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Coal Trade Prospects in Selected Countries in East and Southeast Asia Around the Year 2000

by

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Abstract

Countries in East and Southeast Asia feel the need of resorting back to coal as a major source of energy. Most of the projected requirements would have to be imported from outside the region which would entail a tremendous amount by the year 2000. But economies of scale in ocean shipping exist and a substantial reduction of cost can be achieved using bigger vessels. This paper looks into the possibility that economies of scale could justify construction of one or more transshipment depots in the region at which large loads from the supply sources are broken up and re-distributed in small vessels to small consumers.

Introduction

The uncertainty of a stable oil supply makes possible the improved world prospects of coal utilization as an energy source. It was concluded by the World Coal Study (WOCOL) [1] that even under the assumption of moderate growth, coal will have to supply between one-half and two-thirds of the additional world energy demand during the next years.

The East and Southeast Asian region is not immune from this trend. A substantial amount of the projected coal requirements for each country would have to be imported from outside the region. Since the lead time of a typical coal project is about 5 to 10 years, this means that proper actions have to be taken well in advance.

The cost of transportation of coal from the mines to the consumers accounts for about a half to two-thirds of total delivered cost. Of this, 35-45% is incurred in sea transport and 20-25% in terminal cost. But costs of transport by sea reduce significantly with ship size, e.g., an average freight savings of 20-30% can be realized using 150,000 DWT instead of 60,000 DWT ships.

It is likely that separately, many Asian countries can not achieve full benefits from economies of scale in sea transport. A collaborative scheme within the region

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whereby coal imports carried by big vessels will be received temporarily at big transshipment depots before they are transported to the remaining consuming countries using smaller ships offers the possibility of minimizing the total import cost. It is hoped that the reduction in the cost of sea transport during the first leg of the process will make the scheme economically feasible.

Figure 1 shows the geographical location of the countries under study. Their relative locations will give an impression that ASEAN nations (Indonesia, Malaysia, Philippines, Thailand, Singapore) will be the most likely group to benefit from a transshipment scheme; added to this would be their history of concerted efforts in dealing with regional as well as international affairs. However, the higher projected demands of Japan, South Korea, Taiwan and Hong Kong suggest that economies of scale could reach a high level thus making the transshipment scheme more beneficial. Hence, these nine countries will compose the study area.

Historical flow of coal into the Pacific Rim shows that the major sources are Australia, USA, Canada, South Africa, People's Republic of China, and the USSR. As this is not expected to change, the major five are considered for the study. The USSR is not included because it is not competitive on a delivered cost basis due to the long distance from the major fields to the port (about 2,000 km.)

Supply and Demand Scenarios

A scenario is not a deterministic prediction of a future state but simply a statement of one of the many future possibilities. References 1 to 13 give several demand scenarios from which the base case shown in Table 1 is drawn.

References 1, 2, 5, and 14 provide supply scenarios from which an intuitive average is drawn. This is presented in Table 2 which also includes estimated relative mining costs in 1981 US$ based from a previous work of ICF Incorporated on mining costs in South Africa, Australia, and Canada.

Minimal information is available about the seam characterics of the coal reserves in China and because of the controlled nature of the economy, costs are very hard to assess. The production cost is placed somewhat below the average production costs of the other major suppliers.

Transport Costs

Coal is generally transported in the largest possible vessels compatible with port and storage facilities. Increasing international movement of coal necessitates larger and more efficient vessels and concomitant port expansion both in supplier and importing countries. It is widely known that economies of scale exist in ocean shipping and these economies can be utilized more for longer voyages and larger annual tonnages of freight moved. Therefore, the future trend in coal trade is likely to be using ship sizes of up to 250,000 DWT, especially on longer routes and to countries where high import demand exists.

Total transport costs should include not only those incurred at sea but also the related costs at the terminals at either end of the voyage. The cost per ton delivered incurred at sea includes capital charges and operating cost, mainly labor and fuel; the cost per ton delivered incurred at the ports includes charges on the port and its handling facilities, and capital charges on the ship while it remains idle.

Ship Costs at Sea

Economy of scale in shipping is achieved because the elements of costs are not all proportional to the deadweight tonnage and their combination reduces the cost of each ton carried with an increase in ship size.

Economies in the capital costs can be easily understood: If all dimensions of a ship are doubled, the volume increases eightfold but the weight and surface area increase only fourfold. This is not an exact relation and Du Jonchay [15] estimates that ship size varies between 1/2 and 2/3 exponent of the DWT, while the cost of the propulsion system at a given speed grows only to the 2/3 power of the weight of the ship.

Crew costs for medium size vessels account for about 45-50% of the operating costs but for a 450,000 DWT VLCC, only about 30% is typical. It is widely accepted that as the vessel size increases, the relative cost of crewing decreases.

The Italian section of the WOCOL study provides data for fuel costs of ships for three sizes (100,000; 150,000; and 250,000 DWT). It reveals that for an average speed of 13 knots and voyage distance of 8023 nautical miles, fuel costs go down from about $4.6/ton using 100,000 DWT ship to about $3.8/ton for a 200,000 DWT ship to about $3.8/ton for a 200,000 DWT ship. The cost reduction may not be impressive but big savings can be achieved when the disparity in sizes is great.

A general expression from the Italian data relating costs with vessel sizes and voyage distances is derived but proves to be unreliable when used to extrapolate costs for small ship sizes. Thus, this approach is abandoned.

Another set of data from a study made by the Shell Company provides long-term shipment costs of coal from the five major suppliers to several points in Southeast Asia using ship sizes ranging from 20,000 DWT to 120,000 DWT. They were based on new building costs and operating costs for international flag; capital charges were assumed constant in money of the day terms. Calculations also used 15% discount rate on ship capital, vessel speeds of 13 knots laden and 14.5 knots ballast, and fuel costs of $220/ton for HFO and $350/ton for diesel.

The data points are fitted in a polynomial expressing cost as a function of ship sizes and distances. Representative curves are shown in Figure 2. They include turnaround time of ships based on assumptions of long-term loading and discharge rates at both ends of trips.

Ship Costs at Port

Cost incurred at port is a more complicated matter. It is divided into port charges and lay-time cost of ship.

Port charges are extremely difficult to relate with ship size because they vary from port to port and from country to country. They are often used as instruments of port policy and are subjected to the government of the land.

Generally, port charges increase with ship size but given a particular port, this cost in $/ton delivered appears to be independent from ship size. This is discussed in more detail in references 19 and 20.

There are a lot of disagreements, too, regarding the cost due to idle time of ship at port. Jansson and Shneerson [16] argued that this cost increases with size particularly because of the longer turnaround time. But Robinson [17] reported that in the case of the port of Hong Kong, the time spent by larger ships in port is less than that of smaller ones. Moreover, Bennathan and Walters [18] argued that large vessels are cheaper to operate per DWT. This would mean that though bigger vessels may spend longer time at port, the unit cost per ton at port does not necessarily increase with size. Results from the Shell study support the latter argument as can be seen from Figure 2.

The Mathematical Model

In developing the mathematical model, several simplifying assumptions are made which in no serious way alter the optimal solutions. They are the following:

1. One deadweight ton (DWT) is equal to one ton of coal equivalent (tce).
2. One country is a single point of destination and/or origin.
3. The number of ships available is infinite.
4. Port cost ($/ton) is the same for any ship size in a particular port.
5. Transshipment cost is the sum of the cost discharging coal from a large vessel and the cost of loading the same on a smaller one.

The model is a standard transportation linear programming model designed to minimize total import cost with an option to use transshipment terminals. This cost includes production cost, and shipping and terminal costs. The independent variables are the number of ships of different sizes. (Please see Appendix A for the linear model.)

IBM-MPSX 370 (Mathematical Programming Extended) is used to solve the LP problem. A computer program in Fortran is developed to generate the matrix according to the specified format.

Applications

Preliminary investigations show that with 200,000 DWT as the maximum allowable ship size at sources and terminals, transshipment occurs at some places only if ships no larger than 30,000 DWT were to operate at small consuming countries now called sinks. It also becomes clear that the prerequisites for a good terminal are an excellent geographical location and a high import demand.

Single Terminals

Table 3 shows a summary of results where seven of the countries in the region are considered terminals, one at a time. Lowest functional cost (value of the objective function) is obtained when Japan is considered singly as a terminal, obviously because of her high demand relative to the other consumers. Unfortunately, the country has a poor location for a possible temporary depot. American and Canadian coals are most likely to be received temporarily at Japan before going to the smaller consumers, but these supplies come in such small amounts that they can not even satisfy the Japanese demand.

The same philosophy more or less applies to the cases when Taiwan and South Korea are considered separately as terminals.

Multiple Terminals

Currently, Japan has facilities that can handle vessels sizes up to 250,000 DWT. It is but logical to allow direct shipment to its ports from the sources using these sizes. On the other hand, due to high imports, Taiwan and South Korea are likely to develop their port capabilities to accept bigger vessels and to utilize the economies in transport. The optimal pattern of coal flow where these three countries are accepting big ships is taken as the reference case with which all succeeding patterns are compared.

Singapore, despite having a good location and a moderate import demand, would have difficulty developing a coal terminal for a depot because of land requirements and environmental consequences. The same problems are true for Hong Kong. Only two logical options are left: Philippines and Indonesia.

With Japan, Taiwan and South Korea operating on large vessels, the likelihood of the Philippines and Indonesia becoming a terminal is tested. The results are summarized in Table 4. Savings would refer to the difference of the functional cost of the case under consideration and that of the reference case.

With the Philippines as a terminal, transshipment ceases and therefore depot construction in this country would not benefit any other country in the region other than itself. The Philippines gets its coal from South Africa as do the other four ASEAN member countries, but unfortunately it is farthest from this source.

A terminal in Indonesia will serve at least two small consumers: Singapore and Thailand. These coals come from South Africa; Malaysia is supplied through direct shipment also by South Africa.

Indonesia as Terminal

As seen in Table 4 $20M of annual savings can be realized with a terminal in Indonesia. This is for a low coal demand of 2 mtce per annum in this country – transshipment cost is taken as $4/ton and maximum ship size acceptable at the terminal is 200,000 DWT and 30,000 DWT at the sinks.

Several deviations from the above case are considered and the most significant are presented below.

An increase of 1 mtce in the import requirement of Indonesia generates a $10M increase in savings which would help justify the construction of their terminal. Incidentally, Indonesia is now constructing its Taharan special coal harbor in the southern tip of Sumatra. Its capacity is expected to be as high as 12 mtpy.

Transshipment cost plays a very important role in this study. Referring to Figure 3, SNK (for sink) has two possible ways of importing from SRC (for source): Route A is a direct shipment using a small vessel compatible to SNK or through transshipment via TML (for terminal) where a larger vessel can be used. "A" has a port cost advantage of $2H_1$, which is the cost of transshipment, over "B". Clearly, the latter is only feasible for as long as the cost advantage of "A" is outweighed by the economies of scale achieved in sea transport utilized during the first part of route "B".

Transshipment cost is thus reduced to $2/ton. The result is quite interesting because the five ASEAN nations get their coal supplies from a single source (South Africa) through the transshipment depot in Indonesia with annual savings of about $40M. This will require a port capacity of around 22 mtpy, just about the level that would be capable of accepting ship sizes of about 200,000 DWT.

When supply from South Africa is drastically reduced the ASEAN nations prefer to import from Australia. However, the Philippines will no longer use transshipment option.

Ship sizes are also varied. Keeping 30,000 DWT ships at the sinks transshipment would still be viable if 150,000 DWT ships operate between the source and the terminal. The same pattern occurs when ship size at the sinks is increased to 40,000 DWT while holding the 200,000 DWT ship at the terminal and source.

Lastly, the model is tested for the high coal case and practically yields the same pattern as that of the low coal case. At $2/ton transshipment cost and ship sizes of 30,000 DWT (between terminal and sink) and 200,000 DWT (between terminal and source), annual savings would be about $70M. The capacity of the transshipment terminal would have to be about 30 mtpy to serve the purpose of transshipment to the five ASEAN countries.

Conclusions

Definite conclusions could not possibly be drawn from this study for, among other things, we could not be certain of future possibilities and the results discussed so far are limited by the assumptions made. Outstanding qualitative observations are herein presented.

It is clear that there is no interaction between the countries in the north and the countries in the southern part of the study area. The big markets in the north (Japan, South Korea, Taiwan) would tend to develop their ports to be able to utilize economies of scale in shipping.

Transshipment option appears to be a good alternative for the five ASEAN member countries (Malaysia, Singapore, Thailand, Philippines, Indonesia). Least cost suppliers would be South Africa and Australia. A depot could be constructed in either the Philippines or Indonesia.

The Philippines has a good local demand but it has a poor location relative to the two suppliers and the small consumers. On the other hand, Indonesia has a low demand but it has an excellent location. The annual savings that can be achieved seems to justify the construction of a transshipment depot in Indonesia.

A more rigorous analysis of Indonesia as a terminal for the ASEAN region is presented in Reference 19.

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Table 1: Coal Demand Scenarios in East and Southeast Asia in 2000

Country	Moderate (mtce/yr)	High (mtce/yr)
Japan	132	158
Taiwan	54	65
South Korea	79	99
Indonesia	2	4
Singapore	5	5
Hong Kong	6	9
Philippines	12	12
Malaysia	2	4
Thailand	1	5

Table 2: Coal Supply Scenarios for East and Southeast Asia

Supplier	Limit (mtce/yr)	Marginal Production Cost (1981 $/ton)
Australia	160	26.6
South Africa	55	25.5
United States	66	28.9
Canada	17	33.5
China	15	?

Table 3: Summary of Results for Single Terminals (Any Source)

Terminal	Transshipped Amount (mtce/yr)	Destinations	Functional Costs ($B)
Japan	–	–	13.60
South Korea	–	–	14.14
Taiwan	–	–	14.14
Philippines	6.0/24.0	Hkg/Twn	14.95
Hong Kong	39.0	Twn	15.01
Singapore	6.0/36.0/1.0	Hkg/Twn/Thai	15.08
Indonesia	5.0/6.0/12.0 24.0/1.0	Sin/Hkg/Phil Twn/Thai	15.10

Table 4: Philippines/Indonesia as Terminal

	Philippines	Indonesia
Local demand (mtce/yr)	12.0	2.0
Transshipped amount (mtce/yr)	–	5.0/1.0
Destinations	–	Singapore/Thailand
Savings	$130M	$20M

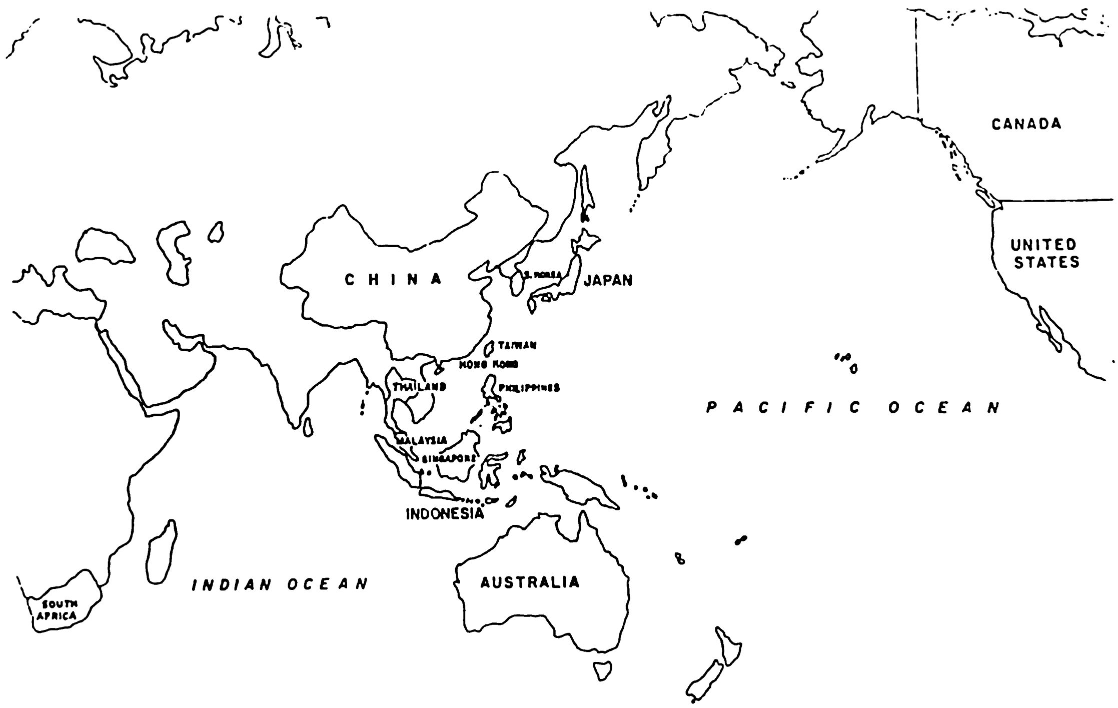

Figure 1. The Study Area and the Supply Sources

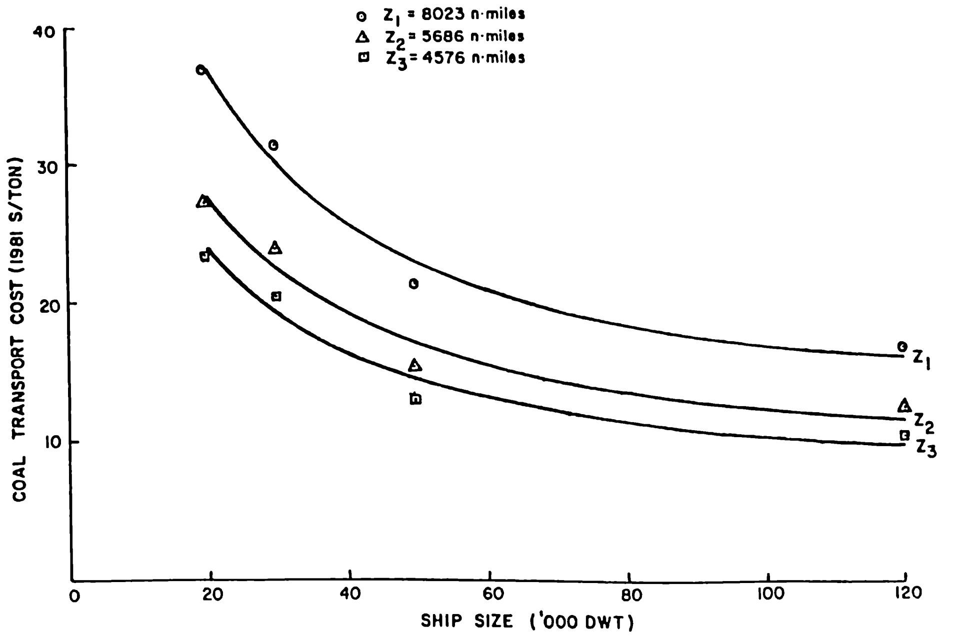

Figure 2. Transport Cost as a Function of Ship Size and Voyage Distance Based on the Shell Study

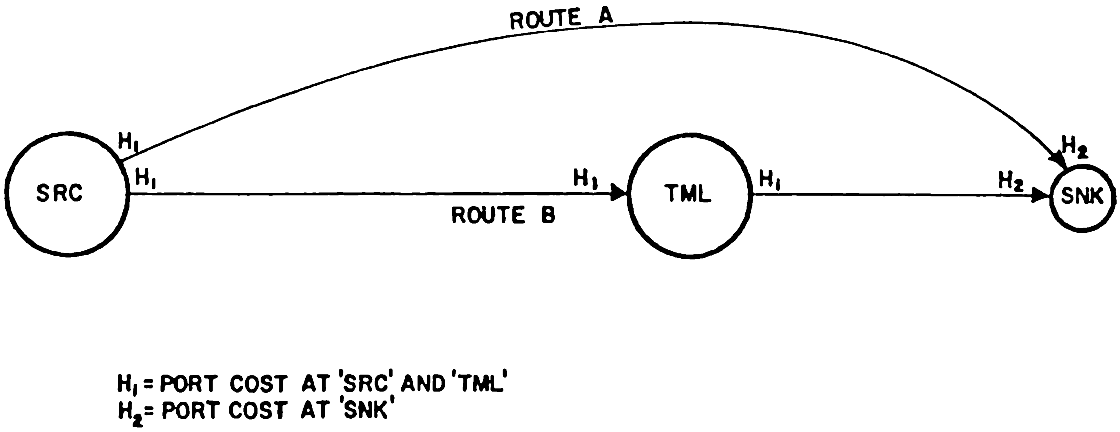

Figure 3. Transshipment and Port Costs

Appendix A

The Linear Model

The linear programming model is designed to minimize the cost of importing coal to nine Asean countries from five major sources with an option to use transshipment terminals.

The objective function is

$$\min \sum_j\sum_k\sum_i (X_i T_{ijk}) N_{ijk} + \sum_j\sum_h\sum_i (X_i T_{ijh}) N_{ijh} + \sum_h\sum_k\sum_i (X_i T_{ihk}) N_{ihk}$$

$$+ \sum_j\sum_k\sum_i (X_i H_{ij}) N_{ijk} + \sum_j\sum_h\sum_i (X_i H_{ij}) N_{ijh} + \sum_h\sum_k\sum_i (X_i H_{ih}) N_{ihk}$$

$$+ \sum_j\sum_k\sum_i (X_i H_{ik}) N_{ijk} + \sum_j\sum_h\sum_i (X_i H_{ih}) N_{ijh} + \sum_h\sum_k\sum_i (X_i H_{ik}) N_{ihk}$$

$$+ \sum_j\sum_k\sum_i (X_i C_j) N_{ijk} + \sum_j\sum_h\sum_i (X_i C_j) N_{ijh}$$

subject to the following constraints

$$\sum_j\sum_i X_i N_{ijh} - \sum_k\sum_i X_i N_{hk} = D_h \qquad \text{for all } h, h \in k \text{ ------ (i)}$$

$$\sum_k\sum_i X_i N_{ijk} \leqslant S_j \qquad \text{for all } j \text{ ------ (ii)}$$

$$\sum_j\sum_i X_i N_{ijk} + \sum_h\sum_i X_i N_{ihk} = D_k \qquad \text{for all } k \text{ ------ (iii)}$$

$$\sum_j\sum_i X_i N_{ijk} + \sum_h\sum_i X_i N_{ihk} \leqslant TC_k \qquad \text{for all } k \text{ ------ (iv)}$$

where, N_{ijk} = number of trips required from source 'j' to sink 'k' using ship size X_i

N_{ijh} = number of trips required from source 'j' to terminal 'h' using ship size X_i

N_{ihk} = number of trips required from terminal 'h' to sink 'k' using ship size X_i

X_i = ith ship size, DWT

T_{ijk} = ocean transport cost from source 'j' to sink 'k' using ith ship size, \$/ton

T_{ijh} = ocean transport cost from source 'j' to terminal 'h' using ith size, \$/ton

T_{ihk} = ocean transport cost from terminal 'h' to sink 'k' using ith ship size, \$/ton

C_j = production cost, \$/ton

H_{ij} = handling cost at source 'j' of ith ship size, \$/ton

H_{ik} = handling cost at sink 'k' of ith ship size, \$/ton

H_{ih} = handling cost at terminal 'h' of ith ship size, \$/ton

D_h = demand at terminal 'h', tce

D_k = demand at sink 'k', tce

S_j = supply from source 'j', tce

TC_k = terminal capacity at sink 'k', tce/year

The decision variable chosen is the number of trips required for a certain ship size on a particular route that will satisfy optimal conditions, i.e., N. The solution therefore tells us the optimal pattern of resource allocation for the given set of sources and sinks in terms of ship sizes and number of trips.

The first constraint (i) makes sure that net consumption of coal in the terminal, that is the amount of coal coming from the different sources using bigger vessel sizes minus the amount transhipped using small ships, is equal to the local demand.

Constraint (ii) sets a maximum limit to the total supply coming from any particular genuine source country; constraint (iii) requires that all shipments going into a sink (any consuming country other than the terminals) be equal to the import demand. Constraint (iv) assures that the import do not exceed the capacity of receiving port in a country.