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ECONOMICS ON TRANSPORTING OF RAW MATERIALS IN LARGE BULK CARRIERS [1]

by

William T. Hogan
United States of America

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

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SUMMARY

Progress in the production of iron and steel over the past two decades has been such that time-tested precepts, related both to basic steelmaking technology and fundamental industry economics, have been challenged suddenly and dramatically. A development outside of the production segment of the industry which has exerted a prodigious influence on the world steel industry has been the use of large bulk carriers for the worldwide shipment of raw materials. It has contributed significantly to the dispersion of steel production activity throughout the world which has made necessary fundamental revisions in long-standing concepts of steel industry economics.

* This is a summary of a paper issued under the same title as ID/WG.14/63.

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Comparative Costs and International Trade

The impact of recent innovations in bulk carrier transportation serve to indicate that modification is in order for the economic theory of comparative costs as it relates to the steel industry, particularly with respect to its emphasis on the possession of raw material resources. It was not too long ago that one of the prerequisites stressed for a successful steel industry was a nation's possession of adequate supplies of raw materials, either within its boundaries or in close proximity. This precondition was interwoven with the comparative cost theory of international trade in which it is generally considered that a nation's industrial activity tends to become specialized in those products which require the use of its most plentiful, highest-quality, lowest-cost resources. Such products wherein the nation has a production cost advantage relative to other nations will be produced at home and other goods which can be produced only at a production cost disadvantage will be imported to provide for domestic requirements.

The World Steel Industry and Comparative Costs

This theory of trade harmonized quite well with the experience of the world steel industry in the late 1940's when steel output was concentrated in relatively few main production centers which either possessed, or were located near, abundant supplies of raw materials. As late as 1947, even though there were 32 steel producing nations around the world, approximately 76 per cent of total world steel output was accounted for by one North American and four European nations. Given this fact, the proximity to raw materials was generally considered an essential requirement for an economically feasible steel plant and it was not considered very likely that a major shift of the industry outside of its principal production centers would occur. Quite to the contrary, however, within the past twenty years the Japanese steel industry has become a major world producer, despite the strict scarcity of local supplies of the essential raw material resources for steelmaking. At present, the number of steel producing nations in the world totals 66, more than double the number of the late 1940's, and the five nations which accounted for 76 per cent of the world's steel output in 1947, now produce only about 43 per cent of the total.

Bulk Carrier Progress and the World Iron Ore Trade

One of the primary reasons for this change has been a revolution in the area of resource availability by virtue of the use of large bulk carriers. During the period 1950-1965 inclusive the world's iron ore output increased by 147.0 per cent, but trade expanded even faster by 418.8 per cent. As a result the portion of world production shipped between nations increased from 16.5 per cent in 1950 to 34.6 per cent in 1965. The participation of developing nations in this trade has grown very sharply, with new mines in Africa, Asia and Latin America accounting for more than 47 per cent of the 1965 total, and with the development in more recent years of Australia as a substantial iron ore exporter. The result has been that the greater portion of trade now takes place over long distances, an accomplishment which of necessity has been accompanied by a substantial addition to the world's fleet of bulk carriers designed for the shipment of ore.

The construction record of the 1947-1968 period is most impressive totaling 331 ore carriers representing 8,810,000 deadweight tons of capacity and 174 ore/oil carriers representing 11,892,000 tons. Ore carrier building increased appreciably from the mid-1950's through the early 1960's, but in more recent years, emphasis has been placed on the construction of huge ore/oil carriers, which explains why fewer such ships contributed a greater tonnage. Since 1961, ore/oil carrier construction has totaled 10,074,600 deadweight tons, 84.8 per cent of the tonnage for the entire 1947-1968 period. This surge in activity is related to the fact that ore/oil carriers have been used more extensively in recent years to increase the potential for backhauling and thus reduce the ocean freight rates on iron ore.

Of particular significance is the trend which has developed toward increased carrier size. Generally, the size of ore carriers increased together with shipbuilding activity in the mid-1950's and early 1960's with the largest ships in the range of 50,000 to 60,000 deadweight tons. In the mid-1960's, ore carriers exceeding 80,000 deadweight tons were built and in 1967 two 180,000 ton carriers were under construction. Most of the ore/oil carriers built during the early to mid-1950's were in the range of 20,000 to 30,000 deadweight tons. In 1957, a trend toward larger combination ships of this type started to develop with sizes approaching 50,000 deadweight tons. By the early to mid-1960's the maximum size range had reached 70,000 to 80,000 deadweight tons, and during the last two years ore/oil carriers of 163,000 and 250,000 deadweight tons have been contracted for.

The Use of Large Bulk Carriers to Benefit Steel Industries in Developing Nations

It is generally agreed that given the necessary raw materials, iron ore, coking coal and limestone, the blast furnace remains the most effective method for production of pig iron. This being the case, large bulk cargo carriers can be used to eliminate what has been a major obstacle to efficient ironmaking in a number of developing nations. Rather than returning in ballast from the steel producing center to the source of ore supply, bulk carriers can be used to backhaul supplies of coal at very reasonable freight rates.

It can be demonstrated, for example, that by shipping iron ore from Monrovia to Norfolk at $2.00 per ton, which is a very competitive rate, the cost of backhauling coal is substantially lower, amounting to $0.72 per long ton with a 75,000 DWT carrier and $0.56 per long ton with a 100,000 DWT carrier. The annual tonnages of coal supplied by this backhauling arrangement are sufficient to support a modern blast furnace operation. The tonnage obtained by using a 75,000 DWT carrier, for example, is adequate to supply a 28 ft. diameter hearth blast furnace producing at least 2,000 tons of pig iron per day, assuming a liberal coke rate of 1,400 pounds per ton of hot metal produced. The pig iron from such an operation would make it possible to establish an effective steel industry.

Development of Port and Ore Shipping Facilities

Parallels to the utilization of backhauling to benefit a steel industry in Africa can be established for other developing regions, particularly since a number of ports in these regions have facilities for the largest capacity carriers either in operation or under construction. Based on the experience of the last few years, the costs of port development have been in the range of $50,000,000 to $60,000,000 for a capacity to ship approximately 10,000,000 to 15,000,000 long tons of iron ore annually. This allows for the utilization of carriers approximating 70,000 deadweight tons maximum. Provision for the use of 100,000 ton carriers would involve an additional capital cost and in instances where coal is to be backhauled, allowance would have to be made for its receipt by the inclusion of such items as unloading equipment, coal handling facilities and additional stockpile areas.

Conclusion

The growth in size of the large bulk cargo carrier has had a profound impact on the world steel industry from the standpoint of its location, economics and composition. In a number of developing nations, its influence has thus far extended to the creation of an export trade in iron ore which has assisted their economies to a significant degree. However, the question which we have considered is how the benefits of bulk carrier transportation might be used to advance steel production in these nations. It has been indicated that the use of backhauling can make available low cost supplies of high-grade metallurgical coal adequate to support an efficient blast furnace operation. With port facilities available or being made ready to handle large bulk carriers for the shipment of iron ore, the prospects for using the bulk carrier for coal on the return voyage have been enhanced and it is now possible for the emerging steel industries to take full advantage of this most attractive opportunity.

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Tables

Progress in the production of iron and steel over the past two decades has been such that time-tested precepts, related both to basic steelmaking technology and fundamental industry economice, have been challenged suddenly and dramatically. In the area of technological development, the foremost example of change has been the wide-spread shift among the world's steel producers from the open-hearth to the basic oxygen furnace. At the same time, the electric arc furnace has proven to be a competitive tool for the large-scale production of carbon, as well as alloy steels, and continuous casting continues to challenge the traditional ingot method for obtaining semifinished steel sections.

As significant as these advances in steel technology have been, another development outside of the production segment of the industry has had an equivalent if not a more pronounced influence on the world steel industry, namely, the use of large bulk carriers for the worldwide shipment of raw materials. In a very real sense, the bulk carrier has been essential to the implementation of modern steel technology by many of the member nations of the world steel community. In fact, a number of countries owe their very existence as steel producers to the large bulk carrier.

The use of new production technology and progress in the transportation of raw materials in bulk carriers have contributed significantly to the dispersion of steel production activity throughout the world. In so doing they have made necessary fundamental revisions in long-standing concepts of steel industry economics.

It was not too long ago, for example, that one of the prerequisites stressed for a successful steel industry was a nation's possession of adequate supplies of raw materials, either within its boundaries or in close proximity. This pre-condition was interwoven with the comparative cost theory of international trade wherein it is generally considered that a nation's industrial activity tends to become specialized in those products which require the use of its most plentiful, highest-quality, lowest-cost resources. Products in which the nation has a production cost advantage relative to other nations should be produced at home and other goods which can be produced only at a production cost disadvantage should be imported to provide for domestic requirements. This theory of trade started to evolve over 150 years ago and until recently was in many respects exemplified by the world steel industry.

Comparative Costs and International Trade

In 1817, in the Principles of Political Economy and Taxation, David Ricardo set forth the principle of comparative cost which remained an integral part of classical trade theory for more than a century. To review this principle briefly, it was maintained that a nation's real income could be expanded by importing foreign goods even if they could be produced domestically at a lower labor cost per unit, provided that its resources were directed to the production of other goods wherein its productive efficiency was even greater. All trading nations would benefit from such a specialization of their production activities, since each nation would be using its labor and capital most effectively.

Ricardo's concept of comparative cost was based on a labor theory of value since labor costs were to determine productive efficiency and the terms of trade. Neoclassical economics abandoned the labor theory of value, and during the 1930's Ricardo's doctrine was superseded by that of Bertil Ohlin, the Swedish economist, who advanced his general equilibrium theory of trade which conformed to the neoclassical approach. According to Ohlin, international trade stems from price differences among countries. He noted that, given competitive conditions, differences in price are determined by differences in production costs which, in turn, can be attributed to the distribution of resources among countries. The primary cause of trade was the relative scarcity or abundance of productive resources in different countries. Goods which require use of the productive resources which a country possesses in abundance will be produced at a relatively low money cost of production, and once an exchange rate is established, the differences in relative costs among countries can be converted into price differences which are the immediate cause of trade.

Ohlin's doctrine, that the possession of resources determines domestic production and trade between countries, harmonized quite well with the experience of the world steel industry of the late 1940's since the possession of abundant raw materials and adequate capital resources determined the steel producers and resulted in the concentration of production in a few geographic areas of the world. However, during the past 15 years, the world steel industry has undergone a pronounced geographic alteration and, at the present time, producing plants are located in nations which are not rich either in capital or the raw material resources for steelmaking. Thus there is a need to reevaluate comparative cost theory as applied to the international steel trade. It will be of interest to examine first, the change in the industry which has occurred; and second, the factors which have brought this change about. The latter will be concerned principally with developments in the industry's use of the bulk carrier.

The World Steel Industry and Comparative Costs

The areas of East Central North America and West Central

Europe were fortunate to have rich reserves of iron ore and coking coal. These allowed them to develop steel industries during the latter part of the 19th century and to maintain a position of dominance in the world steel industry for almost one hundred years. As late as 1947, even though there were 32 steel producing nations around the world, approximately 76 per cent of total world steel output was accounted for by one North American and four European nations.[1] In the short space of a few decades, the U.S.S.R. has developed its industry from one of minimal tonnage into the world's second largest producer and its production, added to that of the five countries already considered, placed 87 per cent of the world's steel output in just six nations.

This concentration of the world steel industry tended to support the economic theory of comparative cost as expounded by Ohlin. The proximity to raw materials was generally considered an essential requirement for an economically feasible steel plant. It was recognized that the raw materials for steelmaking were relatively low in value per unit of bulk or weight and, consequently, entailed substantial shipping costs which could very well constitute the greater part of the total procurement cost. For this reason, it was considered necessary that

1. United States, 57%; United Kingdom, 8%; France, 4%; Western Germany, 4%; Belgium/Luxembourg, 3%.

steel plants be favorably located in relation to supplies of iron ore, coal and limestone, and ideally that they also be relatively close to consuming markets, given the bulk and weight of finished steel products. The number of such ideal locations in various countries around the world was limited and steel industries located in these priviledged areas suppled the steel requirements of other nations less fortunately endowed with essential resources. According to Ohlin's theory, it could be said that the producing nations enjoyed a comparative cost advantage by virtue of the steelmaking resources which they had.

Although the concentration in world steel activity through the late 1940's was related in significant part to the location of resources, several other factors were also instrumental in restricting the number of producing nations. They were: 1) the steel requirements of many nations, particularly those in the early stages of their development, were not sufficient to support steel operations of suitable scale; 2) many did not have the capital resources needed adequately to finance expensive steel investment; 3) many colonized nations obtained their steel from the mother country, foregoing local production; 4) some nations were not aware that they possessed iron ore deposits, while others, with known ore bodies, did not have the capital to develop them; and 5) the steel producing nations, for the most part, still had not depleted their sources of iron ore supply and had not yet launched intensive worldwide exploration efforts.

Notwithstanding these contributing factors, attention was focused on the distribution of raw material resources in explaining why the world's steel needs were traditionally supplied by a few main production centers. This is apparent from the observations on the world steel industry made by an economic geographer in a work published in 1950.[1] His evaluation of the Japanese industry and his conclusions regarding the possible future development of production activity are most interesting in the light of what has taken place in the steel industry and its economics since that time.

Jones maintained that the steel industries of Japan "rest upon a weak economic basis," particularly since the Japanese had to make use of low grade domestic iron ores and imported ore from China and the Unfederated Malay States. "Because of inadequate supplies of excellent basic materials, private iron and steel firms, even with generous government subsidies, operate with difficulty .... Unaided by government support and control, it is doubtful whether the industry could operate on a competitive basis with industries of other regions."[2]

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1. Clarence Fielden Jones, Economic Geography, New York: The Macmillan Company, 1950, p. 487.
2. Ibid., p. 500.

The author noted that a slight decentralization of the industry was apparent in the then current movement of steel plants to seaboard districts and the development of new steelmaking areas in the U.S.S.R. and the Far East. "However," he concludes, "any major shift of the industry outside of the present important areas does not seem likely. The outstanding fact of the iron and steel industry is that two great areas, east central North America and west central Europe, make about four-fifths of the world's coke, pour nearly three-fourths of the pig iron and make nearly four-fifths of the world's steel."[1]

Today, the Japanese steel industry is the third largest in the world with crude steel production for the fiscal year 1967 totaling 63,777,000 metric tons compared with slightly more than 1 million tons in 1947. In short, within the past twenty years, completely contrary to expectations, a major world steel producer has been built from scratch despite the strict scarcity of local supplies of the essential raw material resources for steelmaking.

At present, the number of steel producing nations in the world totals 66, more than double the number of the late 1940's. The one North American and four European nations which accounted for 76 per cent of the world's steel output in 1947, now produce only about 43 per cent of the total.[2] The steel industry of the

1. Ibid., p. 501.
2. U.S, 23%; Western Germany, 8%; United Kingdom, 5%; France, 4%; Belgium/Luxembourg, 3%.

U.S.S.R. now accounts for 22 per cent or double its 1947 share of the total, and the Japanese industry has emerged as a new giant to garner a share of the world's output in excess of 12 per cent. Other steel producing nations which contributed relatively small tonnages in the late 1940's have developed industries of sizeable capacity. India and Italy are prominent examples. In short, contrary to expectations, the trend in new growth in steel producing activity which started to become apparent a few decades ago not only continued but was accelerated. The result has been a thorough redistribution of the total world steel industry's geographic location which had not been changed essentially for almost a century.

The geographic change in steel production activity during the last twenty years has been caused by a variety of factors, economic, political and technological. Among these was the discovery by established steel producers of iron ore deposits in developing nations around the world, and this has encouraged a number of these nations to build steel industries of their own.

Concurrent with these developments, the entire subject of resources availability in steelmaking has been revolutionized by virtue of a particular development in the field of transportation, namely, the use of large bulk carriers for the worldwide shipment of iron ore and coking coal. As a consequence, since the late 1940's successful steel industries have been built with little or no reliance on domestic supplies of raw materials. This serves to indicate that modification is in order for the economic theory of comparative costs as it relates to the steel industry, particularly with respect to its emphasis on the possession of raw material resources.

In view of the economic significance of this change, it is most interesting to trace the progress which has taken place in bulk carrier transportation and to examine the operation of the bulk carrier and its possible utilization by steel industries in developing nations.

Bulk Carrier Progress and the World Iron Ore Trade

The economic utilization of distant supplies of steelmaking raw materials in recent years has been related to the depletion of high-grade reserves in the traditional steel producing regions and to the development of efficient bulk carrier transportation. Given these circumstances, as well as the development of newly discovered supplies of high-grade iron ore, traditional producers have lost once sizeable advantages in raw materials' costs. This has made steel production competitive in many more locations around the world and has contributed to a sharp increase both in world iron ore production and international trade.

The extent of the growth in iron ore output and trade during the period 1950-1965 inclusive can be observed from Table 1. It indicates that whereas annual production increased very considerably over this span of years by 147.0 per cent, trade expanded even faster by 418.8 per cent. As a result the portion of total iron ore production shipped between nations trended upward from 16.5 per cent in 1950 to 29.7 per cent in 1957 and 34.6 per cent in 1965.

The major part of the substantial increase in trade has been accounted for by the newly developed mines in Africa, Asia and Latin America which are far removed from the world's major steel producing centers. In 1965, mines located in these three regions accounted for more than 47 per cent of the total world iron ore trade. This has resulted in the greater portion of trade taking place over long distances as can be observed from Table 2 which traces the growing use by selected steel producing regions of iron ore supplies from distant mines. It should be noted that virtually all of the tonnages listed required shipment over water and, consequently, the sharp growth in such trade has of necessity been accompanied by a substantial addition to the world's fleet of bulk carriers designed for the shipment of ore.

In the past two years, i.e., 1966 and 1967, Australia has entered the picture as a substantial producer and exporter of

Table 1

World Production and Trade in Iron Ore
(in thousands of long tons)

Year	Production	Trade	Trade as % Production
1950	246.1	40.5	16.5
1951	289.4	53.8	18.6
1952	293.0	60.2	20.5
1953	332.0	62.8	18.9
1954	300.1	64.4	21.5
1955	365.7	97.2	26.6
1956	388.5	114.2	29.4
1957	422.6	125.6	29.7
1958	398.4	111.8	28.1
1959	431.7	130.5	30.2
1960	512.3	151.4	29.6
1961	503.8	148.8	29.5
1962	499.4	156.6	31.4
1963	513.7	161.2	31.4
1964	569.3	194.9	34.2
1965	607.9	210 1	34.6

Source: U.S. Bureau of Mines, Department of Interior, Minerals Yearbook, for respective years.

Table 2

Growth in the Utilization of Iron Ore from Distant Sources
(actual tonnage in thousands of long tons)[1]

Importing Region	Exporting Region	1950	1955	1960	1965
Europe	North America	200	2,600	5,600	5,400
Europe	Latin America	1,000	2,000	9,900	15,100
Europe	Africa	4,700	8,600	10,300	26,100
Europe	Asia	14	1,700	4,800	3,300
North America	Latin America	3,400	11,800	22,900	19,300
North America	Africa	800	1,100	900	3,300
Japan	Asia	1,400	4,100	11,400	17,100
Japan	North America	-	800	1,900	4,200
Japan	Latin America	-	9	1,300	11,600
Japan	Africa	-	-	400	2,800

1. Statistics rounded

Source: U.S. Bureau of Mines, Department of Interior, Minerals Yearbook, for respective years.

iron ore. In 1966 exports were over 4 million tons and in 1967 they rose to almost 8 million tons. All of this was shipped by water with the larger share by far going to Japan and a small amount to Europe. During the next five years production will be stepped up appreciably and exports of Australian ore will be in the area of 50 million tons.

The number and average deadweight tonnage of ore carriers and ore/oil carriers built each year since 1947 are set forth in Table 3. The construction record of this period is most impressive, totaling 331 ore carriers and 174 ore/oil carriers. Although many more ore carriers were built during the period, their size averaged 26,616 deadweight tons compared with an average of 69,840 tons for the ore/oil carriers constructed. Consequently, since 1947 the world's bulk carrier fleet has been augmented by 8,810,000 deadweight tons in the former ship category and by 11,892,000 tons in the latter category.

Ore carrier building picked up appreciably from the mid-1950's through the early 1960's. However, in more recent years, emphasis has been placed on the construction of hugh ore/oil carriers. Since 1961, such construction has totaled 10,074,600 deadweight tons, 84.8 per cent of the tonnage for the entire 1947-1968 period. This surge in activity is related to the fact that ore/oil carriers have been used more extensively in recent years to increase

Table 3

Number and Average Deadweight Tonnage of Ore Carriers and Ore/Oil Carriers Built During 1947-1968

Year	Number	ADW	Number	ADW
1947	1	24.4	-	-
1948	1	24.4	-	-
1949	-	-	-	-
1950	5	8.9	-	-
1951	1	15.9	1	15.6
1952	2	15.9	1	15.7
1953	4	5.8	2	23.9
1954	8	20.6	2	26.1
1955	10	21.1	6	19.0
1956	13	26.6	6	32.3
1957	17	18.4	6	26.7
1958	36	17.6	7	23.5
1959	36	20.1	6	35.2
1960	43	19.0	10	31.9
1961	33	17.3	8	25.4
1962	28	27.0	3	42.1
1963	21	23.4	4	51.6
1964	8	36.2	7	56.5
1965	16	42.9	6	55.6
1966	28	60.7	10	45.9
1967[1]	16	81.5	13	54.8
1968[1]	4	51.5	28	95.5
			48	119.8

1. Represents carriers either on order or under construction in the world's shipyards.

the potential for backhauling and thus reduce the ocean freight rates on iron ore. As an example, consider the use of a combination carrier to haul iron ore from Brazil to Japan via the Panama Canal. On its return voyage the ship proceeded to the Persian Gulf to take on crude oil for shipment to the east coast of the United States. In this instance, use of the ship for backhauling resulted in a reduction in freight charges on the iron ore shipment from $4.00 to $3.60 per ton. Although economies such as this are attractive to iron ore users, there have been indications that equivalent benefit does not accrue to petroleum refineries which have found shipping schedules generally less reliable than with conventional oil carriers. The utilisation of combination carriers in the future will undoubtedly be influenced by the behavior of rates on conventionally shipped bulk. The lower such rates become, the smaller becomes the advantage derived from combination shipping. The current emphasis on the construction of ore/oil carriers, however, tends to indicate that at the present time significant economies can be derived from their use.

Of particular significance is the trend which has developed toward increased carrier size. Table 3, although it indicates this trend, understates it by the fact that certain of the average deadweight tonnages listed were given a downward bias by extensive construction programs involving carriers of relatively small size (i.e., under 10,000 deadweight tons) intended mainly for intra-regional use. The increase in carrier size can be more readily observed from Table 4 which presents a frequency distribution on the sizes of carriers built since 1947.

Generally, the size of ore carriers increased together with shipbuilding activity in the mid-1950's and early 1960's with the largest ships in the range of 50,000 to 60,000 deadweight tons. In the mid-1960's, ore carriers exceeding 80,000 deadweight tons were built and in 1967 two 180,000 ton carriers were under construction. Most of the ore/oil carriers built duing the early to mid-1950's were in the range of 20,000 to 30,000 deadweight tons. In 1957, a trend toward larger combination ships of this type started to develop with sizes approaching 50,000 deadweight tons. By the early to mid-1960's the maximum size range had reached 70,000 to 80,000 deadweight tons, and during the last two years ore/oil carriers of 163,000 and 250,000 deadweight tons have been contracted for. This marked increase in size has been one of the most important developments in recent years from the standpoint of bulk carrier operations and reduced shipping costs.

Table 4

Size of Ore Carriers and Ore/Oil Carriers Added to the World's Fleet
(1947 - 1968)[1]

Construction Period	Frequency Distribution of Size in Thousands of Deadweight Tons								
	0-19	20-39	40-59	60-79	80-99	100-119	120-159	160-199	200 & Over
1947-1949		2							
1950-1952	10	2							
1953-1955	21	12	3						
1956-1958	53	25	7						
1959-1961	84	38	11						
1962-1964	27	22	17	7	1				
1965-1968	12	14	36	37	29	7	13	10	5

1. Data for 1967 and 1968 included in the distribution represents carriers either on order or under construction in the world's shipyards.

The Use of Large Bulk Carriers to Benefit Steel Industries In Developing Nations

Having reviewed the recent progress in bulk carrier transportation and the related development of a substantial growth in the world iron ore trade, primarily accounted for by exports from developing nations, the question arises as to how large bulk carriers might be utilized to the economic benefit of steel industries in these nations.

As noted previously, during the past two decades dwindling supplies and the declining quality of iron ore in the principal steel producing regions prompted a worldwide search for new sources of supply, with much of the exploration and most of the eventual discovery in developing nations. As a result, these nations have a two-fold advantage. First, they have been able to use their ore resources as an article of commerce, providing an inflow of foreign exchange and advancing their general economic development; and second, given a local source of high-grade, low-cost iron ore, they have been able to establish or expand domestic steel production.

In order to produce and ship the newly discovered high-grade iron ore a considerable investment is necessary. In a number of instances, railroad lines had to be built to sea ports which in turn had to be equipped with docking and loading facilities.

In most cases, port development was dictated by the location of the new mines in relation to the world's steel production centers which made it necessary to use bulk cargo carriers of sufficient size to transport the ore economically over long distances, sometimes up to 10,000 miles. Consequently, the recent development of the huge bulk carrier has made it possible for many developing nations to engage in world commerce on a significant scale.

The bulk carrier can also be used to assist the steel industries of these nations. This consideration is related to the second advantage occurring from the discovery of iron ore, namely, the possibility which it affords for establishing or expanding local steel production. In this respect, as demonstrated by the experience of several Latin American and African nations, a lack of sufficient metallurgical coal for coking purposes has proved a deterrent to efficient iron production by means of the traditional blast furnace process. A number of attempts have been made to utilize smelting processes other than the blast furnace, particularly in nations with abundant reserves of oil and gas. In general, however, these attempts have not been highly successful. Another alternative, a large-scale electric furnace plant using scrap does not provide a solution, not only because the amount of scrap generated locally is usually insufficient to supply such an operation, but also because it fails to exploit the economic benefits attendant on the use of available local reserves of rich iron ore.

It is generally agreed that given the necessary raw materials, iron ore, coking coal and limestone, the blast furnace remains the most effective method for the production of pig iron. This being the case, large bulk cargo carriers can be used to eliminate what has been a major obstacle to efficient ironmaking in a number of developing nations. Rather than returning in ballast from the steel producing center to the source of ore supply, bulk carriers can be used to backhaul supplies of coal at very reasonable freight rates.

Most of the bulk carriers which move iron ore from the west coast of Africa to the United States, for example, currently return in ballast. Instead, if coal is loaded at Norfolk and backhauled to west Africa at low ocean freight rates, coke could be made at a very reasonable cost to supply a blast furnace in that area. At the present time, a steel industry is being planned in west Africa and it would be beneficial to have as its nucleus an efficient blast furnace operation using high-grade west African iron ore and high-grade coke made from coal backhauled from the United States.

The economic advantages of using the return trip to Africa to carry coal stem from the fact that the ship has a round trip rather than a one way cargo. These are set forth in Table 5. The comparison is based on the utilization of 75,000 and 100,000 deadweight ton bulk carriers. It will be observed that by shipping iron ore from Monrovia to Norfolk at $2.00 per ton, which is a very competitive rate, the cost of backhauling coal is substantially lower, amounting to $.72 per long ton with a 75,000 DWT carrier and $.56 per long ton with a 100,000 DWT carrier. The annual tonnages of coal supplied by this backhauling arrangement are sufficient to support a modern blast furnace operation. The tonnage obtained by using a 75,000 DWT carrier, for example, is adequate to supply a 28 ft. diameter hearth blast furnace producing at least 2,000 tons of pig iron per day, assuming a liberal coke rate of 1,400 pounds per ton of hot metal produced. The pig iron from such an operation would make it possible to establish an effective steel industry.

Parallels to the utilization of backhauling to benefit a steel industry in Africa can be established for other developing regions. In Latin America, for example, coal could be backhauled to Brazil and Venezuela in bulk carriers used to ship iron ore. In some instances the backhauling principle might be utilized in a triangular voyage, as would be the case if a bulk carrier were used to haul iron ore from Latin America to Rotterdam, moved in ballast from Rotterdam to Norfolk, Virginia and then carried

Table 5

The Advantage of a Combined Trade Wherein Iron Ore Is Shipped from Monrovia to Norfolk (4,200 miles) and Coal is Backhauled to Monrovia

	Iron Ore From Monrovia/ Norfolk and Ballast on Return		Iron Ore From Monrovia/ Norfolk and Coal on Return	
Vessel Size/DWT	75,000	100,000	75,000	100,000
Beam	106	116	106	116
Draft	44	46	44	46
Average Speed	15.0	15.5	15.0	15.5
Time Charter Rate	$2.00	$1.80	$2.00	$1.80
Time Requirement:				
Steaming Days	23.4	22.6	23.4	22.6
Load Ore/4,000 TPH	1.0	1.5	1.0	1.5
Discharge Ore/2,000TPH	2.0	3.0	2.0	3.0
Load Coal/ 4,000 TPH	-	-	1.0	1.5
Discharge Coal/2,000 TPH	-	-	2.0	3.0
Delay Allowance	2.0	2.0	3.0	3.0
Total (Days)	28.4	29.1	32.4	34.6
Annual Voyages/350 days	12.3	12.0	10.8	10.1
Variable Costs:				
Fuel	$23,000	$25,000	$23,000	$25,000
Port Costs/Monrovia	3,000	4,000	3,000	4,000
Port Costs/Norfolk	10,000	12,000	10,000	12,000
Totals (per voyage)	$36,000	$41,000	$36,000	$41,000
Annual Costs:				
Variable	$ 443,000	$ 492,000	389,000	$ 410,000
Time Charter Hire	1,725,000	2,070,000	1,725,000	2,070,000
Total (per year)	$2,168,000	$2,562,000	$2,114,000	$2,480,000

Table 5, continued

Vessel Size/DWT	Iron Ore From Monrovia/ Norfolk and Ballast on return		Iron Ore From Monrovia/ Norfolk and Coal on Return	
	75,000	100,000	75,000	100,000
Tonnages Shipped:				
Iron Ore/per voyage/LT	72,000	97,000	72,000	97,000
Iron Ore/per year/LT	885,000	1,164,000	777,000	970,000
Coal/per voyage/LT	-	-	72,000	97,000
Coal/per year/LT	-	-	777,000	970,000
Costs and Revenues:				
Iron Ore Cost per LT	$2.45	$2.20		
Iron Ore Revenue @ $2.00/LT			$1,554,000	$1,940,000
Coal Revenue			560,000	540,000
Coal Cost per LT			.72	.56

coal from Norfolk back to Latin America.

The steel industries of Brazil and Venezuela could derive significant benefit by obtaining coal in such a backhaul arrangement. A plan is currently underway to expand the steel industry in Brazil, and yet very little metallurgical coal is available from local sources. The Brazilians are currently blending 60 per cent imported coal with 40 per cent domestic coal of undesirable quality. An increase to 80 per cent or more of imported coal could mean a great deal to the effective operation of the Brazilian blast furnace and, consequently, to their steel industry. Venezuela has a relatively large steel mill which depends on electric furnaces for the direct reduction of iron ore. These could be supplemented by a conventional blast furnace using inexpensive, high-grade metallurgical coal obtained by backhauling.

Development of Port and Ore Shipping Facilities

The essential counterpart of the large bulk carrier, particularly that which hauls dry bulk, is the deepwater port with its facilities to load and discharge cargo. Unlike oil tankers from which cargo can be pumped into a pipeline at a distance offshore, dry bulk carriers, such as those used to transport iron ore, require berthing facilities with adjacent waterways dredged to sufficient depth. Since most of the world's trade in iron ore currently originates in developing countries, with increasing tonnages in prospect during the next few years, ports in these countries must be made capable of accommodating carriers of 100,000 and more tons of cargo capacity.

At the present time, a number of ports in developing nations have facilities for the largest capacity carriers either in operation or under construction. In Africa, Lower Buchanan on the west coast can handle 70,000 ton carriers and in the near future will be capable of accommodating 100,000 ton ships. In Latin America, Tubarao, Brazil and San Juan, Peru are capable of handling 100,000 ton ships. In Australia, Port Hedland and Port Dampier are being prepared to accommodate 100,000 ton vessels. In addition to these ports, a number of others in Africa, Latin America and Australia are being developed for the large bulk cargo carrier. Thus it is reasonable to expect that within the next few years, the 100,000 ton carrier will enter ports in the developing nations with great frequency to load cargoes of iron ore.

As an example of the requirements for developing a port facility which is adapted to the shipment of dry bulk cargo using carriers of up to 100,000 deadweight tons, a review of the project to develop Port Hedland in Australia indicates some of the consideration governing such an undertaking, as well as the facilities which are required and the factors affecting their installation.

The two primary considerations governing the Port Hedland project were the annual tonnages of iron ore to be shipped and the capacities of the vessels to be utilized. Initial requirements called for facilities to ship 12,000,000 tons of iron ore annually, with provision to expand this tonnage to 20,000,000 and possibly 30,000,000 tons in the future. Allowance was made for the initial use of bulk carriers ranging in size from 20,000 to 68,000 deadweight tons, with 100,000 ton ships planned for the future.

Depths of water adequate for 68,000 ton vessels did not exist within six miles of shore and underwater reefs were located which extend approximately 20 miles offshore. This required 12,000,000 cubic yards of dredging to provide a channel for ships ranging up to 68,000 tons, as well as the location and marking of passages through the reefs with sufficient depth to permit safe passage of fully loaded 68,000 and 100,000 deadweight ton ships. It was determined that additional dredging of about 4,500,000 cubic yards would be necessary in the future to accommodate 100,000 deadweight ton vessels.

On the basis of vessel dimensions and tide characteristics, the criteria listed in Table 6 were adopted for the dredging project. The bottom width of the channel was set at 600 feet and a turning basin 1,800 feet wide was provided, assuming that tugboats will be used.

Table 6

Port Hedland, Australia: Required Depth of Water in Feet Below Admiralty Datum

Location	For 68,000 DWT Bulk Carriers	For 100,000 DWT Bulk Carriers
Outshore Channel	37	40
Channel in Harbor	34	37
Turning Basin[1]	20	20
Berth	47	56

1. Depth in turning basin for partially ballasted vessels.

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The project provided two loading berths to permit shipment of about 20,000,000 tons of ore annually. Plans called for the initial installation of a single berth 1,050 feet long, with a 6,000 ton per hour shiploader, and the construction of a 1,000 foot standby berth by the time shipments reached 9,000,000 tons of ore. The berth was to be converted to a loading berth when shipments reached 15,000,000 tons per year. The single ship loader was considered adequate to serve the two berths.

Provision was made in the port area for sufficient space initially to stockpile 1,400,000 tons of iron ore, with an area for future expansion. Ore dumping and stacking facilities were designed for ore piles 60 feet in height.

The auxiliary facilities and equipment required by the Port Hedland development project included a power plant, oil storage and distribution facilities, warehouses, shops, a water tank, and office building. It was determined that at least two, 2,000 horsepower tugboats were needed, as well as a variety of trucks, autos, tools, and various maintenance and repair items. Housing and recreational facilities for a population of about 1,500 was planned in an area of 160 acres. Suitable water distribution and sewage disposal facilities also were to be provided.

The estimated capital outlay for the initial phase of the Port Hedland development project totals $47,200,000 in 1966 prices, a figure which currently would be modified upward by approximately $3,000,000. Provision for the use of bulk carriers of up to 100,000 tons would require additional dredging expenses of about $11,000,000, as well as additional expenses for pier, ore handling and stockpiling facilities.

The estimated capital cost for the initial phase at Port Hedland is at approximately the same level as that sustained at Lower Buchanan, Africa where port facilities for shipping 10,000,000 tons of iron ore annually were developed for $52,000,000. At Port Dampier, Australia facilities for shipping 17,000,000 tons of ore were obtained for approximately $60,000,000. It must be noted that all of these capital requirement totals relate exclusively to facilities for the shipment of iron ore, and in instances where coal is to be backhauled, provision would have to be made for its receipt by the inclusion of such items as unloading equipment, coal handling facilities and additional stockpile areas.

Conclusion

The growth in size of the large bulk cargo carrier has had a profound impact on the world steel industry from the standpoint of its location, economics and composition. In a number of developing nations, its influence has thus far extended to the creation of an export trade in iron ore which has assisted their economies to a significant degree. However, the question which we have considered is how the benefits of bulk carrier transportation might be used to advance steel production in these nations. It has been indicated that the use of backhauling can make available low cost supplies of high-grade metallurgical coal adequate to support an efficient blast furnace operation. With port facilities available or being made ready to handle large bulk carriers for the shipment of iron ore, the prospects for using the bulk carrier for coal on the return voyage have been enhanced and it is now possible for the emerging steel industries to take full advantage of this most attractive opportunity.

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