (Sparrows Point = 100)*	*Assembly costs in relation to finished steel costs adjusted to size of markets*
San Nicolás[a]	59.15	218	..
San Nicolás[b]	42.74	158	..
San Nicolás[c]	38.88	143	42
Volta Redonda	37.33	138	44
Huachipato	23.05	85	28
Belencito	17.62	65	23
Monclova	26.74	99	32
Chimbote	18.80	69	21
Barcelona[d]	21.68	80	..
Barcelona[e]	26.40	98	25
Average[f]	26.26	96	..
Sparrows Point[g]	27.14	100	37

[a] Zapla ore.
[b] Itabira ore.
[c] Sierra Grande ore.
[d] Coke from asphalt or petroleum residues.
[e] Coke from imported coal.
[f] Unweighted arithmetic average, considering: in Argentina, Sierra Grande ore; in Venezuela, coke from imported coal.
[g] Venezuelan ore, West Virginia coal.

gether with transport costs of finished steel to the markets, are important for the determination of the site of a steelworks. Table 8 shows assembly costs for the locations selected in Latin America and for Sparrows Point.

It would therefore appear that the highest assembly costs correspond to those locations which have been selected near major markets: Buenos Aires and Rosario in Argentina, São Paulo and Rio de Janeiro in Brazil. In Chile, Colombia, Peru and Venezuela, sites closer to the raw materials were chosen and therefore the assembly costs appear to be lower. Mexico occupies an intermediate position, since the plant location falls within a triangle consisting of the principal markets, the iron ore reserves and the coal deposits.

Table 9

HYPOTHETICAL COSTS OF DOMESTIC AND IMPORTED STEEL AS AFFECTED BY LOCATIONAL FACTORS
(1948 dollars)

	Domestic steel			*Imported steel*	
	Production costs for hypothetical plants			*United States' steel prices plus transport differential to Latin-American Markets*[a]	
	Equal size plants of 250,000 tons annual capacity	*Plants of size appropriate to markets*[b]			
Plant	*Wages and capital charges equal to U.S. figures*	*Wages and capital charges at domestic rates*		*Delivered costs of imported steel from Sparrows Point*[c]	*Delivered prices o imported steel from Pittsburgh*[d]
	(1)	(2)	(3)	(4)	(5)
San Nicolás[e]	119	105	92	91	115
Volta Redonda	114	102	85	86	110
Huachipato	94	84	82	87	111
Belencito	81	76	76	84	108
Monclova	99	90	83	84	108
Chimbote	93	82	90	86	110
Barcelona[f]	105	104	94	82	106
Average	101[g]	92[g]	87[h]	87	111
Spread as percentage of average	37	32	21	40	8
Sparrows Point	100	100	72	..	..

Source: Economic Commission for Latin America (Chapters II and III of Part Two).

[a] To prices in the United States, transport costs to the Latin-American markets have been added and transport costs of Latin-American plants to their markets have been subtracted.

[b] Size of plants (thousand tons): San Nicolás 850; Volta Redonda 716; Huachipato 230; Belencito 250; Monclova 430; Chimbote 150; Barcelona 300; Sparrows Point 1,000.

[c] Assuming Sparrows Point capacity as one million tons.

[d] Based on a composite steel price in Pittsburgh of $86 per ton in 1948. The assortment considered is analogous to that envisaged for the production of the Latin-American plants.

[e] Using Sierra Grande ore.

[f] Using imported coal.

[g] Unweighted average.

[h] Weighted average.

(ii) *Costs of finished steel.* Column 2 of Table 9 shows the estimated costs obtained in plants of equal size if local wage rates and capital costs are considered in the calculations. In column 1, the same data are given but using United States wage rates and capital costs. The figures in column 3 correspond to cost estimates for plants of sizes appropriate to the Latin-American markets, using local wage rates and capital costs. The figures in column 4 represent the estimated costs of a one million ton a year plant located at Sparrows Point, plus the transport cost differentials to Latin-American markets.[18] These figures have been termed "delivered costs of imported steel". Finally, the data in column 5 are obtained from adding to the 1948 steel prices[19] in the United States, the transport cost differentials to Latin-American markets. Such data were called "delivered price of imported steel".

(iii) *Influence of geographical factors.* Column 1 of Table 9 shows, therefore, the variations in costs resulting from purely natural and geographical factors, such as location, and the quality and cost of raw materials. The assumptions are that all the plants are of similar size and that the price of labour and capital are equal to those in the United States. It may be noted that the spread in costs of finished steel amounts to 37% of the average. On the other hand (to the extent that average figures are significant) the Latin-American locations taken as a whole have production costs determined by purely geographical considerations, which are practically equal to those corresponding to the Atlantic seaboard of the United States.[20]

(iv) *Influence of wage rates and capital costs.* The above comparison is relevant for a long-term evaluation of the importance of Latin-American locations,

[18] These differentials correspond to average transport costs of finished steel from the United States centres (Sparrows Point or Pittsburgh, whichever is selected) to Latin-American markets, minus average transport costs from Latin-American steelworks to their respective markets. It was estimated that in 1948 transport costs for the finished product were $10 higher for Sparrows Point than for domestic steel in the case of Venezuela, $12 for Colombia and Mexico, $14 for Peru and Brazil, $15 for Chile and $19 in the case of Argentina. Transport costs from Pittsburgh to the Atlantic seaboard were estimated at $10. The above estimates of transport costs are rough approximations. No account has been taken of insurance and demurrage charges in ports. Similarly, additional expenditure such as delays involved in obtaining imported steel, storage necessities, customs duties, taxes and profits of intermediaries have not been taken into account, both for domestic and imported steel, in view of their highly variable character and of the fact that they are not readily comparable with production costs.

[19] These prices correspond to the series "Composite Finished Steel", compiled and published by the *American Metal Market.* It represents the weighted price of an assortment similar to the programme of the Latin-American plants. For transport differentials, see note [18] above.

[20] On the assumption of using Venezuelan ore at Sparrows Point.

when, as a result of accelerated economic growth it might be assumed that labour and capital costs would tend to equalize between Latin America and the more industrialized countries. For short- and medium-term prospects, the lower and variable costs of labour in Latin America and the higher rates of interest must be taken into account. In this case, the figures in column 2 of Table 9 should be considered. Here costs are less diversified. Due to the considerably lower wage levels, Latin-American locations as a whole appear in a more favourable light. Thus, the unweighted average for the seven locations is $8 below the Sparrows Point figures.

(v) *Influence of size of plant.* The relation between the costs of similar size plants would be relevant to a study of the advantages of steel production in Latin America if the erection of large optimum size plants could be justified from an economic aspect. Since this is not the case at present, however, a realistic examination of the problem involves some consideration of costs in plants appropriate to the size of Latin-American markets. The corresponding calculations are included in Chapter III, Part Two, and the respective production costs of finished steel appear in column 3 of Table 9. Because of the considerably smaller size of individual Latin-American markets compared with that of the United States, the influence of the size factor greatly increases Latin-American costs while moderately reducing the spread, since steelworks which have the highest raw material costs face the largest domestic markets, and vice versa.[21] The average of the Latin-American figures gives a production cost which is higher by $15 or 21% than the Sparrows Point cost.

(vi) *Comparison with imported steel costs.* On the assumption that manpower, raw materials and capital resources required for steelmaking are all scarce, and could be used for alternative output to strengthen foreign exchange reserves, either by expanding exports or substituting imports, the relative advantages of domestic steel production as against imports can be measured by the differential between production costs in the respective Latin-American countries and the costs of imported foreign steel. Ignoring unpredictable considerations of commercial policies of potential steel exporters, and assuming that "normal" profits are equal in Latin America and elsewhere, production costs in Latin America should be compared first with the cost of production abroad; and secondly the price at which a similar steel assortment was sold in Latin America by exporters during the base year. In both cases, account has to be taken of differences between transport costs of the finished product to the Latin-American market, both from the Latin-American and the foreign steelworks. To simplify, the foreign costs with which comparisons may be made can be assumed to be those of steel delivered from Sparrows Point to the Latin-American market.

The centres of gravity of consumption have been determined for the Latin-American countries and "transport cost differentials"—or differences in the cost of transport from the domestic mill and Sparrows Point to these centres—calculated. These were added to the Sparrows Point production cost to give the figures of column 4. A comparison between columns 3 and 4 of Table 9 therefore indicates the influence of all the principal factors (raw materials, labour and capital costs, size of plant, and transport of finished products).

Here again considerable differences appear between the advantages and disadvantages of the various locations, some showing lower costs for the domestic product and some higher. All in all, the weighted average of the seven Latin-American countries is equal to the delivered cost of imported steel.

(vii) *Comparison with imported steel prices.* If, instead of comparing costs in selected Latin-American sites with those obtained in a hypothetical one million-ton plant at Sparrows Point, the average selling prices in the United States are taken into account, the situation is substantially modified. Columns 3 and 5 of Table 9 show the corresponding figures. The average delivered selling price of imported steel would be $24 (28%) higher than the average cost at the Latin-American sites. For each of the Latin-American countries under consideration, production costs for domestic steel sold on the local market are less than the price for North American steel on the same market.

3. Effect of steel production on the balance of payments

It has been noted that some productive resources are not in short supply in the region and that, without directly affecting the balance of payments, both manpower and raw materials are available for steelmaking. It has been noted also that in many countries the possibility of improving the balance of payments by increasing foreign exchange earnings is limited. The method of cost calculation permits an analysis of the advantages to be gained by establishing steel plants if these facts are taken into account. Obviously, the degree to which resources are scarce, and to which they can be utilized to accrue foreign currency (alternatively to steelmaking), varies from country to country, and cannot be examined in detail here.

An extreme case, however, may involve the assumption that all home resources are not scarce and that they would be unemployed if steel production were not developed. On the other hand, capital and imported raw materials are obviously scarce and, in addition to some share of overheads and other costs, must be paid for in foreign exchange.[22] Inasmuch as Chapters II and III of Part Two include a breakdown of production costs from raw materials to finished steel, it is possible to separate scarce and non-scarce factors. A calculation can be made of the proportion of the cost of finished steel which corresponds to scarce factors. These proportions are shown in Table 10. The necessary expenditures in foreign currencies can in turn be compared with the delivered cost of imported steel. The figures show that in every Latin-American location, steel production represents a considerable saving in foreign exchange, if compared with steel imports, and represents an addition to aggregate income, by utilizing factors which would otherwise remain unemployed. This fact is still more striking if a comparison is made with the delivered price

[21] Venezuela is an exception to this rule.

[22] The two concepts—scarcity and expenditure in foreign currency—do not correspond strictly, the second being more limited than the first. For instance, capital is always scarce, but all of it should not necessarily come from abroad. In Table 10, certain adjustments have been made to allow for this fact. This calculation should therefore be considered an extreme example.

of imported steel (column [5] of Table 9), instead of with delivered cost.[23]

Table 10

PROPORTION OF FINISHED STEEL COSTS[a] TO BE PAID IN FOREIGN EXCHANGE

Plant[b]	Proportion of cost (percentage)	Expenditures (1948 dollars)	Delivered cost of imported steel from Sparrows Point (1948 dollars)	Delivered price of imported steel from Sparrows Point (1948 dollars)
San Nicolás[c]	57	52	91	115
Volta Redonda	48	41	86	110
Huachipato	44	36	87	111
Belencito	45	34	84	108
Monclova	44	30	84	108
Chimbote	47	41	86	110
Barcelona[d]	47	44	82	106

Source: Economic Commission for Latin America (Chapter III, Part Two).

[a] It has been estimated that the following shares of integrated plant costs must be paid for in foreign exchange:

	Per cent
Imported fuel	100
Ferroalloys	50
Wages and salaries	5
Miscellaneous	33
Capital charges	75

[b] Plant capacities are the same as in Table 9.

[c] Using Sierra Grande ore.

[d] Using coke from imported coal.

4. RELATIVE CAPITAL INTENSITY IN STEEL PRODUCTION AND OTHER ACTIVITIES

Capital is a scarce factor of production in all Latin-American countries. As a consequence, productivity in steel production as against other activities should be studied carefully. It has already been noted that steel production has a high capital intensity relative to other activities. In other words, the relation between capital investments and the value added to raw materials through the productive process (output-capital ratio) is relatively high.

Table 11

OUTPUT-CAPITAL RATIO[a] FOR STEEL PRODUCTION IN VARIOUS LOCATIONS[b]

Plant[c]	
San Nicolás[d]	4.9
Volta Redonda	4.8
Huachipato	4.9
Belencito	4.5
Monclova	4.8
Chimbote	5.4
Barcelona[e]	4.9
Sparrows Point	5.2

Source: Economic Commission for Latin America.

[a] Ratio between investments necessary to produce a certain quantity of steel and value added by the production process.

[b] Assuming that the steelworks purchase the raw materials.

[c] Plant capacities are the same as in Table 9.

[d] Using Sierra Grande ore.

[e] Using coke from imported coal.

Output-capital ratios for various locations are shown in Table 11. The values emerge as an average of 5, and are well above figures generally observed for other manufacturing activities. This relative disadvantage for steel production should be borne in mind when examining the problem of the economic advisability of establishing steelworks. It is especially relevant for countries where domestic capital is extremely scarce and where credit from international agencies must be used for other economic development projects.

However, in several Latin-American countries, including four of the locations studied, Volta Redonda, Huachipato, Belencito and Monclova, large steel plants already exist. Thus the marginal output-capital ratio between the additional capital necessary to increase production and the resulting value added, should be taken into account. The figures in Chapter III of Part Two do not permit an analysis of this type, but it should be recalled that expansions in Latin-American steel plants to date have resulted in a decrease of investment per unit of production.

The establishment of a domestic source of steel is often a prerequisite for the development of steel transforming industries which have a lower capital intensity than steel production. Thus it may be seen that the output-capital ratios in steel production (taken as 100) and in various sectors of the steel transforming industry are as follows. (See Table 12).

Table 12

OUTPUT-CAPITAL RATIOS IN STEEL TRANSFORMING INDUSTRIES AND IN STEEL PRODUCTION

(Output-capital ratio in steel production = 100)

	Brazil 1949	Chile 1948	United States[a] 1945
Primary transformation of steel (wire, screw, tubes, drums, etc.)	52	92	..
Mechanical industries	30	53	46
Transport equipment industries	83	75	32

Source: Economic Commission for Latin America.

[a] Combined output-capital ratio for steel and primary metallurgical industries.

On the other hand, the capital costs used in Chapter III of Part Two correspond to the installation of new and very modern equipment and could be substantially reduced if the utilization of somewhat older equipment were considered. Such a solution would also reduce the absolute total of investment, thus eliminating some of the difficulties in the establishment of steelworks.[24]

VI. Other factors affecting the economics of steelmaking in Latin America

The nature and scope of Chapters II and III of Part Two have limited the number of both cases to be examined and of the cost comparisons. It should be recalled, however, that the cases studied are taken only as examples of costs corresponding to steel output in selected Latin-American countries and elsewhere. No

[23] It should be emphasized that the assumption of non-scarcity of domestic resources is applicable with varying degrees to each country, particularly in so far as domestic fuel is concerned. Whereas in Brazil it might be assumed that domestic metallurgical fuel would not be mined if there were no steel plants within the country, this is not the case for Chile where metallurgical fuel is extracted from the same mines as other fuel and would find an alternative utilization if it were not used in steel plants.

[24] It should also be noted that for many Latin-American countries, the foreign exchange saving in capital investment for steel production as compared with other activities, may be more important than the relationship between capital and value added. A comparison between the saving of foreign exchange which could be obtained with the investment of some capital in a variety of sectors, should supplement the figures of Table 11.

doubt, a careful examination of additional factors would be indispensable in order to form a complete opinion on the problem of costs within any given Latin-American country, and of their comparison with the costs of imported steel.

1. Specialization of production

In section IV of this chapter an analysis was made of the advantages which might arise from using reduction, refining and steel finishing methods which differ from the classical processes. Section V dealt with the selection of the sites for steelworks and the possible benefits accruing from the choice.

In addition, production costs would be considerably reduced if, instead of plants turning out an assortment of finished products wide enough to cover almost all the needs of a country, consideration were given to the establishment of specialized plants. A substantial reduction in costs could be obtained if production were limited, for instance, to sections (bars, shapes, wire, rods, possibly rails); to flats (plate, sheet, tinplate); and also possibly to tubes or special steels. For the major consuming countries, such specialization might be undertaken within the country itself. For the others it would only be possible if some degree of regional integration took place.

Given considerable economies of scale connected with the mass production of high quality flat products, which are impossible in small hand-operated mills, it would be desirable to reach optimum conditions which would allow the installation of a continuous wide strip mill.

It may be noted that a reduction in the cost of steel production at Chimbote could be obtained if substantial quantities of semi-finished products (such as pig iron or crude steel) were exported to Argentina. This fact, together with the benefits of specialization, points to the need for considering at least some Latin-American integration in the field of steel production and trade.

2. Factors affecting imported steel costs

The foreign production centre analysed for purposes of cost comparison with Latin-American locations was a hypothetical plant at Sparrows Point, operating with high quality iron ore imported from Venezuela. This single comparative point of reference, limited in addition to hypothetical production costs and transport charges to Latin America, it naturally inadequate. A more detailed examination would require analysis of production costs in several sites outside the region, of transport charges and of other factors, such as the price policy followed by exporters.

(a) *Steel production costs outside Latin America*

The same factors as those influencing costs of Latin-American steel production should be borne in mind for other countries, except perhaps that of alternative reduction processes.[25]

It is impossible to consider in detail here relative costs of steel production in various North American, European and possibly Japanese locations. It should, however, be borne in mind that production costs of the hypothetical plant at Sparrows Point, exclusively using Venezuelan ore, are not truly representative of typical production costs in the United States. It is more than probable that the costs calculated in Chapter III, Part Two for the Sparrows Point steelworks are higher than average United States costs. First, the capital charges included are higher than those corresponding to existing United States' plants, since many are entirely amortized and almost all were built at a time when the costs of equipment were considerably lower than today. Secondly, assembly costs of raw materials for Sparrows Point are higher than average United States' costs. The difference may be of the order of $5 to $10 per ton, at 1948 prices. When comparing the United States and other main producing areas, reference may be made to recent studies of the United Nations concerning competition between European, North American and Japanese steel in third markets.[26] The conclusion was drawn that, on the whole, European steel production costs are competitive with those of the United States and of Japan.

One of the main advantages for non-Latin-American producers is that of specialization. The United States steelworks and an increasing number of European plants (particularly since the creation of the European Coal and Steel Community) can specialize and thus reduce costs. For instance the United States has held until now a substantial cost advantage over both Europe and Latin America in flat products, some 63% of which are produced on continuous wide strip mills. As soon as Latin-American plants can begin specializing, they will regain a part of this advantage.

(b) *Price policies*

Apart from those so far examined, two other factors considerably influence the cost of imported steel. These are the pricing policies of steel exporters, and the transport costs for finished steel.

A detailed examination of pricing policies and differentials between domestic and export prices cannot be included here, and little speculation may be undertaken as to how they will affect the cost of future steel imports into Latin America. In fact substantial differentials have been observed in the past, European exporters (who accounted for 70 to 80% of all Latin-American imports in the 1930's and represent about two-thirds at present) in general tended to quote exports below home-market prices before 1939 and especially during the depression years. Conversely, in the postwar years, when steel was in short supply, considerably higher prices were quoted for exports than for deliveries to domestic European markets.[27]

A reasonable supposition is that world market prices will continue to exceed domestic market prices as long as steel remains scarce. However, the considerable increases in steelmaking capacity taking place in the United States and in Europe, and an eventual slackening of the demand for rearmament, could well result in a decline of export prices.

Throughout 1948, steel prices in the exporting countries remained high, as did those in Latin America. For

[25] In fact the application of these processes to industrialized regions which already possess abundant "classical" equipment for steel production and operate for mass production, appears more remote than in Latin-American countries which are not yet equipped and have smaller markets.

[26] See *European Steel Exports and Steel Demand in Non-European Countries, op. cit.*

[27] A detailed examination of these quotations appears in *European Steel Exports and Steel Demand in Non-European Countries, op. cit.*

this reason, in order to obtain a more realistic basis for comparison, estimates of production costs at Sparrows Point, and average United States' prices for an assortment similar to that assumed for a programme for the Latin-American locations, were studied; the results are shown in column 5 of Table 9. The figures correspond to the series entitled "composite finished steel", prepared by the *American Metal Market*, plus transport cost differentials as explained elsewhere in this report. The final total is substantially higher than the "delivered costs" from the hypothetical Sparrows Point plant.

No consideration has been given in this study to the commercial policy of importing countries, nor to the protection which domestic steel may derive from customs tariffs or other discriminatory practices. On the whole, it appears from Table 9 that many Latin-American steel locations might not require any tariff protection, except perhaps for a few initial years when productivity will be below that of traditional producing centres.[28]

(c) *Transport costs*

The variations in transport costs, particularly maritime freight rates, are often more pronounced than world price fluctuations. For this reason, and in view of the impossibility of accounting for such factors as the existence of return freights, congestion of ports and demurrage charges, etc., the allowance made for transport costs in the preceding sections should be considered as indicative only.

In comparing delivered costs from Sparrows Point and from the United States and European production centres, there are two main considerations.

First, in relation to the principal inland producing centres in the United States and particularly to the midwestern mills, the freight advantage of Sparrows Point on shipments of finished steel to markets[29] is probably larger than the disadvantage resulting from longer haulage of ores. Thus Sparrows Point has probably on the whole a more favourable location than the average United States' producer. The comparison of Latin-American costs with those of steel imported from Sparrows Point thus appears to be justified as it involves the utilization of figures for imported costs which are rather low and therefore provide a security margin. Secondly, for the comparison between steels imported from Europe and the United States, it is understood from the study of the Economic Commission for Europe that freight costs from European ports and those from ports on the Atlantic seaboard of the United States are similar. The fact that Europe and the United States have approximately the same production costs has already been established.

3. Regularity of steel supplies

The capacity to import of many Latin-American countries is not only limited, but in addition may fluctuate widely, depending upon changing levels of world economic activity. Fluctuations in demand and price for raw materials are usually more pronounced than variations in world income or production. A domestic steel industry producing most of a country's requirements would serve to reduce the dependency upon foreign exchange reserves as a means of buying imported steel. Thus some of the unfavourable consequences of world economic fluctuations might be eliminated.[30] This is particularly important for countries developing steel transforming industries, since they will require a regular supply of steel to prevent their manpower and equipment from remaining idle. In addition, domestic output of steel would obviate the maintenance of substantial stocks, thus liberating foreign exchange which is otherwise immobilized, and providing a financial advantage.

[28] This applies to finished steel only. The question of the relative costs of production and of imports for steel transforming industries and of the corresponding commercial policies would require special research.

[29] In 1948 the rail freight charges from Pittsburgh to New York were around $12 per ton. The allowance made for transport from Pittsburgh to seaboard in the above calculations is $10.

[30] In 1932 steel consumption in Argentina and Brazil had declined to a third of the 1928 level.

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PART TWO

NOTE: Part Two of this volume represents three of the studies presented to the Meeting of Experts on the Iron and Steel Industry in Latin America by the Secretariat of the Economic Commission for Latin America, as follows:

Chapter I ST/ECLA/CONF.1/L.86

Chapter II ST/ECLA/CONF.1/L.87

Chapter III ST/ECLA/CONF.1/L.91

Chapter I

Factors influencing iron and steel consumption in Latin America

I. Foreword

The purpose of this chapter is to ascertain the determining factors in Latin America's iron and steel consumption.[1] Average steel consumption for the region is low, probably not much more than 20 kg. per capita in terms of crude steel. There are very marked individual deviations from this average, ranging from 5 to 8 kg. per capita in Bolivia, Ecuador or Guatemala, to almost 80 kg. per inhabitant in Argentina.

Mention of these broad differences in per capita consumption justifies the attempt to explain such remarkable disparities. In countries planning or developing their own iron and steel industries, however, there is also the practical problem of having to make an accurate estimate of actual and potential market capacity. The high investments required for this industry and the influence of the size of the plant on production costs make it essential to analyse these possibilities carefully. Excessive investment can be the consequence of over-estimating the market which causes high costs. In contrast, the necessity for immediate expansion may result from an underestimation of the market.

For certain Latin-American countries such a study is indispensable to determine whether, according to the size of the potential market, the establishment of a domestic steel industry would be economically justified.

Recent events in Latin America, especially in Brazil, show that historical consumption trends, when steel supplies are mainly provided by imports, are insufficient to decide whether or not a steel industry should be established and what its size should be. A more detailed analysis should be carried out, to ascertain which factors have influenced consumption and to examine their possible future behaviour.

In highly developed countries, a marked degree of interdependence between steel consumption and the fluctuations in the level of manufacturing output is known to exist.[2] In Latin America, the problem obviously cannot be studied in this manner, not only because of the prevailing low level of industrial development, but also because within the field of development as a whole, the industries actually consuming steel primary products rarely reach a position of any importance. It was therefore decided to investigate the determining factors by attempting an analysis of the development of steel consumption over the last quarter of a century. To this end, the relationship was established between steel consumption and other important indices of economic activity in six Latin-American countries, namely, Argentina, Brazil, Chile, Colombia, Cuba and Mexico.

In selecting these countries, emphasis was laid on the availability of adequate statistical data and on those countries having such widely differing characteristics as to be sufficiently representative of the whole region. Of those chosen, two—Brazil and Mexico—have for some considerable time been producing certain finished steel products; moreover, their steel industries are now in an active phase of expansion. Argentina, with the highest per capita consumption in Latin America, has mainly relied upon imports; nevertheless, notwithstanding its comparatively poor resources for primary steel production, rolling capacity is constantly growing. Chile has become the third largest primary steel producer in the region since the Huachipato plant was opened in 1950. Lastly, Colombia and Cuba have, to date, relied exclusively upon imports. A study of the position in Colombia is especially interesting since a steel plant is currently being built there.

An analysis of the particular conditions concerning each of these countries permits conclusions to be drawn which may be applied to the majority of the remaining Latin-American countries.

Steel consumption from 1925 until 1952 has not risen as rapidly as the population; in some instances even, a powerful tendency for consumption to remain stationary was observed, causing a sharp decline in per capita consumption. In many cases this has led to deferred demand which causes problems representing a serious obstacle to economic development. A typical example is the consumption of rails, railway equipment and, in general, of all transport material. In most countries, not only was it impossible to extend railway milage and improve rolling stock after 1925 but the supply of replacement materials has been postponed from year to year.

Consumption of other groups of steel products has also been delayed, though to a lesser degree in relation to other factors which determine the demand for these products. The building industry is one of the single factors with the greatest bearing on steel consumption. All bars, shapes and structural steel are almost directly associated with it, as well as a fair amount of tubular products and, to a lesser extent, plate and sheet. Fluctuations in building activity measured either by the surface being built or by cement consumption were closely related to bar and shape consumption in these six Latin-American countries. Nevertheless, the upward trend of these indicators surpasses that of consumption for this group of steel products. It may thus be concluded that there has been a downward trend in the amount of steel employed per square metre and per ton of cement in constructions.

Population growth, a faster development of urban centres, and the existence in many cases of an actual housing shortage, are factors which should maintain a future high level of building activity in Latin America. Demand for steel products by this industry will not only be influenced by the existing backlog in their consumption requirements but also by a probable increase in building activity.

In countries for which statistics are available, the trend of steel consumption has also been compared with the

[1] The analysis has been limited to the consumption of pig iron and rolled steel plus primary transformation products such as tubes, wire, nails, screws, etc. Consequently imports of steel contained in durable consumer goods, or equipment requiring a more advanced process of transformation, were not included.

[2] In *European Steel Trends in the Setting of the World Market, op. cit.,* a relationship such as this was used, in preference to other methods, for discussing the prospects of iron and steel industries in Europe.

development of manufacturing activity. The resulting relationship is less significant than that existing between the consumption of bars and shapes and building activity. While a general upward trend in Latin-American manufacturing activity has taken place during the past quarter of a century, iron and steel consumption remained fairly stationary. The explanation for this different behaviour appears to be that, except in Argentina where transforming industries have existed for some time, industrial development has been concentrated in the manufacture of consumer goods. These are not dependent upon a supply of iron and steel products as raw materials (foodstuffs, textiles, chemical products, etc.). Thus industries directly consuming iron and steel products have only recently begun to develop in a few Latin-American countries, principally those in which primary iron and steel production exists.

The rapid development of steel transforming industries in Argentina, Brazil and Mexico, for example, has influenced steel consumption, especially of flat products (plate and sheet), indicating that, as steel production progresses, demand will also expand rapidly.

The preserved food industries, older than those mentioned above, and which exist to a greater or lesser extent in all the countries studied here, have exerted considerable influence on tinplate consumption. In many cases, however, the industry has developed faster than the supply of tinplate so that this expansion has been limited by the shortage and substitutes for tinplate have been used in some instances.

A similar tendency to replace other iron and steel products by substitutes was noted in many activities in which such replacement was possible. For instance, asbesto-cement tubes were increasingly used in sewerage systems, while asbesto-cement sheets replaced galvanized sheets for roofing. Although in many cases these substitutions resulted from favourable price relations, the most important reason appears to be the difficulty in obtaining steel supplies; they must normally be imported and are therefore restricted by foreign exchange availabilities.

These considerations alone are insufficient to explain past tendencies in steel consumption or to provide indices which will determine future trends. In fact, it is clear that the dynamic role is played by variations in national income and the investment level, among the factors which have been related directly to steel consumption.

With limited statistical data, it is exceedingly difficult to relate changes in steel consumption with fluctuations in national income and in investments in each coutry. Adequate net investment figures are not available; national income data refer only to relatively short periods, insufficient to measure the influence of their variations on steel consumption. Most Latin-American national income estimates do not reach beyond 1939; thus the initial data refer to the war period during which restrictions existed for steel exports. No significant relationship between these factors can therefore be established.

The available information does, however, permit a comparison for a given year of the relationship between income and investment on the one hand, and steel consumption on the other in various Latin-American countries. Such a comparison would not only clarify the factors affecting steel consumption in a given country, but also the different levels of consumption in comparison with other Latin-American countries. Such differences are considerable, and per capita income does in fact appear to be one of the determining factors. Chart II shows the relation between steel consumption, in terms of crude steel,[3] and national income in 1949 dollars for 12 Latin-American countries. For three of them (Brazil, Chile and Mexico) a prewar year and a more recent year have been included, not only because the statistics were available but also with the object of providing a comparison of the changes which have occurred with the expansion of domestic output. For the remaining countries—Argentina, Bolivia, Colombia, Cuba, Ecuador, Guatemala, Peru, Uruguay and Venezuela—national income figures correspond to 1949, and steel consumption to the average for 1947-49. This has been done to level out the considerable fluctuations from one year to the other.[4] Thus 15 observations were used to analyse the relationship between the two series.

The coefficient of correlation, based on this analysis, is fairly high—0.898—indicating a close relationship between per capita income and steel consumption. Nevertheless considerable deviations for individual countries appear from the regression line. The equation for the latter is $X_1 = 0.170 X_2 + 0.5733$ on which X_1 corresponds to crude steel consumption and X_2 to national income in 1949 dollars, both per capita. For instance, Cuba and Uruguay have a lower steel consumption ratio compared with their income than the other countries. Thus, although a close correlation has been established for the region in general, this factor alone seems unable to explain some of the individual deviations. It is therefore necessary to take additional factors into account.

Assuming that steel is mainly used for capital goods and that distribution of income between capital and consumer goods is not uniform in Latin America, it appears that some of the remaining deviations could be explained by considering the level of investment as well. Unfortunately, lack of data regarding investment creates a serious difficulty. Recourse had thus to be made to some indicators related to investments; imports of capital goods, building activity and public works were selected for this purpose. The former have been measured by aggregate imports of capital goods in terms of 1949 dollars per capita,[5] while cement consumption has been considered as representative of building activity. The corresponding figures for the 12 countries are shown in Table 13.

The scatter points for the ratio between steel consumption and imports of capital goods appear in Chart III, with the corresponding regression lines: $X_1 = 1.519 X_3 + 7.303$, in which X_3 represents the imports of such goods in dollars per capita and X_1, as previously, the per capita steel consumption. The correlation (0.861) is also fairly high.

[3] Crude steel figures for consumption were obtained from import statistics for finished steel, on the assumption that they represent an average of 70% of crude steel consumption. In the case of Venezuela, imports of tubes for the petroleum industry and mainly financed by it, have been excluded.

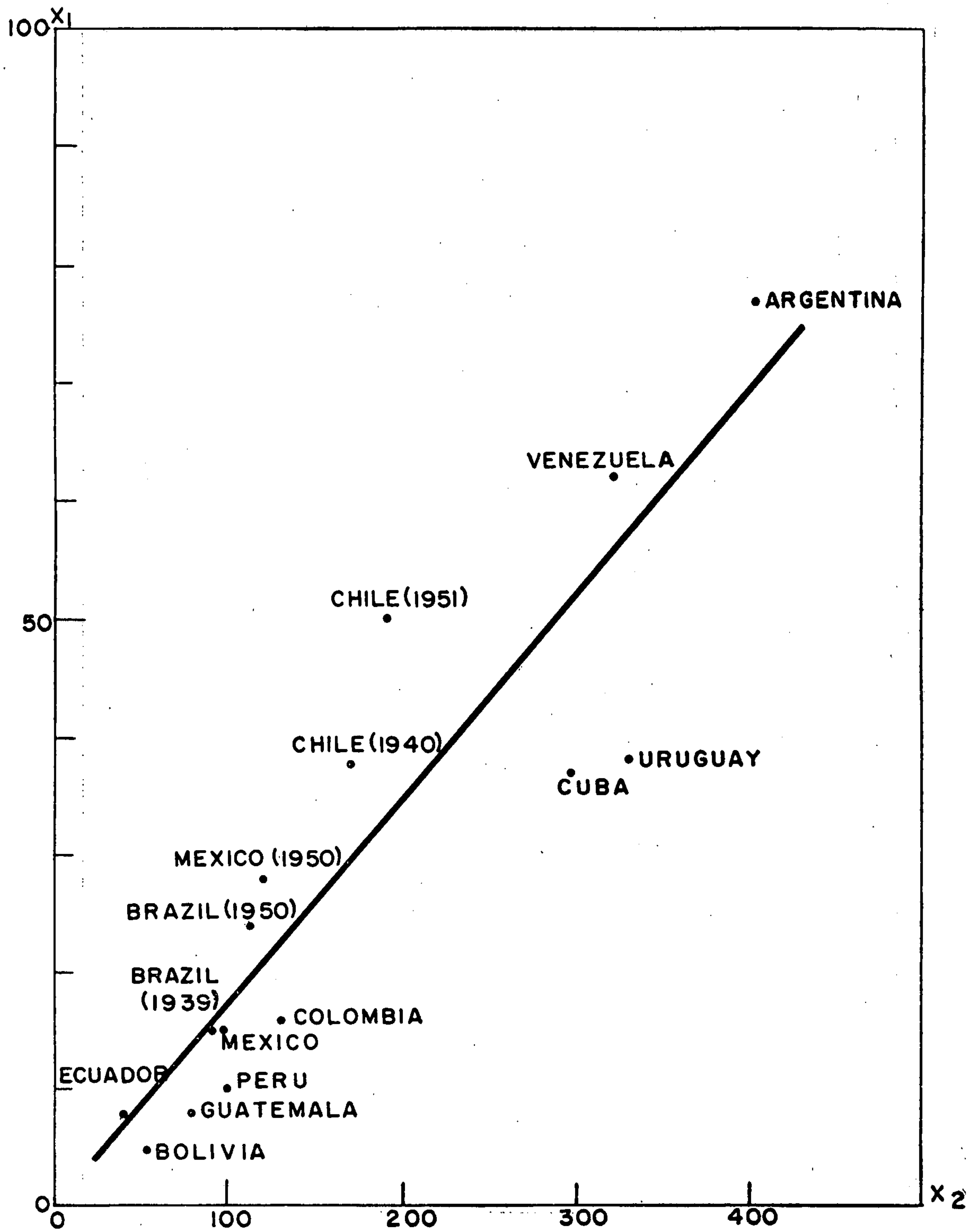
[4] National income figures for 1949 were taken from *National and Per Capita Income of Seventy Countries, 1949* (United Nations Publication, Sales No.: 1952.XVII.8), with the exception of Argentina, for which a higher figure was estimated. Figures for Mexico for 1939 have been prepared by the Economic Commission for Latin America. For Chile, 1940 estimates were based on the changes in monetary income, population and the cost of living index between 1940 and 1949. For Brazil, the changes in the quantum of production were taken from the *Economic Survey of Latin America, 1949* (United Nations Publication, Sales No.: 1951.II.G.1).

[5] With the exception of Brazil, Chile and Mexico, figures correspond to average per capita imports for 1947-49, expressed in dollars at 1949 value, deflating the other annual data by United States export price indices.

Chart II

RELATION OF PER CAPITA STEEL CONSUMPTION TO PER CAPITA INCOME

x_1 : Steel consumption (kilogrammes per capita).
x_2 : Income (1949 dollars per capita).



Source: Economic Commission for Latin America.

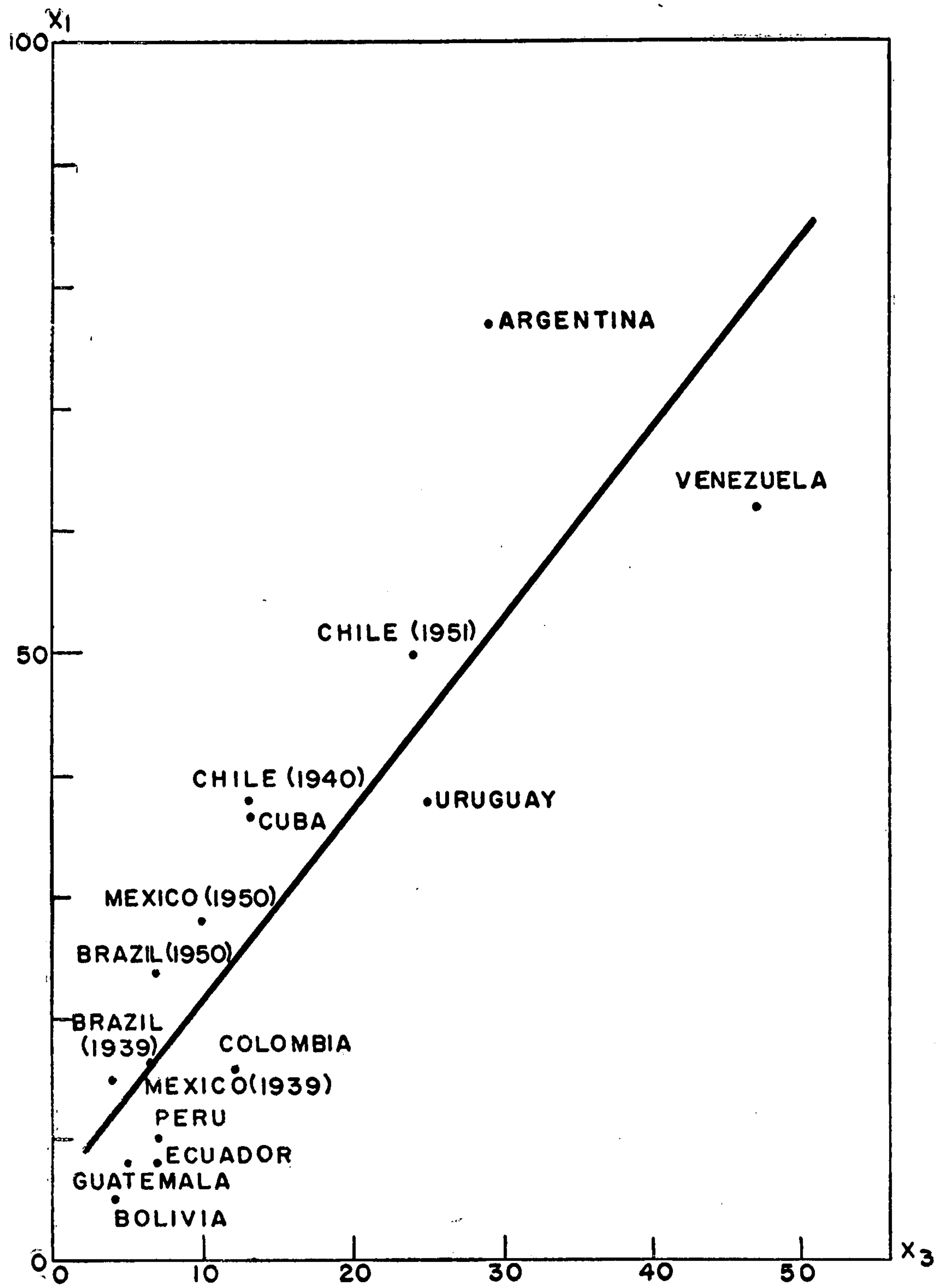
Chart III

RELATION OF STEEL CONSUMPTION TO IMPORTS OF CAPITAL GOODS

x_1: Steel consumption (kilogrammes per capita).

x^3 : Imports of capital goods (1949 dollars per capita).

(natural scale)



Source: Economic Commission for Latin America.

Table 13

STEEL CONSUMPTION, NATIONAL INCOME, IMPORTS OF CAPITAL GOODS AND CEMENT CONSUMPTION, IN SELECTED LATIN-AMERICAN COUNTRIES
(Kilogrammes and 1949 dollars per capita)

Country	*Year*	*Steel consumption*[a] *(kilograms)*	*National income*[b] *(dollars)*	*Imports of capital goods (dollars)*	*Cement consumptions (kilograms)*
Bolivia	1947–49	5	55	4	10
Ecuador	1947–49	8	40	7	17
Guatemala	1947–49	8	77	5	14
Peru	1947–49	10	100	7	36
Mexico	1939	15	95	4	22
Brazil	1939	15	90	4	18
Colombia	1947–49	16	132	12	42
Brazil	1950	24	112	7	34
Mexico	1950	28	121	10	55
Cuba	1947–49	37	296	13	69
Chile	1940	38	170	13	80
Uruguay	1947–49	38	331	25	120
Chile	1951	50	190	24	90
Venezuela	1947–49	62	322	47	133
Argentina	1947–49	77	404	29	94

Source: Economic Commission for Latin America.
[a] In terms of crude steel.
[b] Income figures correspond exclusively to 1949 in those countries for which imports of capital goods and consumption of steel and cement are shown by the average 1947–49.

This relation provides new elements for analysis, especially for some of the major deviations which appear in the previous comparison. For instance, in the case of Cuba, where the ratio of steel consumption to national income is below the regression line, it appears in Chart III above the regression line, showing that, although steel consumption is low if compared with national income, it is high in relation to investments in imported capital goods.

On the other hand, the deviations shown by Argentina and Venezuela are greater than in Chart II. In Argentina consumption is higher, in Venezuela it is lower than the relation of steel consumption to investment.

In Chart IV the relation between steel consumption and consumption of cement (X_1 and X_4 respectively) are shown. The equation for the regression line is $X_1 = 0.467 X_4 + 2.679$, and the correlation is 0.869.

To summarize, a high correlation seems to exist between per capita steel consumption on the one hand, and national income, investments in capital goods, building activity and public works, on the other. The possibility cannot be discarded that some of these relations are only apparent and that steel consumption as well as some of these indicators depend directly upon one of the other factors. Thus, it may be that the correlation between steel consumption and investments in capital goods, for instance, may arise from the fact that both of them depend on the per capita income. To investigate this possibility, it becomes necessary to measure the degree of association between steel consumption and each of the other factors, after eliminating the influence of all the others. This has been attempted through a partial correlation and the coefficients obtained were as follows:

(i) Between steel consumption and per capita income 0.581

(ii) Between steel consumption and per capita imports of capital goods 0.343

(iii) Between steel consumption and per capita consumption of cement 0.033

The first indicates the degree of correlation between per capita steel consumption and income, if imports of capital goods and cement consumption are maintained constant. The decrease of the correlation coefficients as compared with those obtained originally, before eliminating the effect of the other factors, indicates that none of the three can individually explain the variations in steel consumption. Per capita income shows the most powerful influence whereas the weakest corresponds to cement consumption. Nevertheless, each of the three indicators has a certain independent influence. A simultaneous relation between steel consumption, income, imports of capital goods and consumption of cement, seems to be the most adequate explanation so far. The correlation coefficient, in this case, is 0.925 and the relation between steel consumption and the three indicators is expressed by the equation $X_1 = 0.108 X_2 + 0.622 X_3 + 0.023 X_4 + 0.418$ in which the symbols have the same meaning as in the previous cases.[6]

Substitution of the actual figures for income, imports of capital goods and cement consumption in this regression equation, yields the theoretical steel consumption data, shown in Table 14.

Table 14 shows that even the joint action of the three indicators does not satisfactorily explain the steel consumption of several individual Latin-American countries. The theoretical consumption, which corresponds to the average relation between these three indicators, dif-

[6] The relative influence of the three factors on steel consumption can also be appreciated considering the multiple correlation coefficients for any two of these factors with steel consumption. That of steel consumption with income and imports of capital goods is 0.924; with income and cement consumption 0.914 and with imports of capital goods and cement consumption 0.883. The equations are respectively: $X_1 = 0.1110 X_3 + 0.6664 X_4 + 0.5310$; $X_1 = 0.1116 X_2 + 0.1875 X_4 = 0.6127$; $X_1 = 0.7022 X_3 + 0.02711 X_4 + 3.7153$.

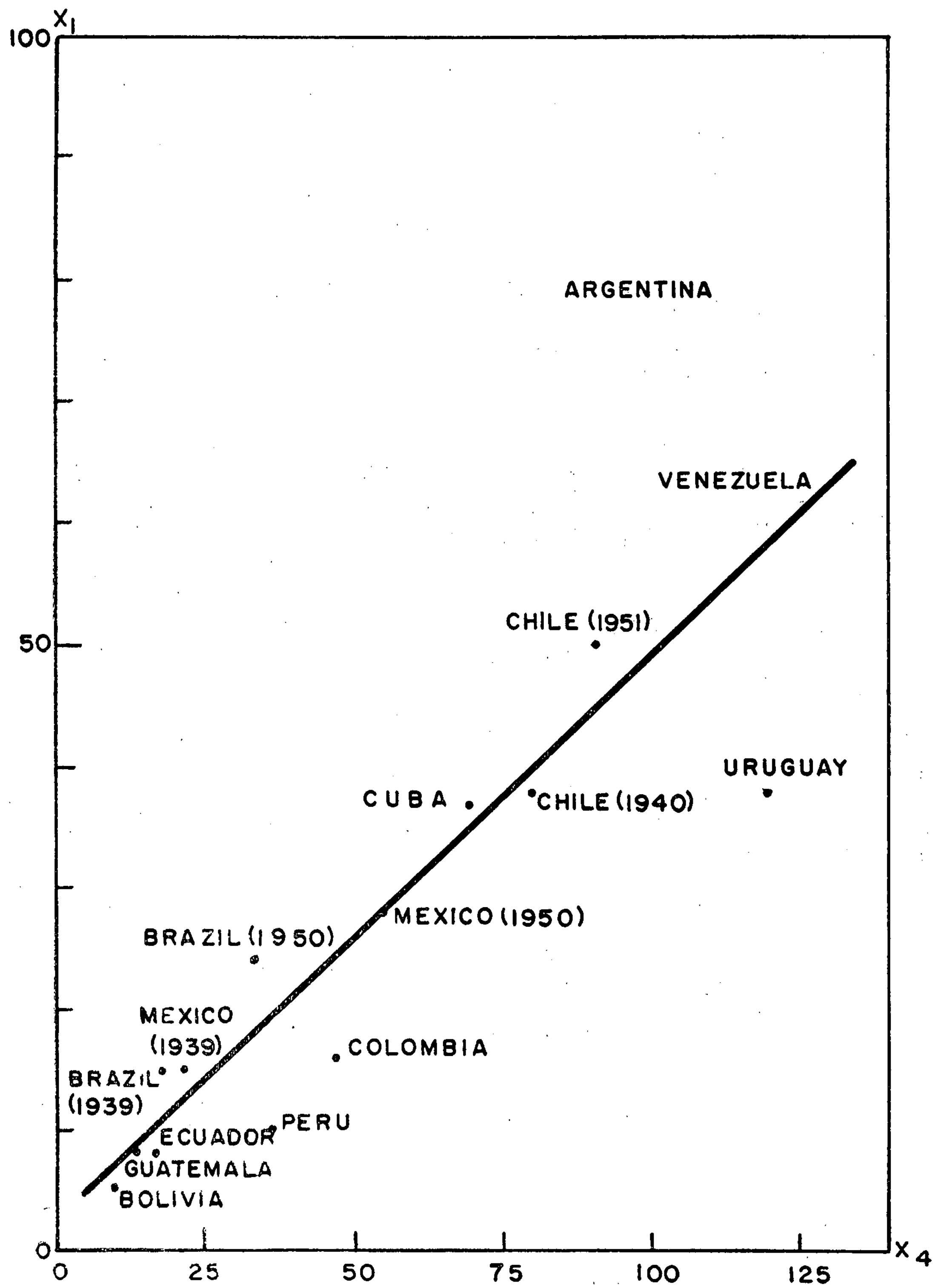
Chart IV

RELATION BETWEEN STEEL AND CEMENT CONSUMPTION

x_1 : Steel consumption (kilogrammes per capita).

x_4 : Cement consumption (kilogrammes per capita).

(natural scale)



Source: Economic Commission for Latin America.

Table 14

ACTUAL AND THEORETICAL CRUDE STEEL CONSUMPTION
(Kilograms of crude steel equivalent per capita)

Countries	*Years*	*Steel consumption* *Actual*	*Theoretical*	*Difference (percentage)*
Brazil	1950	24	18	+33.3
Mexico	1950	28	21	+33.3
Chile	1951	50	38	+31.6
Argentina	1947-49	77	64	+20.3
Venezuela	1947-49	62	67	− 7.5
Ecuador	1947-49	8	9	−11.1
Cuba	1947-49	37	42	−11.9
Uruguay	1947-49	38	54	−29.6
Colombia	1947-49	16	23	−30.4
Guatemala	1947-49	8	12	−33.3
Peru	1947-49	10	16	−37.5
Bolivia	1947-49	5	9	−44.4

Source: Economic Commission for Latin America.

fers considerably from the actual consumption:[7] in Brazil and Mexico the latter is 33% higher than theoretical consumption; in Peru and Bolivia 38% and 44% lower respectively.

The only countries showing a steel consumption higher than the theoretical figure are Brazil, Mexico, Chile and Argentina, in other words, precisely those where there is a steel industry. The other countries depend almost exclusively on imports and their availability is therefore limited by their foreign exchange resources.

Thus, together with the influence of the factors analysed so far, it appears necessary to consider a limiting element which prevents the requirements for iron and steel which would correspond to a normal level of income and investments from being attained. This element has caused the restriction of iron and steel imports which most of the Latin-American countries have encountered.

It is not fortuitous that among the countries considered, Venezuela and Cuba show the smallest negative differences from the theoretical consumption; they are the Latin-American countries which have the highest export figures in dollars per capita, placing them in a highly favoured position to pay for imports. (See Table 14.)

In section II of this chapter, the individual position of six Latin-American countries is analysed. A similar conclusion is obtained there through a direct comparison of steel consumption with the capacity to import.[8]

As mentioned earlier, steel consumption has developed unfavourably in many countries where it is improbable that per capita income has deteriorated and where investments, particularly in building and public works, have maintained a more satisfactory level. To some extent, steel consumption thus failed to keep pace with the increased demand caused by the growth of certain factors influencing it. Conversely, this unfavourable trend in steel consumption has coincided, in most cases, with an equally unfavourable tendency in the capacity to import.

The deterioration in the terms of trade has been fundamentally responsible for the reduction or restriction of the growth of the capacity to import. While, in comparison with 1925-29 averages, Latin-American countries have in general been able to increase their export quantum, export prices dropped during the 1930's to a much greater degree than those of the products imported into the region. This unfavourable situation has disappeared only very recently in the postwar period.

Steel has not been an exception to this general rule. Chart V shows that the average price of finished steel fell much less during the 1930's than the main export products of Latin America (figures from Table 15), having also recuperated at a faster rate. The price ratio, as shown in Chart VI, has been, during the major part of the last 25 years, favourable to steel. This means that the countries of the region would have had to export more products in comparison to 1925-29, in order to maintain the import figures for finished steel.[9]

In addition, imports into most Latin-American countries consist of a high percentage of products having a very inelastic demand: foodstuffs, chemicals, pharmaceutical goods and fuels. They tend to absorb a higher proportion of the foreign exchange availabilities when the latter are in short supply. The obstacles to maintaining an adequate level of steel imports to satisfy the demand are therefore considerable.

If the results of the preceding analysis are considered jointly with those of section II below referring to the six countries, the following conclusions can be drawn, which are valid for most Latin-American countries:

(*a*) Steel consumption trends have been unfavourable in the region during the last 25 years. In general, the increase has not been higher than that of population and, in many cases, has remained below it. In addition, steel consumption has not varied in accordance with several indicators for demand, so that deferred demand has accumulated. This will probably necessitate additional quantities of steel in the future which will be above normal requirements.

(*b*) Shortages of steel appear to be especially important for the consumption of rails and railway equipment in general. In this sector, since the depression in the 1930's, replacement has covered only some of the requirements.

(*c*) The relationship between steel consumption and manufacturing activity has also deteriorated progressively. This might be partially explained by the recent creation of steel transforming industries which has oc-

[7] The theoretical consumptions thus obtained have no other value than to permit comparisons to be made between various Latin-American countries. They could not be used to sustain any final conclusion regarding the level of Latin-American steel consumption in relation to the indicators, compared with the same relation in non-Latin-American countries. The same analysis should be extended to such other countries, but there are considerable statistical difficulties emerging from variations in the definitions of steel consumption. Consumption of flat products has a different meaning in industrialized countries, which have an industry transforming them into consumer goods, equipment, machinery, etc. To obtain a comparable basis in under-developed countries, it would be necessary to include the steel contained in imported goods of such types.

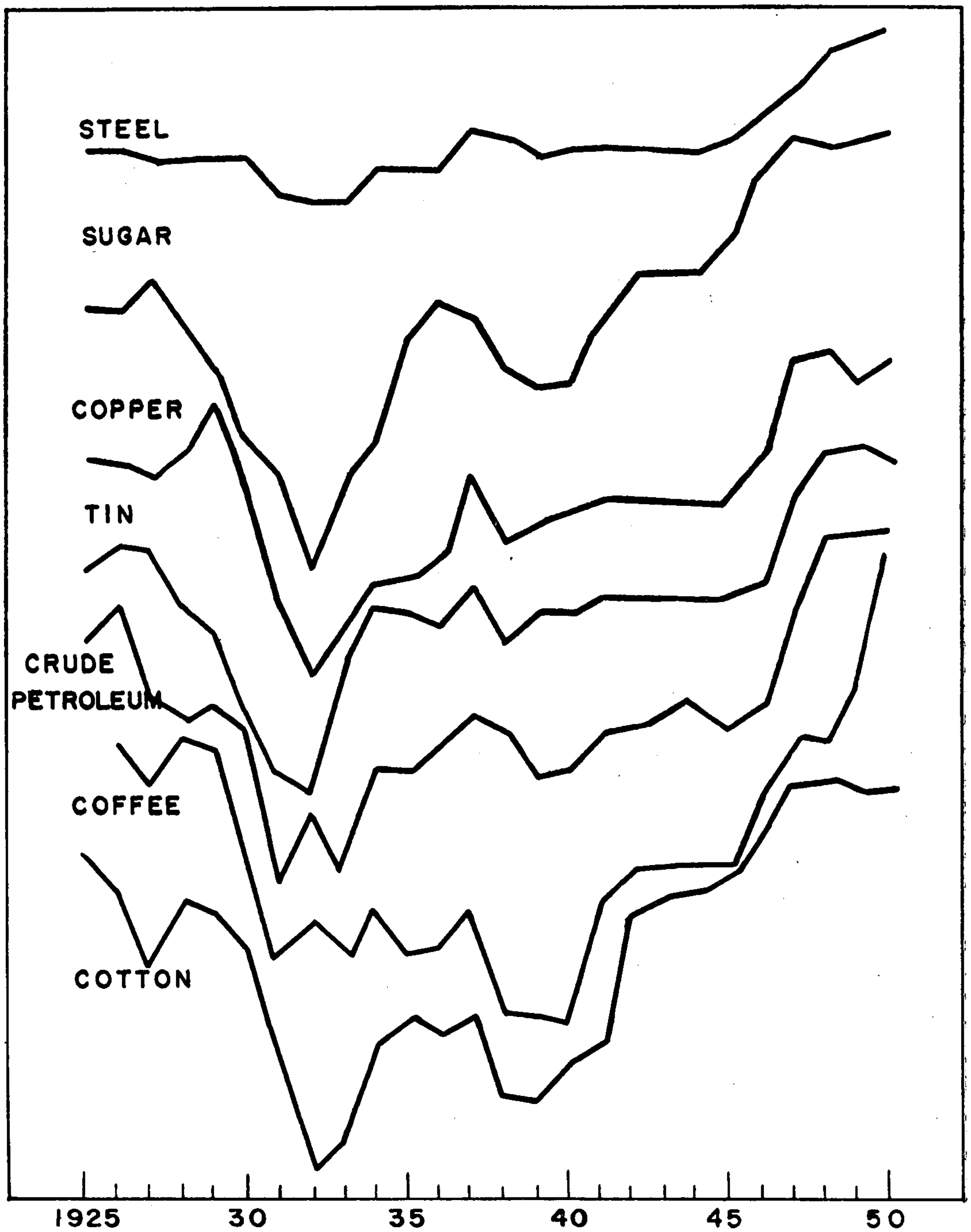
[8] The index of the capacity to import, a concept often used by the Economic Commission for Latin America, is the product of the quantum of exports multiplied by the terms of trade. It reflects, in a certain measure, the quantum of goods which a country can import with the proceeds of its exports.

[9] Assuming that in 1925-29 a given tonnage of steel could have been purchased with one ton of certain Latin-American export products, in 1935-39, when the terms of trade had already improved notably, it would have been necessary to export the following quantities to pay for the same amount of steel: sugar, 1.1 tons; tin, 1.2 tons; electrolytic copper or crude petroleum, 1.4 tons; cotton, 1.8 tons, and coffee, 2.4 tons.

Chart V

PRICES IN THE UNITED STATES OF STEEL AND SELECTED LATIN-AMERICAN EXPORTS

(semi-logarithmic scale)



Source: Economic Commission for Latin America.

Table 15

UNITED STATES' STEEL PRICES AND EXPORT PRICES OF SELECTED LATIN-AMERICAN PRODUCTS

Year	Steel	Electrolytic copper	Tin	Crude petroleum (dollars per 42 gal. barrel)	Coffee	Sugar	Cotton
	(US cents per lb.)				(US cents per lb.)		
1925	2.68	14,042	57.89	1.65	..	2,565	24.74
1926	2.64	13,795	65.29	1.92	22,125	2,565	20.53
1927	2.53	12,920	64.35	1.30	18,500	2,948	15.15
1928	2.50	14,570	50.43	1.20	23,000	2,434	20.42
1929	2.54	18,107	45.16	1.25	22,000	1,993	19.73
1930	2.32	12,982	31.69	1.15	12,875	1,471	16.60
1931	2.20	8,116	24.47	0.60	8,625	1,333	10.38
1932	2.15	5,555	21.98	0.80	10,500	0,930	6.34
1933	2.16	7,025	39.12	0.60	9,000	1,220	7.37
1934	2.42	8,428	52.23	0.95	11,125	1,499	11.09
1935	2.44	8,649	50.39	0.95	8,975	2,331	12.44
1936	2.41	9,474	46.42	1.05	9,375	2,694	11.75
1937	2.84	13,169	54.29	1.20	11,000	2,543	12.93
1938	2.78	10,000	42.28	1.15	7,625	2,036	8.75
1939	2.64	10,965	49.11	0.95	7,500	1,905	9.00
1940	2.65	11,296	49.84	0.95	7,000	1,886	10.40
1941	2.65	11,797	52.03	1.10	11,125	2,478	11.55
1942	2.65	11,780	52.00	1.15	13,375	2,988	19.13
1943	2.65	11,780	52.00	1.15	13,375	2,990	21.00
1944	2.65	11,750	52.00	1.15	13,375	2,990	21.30
1945	2.73	11,750	52.00	1.15	13,375	3,422	22.57
1946	3.00	14,040	54.54	1.25	17,375	4,610	26.68
1947	3.42	21,300	77.95	1.80	22,750	5,458	35.45
1948	3.91	22,330	99.25	2.50	22,625	5,045	35.45
1949	4.22	19,510	99.34	2.50	27,375	5,307	32.98
1950	4.40	21,540	95.54	2.50	49,500	5,432	32.68

Sources: Statistical Abstract of the United States; Agricultural Statistics of the United States; *Cotton Yearbook; Metal Statistics of the American Metal Market; Anuarios Azucareros de Cuba; Relatórios do Banco do Brasil.*

Note: The price of "composite finished steel" was used for steel in general. Quotations generally correspond to New York market prices with the exception of petroleum (Kansas and Oklahoma), and copper since 1945 (Connecticut Valley).

curred only in some countries. A certain delay in the growth of consumption of specific steel products can also be noted, for instance, in building activity in general and in food preparation industries.

(*d*) If statistics for various Latin-American countries are compared, a high degree of correlation between per capita steel consumption, national income and investment can be established. Nevertheless, significant individual deviations from theoretical consumptions, corresponding to these correlations, appear in some instances. Those countries possessing a local steel industry usually have a higher steel consumption and availability, whereas the countries supplied exclusively by imports show a lower ratio.

These results, jointly with the verification of steel shortages in relation to requirements, emphasize the influence of the limiting factor: the capacity to import. Its evolution has been very similar to that of steel consumption, in particular to steel imports, during the last 25 years.

The evolution of steel consumption thus follows the trend of the tonnages which countries were able to buy and not the size of the potential demand upon the respective markets. This fact is apparent in those Latin-American countries which have established a domestic steel industry; consumption has not only been able to absorb increasing domestic production but has also obliged a certain level of imports to be maintained.[10]

[10] This cannot, of course, be interpreted as meaning that substantial automatic increases in consumption may be anticipated. Such increases depend to a large extent on the greater or lesser speed with which transforming industries are developed to absorb part of the growing domestic output. It would not be surprising, therefore, if new steel industries had, for a time, to face difficulties in placing their products, while sufficient investments are being channelled towards the transforming industries.

II. Steel consumption in six Latin-American countries

Although some general conclusions regarding the trend of regional steel consumption can be established, the position of individual countries may differ from it substantially. A first impression may be obtained from the data in Chart VII, where changes in steel consumption since 1925 are shown for six countries.

Argentina has to date been the largest steel consumer in the region, exceeding the million-ton per year mark on several occasions. The per capita consumption is also more than double the average prevailing in the region. As regards steel consumption trends, Argentina seems to be a typical example of what has happened to most of those countries depending upon imports for their steel supplies. In Argentina imports show an unfavourable tendency.

Table I of the statistical annex shows that Argentine imports of finished steel in 1925-29 were approximately 900,000 tons; they dropped in 1930-34 to about 500,000 tons. The improvement in the economic position during the late 1930's was unable to provide a level similar to 1925-29 and imports averaged only 660,000 tons in 1935-39. There followed a serious contraction during the war years and in 1940-44 they stood at 240,000 tons per year. In the postwar period, 1945-49, imports reached only an average of 560,000 tons, although in 1951 they again exceeded 800,000.[11]

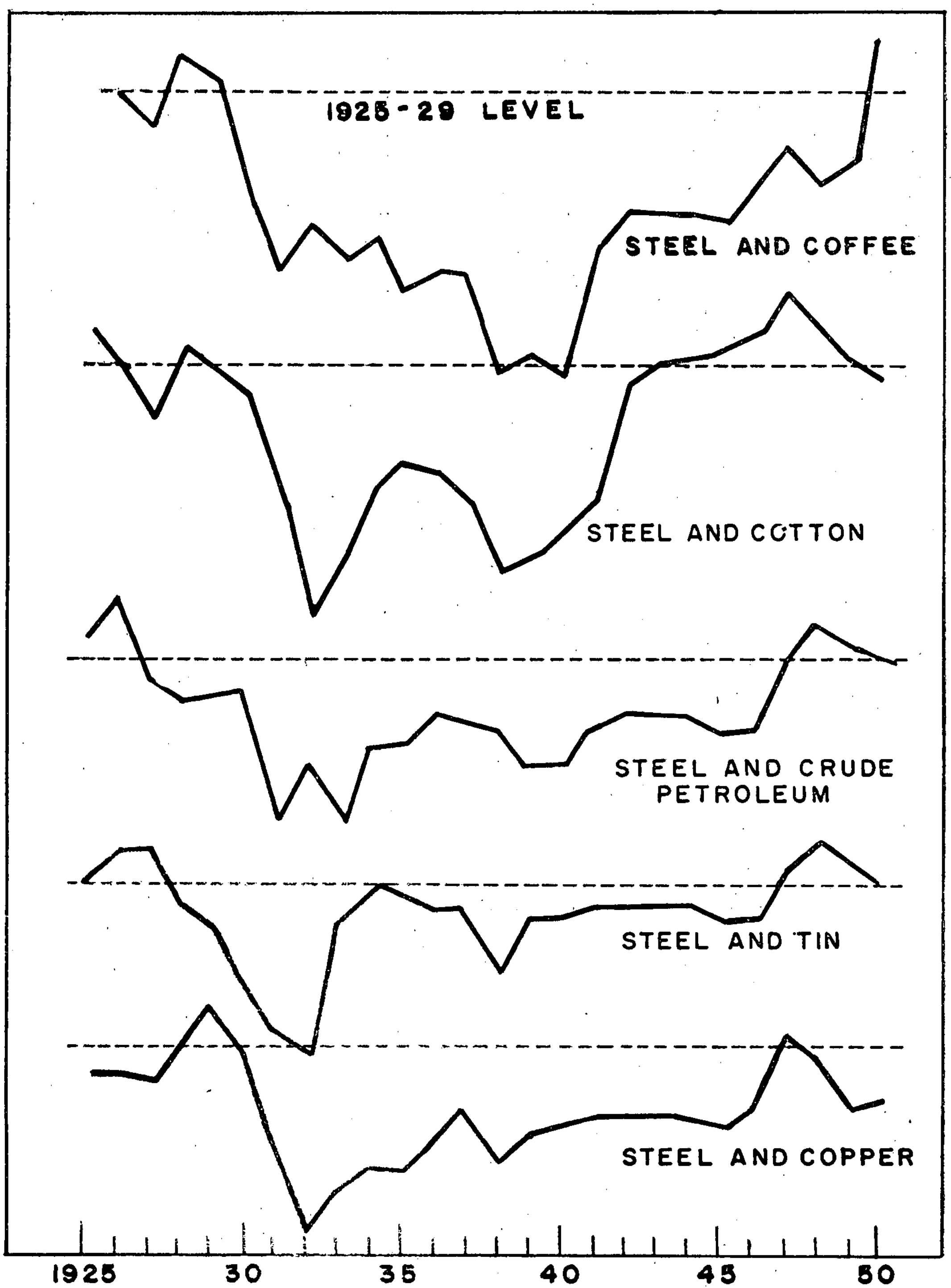
The unfavourable evolution of imports has only partially been offset by domestic production. Since 1938,

[11] All consumption figures used in this paper are obtained by the addition of the tonnages of the various products, ignoring the influence which changes in the assortment may have in terms of crude steel.

Chart VI

RELATION OF STEEL PRICES TO PRICES OF SELECTED LATIN-AMERICAN EXPORTS

(semi-logarithmic scale)



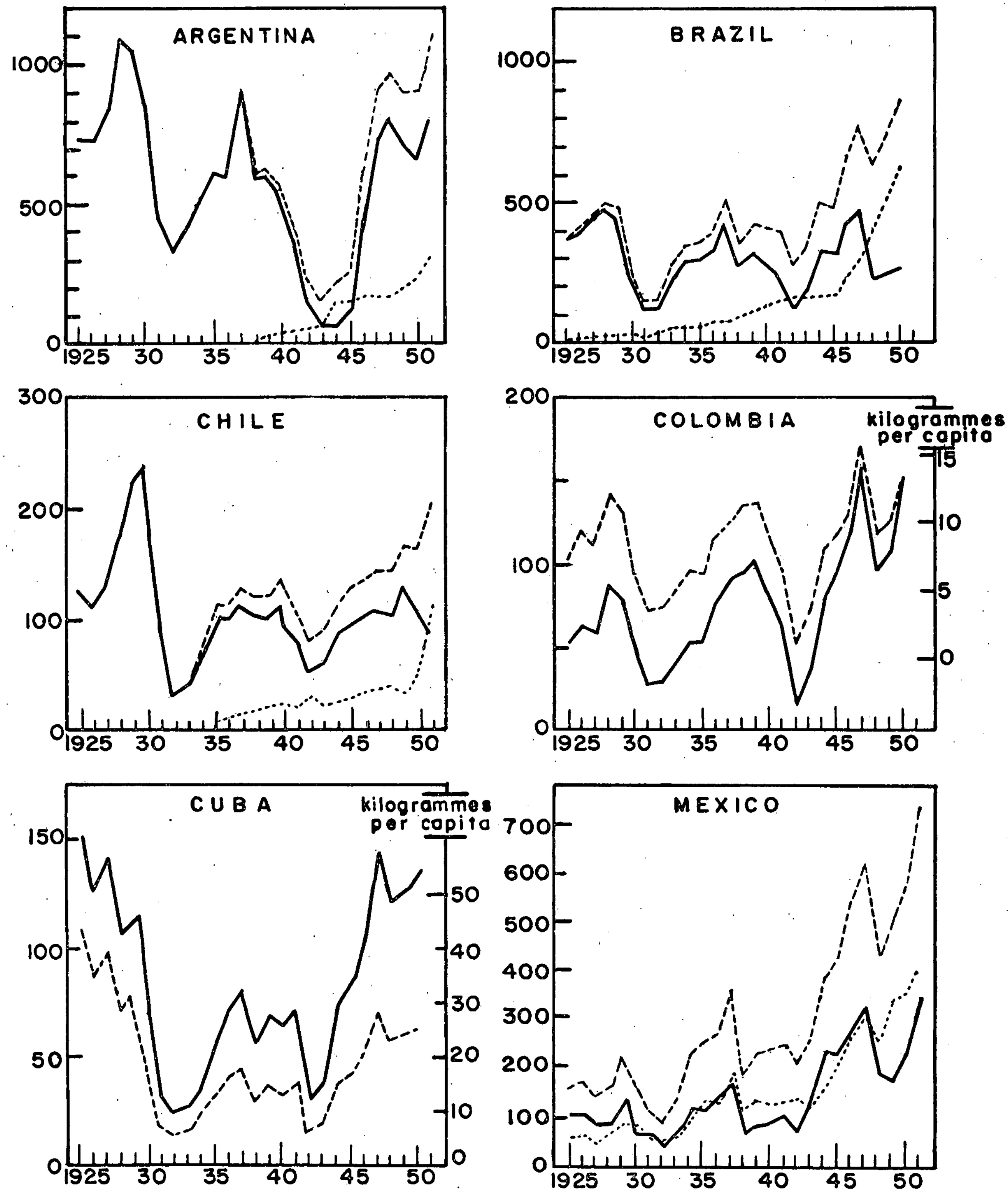
Source: Economic Commission for Latin America.

Chart VII

APPARENT IRON AND STEEL CONSUMPTION
thousands of tons
(natural scale)

ARGENTINA, BRAZIL, CHILE AND MEXICO
- - - - consumption. ——— imports. . . . . . . production.

COLOMBIA AND CUBA
- - - - - - per capita consumption.
——— aggregate consumption.



Source: Economic Commission for Latin America.

Argentina has possessed various re-rolling mills, which had a very small initial output but gradually increased capacity to around 300,000 tons during 1950-51. Domestic production, added to relatively high imports, brought the 1951 consumption to higher levels than 1928-29 for the first time.

If the increase in population is considered, the trend of steel consumption appears even more unfavourable. Per capita consumption decreased from 81 kg. in 1925-29, to 48 and 45 kg. in 1935-39 and 1945-49, respectively. In 1950-51, the figure was slightly under 60 kg. Moreover, the high figures in 1925-29 are by no means abnormal compared with the tonnages imported since the beginning of the century because they have been exceeded on more than one occasion. The reduction in iron and steel per capita consumption since 1900 can be observed from the following figures:

Periods (Annual averages, kilogrammes per capita)	*Iron and steel consumption*
1900–04	45 [a]
1905–09	107 [a]
1910–14	96 [a]
1915–19	25 [a]
1920–24	50 [a]
1925–29	81
1930–34	42
1935–39	48
1940–44	21
1945–49	45
1950–51	58

[a] Approximate figures.

In *Brazil* the situation has been more favourable. In spite of strong fluctuations, imports have remained more or less stationary. Substantial reductions, first during the depression and later during the Second World War, have been followed by a rapid recovery, after which imports were only slightly lower than those for 1925-29.

The main difference between these two periods emerges from the development of a domestic steel industry. Domestic production grew almost continuously since the first half of the 1920's, finding, in the unsatisfied demand accumulated during the earlier periods, an additional stimulus for its development. Its share of the supply increased from 18% in 1935-39 to about 40% in 1940-44; during the latter period absolute production figures continued to improve while imports contracted. In the postwar period, with a more normal level of imports, output covered 48% of consumption, rising to 71% in 1950. (See Table II of the statistical annex.)

Apparent consumption appears thus influenced by variations in imports and the increasing volume of domestic production.

Iron and steel consumption

(Annual averages in thousands of tons)

1925–29	447.5
1930–34	239.5
1935–39	406.3
1940–44	386.5
1945–49	662.0
1950	874.9

Consumption growth between 1925-29 and 1950 represents a 3% cumulative rate annually, whereas between 1935-39 and 1950 the rate is higher than 6%. Analysis of the per capita consumption shows similar fluctuations, although the figures for 1925-29 are not exceeded in 1945-49, having been lower during the whole period. In 1950 for the first time a per capita consumption substantially higher than that of 1925-29 was attained.

In *Chile,* availability of steel has depended to a greater degree upon imports than in Brazil, resulting in a consumption trend similar to that of Argentina. Although the first attempts to produce iron date from the beginning of the century,[12] only since 1935 has domestic output been of any importance, having contributed 10% to the total consumption; its relative importance increased to 25% in 1945-49. The entry into operation of Huachipato increased the relative importance of domestic production to 32% in 1950, and 55% in 1951.

If consumption figures for 1925-29 are again taken as a basis, domestic production, even in 1951, has not been sufficient to compensate for the reduction of imports. In 1925-29, average annual consumption was approximately 153,000 tons; in 1932 it dropped to 28,000 tons, increasing gradually to an average of 120,000 in 1935-39. War restrictions brought the average figures back to 100,000 tons for 1940-44, to reach in 1945-49 the average level of 1925-29. The 1951 figure, with a substantial tonnage of domestic steel, has still not exceeded the record 1929 and 1930 figures (225,000 and 245,000 tons respectively), against 206,000 tons in 1951. (See Table III of the statistical annex.)

If steel consumption is related to the increase in population, a substantial reduction in per capita values appears: 37.7 kg. in 1925-29 against 28.9 kg. in 1947-51.

Colombia is one of the very few countries of the region showing a firm upward trend in steel consumption, despite being exclusively dependent upon imports. The decrease caused by the depression of the 1930's, is followed by a rapid recovery, raising consumption in 1935-39 to higher figures than those prevailing in 1925-29. For the earlier period, imports averaged 77,000 tons a year, while in 1935-39 they reached 86,000 tons. Wartime supply restrictions brought consumption below the depression figures. Immediately after the war, accumulated unsatisfied demand resulted in an increase of imports to 164,000 tons in 1947. (See Table IV of the statistical annex.)

Although in subsequent years a decline is shown, the average for 1945-49 is approximately 117,000 tons, that is 52.8% above the 1925-29 figure. In 1950 imports rose again, reaching approximately 150,000 tons. Although these increases are high in absolute value, fluctuations in relation to population growth have been different. Per capita consumption drops slightly from 1925-29 to 1935-39 (from 10 to 9.8 kg.), while high postwar imports raise it to only 11.1 kg. in 1945-49 and to 13.5 kg. in 1950.

Although *Cuba,* like Colombia, depends exclusively upon imports for its steel supplies, its position differs considerably. The decrease during the depression was more intense than in most of the other countries, the reduction being from 129,000 tons in 1925-29 to only

[12] The Corral plant was built in 1906 but had to suspend activities owing to limitations of the market and to the uneconomical use of wood instead of charcoal.

38,000 tons in 1930-34. The subsequent recovery raised the average to 68,000 tons, after which a new fall is apparent during the war. The pressure of deferred demand raised the average from 56,000 tons, in 1940-44, to 127,000 tons in 1946-50, but was still below 1925-29. The highest postwar imports, corresponding to 1947 (146,000 tons), are still inferior to the 1925 figure (151,000 tons). (See Table V of the statistical annex.)

Due to this unfavourable import trend, reduction of per capita consumption has been drastic; from 35.8 kg. per capita in 1925-29 to 24.8 kg. in 1946-50.

Mexico appears in an exceptional position within this general picture. Three Latin American countries—Argentina, Chile and Cuba—show a considerably decreased per capita consumption, while two others—Brazil and Colombia—have been able to increase their per capita consumption only slightly since 1925-29. Perhaps the 1925-29 average for Mexico was still somewhat affected by the revolution and thus cannot be considered as a good comparative basis. But, since 1925, there has been an upward trend both in steel imports and domestic production.

Mexican imports increased from an average of 107,000 tons in 1925-29 to 116,000 tons in 1935-39 and 234,000 tons in 1945-49. In 1951 the tonnage stood at 342,000, or higher than any previous year since 1925. (See Table VI of the statistical annex.)

An even faster growth has been attained by domestic production. Mexico possesses one of the oldest steel industries in Latin America, although its progress was slight in the first quarter of the century. In 1925-29 average annual production was 67,000 tons. Since then, domestic output increased rapidly, almost doubling its tonnage every decade: in 1935-39, 138,000 tons annually and in 1945-49, 271,000 tons. In 1950-51, output exceeded 350,000 tons.

Imports and domestic production have maintained almost similar proportions since 1935. The latter increased from 39% in 1925-29 to 54% in 1935-39 and 53% in 1945-49. In 1950 it rose considerably, because of reduced imports, but again reached 53% in 1951.

Aggregate consumption grew from 174,000 tons in 1925-29 to 253,000 tons in 1935-39, and exceeded half a million tons in 1945-49. In 1951, which shows the highest import and production records, consumption rose to about 740,000 tons of finished steel. Steel consumption increased faster than the population increment, especially in the last few years. It represented 11.1, 13.5 and 21.4 kg. per capita in each of the five-year periods mentioned above. In 1951 steel consumption per capita was 28 kg.

The tables in the statistical annex show the changes in composition of consumption for each of the six countries. Within the limits permitted by definitions which do not always coincide, the products have been united in a few groups as homogeneous as possible, to permit analysis and to maintain a higher degree of comparability.

The figures indicate that in each country the evolution of aggregate consumption of finished steel has been determined by very uneven variations in the different groups of products, involving very substantial changes in the structure of consumption. In Argentina for instance, a comparison of 1945-49 figures with those for 1925-29 shows that the more significant decrease corresponds to rails and accessories. Their relative importance within the total consumption of finished steel products decreases from 15.6% to 5.7% within those periods. Consumption of bars, shapes and structures has remained almost stationary, while an increase is visible in wire and wire products, tinplate and piping. Consumption of plate and sheet, after a long depression, in 1951 finally attained the same figures as those for 1925-29.

In Brazil also, the most important decrease corresponds to rails and accessories. Their relative importance was great in 1925-29, with 27% of the total. It declined to 14% in 1945-49, and to only 8% in 1950. Consumption of bars, shapes and structures shows the largest relative increase, from 24% in 1925-29, to 37% in 1945-49. This increase is almost entirely due to domestic production since imports have never regained the pre-depression figures. Imports of plate, sheet and tinplate increased until 1947, when they lost some ground through the entry into production of Volta Redonda, the contribution of which has considerably increased the rate of growth. Thus, the relative importance of flat products, within the total, increased from 10.5% in 1925-29 to 15.7% in 1945-49, and 17.6% in 1950. For tinplate they are respectively 6.0%, 9.5% and 9.8%. Finally, consumption of wire and piping has grown in a smaller proportion.

In Chile, only two groups show an increase between these periods: tinplate and bars, and secondly shapes and structures. Considerable decreases appear in the consumption of rails and accessories and also, although to a lesser degree, in plates, wires and piping.

In Colombia, the main increase corresponds to piping, bars, shapes and structures, while the increment in wire and tinplate is smaller. Consumption of plate and sheet has been stationary. Rails and accessories have appreciably declined, the proportion within the total dropping from 26.8%, in 1925-29, to 5.5% in 1945-49.

A major contraction is shown by bars, shapes and structures in Cuba, which in 1925-29 represented 50% of the total consumption, whereas in 1945-49 they contributed 34%. Plate and sheet consumption has not altered, while wire shows a small increase. Tinplate has risen from 4.6% in 1925-20 to 14% in 1945-49, thus showing the highest percentage for this type among the countries analysed here.

Finally, in Mexico, the rise in total consumption results from a parallel increase in most of the groups, including rails. Nevertheless, consumption of bars, shapes and structures and of wire and wire products has risen a little faster than those of the other types, probably because, within these groups, there is a higher percentage of local production.

Table 16 shows, in greater detail, the structure of consumption in these countries during 1945-49.

III. Factors influencing consumption

The foregoing analysis has indicated that, although there are differences from one country to another, iron and steel consumption in Latin America has had a tendency to remain stationary, at least during the last 25

Table 16

CONSUMPTION OF STEEL PRODUCTS, BY GROUPS

Groups	Argentina	Brazil	Chile	Colombia	Cuba	Mexico
Rails, ties and accessories	5.7	14.1	11.5	5.5	9.2	12.8
Bars, shapes and structures	42.9	37.3	44.8	34.6	33.9	42.1
Wire and wire products	15.7	15.5	13.7	17.5	17.3	12.6
Plate and sheet	17.9	15.7	11.8	10.4	14.1	18.8
Tinplate	7.1	9.5	5.8	3.4	14.0	3.4
Pipes and tubes	9.9	7.2	9.3	28.6	10.5	10.3
Other products	0.8	0.7	3.1	—	1.0	—
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

Source: Economic Commission for Latin America.

years. This naturally implies a drop in the per capita consumption. In the following chapter an analysis will be made of the obstacles which hindered a more favourable development.

Lack of statistical data regarding several indices and indicators in the countries of the region complicates this analysis, but there are also factors of difficult quantitative evaluation, as, for instance, restrictions imposed upon the exporting markets or shortages in foreign exchange to pay for imports. A further complication is the varying effect with which such factors influence consumption of the different types of steel.

An attempt was therefore made to draw a distinction between factors which probably influence total steel consumption and those which influence consumption of specific products. Among the former a further distinction can be made between factors such as the national income, investment activity or manufacturing activity which operate upon the demand, increasing or decreasing it, and the factors which operate on the availability, among which domestic production and the capacity to import are the most important.

1. FACTORS INFLUENCING DEMAND

(a) *Fluctuations in national income*

In each country it is apparent that the fluctuations in national income must appreciably affect iron and steel consumption. A comparison between two such series is unfortunately limited, in some cases by insufficiently representative income figures, in others because the period covered by the series is inadequate. Nevertheless, approximate comparisons can be made, using certain indices which, within certain limits, are indicative of the evolution of income.

In the case of Argentina, for example, there are strong probabilities that national income during the last 25 years has increased, in real terms, faster than population, whereas steel per capita consumption has decreased. The value of domestic production, at constant prices, increased by 70.3% between 1925-29 and 1945-49, and available goods by 78.5%, against an increase in population of about 50% within this period.[13]

In Brazil, if the value of available goods is also taken as an indication for the changes in real income, the increase was about 70% between 1925-29 and 1945-49. Consumption of finished steel alone has risen by 50%, although if figures for 1950 are used, the increase is more than 90%. In spite of variations in the trends of the two series, it appears that the low level of income explains to a substantial degree the reason for a very low level of per capita steel consumption in relation to that obtained by other Latin-American countries. The Brazilian figure is less than half of that for Chile, and about one-third of that for Argentina. This proportion also corresponds approximately to the respective per capita incomes: it has been estimated that in 1949 they were of $400 in Argentina, $190 in Chile and only $112 in Brazil.[14]

In Chile, the net value of domestic production, at constant prices, increased between 1925-29 and 1945-49 at an appreciably faster rate than the population and the volume of available goods per capita hardly varied, while per capita consumption of steel fell substantially during this period.

For Colombia and Cuba no figures are available to permit an appreciation of the changes in national income compared with 1925-29. Some estimates have been made for Colombia deflating the figures for monetary income. Accordingly, real income would have increased by about 63% between 1939-50, whereas steel consumption has risen only by 50%.

Finally, Mexico, where steel consumption has increased exceptionally, also shows a substantial growth of its real income, measured through changes in available goods.[15] In this way, the ratio between the two series improves for steel consumption between 1925-29 and 1935-39, but no variation is shown between the latter period and the earlier postwar years. If the trends in steel consumption are compared with what presumably have been the changes in real income, the growth of steel consumption does not appear exaggerated.

Thus trends in iron and steel consumption in Latin America during the last 25 years, have been substantially less favourable than the trends of real income. Steel consumption per capita has not kept pace with the improvement in the standard of living of the population, remaining relatively below the increased demand which might be expected from such improvement.

[13] *Economic Survey of Latin America 1949, op. cit.* Much of the following analysis is based on this study.

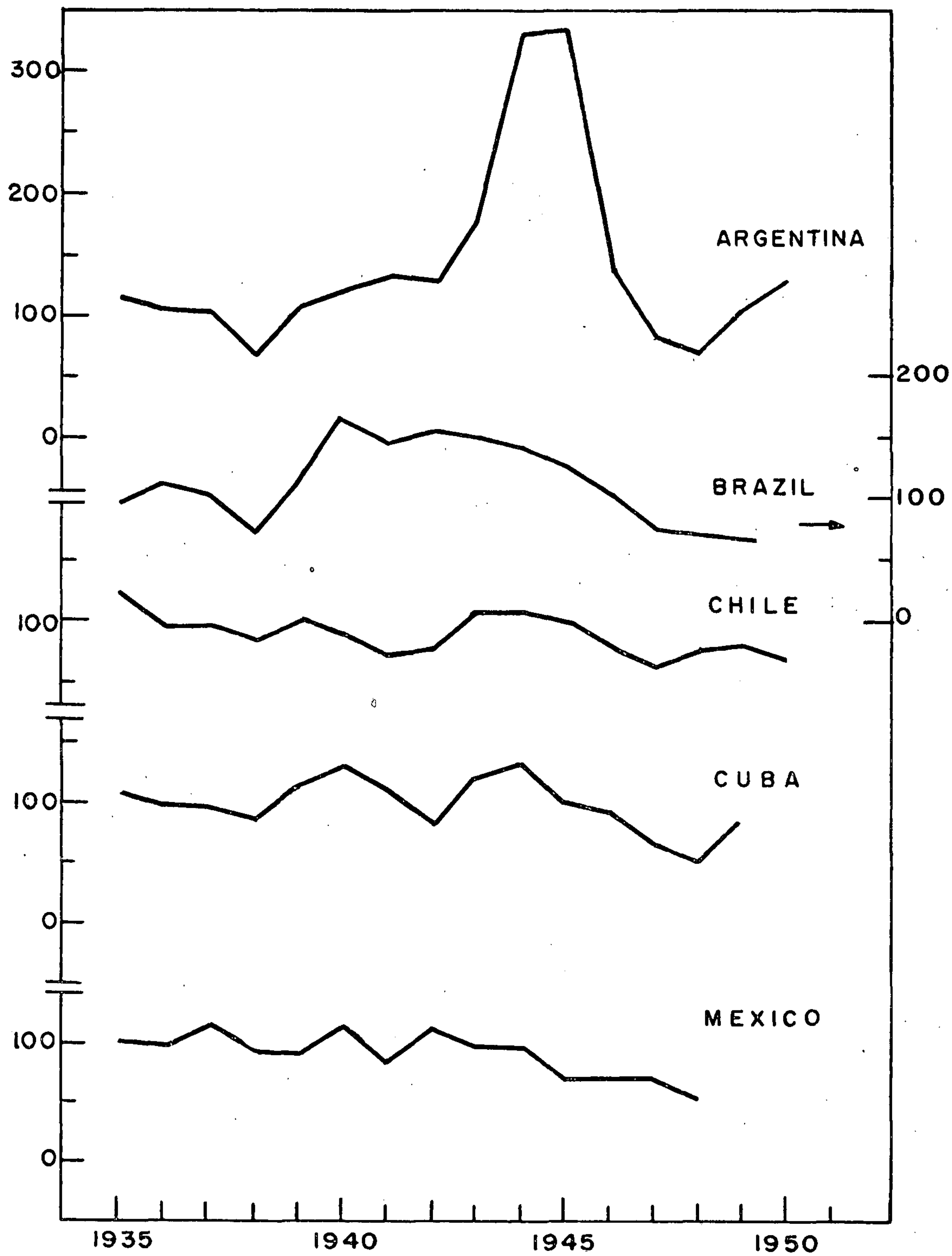
[14] Estimates of the United Nations Statistical Office.

[15] Figures related to the monetary income are available for Mexico since 1929, but it is difficult to select an index of prices adequately to appreciate the changes in real terms. A wholesale price index, a retail price index and an index of cost of living for workers in Mexico City, are officially compiled. The results obtained using one or the other to deflate the monetary income, differ substantially in certain periods. The series of available goods to which reference is made here was published in the *Economic Survey of Latin America, 1949, op. cit.*

Chart VIII

RELATION OF STEEL CONSUMPTION TO THE QUANTUM OF IMPORTS OF OTHER CAPITAL GOODS

Basis of indices: 1935–39 = 100.
(natural scale)



Source: Economic Commission for Latin America.

(b) *Variations in investment activity*

As larger proportions of iron and steel are used in producing capital goods, investment activity is another factor which may have an important bearing upon their consumption. A substantial part of the high consumption attained in 1925-29, seems to have coincided with large investments, mostly financed with foreign capital, and intended for the development of export industries. Since then, foreign investments have decreased, exports have risen in a small proportion only and the terms of trade have deteriorated. Thus it became difficult to maintain the level of essential imports, so that the purpose of investment had to be changed, mainly focusing it towards production of goods intended to satisfy domestic demand. In this way, investment activity has decreased, remaining closer to levels imposed by the countries' saving capacity.

No figures are available adequately to reflect these changes in investment activity, as no indices exist to represent actual capitalization. To obtain an approximate indication, the trends in imports of capital goods at constant prices have been used.

In comparison with 1925-29, steel consumption shows slightly more favourable trends than the imports of capital goods. Consumption shows a greater inelasticity than capital goods faced by restrictions of total imports, and has been supplemented, in several countries, by domestic steel production. If, instead of 1925-29, the years 1935-39 are used as a basis for comparison, the results are slightly different. Imports of capital goods at constant prices have risen faster in the postwar years, compared with 1935-39, than has steel consumption. This was the case for Argentina, Brazil, Chile, Cuba and Mexico, where figures were available.

It should be noted that this deterioration of the ratio of steel consumption to imports of capital goods appears in some countries, such as Brazil and Mexico, which show the highest increases in steel consumption and where domestic production has developed very rapidly.

The evolution of this ratio in each of the five countries can be seen in Chart VIII, which has been prepared with the figures in Table 17.

Table 17

RELATION BETWEEN STEEL CONSUMPTION AND IMPORTS OF OTHER CAPITAL GOODS AT CONSTANT PRICES
(1935–39 = 100)

Year	*Argentina*	*Brazil*	*Chile*	*Cuba*	*Mexico*
1935	115.1	98.5	121.8	108.5	100.4
1936	105.1	112.1	96.2	97.9	98.0
1937	104.2	103.7	98.5	95.5	114.5
1938	68.3	71.1	83.4	85.7	94.5
1939	107.3	114.6	100.1	112.4	92.6
1940	124.3	166.0	90.2	130.4	115.4
1941	135.2	143.9	73.9	110.9	84.9
1942	129.7	154.2	77.4	79.8	111.3
1943	178.5	150.7	107.4	120.0	99.3
1944	330.4	142.6	107.4	132.9	97.8
1945	332.2	127.2	100.7	100.5	70.9
1946	136.8	104.8	78.0	92.7	69.8
1947	80.6	75.4	62.6	67.6	69.7
1948	69.6	73.0	74.5	60.5	52.3
1949	101.4	72.5	77.2	84.3	—
1950	128.4	—	67.5	—	—

Source: Economic Commission for Latin America: Data on steel consumption have been taken from Tables I–VI; imports of other capital goods at constant prices mainly from the *Economic Survey of Latin America, 1949, op. cit.*

It should be recalled that imports of capital goods form only part—although the major one—of Latin America's capitalization efforts. Some of the countries have recently developed, to a greater or lesser degree, an incipient industry producing capital goods, consideration of which would show a more favourable evolution in the level of investment. In the case of Argentina, for instance, value added in mechanical and steel transforming industries shows an increase of 370% between 1935 and 1947, whereas imports of capital goods at constant prices have risen by less than 160% during that period.

If indices of investment were to include both imported and domestically-produced capital goods, they would probably show that steel consumption increases with considerable delay with respect to changes in investments —at least if the comparison were based on pre-war years.

(c) *Development of manufacturing output*

A third factor which might have an important bearing on steel consumption trends is the development of manufacturing.

Chart IX compares the fluctuations of both series in four countries,[16] figures having been obtained from Table XIII of the statistical annex.

Correlation, in general, does not seem to be very close, especially in the cases of Brazil and Chile from 1925 to 1935. During this period manufacturing output maintained a fairly constant upward trend, while steel consumption, affected by the depression, decreased considerably. Whatever industry existed in those years, with the exception of cement, was mainly producing consumer goods (textiles, foodstuffs, etc.) and did not therefore imply any major steel consumption.

Beginning in 1935, manufacturing output rose more rapidly, and steel consumption also showed a more favourable trend. Nevertheless, even if the war years are excluded, with the sole exception of Mexico, steel consumption grew at a slower rate than manufacturing output. The quantum of industrial production increased,

[16] No indices of the quantum of manufacturing output are available for Colombia and Cuba. Argentine figures begin in 1935.

Chart IX

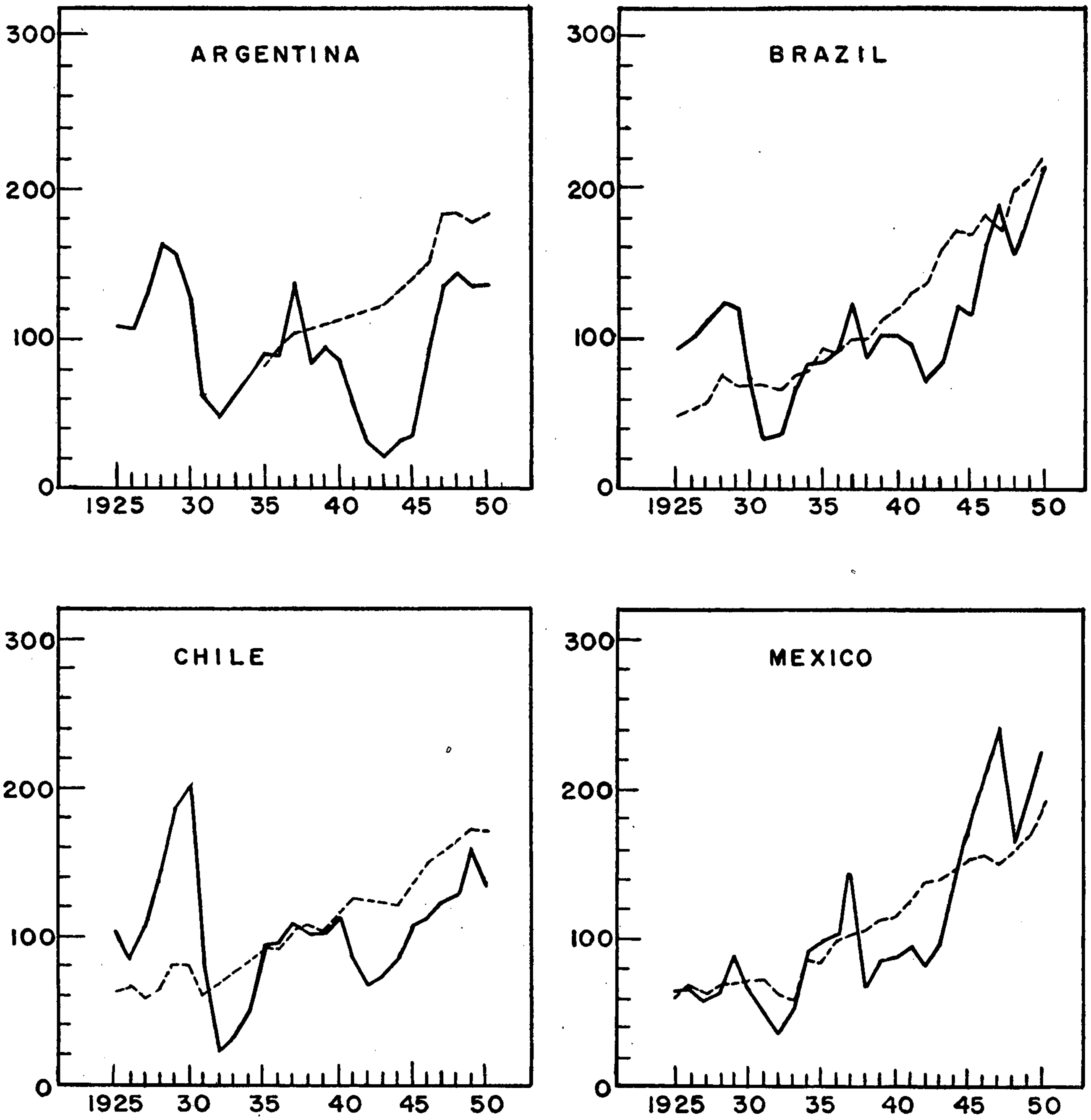
Relation of steel consumption to manufacturing output

Basis of indices: 1935–39 = 100.

(natural scale)

——— Steel consumption indices.

- - - - - - - - Quantum indices of manufacturing output.



Source: Economic Commission for Latin America.

between 1935-39 and 1945-49, by 68% in Argentina, 86% in Brazil and 56% in Chile, whereas steel consumption rose by 9.5%, 63% and 26% respectively. In Mexico, manufacturing output grew only by 58%, compared with a 98% increase in steel consumption.

A relative delay in the growth of steel consumption is thus apparent with respect to that of manufacturing output. Considering that, in the period under analysis, the industrial structure has changed, the situation appears even worse. Iron and steel transforming industries were created in the later years, showing a faster growth than the average for the previous existing industry. In Argentina, for instance, the growth of total manufacturing output, between 1937-39 and 1948-50, is about 69%, the indices for the manufacture of transport vehicles and equipment on the one hand, and electrical equipment on the other, increased by 85% and 172% respectively.

In some of these countries, creation of steel transforming industries has been one of the consequences of the installation of steel producing industries. Regular availability of steel, independent of fluctuations in foreign exchange holdings, have been an important stimulus for the development of steel transforming industries.

In Argentina, the manufacture of some types of machinery, motors and spare parts grew rapidly; shipyards devoted partly to repairs and partly to the building of small craft reached, in 1947, a four-fold capacity compared with prewar figures, while electrical equipment tripled between 1937-39 and 1950.

Something similar has happened in Brazil, where steel transforming industries are helping to solve the serious transport problem. Railway material had not previously been replaced when necessary, as a consequence of shortages in iron and steel products.[17] During the war many plants manufacturing rolling stock were established or expanded. This activity gained an additional impetus when raw material from Volta Redonda became available; in 1950, four large enterprises had an annual capacity of 10,000 wagons a year, sufficient to cover the necessities of the domestic market, plus some margin for export. Assembly and manufacture of steam, diesel and diesel-electric locomotives up to about 1,000 h.p. have been undertaken. Manufacture of rails has also advanced. But progress has not been limited to the production of railway materials as there has been some activity in the assembly of cars and trucks and manufacture of parts of motor vehicles.

Domestic production of other engineering and mechanical equipment has also been undertaken during the last few years: machinery and spare parts for the textile, sugar, alcohol, paper, vegetable oils, and chemical products industries; farming and electrical equipment, plus other goods for domestic use (one plant has a capacity for 20,000 refrigerators a year); tanks and drums for storage and transport of liquids or grains, etc.

In the case of Mexico, it may well be that these changes in the structure of industry are responsible for a faster growth of steel consumption than of total manufacturing output. The development of steel transforming industries producing capital goods or durable consumer goods has been impressive. The rate of growth of some of these activities can be appreciated from the following figures which refer to the period between 1939 and 1950.[18]

	Percentage
Refrigerators	151
Heaters	1,398
Irons	122
Coolers	556
Washing machines	255
Transformers	632
Switches	495
Electric meters	1,295

Imports of many of these products have decreased considerably, saving foreign exchange which the country needs to pay for other imports. Imports of refrigerators, for instance, are now almost non-existent, after having reached more than 2,000 tons in 1941; the capacity of domestic industry today has been estimated at 60,000 units a year. Washing machines are in a similar position: 1947 imports stood at 15,000 units, but from 1948 to 1950 about 100 have been imported annually. In 1948 two plants began operation with an annual capacity of 17,000 units.

As occurred in Brazil, many of these industries have been created in order to solve some of the major problems of the country, such as transportation and low productivity in agriculture.

The exclusive domestic manufacture of transport spare parts (springs, wheels, etc.) was considered insufficient and the construction of a plant producing 1,000 freight cars per year has been envisaged. As regards motor vehicles, several assembly plants exist in the country, as well as the manufacture of spare parts and of truck, bus and car bodies.

In agriculture the prevailing low productivity has been attributed to a shortage of equipment and machinery.[19] Industrial development has to a certain degree contributed to solving this problem by producing some machinery and equipment. But there is still a wide field for further growth of this activity.

2. Factors influencing specific steel products

The aforementioned factors have probably had a general influence on all steel consumption, although manufacturing output has probably had more influence on the consumption of flat products. A lack of uniformity in the development of consumption of different steel products points to the existence of other factors which exclusively influence consumption of specific types of steel products.

In the following paragraph, the evolution of each of the groups of products, into which total consumption has been classified, will be analysed in relation to some such specific factors.

[17] The following data obtained from the *Economic Survey of Latin America, 1949, op. cit.* and *Recent Developments and Trends in the Brazilian Economy, 1950* (E/CN.12/164. Annex H) throw some light on the importance of this problem: while the passenger-kilometres increased by 119% and ton-kilometres by 101% between 1934 and 1945, extension of the railway lines increased only by 6.6%, the number of locomotives by 8.6% and the number of the freight cars by 23.7%. At the end of the war 54,294 freight cars were available and the immediate additional necessities were estimated at 20,408 new units. There were 3,698 locomotives in operation, mostly under repair or old models.

[18] Figures from *Informe a la Décimoséptima Asamblea General Ordinaria de Accionistas,* Nacional Financiera, S.A., Mexico, D.F., 1951.

[19] According to estimates, productivity of workers in agriculture for 1946 was equivalent to one-seventh of the figure attained in manufacturing and only one-eighteenth of that in mining. (*Industrial Development of Mexico,* document E/CN. 12/164, annex K, 1949.)

Chart X

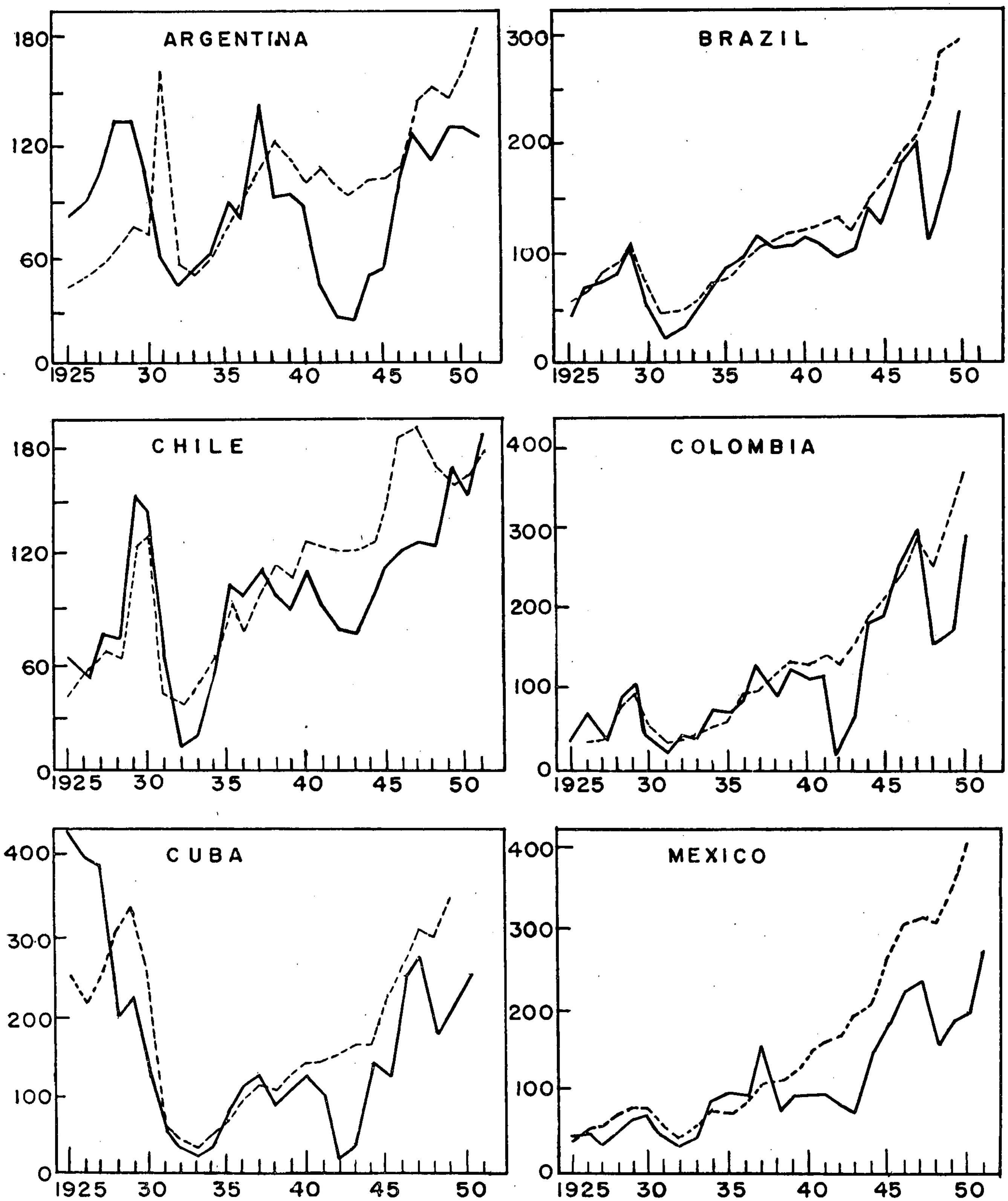
RELATION OF CONSUMPTION OF BARS AND SHAPES TO CEMENT CONSUMPTION

Basis of indices: 1935–39 = 100.

(natural scale)

———— Steel bars and shapes consumption.

- - - - - - - - Cement consumption.



Source: Economic Commission for Latin America.

(a) *Bars, shapes and structures*

These products generally make up a substantial percentage of total consumption. They range from 34% in Colombia and Cuba to about 45% in Chile. In general, demand for these types of steels is closely linked to the building industry, which not only influences consumption of concrete bars, but also that of many other steel products.

No series of indices exists reflecting the trends of building activity during sufficiently long periods in the six countries. Nevertheless, in some of them—especially Argentina and Chile—a close correlation has been established between building activity and cement consumption. A similar correlation has been assumed to be valid for the other countries. Comparisons have therefore been established between consumption of bars, shapes and structures with cement consumption. The results are shown in Table XIV of the statistical annex and in Chart X. With the exception of the depression and war years there is generally a close similarity in the fluctuations of both series. Although cement consumption remained more or less stable, steel consumption dropped considerably during the war and depression years. Apparently this was because domestically produced cement was not subject to the export restrictions during the war or the import difficulties during the depression.

Another general conclusion to be drawn from these comparisons is that, except in the case of Chile, the level of cement consumption is much higher than that shown by consumption of steel bars, shapes and structures in recent years, as compared with the prewar period. In fact, the chart shows that although the consumption curve for these products has risen rapidly since the early postwar years, it has not reached the level of cement consumption.

Argentina provides an extreme example. Bar and shape consumption decreased by about 10% between 1925-29 and 1935-39, while cement consumption grew by more than 70%. Between 1935-39 and 1945-49, consumption of steel bars remained practically stable, whereas cement increased by 30%. Consumption of bars, shapes and structures per ton of cement was, therefore, in the later five years about half that of 1925-29 and 75% of the 1935-39 averages.

In Brazil the relation between consumption of both products remained virtually constant from 1925 to 1946. From 1947 onwards, consumption of cement tended to increase faster than that of steel bars. The ratio has dropped from 243 kg. of steel per ton of cement in 1935-39 to 132 kg. in 1948-49 and to 190 kg. in 1950.

Something similar has occurred in Colombia and Cuba, where high imports immediately after the war led to a recovery in the relation of consumption between bars and shapes and cement similar to the 1925-29 and 1935-39 levels. A stagnation in the consumption of bars and shapes since 1947 has tended to a deterioration in this relation.

Although Mexico is the country in which consumption of finished steel increased at the most rapid rate, since the prewar period, consumption of bars, shapes and structures has been growing at a slower rate than that of cement. The deterioration of the ratio between the two series is substantially more important than in any other country. Consumption of these types of steel per ton of cement dropped by 50% between 1935-39 and 1948-50.

In Chile a similar situation prevailed until 1948. Since then, a substantial increase in consumption of bars, shapes and structures on the one hand, and a reduction that of cement on the other, have tended to re-establish the ratio of the 1920's.

The above data appear to indicate that there has been a certain delay in the upward trend of steel products consumption as compared with that of building activity. It is possible that the relatively larger cement consumption can be otherwise explained, for instance, through public works programmes using more cement, for example in road construction. Also there might be technological changes in building, reducing the amount of steel to cement, such a trend perhaps being aided by changes in relative prices. In some cases, investments in public works have been considerable. In Mexico, for instance, cement consumption for irrigation and highways may have absorbed 30% of total production between 1944 and 1946. From 1939 to 1951 the highway network increased from 8,800 km. to almost 22,000 km. Conversely, some parts of the products included in this group have been used in steel transforming industries. This has become important, especially during the last few years, and the growth of these industries has been faster than that of building activity. Therefore, if the consumption of steel actually used in building could be isolated, the relation between steel and cement consumption would be even more adverse.

A shortage of bars, shapes and structures undoubtedly exists and with more favourable supply conditions consumption of these types of steel would increase. This conclusion seems important when the prospects of Latin-American markets are investigated. If more steel were available, an increased potential market would therefore result from an improvement of the relation between bars and shapes and cement consumption. It would also originate in the indispensable expansion of the building industry. The building industry cannot be expected to attend exclusively to replacement and to the natural increase of population. In most cases, Latin America faces an actual shortage of housing, to which the fast urban rate of growth must be added.

In Argentina the 1914 and 1947 censuses give the percentage of population living in rural areas, or in towns of under 2,000 inhabitants, as 52.7 and 38.6 respectively. In Colombia, similarly, it has been estimated[20] that while the average yearly growth of population in the country has been 2.1% between 1938 and 1950, the more important towns show much higher rates (Bogotá, 4.2; Medellín, 3.8; Barranquilla, 4.4; Cali, 4.1). The average number of persons per house was estimated at 6.3, and as a result it appeared urgent that 160,000 houses were either built or considerably repaired. In Mexico, the number of cities with more than 100,000 inhabitants increased from 4 in 1940 to 10 in 1950, while public buildings in Mexico City increased from 3,000 in 1939 to 10,000 in 1945. Similar figures prevail in the other countries.

[20] *The Basis of a Development Program for Colombia,* report of a mission headed by Lauchlin Currie and sponsored by the International Bank for Reconstruction and Development, Washington, D.C. IBRD Special publication (Sales No.: IBRD. 1950.2).

(b) *Plate and sheet*

Part of the consumption of sheet is linked to the building industry, in the form of galvanized roofing. In several countries there has been an increasing trend to replace steel plate by asbesto-cement plate. Supply shortages of the former, or relative price variations, seem to be responsible for this change.

A more important part of plate and sheet consumption may be influenced by manufacturing output in general and by the steel transforming industries in particular. These products are a basic raw material for production of many durable consumer goods (kitchen stoves, refrigerators, metallic furniture, etc.) and also of some capital goods' manufacturing industries (shipyards, tanks, machinery and farm implements, motor vehicle bodies, etc.).

This explains why the recent growth of consumption has been considerable, coinciding with expansion or creation of steel transforming industries. The relative importance of this group is larger in countries having attained more progress in such industries. As shown in the tables, in 1945-49, plate and sheet consumption represented about 19% of total steel consumption in Mexico, 18% in Argentina and 16% in Brazil. In the three remaining countries—Chile, Colombia and Cuba—it fluctuated between 10% and 14%.

The analysis of the influence of manufacturing output on consumption of finished steel seems, therefore, particularly applicable to the consumption of plate and sheet. The same is true for the prospective future demand. Any quantitative appreciation of the future consumption of these products is difficult, in view of the large field available for their application to steel transforming industries. This is the same, even in countries like Mexico and Brazil, where the recent growth of plate and sheet consumption has been considerable. In both countries, demand grew even faster making some kind of rationing indispensable.[21]

(c) *Tinplate*

While steel plate consumption has remained stationary during the larger part of the last 25 years, growing rapidly only in recent years, tinplate consumption has continued to increase. This is true, even in countries such as Cuba, where consumption of other steel products has considerably decreased. Tinplate consumption was also affected, to a lesser degree, by the contraction of steel consumption during the war, because Latin-American countries obtained relatively substantial tinplate quotas from the United States.

The fact that tinplate is mainly used in food processing industries, and that these are no new development for Latin America, may explain the different behaviour. Conversely, steel transforming industries, which are the main consumers for plate and sheet, have only recently appeared.

Nevertheless, tinplate consumption has not maintained the same general trend shown by the food processing industries. Chart XI shows (in logarithmic scale in order to make the series comparable) the changes in tinplate consumption and some of the food processing industries in Chile and Mexico. While in Chile, tinplate consumption increased between 1937 and 1948 by less than 50%, production of preserved foodstuffs increased 53%; biscuits, 71%; fish product, 104%; condensed milk, 258%, and powdered milk, 287%. In Mexico, tinplate consumption increased, between 1939 and 1950, by about 30% and by almost 100% between 1939 and 1951. Food processing industries have increased by some 300% during the latter period. Something similar seems to have occurred in Cuba, where the tonnage of exported preserved food increased from an average of 3,500 tons in 1935-39 to 25,000 tons in 1947-49.

The slight increase in tinplate thus seems surprising. It may be that some technological factors have compensated for part of the apparent shortage: use of thinner tinplate, of larger containers, or other improvements. The most important factor, however, seems to be a progressive substitution of tinplate by other materials such as cardboard, wood, glass, etc. In this way a larger proportion of limited tinplate supplies may have been reserved for industries such as canned fish, shellfish and condensed milk, which cannot use other materials.

Insufficient growth of tinplate consumption in relation to factors which obviously determine demand has unfavourably influenced the development of food processing industries. Their rate of growth would probably have been still faster if sufficient containers had been available. This fact should be recalled when future tinplate consumption is considered, since it is determined not only by the present trend but also by the effects of a greater supply of containers and by the possibilities of recovering the market absorbed by substitutes.[22]

(d) *Wire and wire products*

Nails, bolts, screws, nuts, rivets and wire net have been included in this group, in addition to wire. Although they are not direct rolling mill products, a relatively simple and highly mechanized transformation is required.

It is possible that the consumption figures for these products given in the statistical annex are not entirely accurate. This is due to classification problems and because complete information regarding domestic production is lacking.

The heterogeneous character of this group complicates its correlation with some specific factors. The group is used in agriculture (fencing wires, wire netting, etc.), in the manufacturing industry (special wires, bolts, nuts, rivets, etc.) and in the building industry (wire, wire rod, nails, etc.). Consequently many of the conclusions obtained in the previous sections are also partly applicable to these products.

(e) *Pipes and tubes*

The same statistical reservations mentioned above apply to tubes and pipes. In most cases the building industry and urban public services have been the main factor influencing consumption of pipes and tubes. The manufacturing industry has lately been using this type

[21] In Mexico, for instance, the Government has assigned monthly quotas to the steel transforming industries.

[22] Naturally the prospects for growth in tinplate consumption depend on specific conditions in each country. It is probable that in Argentina, with a long-established food processing industry, the rate of growth will be smaller than in Colombia, where such industry is incipient. Tinplate consumption in Colombia is quite small: 4,600 tons in 1946-50. In contrast, 8,600 and 18,000 tons were used respectively in Chile and Cuba—countries with a considerably smaller population than Colombia.

Chart XI

RELATION OF TINPLATE CONSUMPTION TO OUTPUT OF FOOD PROCESSING INDUSTRIES

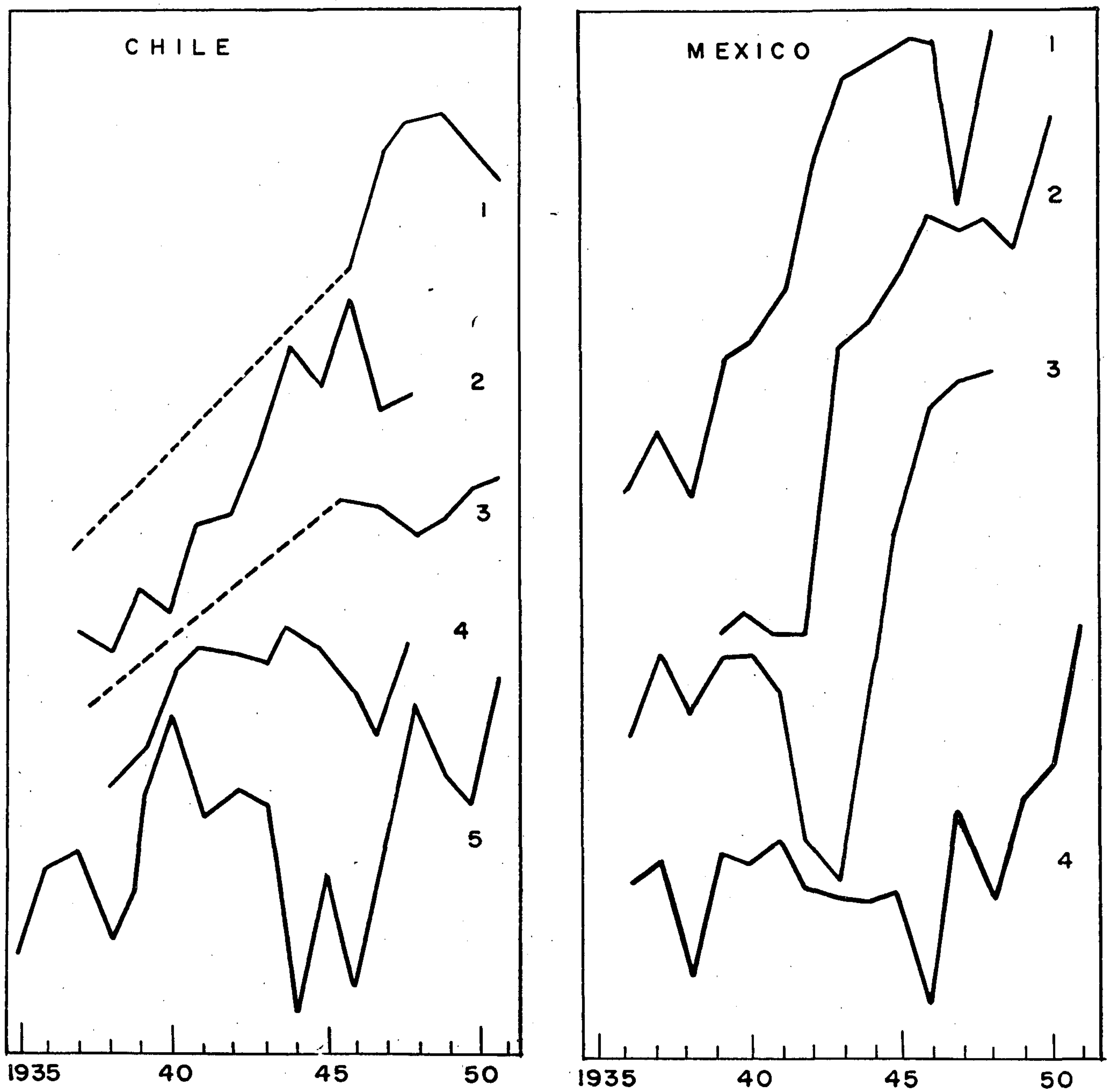
(semi-logarithmic scale)

CHILE

1. Condensed milk production.
2. Production of canned fish and sea foods.
3. Biscuit production.
4. Production of canned fruits and vegetables.
5. Tinplate consumption.

MEXICO

1. Production of canned fruit and vegetables.
2. Index of volume of production of canned foods.
3. Production of canned sea foods.
4. Tinplate consumption.



Source: Economic Commission for Latin America.

of product to a growing extent, but still to much lesser degree than for construction and public works. In addition, in some of the countries, the main consumer is the petroleum industry.

Under these circumstances, it is almost impossible to trace the individual factors which have influenced consumption in the past and even less to make estimates for future consumption. In many cases, the availability of these products has not been sufficient to satisfy demand, and many other products have been used as substitutes, such as asbesto-cement.

(f) *Rails and accessories*

These products show the most unfavourable evolution during the last 25 years. In Argentina, imports in 1945-49 were less than one-third of those for 1925-29, whereas in the intermediate years even larger reductions took place. Thus, aggregate imports, for 1930-51, have been 706,000 tons of rails and accessories, almost equal to those of 1925-29. Conversely, about 5,000 km. of new railway lines were laid during those 22 years, while in the previous five years the increase was just under 4,000 km.[23] This comparison suggests that rail imports, since 1930, have been mainly used for new extensions, leaving almost no margin for replacement.

In Brazil, rails and their accessories are the only group of steel products showing a decrease since 1925-29. They have never again attained the 1925-29 figures, and in many periods were less than half. When it is remarked that the increase in railway milages was small in 1925-29, it is apparent that the relatively high consumption in those years must have been used for replacement purposes. The recent decrease in imports has therefore probably resulted in insufficient supplies to cover such replacement necessities. The situation has been aggravated by traffic increases and by the enlargement of the railway system.[24] In 1945 it was estimated[25] that the accumulated requirements for postponed replacement had resulted in the immediate need to renew about 40% of the rails. The requirements were estimated at more than one million tons.

Something similar has occurred in Chile. A detailed investigation of the market by the Chilean steel plant in collaboration with railway officials during 1948,[26] indicated that normal replacement necessities for the country amounted to 19,665 tons annually. At that time, about 80,000 tons of obsolete rails were still in use, because no steel was available to replace them. If this accumulated shortage was to be eliminated in 20 years, the requirements for rails and accessories for replacement would total 23,966 tons annually. Finally new lines were under construction, demanding an additional 2,750 tons of new rails each year. Total requirements for the next 20 years were thus estimated at 26,415 tons annually.

Since 1930, the only year in which such a figure has been attained was 1951 (imports of 28,000 tons of rails and accessories). Average consumption between 1935 and 1951 has been less than 50% of such requirements.

In Colombia also, excluding sporadic imports such as those of 1947, the availability of rails has been very low since the depression of the 1930's. The total length of railways is small in Colombia (about 3,000 km.) and replacement requirements are therefore also small, but several new railway lines are planned. Law No. 26 of 1945, authorized the construction of 1,800 km., for which about 110,000 tons of rails are necessary. This figure alone is greater than total rail imports since 1930.

In Cuba, rail imports have amounted to about 60,000 tons during the last 20 years (14,600 tons in 1947 alone); the annual average is thus 3,000 tons. The situation in Cuba compares with that of Chile, where 10,000 railway-kilometres require 20,000 tons of rail replacements a year. The need should be higher in Cuba, which has about 18,000 km. of railway.[27]

Since the depression of the 1930's, Mexico has been faced by serious transport problems for the improvement of some railway lines, to make them available for heavier traffic and higher speeds. Thus Mexico needs rails for these purposes as well as for the probable replacement requirements, dating from the 1930's.

To summarize, inadequate replacement of rails and the accumulated shortage seems to be general in all Latin-American countries. To these, the necessity for railway expansion must be added, which in many instances has also been postponed, owing to the unavailability of steel.

3. Other factors influencing availability

From the analysis so far, the conclusion emerges that steel consumption in Latin America has not kept pace with the progress of some factors which should influence its demand. This conclusion is valid even for Mexico, which shows the highest rate of increase in consumption.

If the present ratio between steel consumption and some of these factors is compared with the ratio prevailing before the depression or the Second World War, it becomes evident that steel consumption has not increased correspondingly. This is true if it is compared with real income. If the comparison is made with investments, represented solely by imports of capital goods, both trends are more or less equal, but if domestic production of capital goods is added, steel consumption trends appear to be lower than the trends of investments. The comparison is also unfavourable with manufacturing output, especially with industries producing durable consumer goods, machinery and equipment. Consumption of certain special types of steel products also falls considerably behind the evolution of some specific factors to which they should be linked. Consumption of bars, shapes and structures increases less than building activity; consumption of steel plate less than the development of food processing industries, and, finally, consumption of rails is usually inadequate to fill the normal requirements for replacement.

These comparisons suggest that the present consumption figures cannot be considered representative of demand. An additional factor must have hindered the demand from appearing fully. Unavailability of steel products could be such a limiting factor.

In some of the countries, steel supply has been based exclusively on imports, in others these have been supplemented by some domestic production. An analysis of the influence on steel consumption, both of local production and of the capacity to import, will be made in the following pages.

(a) *Capacity to import*

Of the six countries included in this study, the steel supply of Colombia and Cuba has been based exclusively on imports; since the late 1930's Argentina and Chile have a limited contribution from domestic production for specific types of steel, but imports have been the

[23] The following figures represent total length of railway lines in kilometres:

1800	2,516	1925	24.468
1890	9,432	1930	38,634
1900	16,563	1935	40,587
1910	27,994	1941	42,889
1920	33,907	1947	43,666

[24] The growth has been 32,478 km. in 1930, 33,330 km. in 1935, 34,252 km. in 1940, 35,280 km. in 1945 and 36,681 km. in 1950. The additions were therefore more than 4,000 km. in the twenty-year period.

[25] *Economic Survey of Latin America, 1949, op. cit.*

[26] Mimeographed report of limited circulation entitled *Mercado Nacional de Productos de Fierro y Acero,* Compañía de Acero del Pacífico, Santiago, 1949.

[27] This comparison can be taken in only a limited sense, because a considerable milage of the Cuban lines belongs to the sugar industry and probably has lower replacement requirements in view of the sharp seasonal fluctuations in traffic.

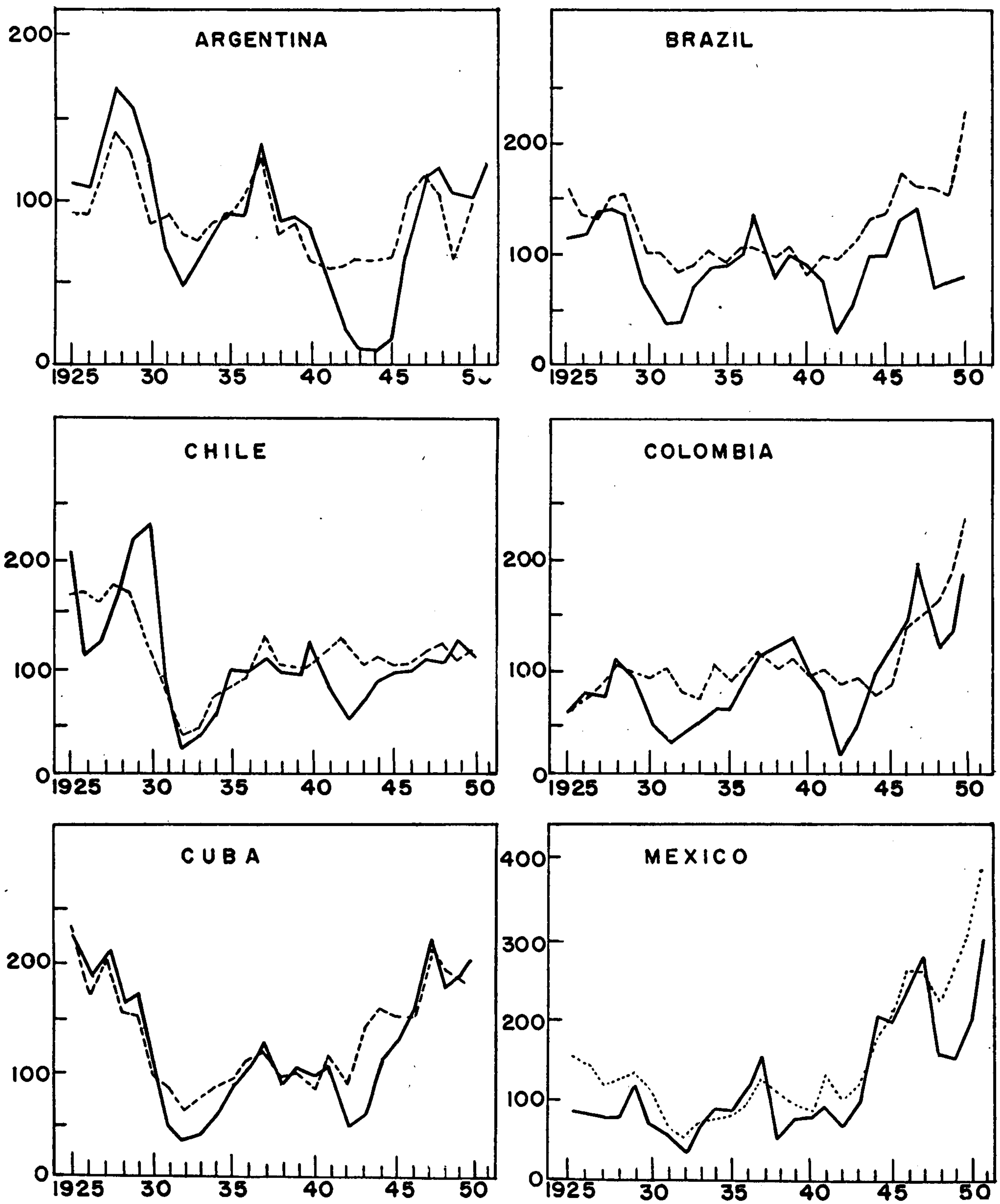
Chart XII

RELATION OF IRON AND STEEL IMPORTS TO THE CAPACITY TO IMPORT

Basis of indices: 1935–39 = 100.

(natural scale)

——— Iron and steel imports. - - - - - - Capacity to import.
. . . . Quantum of total imports.



Source: Economic Commission for Latin America.

major contribution to the supply; finally, Brazil and Mexico, although possessing older steel industries, have also had to resort to substantial imports. Thus, the capacity to purchase steel on foreign markets must have greatly influenced consumption.

In evaluating the purchasing power through indices for the capacity to import, it may be seen that iron and steel imports show a very close correlation to it during the last 25 years. Chart XII shows the relationship between the two series, based on the figures contained in Table XV of the statistical annex.

In Argentina the unfavourable import trend of finished steel coincided with an equal trend of the capacity to import. The only differences appear during the depression and during the Second World War. The first is due to the greater elasticity of other import groups, tending to use a larger proportion of the scarce exchange availability. The second is due to restrictions imposed on steel exports in the producer markets.

In the case of Brazil, correlation between both series is also good until the war, excluding of course the depression period. In the early postwar years, imports of steel grew rapidly, until in 1947 they reached a level close to that of the capacity to import. The development of domestic industry, especially Volta Redonda, has permitted the substitution of part of the imported steels, liberating foreign exchange for other necessities.

In Chile, where dependency upon imports has been stronger than in Brazil, the correlation is also closer. Capacity to import shows a steep contraction during the depression, stabilizing afterwards at a lower level than had been attained in 1925-29. Iron and steel imports follow very closely the variation of the former.

In Colombia the capacity to import has had a more favourable tendency,[28] permitting increased imports of iron and steel. The correlation between the two series has been relatively close, with the exception of the depression and the war. Steel imports grew faster than the capacity to import in the years immediately after the war. This was probably motivated by accumulated deferred demand. The highest figures were attained in 1947 and, since then, steel imports have been below what the capacity to import would have permitted.

In Cuba, comparison of the variations between the two series shows how closely linked they are together. Linear coefficient of correlation based on all the annual figures for the period, including the depression and the war, is equivalent to 0.914.

In Mexico, which shows a much smaller correlation than the other countries, some other factors, in addition to the capacity to import—as defined here—influence the availability of foreign exchange.[29] An outstanding example is the income from tourist revenue. In the immediate postwar era these factors represented $90 million per year and have reached $156 million in 1950. For this reason the capacity to import has been substituted by indices of total imports in Chart XII. As in Brazil, the correlation is close until the early postwar years; after this, imports of iron and steel remained below the capacity to import, probably because of the considerable increase in domestic production.

Capacity to import therefore seems to establish specific limits in each country, above which iron and steel imports have risen only occasionally. No matter how strong the pressure of internal demand for greater quantities of steel products, there have been no available means to purchase them abroad. Additional imports of steel could have been obtained only by using a higher proportion of the available foreign exchange; but the main obstacle is the structure of imports, which hardly permits limiting purchases of other products. A substantial percentage of imports consists of extremely inelastic products: mainly foodstuffs in Chile; fuel, lubricants and basic chemical products in Argentina and Brazil. In addition it should be noted that imports of capital goods, including iron and steel, have been fairly high in some countries: up to 40% of the value of total imports in Brazil in 1947.[30]

(b) *Domestic steel production*

Insufficient increases, or even decreases, of the capacity to import are responsible for the relatively small steel consumption, faced with the trend of the factors linked to its demand. In this way, deferred demand has accumulated, becoming in some cases an obstacle to economic development. Under such conditions, the possibility of domestic supplies becomes very important. It provides a more regular availability, independent of foreign exchange problems or of restrictions on export markets.

In Brazil and Mexico, the influence which local steel industries have had on their consumption trends has been substantial. It is probable that if, in the first of these countries, availability of iron and steel could have been determined exclusively by the capacity to import, in 1945-47, a considerable decrease in total consumption would have taken place; from an average of 430,000 tons in 1925-29 to an average of 406,000 in 1945-47.[31] In the case of Mexico, in 1945-48, it has been estimated that in order to equal, exclusively through imports, the steel supply at that time, such imports would have had to represent 13.4% of the value of total imports, instead of 5.8%.

Although on a smaller scale, the influence of domestic production upon the trend of steel consumption was considerable in Argentina and Chile. In the former country, particularly during the war years, domestic production limited the effects of the drastic reduction in imports. In Chile, the influence of domestic output becomes apparent in recent years, because steel consumption has increased considerably since the opening of the Huachipato plant.

[28] It has not been possible to prepare indices of the capacity to import along the same lines used for other countries, because of lack of data. An estimate has been made by deflating an index of the dollar value of exports by the index of export prices from the United States.

[29] The index of the capacity to import considers exclusively the changes related to the quantum of exports and the terms of trade. It does not include other items of the balance of payments. If the additions maintain a certain relation with foreign trade, this problem is of no importance, but in Mexico, these other sources of foreign exchange have attained a growing importance within the balance of payments.

[30] For the inelasticity in some of these products, a clearer view can be obtained from data for Chile, in which the following coefficients of elasticity for import products in relation to total imports prevail: foodstuffs, 0.36; chemical products, 0.70; fuel, 0.73; textiles, 0.77; and capital goods, 1.48.

[31] Here, of course, the possibility that the investments used in the steel industry could have been applied to increase production of export products, has not been considered. The possibility may exist that by thus increasing the capacity to import, higher imports of iron and steel could have been reached. In analysing such a possibility, it would become necessary to investigate the existence of export markets for such additional products.

In those Latin-American countries whose domestic steel industries are fairly developed, production of steel does not fully cover the fundamental objectives of the substitution of imports. Increased domestic demand absorbs the greater availability, without reducing the pressure on certain purchases from abroad, thus obliging the maintenance of a variable level of imports. This is, probably, additional proof of the existence of a considerable unsatisfied potential demand, which cannot be evaluated on the basis of historical consumption trends.

The reciprocal influence of availability and demand for steel products must also be taken into account. Regularity of supply tends to develop transforming industries, which soon establish industrial centres originating in the steel industry. They again represent a new factor which increases demand.

These findings help to explain why those countries having steel industries are periodically compelled to plan extensions. In Brazil, in 1951, for instance, Volta Redonda produced over 340,000 tons of finished steel, this being the limit of its capacity. The importance of immediate plans can be appreciated from the following extracts from the 1951 Report of the Board of Directors of the Companhia Siderúrgica Nacional:

> "The inevitable delay in completing the first expansion of the plant (to raise steel ingot production to 680,000 tons, or about 460,000 tons of finished products), and the growing rate of increase for the market's requirements, due to the progressive industrialization of the country, have led the Board of Directors of the Companhia Siderúrgica Nacional to the conclusion that when the new enlargements are finished, the production capacity of all facilities will already be unsatisfactory.
>
> "Under these conditions, the necessary steps to meet the growth of the market have been studied.
>
> "These early studies led to the conclusion that production at Volta Redonda should be raised to one million tons capacity of steel ingot annually (about 750,000 tons of finished steel), within the present production lines and while the first expansion of the blast furnace proceeds."

These enlargement plans for Volta Redonda appear entirely compatible with the capacity expansions of other smaller companies—like Belgo-Mineira, second in importance—which are also considering enlargements to their facilities. In addition, several major projects are being built or are in the blueprint stage: two plants in the State of São Paulo, one in Santos and one in Belo Horizonte, each with a capacity above 250,000 tons.

The existence of considerable potential demand and the increase in demand resulting from domestic steel industries are factors which make estimates of the size of future domestic markets difficult in those countries which are planning to build steel industries. Quite often, in such cases, consumption figures for previous years have alone been used as the criterion.[32]

[32] Colombia is probably one of the most interesting examples of the difficulty to evaluate accurately the size of the domestic market. Possessing very valuable, well located natural resources for a steel industry, the possibility of their utilization was discussed on the basis of the small-scale demand. Some appreciations, based exclusively on import figures corresponding to definite periods, were frankly discouraging. One large firm, for instance, estimated domestic demand in 1944 at 25,000 tons of finished steel, probably based on imports for the immediately preceding years. Nevertheless, consumption had already been close to 100,000 tons in 1937-39. Immediately after the war, in 1947, imports stood at 164,000 tons. The initial capacity for the plant at present being constructed is 105,000 tons annually of bars, shapes and derived products, to the exclusion of flat products.

IV. Statistical Annex

Table I

APPARENT CONSUMPTION OF IRON AND STEEL IN ARGENTINA

Years	*Imports*	*Production*[a]	*Consumption*	*Population (thousands of inhabitants)*	*Per capita consumption (kilograms)*
		(thousands of tons)			
1925	734.4	—	734.4	10,429	70.4
1926	728.2	—	728.2	10,691	68.1
1927	850.9	—	850.9	10,954	77.7
1928	1,091.4	—	1,091.4	11,231	97.2
1929	1,054.0	—	1,054.0	11,510	91.6
1930	848.1	—	858.1	11,804	72.7
1931	437.7	—	437.7	12,098	36.2
1932	321.9	—	321.9	12,400	26.0
1933	416.1	—	416.1	12,710	32.7
1934	520.7	—	520.7	13,028	40.0
1935	612.9	—	612.9	13,354	45.9
1936	606.1	—	606.1	13,688	44.3
1937	916.7	—	916.7	14,093	65.0
1938	581.7	5	586.7	14,202	41.3
1939	603.5	18	621.5	14,397	43.2
1940	553.5	24	577.5	14,591	39.6
1941	356.7	45	401.7	14,796	27.1
1942	164.2	55	219.2	15,004	14.6
1943	74.6	70	144.6	15,216	9.5
1944	69.5	150	219.5	15,441	14.2
1945	105.3	150	255.3	15,674	16.3
1946	437.3	170	607.3	15,912	38.2
1947	744.9	170	914.9	16,109	56.8
1948	803.8	170	973.8	16,420	59.3
1949	712.6	200	912.6	16,818	54.3
1950	671.0	240	911.0	17,196	53.0
1951	811.7	300	1,111.7	17,641	63.0

Source: Economic Commission for Latin America.

[a] Figures for the years 1938–48 taken from *El Problema Siderúrgico Argentino* by Ingeniero Militar Coronel Pedro J. Maristany, Buenos Aires, 1950. Figures for the years 1949–51 are estimates.

Table II

APPARENT CONSUMPTION OF IRON AND STEEL IN BRAZIL

Years	Production (thousands of tons)	Imports (thousands of tons)	Consumption (thousands of tons)	Population (thousands of inhabitants)	Per capita consumption (kilograms)
1925	0.3	380.9	381.2	32,813	11.6
1926	16.0	393.0	409.0	33,223	12.3
1927	16.6	442.2	458.8	33,638	13.6
1928	26.2	473.9	500.1	34,058	14.7
1929	30.0	458.3	488.3	34,484	14.2
1930	25.9	247.9	273.8	34,915	7.8
1931	18.9	125.5	144.4	35,351	4.1
1932	29.5	125.6	155.1	35,793	4.3
1933	42.4	237.8	280.2	36,240	7.7
1934	48.7	295.2	343.9	36,693	9.4
1935	52.3	297.1	349.4	37,152	9.4
1936	62.9	324.8	387.7	37,616	10.3
1937	71.4	435.1	506.5	38,550	13.1
1938	85.7	272.2	357.9	39,477	9.1
1939	101.0	329.0	430.0	40,286	10.7
1940	135.3	291.0	426.3	41,100	10.4
1941	149.9	249.3	399.7	42,088	9.5
1942	155.1	119.4	274.5	43,100	6.4
1943	157.6	182.0	339.6	44,137	7.7
1944	166.5	325.8	492.3	45,198	10.9
1945	165.8	316.5	482.3	46,285	10.4
1946	230.2	431.4	661.6	47,398	14.0
1947	296.7	476.5	773.2	48,537	15.9
1948	403.5	236.3	639.8	49,704	12.9
1949	505.5	247.6	753.1	50,900	14.8
1950	623.2	251.7	874.9	52,124	16.8

Source: Economic Commission for Latin America.

Table III

APPARENT CONSUMPTION OF IRON AND STEEL IN CHILE

Years	Imports (thousands of tons)	Production (thousands of tons)	Consumption (thousands of tons)	Population (thousands of inhabitants)	Per capita consumption (kilograms)
1925	126.1	—	126.1	3,929	32.1
1926	113.0	—	113.0	3,977	28.4
1927	129.1	—	129.1	4,034	32.0
1928	174.8	—	174.8	4,118	42.4
1929	224.5	—	224.5	4,199	53.5
1930	245.6	—	245.6	4,287	57.3
1931	92.3	—	92.3	4,323	21.4
1932	27.6	—	27.6	4,391	6.3
1933	40.4	—	40.4	4,461	9.1
1934	61.8	—	61.8	4,534	13.6
1935	103.1	10	113.1	4,605	24.6
1936	102.2	12	114.2	4,697	24.3
1937	113.2	15	128.2	4,754	27.0
1938	103.2	18	121.2	4,831	25.1
1939	100.6	22	122.6	4,907	25.0
1940	112.5	23	135.5	4,985	27.2
1941	84.6	22	106.6	5,057	21.1
1942	56.6	26	82.6	5,130	16.1
1943	67.7	22	89.7	5,199	17.2
1944	86.0	25	111.0	5,273	21.0
1945	99.4	28	127.4	5,349	23.8
1946	101.7	33	134.7	5,430	24.8
1947	109.5	36	145.5	5,525	26.3
1948	105.5[a]	40	145.4	5,620	25.9
1949	130.4[a]	37	167.4	5,709	29.3
1950	111.5	53[b]	164.5	5,809	28.3
1951	93.2	113[b]	206.2	5,920	34.8

Source: Economic Commission for Latin America.

[a] Excluding some imports for assembling the Huachipato plant.

[b] Production for domestic consumption, excluding exports.