Intercontinental transportation and the Marine Container System

by
YOSHIMI NAGAO
Department of Transportation Engineering,
Faculty of Engineering, Kyoto University
and
MICHIHIKO NORITAKE
Department of Civil Enigineering,
Faculty of Engineering, Kansai University

INTRODUCTION

Matters related with transportation are, economically speaking, to be placed in the middle of the junction of the "production" and "consumption". Any improvement in a transportation system gives a significant effect on the production and consumption activities of either a region or nation. There are many cases in the so called developing countries where the improvement of intercontinental marine transportation system had played vital roles for the improvement of the foundation of the national economy, by means of improving ports and harbours thereby enabling to export their natural resources to other countries. [1]

There are many problems to be overcome for the improvement of intercontinental marine transportation system, because of differences of customs and traditional deed involved in the countries involved. Nevertheless, the remarkable expansion of intercontinental trades can be raised as one of characteristics of the world economy in the latter part of the twentieth century. This will be proved by the fact that the growth rate of world trade had been exceeding the rate of production. [2]

Table 1.1 - Selected Series of World Transport Statistics

Annual	Population (million)	Industrial Production Index of Industrial Production, Total 1963=100 1)	World Trade Value (FOB) of Exports in U.S. $ 10^6 at 1963 3)	World Traffic (10^9 net ton km)			Share Rate on this table (%)		
				Rail 1)	Marine 2)	Air 3)	Rail	Marine	Air
1963	3,174	100	135,400	3,793	8,712	2.1	30.3	69.7	0.017
1964	3,234 (1.9)	108 (8.0)	149,100 (10.1)	4,008 (5.7)	9,914 (13.8)	2.4 (15.6)	28.8	71.2	0.018
1965	3,295 (1.9)	115 (6.0)	159,400 (6.9)	4,195 (4.7)	10,832 (9.3)	3.1 (29.4)	27.9	72.1	0.021
1966	3,354 (1.8)	123 (7.0)	172,100 (8.0)	4,346 (3.6)	11,553 (6.7)	3.8 (22.7)	27.3	72.6	0.024
1967	3,421 (2.0)	126 (2.0)	181,700 (5.6)	4,454 (2.5)	13,390 (15.9)	4.4 (15.2)	25.0	75.0	0.025
1968	3,490 (2.0)	135 (7.0)	205,200 (12.9)	4,642 (4.2)	15,505 (15.8)	5.4 (21.7)	23.0	76.9	0.027
1969	3,561 (2.0)	145 (7.0)	227,600 (10.9)	4,813 (3.7)	17,361 (12.0)	7.0 (29.9)	21.7	78.3	0.032
1970	3,610 (1.4)	150 (3.0)	250,000 (9.8)	5,020 (4.3)	19,731 (13.7)	7.7 (9.3)	20.3	79.7	0.031
1971	3,679 (1.9)	156 (4.0)	263,000 (5.2)	5,171 (3.0)	21,722 (10.1)	8.2 (6.2)	19.2	80.7	0.031
1972	3,748 (1.9)	168 (8.0)	288,000 (9.5)	5,397 (4.4)	24,267 (11.7)	9.3 (13.5)	18.2	81.8	0.031
1973	3,818 (1.9)	183 (9.0)	325,500 (13.0)	5,764 (6.8)	28,526 (17.6)	11.0 (18.0)	16.8	83.2	0.032
1974	3,890 (1.9)	191 (4.0)	– –	5,982 (3.8)	30,347 (6.4)	12.2 (11.4)	16.5	83.5	0.034
1975	3,967 (2.0)	186 (Δ 3.0)	– –	5,992 (0.2)	28,452 (Δ 6.2)	– –	–	–	–

Note; This table is made from the following data.
1) Monthly Bulletin of Statistics, published by U.N..
2) Review 1973-1976, published by Fearnley & Egers Chartering CO.LTD..
3) Statistics Yearbook, published by U.N..
4) The figures of Rail traffic relate to the domestic and international traffic.
5) ( ) Annual Rate, Δ Reduce.

In the field of intercontinental transportation, most commodities are transported by sea and rail and a few by air and pipeline. By reason of the time-value of commodities and the comfort of travellers, costly commodities, as well as travellers, will tend to be transported by air in the future. The intercontinental transportation of the great amount of low cost commodities, however, will continue to depend on marine transport, because of its more economical nature.

The importance of marine transport is most typically shown in the case of Japan. Japan is an island country with few natural resources and all her trading partners located far beyond her shores. Until about one hundred and twenty years ago, Japan was an isolated country with a self-supporting and self-sufficient economy which mainly depended on agriculture. Hence, economic activity, as wel as the general standard of living, was at a low level. In 1854, however, Japan opened her ports to foreign countries and entered the world of international shipping and trade, thus transforming the country from an agricultural nation to an industrial and commercial one. After that, many ports were constructed in Japan, and a number of industrial districts and cities were situated behind them. By means of such advantageous locationing, import and processing of raw materials, as well as export and domestic consumption of manufactured goods, are made cheap and rapid by marine transport; this supports the current national economy in Japan.

INCREASE OF TRADE AND COUNTER MEASURES

Intercontinental marine transportation system can be subdivided into:

1. Domestic cargo transport activity
2. Cargo handling activity at ports
3. Carriage of goods by sea.

Each of such activities is carried out by land transporters, shipping firms, forwarders, port authorities and a great many others. Each of such business activity works under the principle of achieving the best possible benefits with the least possible costs and has been exerting itself for the improvement of the system on which it has to live.

The following five points will be major factors for the decisionmaking for the improvement of such systems:

First is the trend toward a thorough understanding of the intercontinental marine transportation system. In other words, instead of each management authority measuring things purely in terms of his own subsystem, he is now inclined to consider optimization of the total intermodal transportation system. [3] (Fig. 2.1). Recently, management authorities have endeavored to consider also regional environmental preservation and regional economic development within the decisionmaking process.

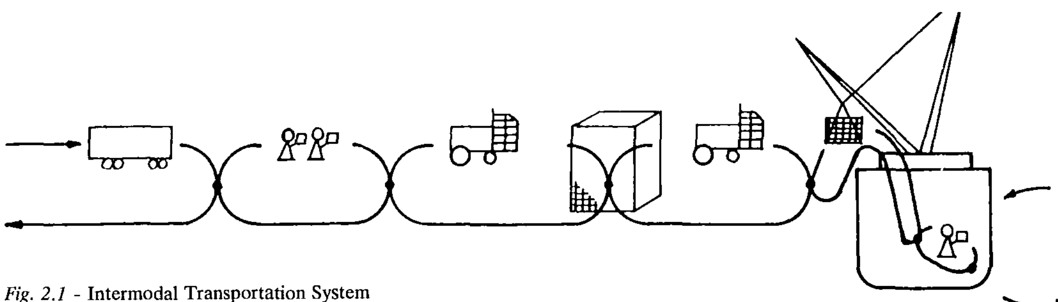


Fig. 2.1 - Intermodal Transportation System (after Sauerbier) [3])

The second characteristic is specialization of transport methods. The conventional transport system employed liner ships of about 3,000 GT to 10,000 GT in size, but the new transport system which is coming into use employs ships which are specialized according to commodities. The kinds of specialized ships range widely, (e.g.: oil tankers, LPG ships, LNG ships, ore carriers, grain carriers, cement carriers, refrigerator boats, auto carriers, etc.) [4]. (Fig. 2.2). Furthermore, terminal facilities, such as port facilities, have come to be designed in coordination with the specifications (ship type, ship size, etc.) of specialized ships. In this way, the specialized transportation system has enabled a remarkable rise in the efficiency of transportation; the merits of this system are so great that it represents an improvement over the conventional one even when ships return from their voyages empty.

The third development is standardization or unitization of the size of transport commodities. Standardized receptacles, such as container vans and pallets, were devised to facilitate loading or unloading of general cargoes which differed in their shapes. The container transportation system, in particular, using container vans as receptables, made possible great savings in packing costs, which had previously comprised a large percentage of the total cost of shipping. Until about ten years ago, general cargoes used to be handled by mast cranes or wharf cranes, which had a handling ability of about two tons; but containerization made it possible to handle commodities of 20 to 40 tons at one time, thus raising the productivity of transport by some 10 to 20 times. This fact made possible the quick dispatch of container ships in port, and contributed to the decrease of the system's cost.

Fourth is the development of larger and faster ships and transport equipment for use in the intercontinental marine transportation system. In the area of oil tankers, ships of the specifications of 484,337 DW, 15.55 knots have entered service, and with regard to container ships, the Trio Group has put a fleet of ships of the specifications of 58,889 GT (2,200 containers), 26 knots on the line between the Far East and Europe. [5] (Fig. 2.3). Hence the construction of huge berths, the waterway and anchorage with deep depths are necessary at ports which accept the entrance of such large-scale ships.

Fifth is the introduction of automation and comprehensive information into the transportation system. When many management authorities which are concerned with the intercontinental marine transportation system actually make decisions relating to the above mentioned four factors, many risks are involved due to lack of information. In order to minimize and eliminate those risks, methods of collecting, analyzing and transforming large amounts of information concerned with the operation of the transportation system have been developed.

Many studies have been performed at research institutes in various countries for the last ten years, to provide theoretical background and to assist in decisionmaking with regard to the above mentioned developments. The results obtained from these studies have contributed greatly to the site-location and size-determination of ports and inland depots in each country, as well as to the evaluation of alternatives concerning the type or quality of ships and handling equipment on berth. Examples of this will be dealt with briefly in the following section with regard to design of the international marine container transportation system.

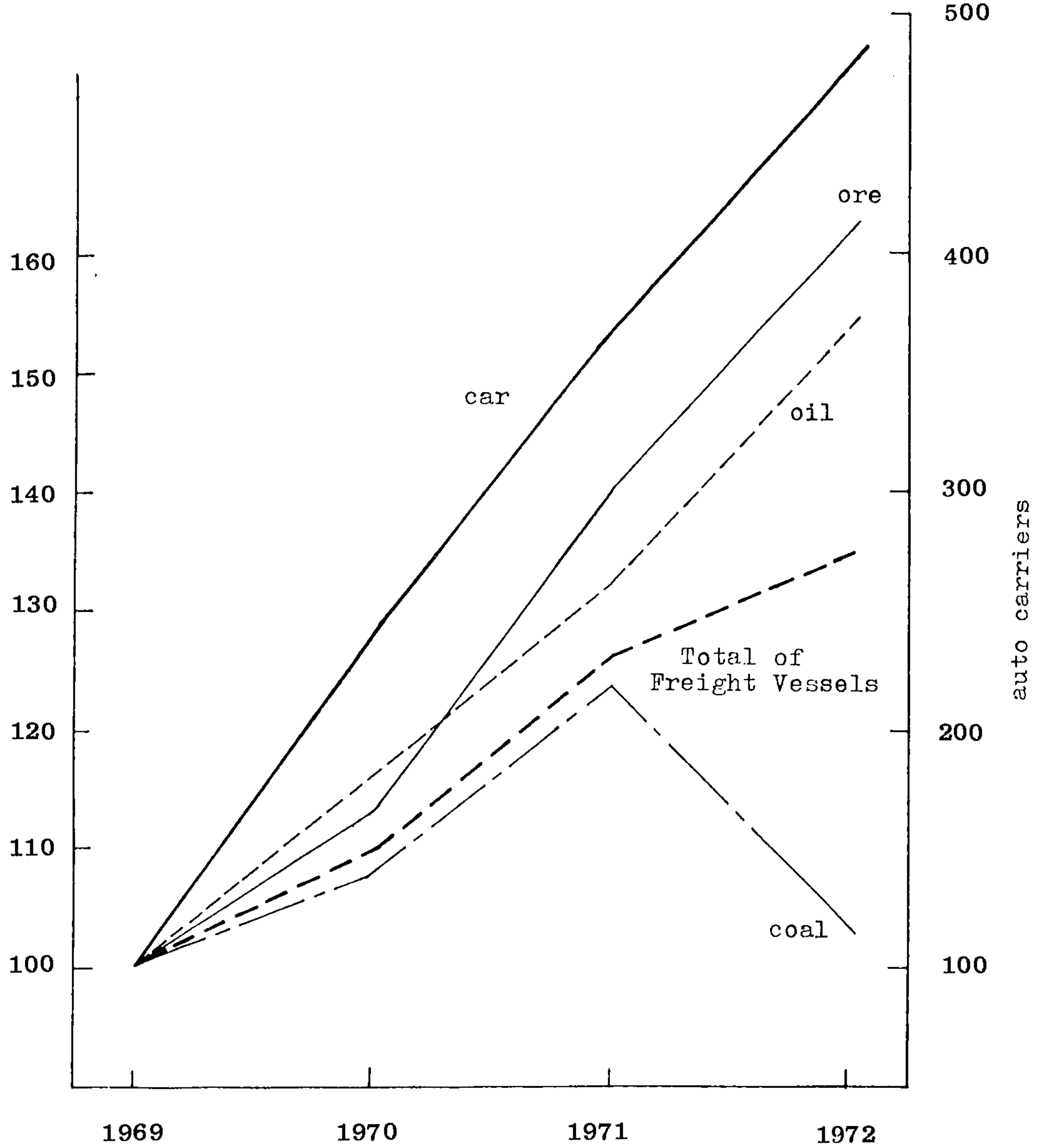


Fig. 2.2 – Changes of Total Tonnage of Specialized Ships

Note; 1) This Figure is made from: "Annual Report", Ministry of Transportation, 1974.
2) Each Index is fixed to 100 at 1969.

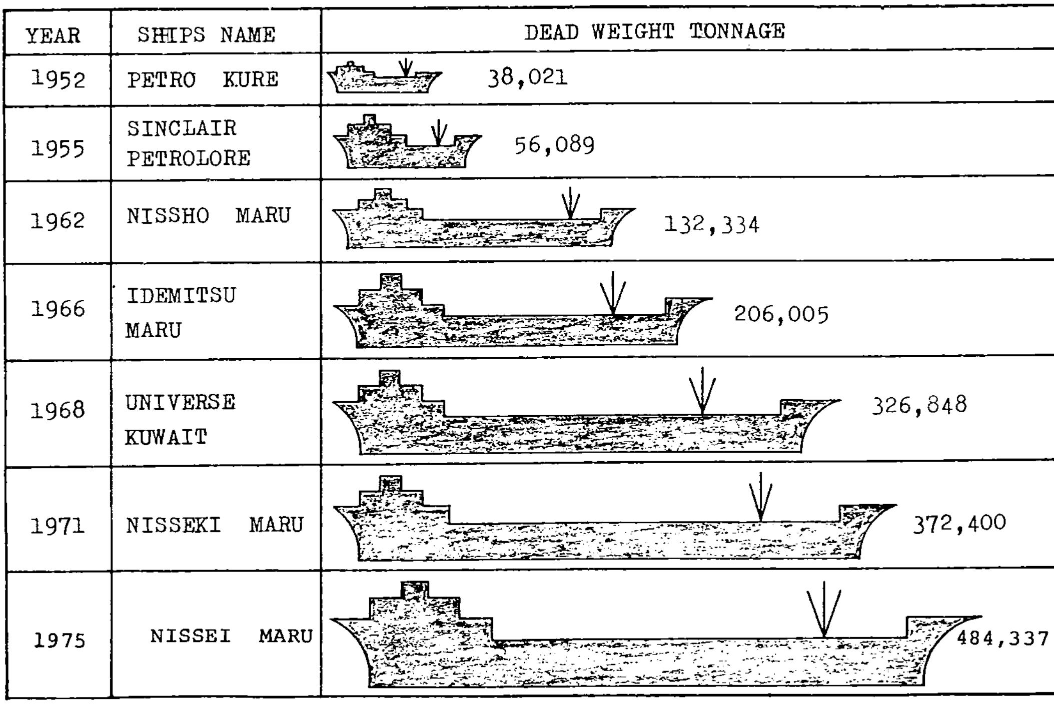


Fig. 2.3. – Changes of Ship's Size

DESIGNING OF INTERCONTINENTAL MARINE CONTAINER TRANSPORT SYSTEM

It will be appropriate to note some examples of the contributions derived from such studies for the improvement of intercontinental marine container transport system.

It is a well known fact that the intercontinental marine container transport system was first introduced in 1966 by Sea-Land Services Inc., into the Transatlantic services with a modest fleet of four container ships capable of taking two hundred and twenty-six containers respectively.

Containerization realized the intermodal transport of "door to door" services, and contributed immensely to the economization of costs and labour hours involved in the cargo handling. [6] (Table 3.1).

Table 3.1. – Comparison of Costs between Containerized Transport and Conventional Transport Systems

Cost Item	Cargo Item	Home electric appliances	Frozen tuna	Soy sauce	Furniture	Stainless steel sheet	Toys	Table ware	Machine parts
Cost related to empty containers	Truck loading charge	–	–	–	–	–	–	–	–
	Transport to container packing site	* 1.5	* 0.4	* 5.9	* 6.3	–	* 13.7	–	–
Container packing cost	Material inspection cost, travelling cost	–	* 1.8	–	* 1.6	* 1.7	* 2.8	–	–
	Cargo packing cost	–	* 18.0	–	–	* 5.1	–	* 5.8	–
	Sealing cost	–	–	–	–	–	–	–	–
Inland transport cost	Transportation to the port	0.7	4.2	10.4	6.1	15.9	* 3.9	17.1	0
	Truck unloading charge	–	–	–	–	–	–	–	–
Shipping charges	Customs fee	0	0	0	0	0	0	0	0
	Various shipping expenses	12.5	18.0	18.7	13.3	17.9	12.2	4.0	25.5
Other costs	Packing charges	35.6	–	58.7	3.1	35.1	12.2	0	2.2
	Storage	1.4	26.6	2.9	–	–	–	–	–
Total		48.7	28.6	84.8	14.6	62.1	4.0	15.3	27.7

Note: Figures shown represent the ratio of decrease in cost to the total cost of conventional transport which is 100.
However, figures affixed by * show increase.

Skirting fields of its contribution are widely spread to achieve the dependable availability of cargo handling, stabilization of employment, improvement of working conditions, as well as the prevention of damages to cargo, wetting, rats, dropping pilferage and so on. Effects are not only limited to the improvement of physical aspects but also to social aspects.

However, the system necessitates the vast amount of capital investment for the fulfillment of itself, namely the construction of specialized vessels, the keeping of a numerous number of container vans, acquisition of much space for terminals, provisions for cranes and affiliated mechanical equipment, construction of inland depots etc.

Crucial consideration must be experted to the decision of the size of vessels, because it is a matter of simple calculation that the bigger the vessel size might be, the higher the productivity should be, provided that the very question of how to secure sufficient cargo is out of concern. Also, even a slight congestion in the port or malfunctioning of delivery of vans will cause a bad effect in the economic efficiency of the system as a whole. Location of container terminals, number of vans to be handled, cargo handling capacity and many other factors are under the strains of these conditions.

Improvement works for the facilities as well as the usage of facilities had been sought after by shipping firms, forwarders, intra-port cargo forwarders or by the port authorities respectively and independently for individual benefits. However, improvement of a section or subsystem (might be called a "local optimum") is not the total system, and might even involve the risk of the whole idea of the system collapsing.

Therefore, in order to evaluate the intercontinental marine container system, the wholesome realization of the system must be established; the magnitude of each of consistent subsystems can be placed thereby accordingly. [6]

Fig. 3.1 illustrates, in a net-work model, the components of an intercontinental marine container transport system. [6]

i: Place of cargo generated
j: Place of cargo required
k: Place of container terminal

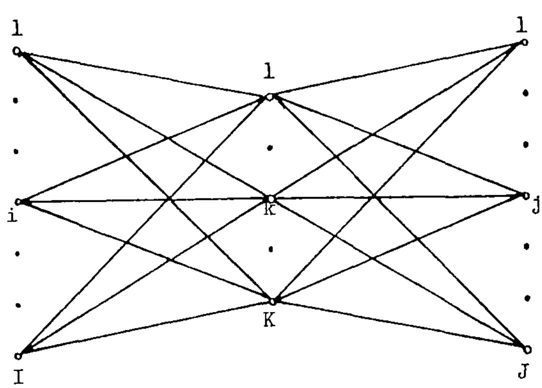


Fig. 3.1 - Network Model of Intercontinental Transportation System

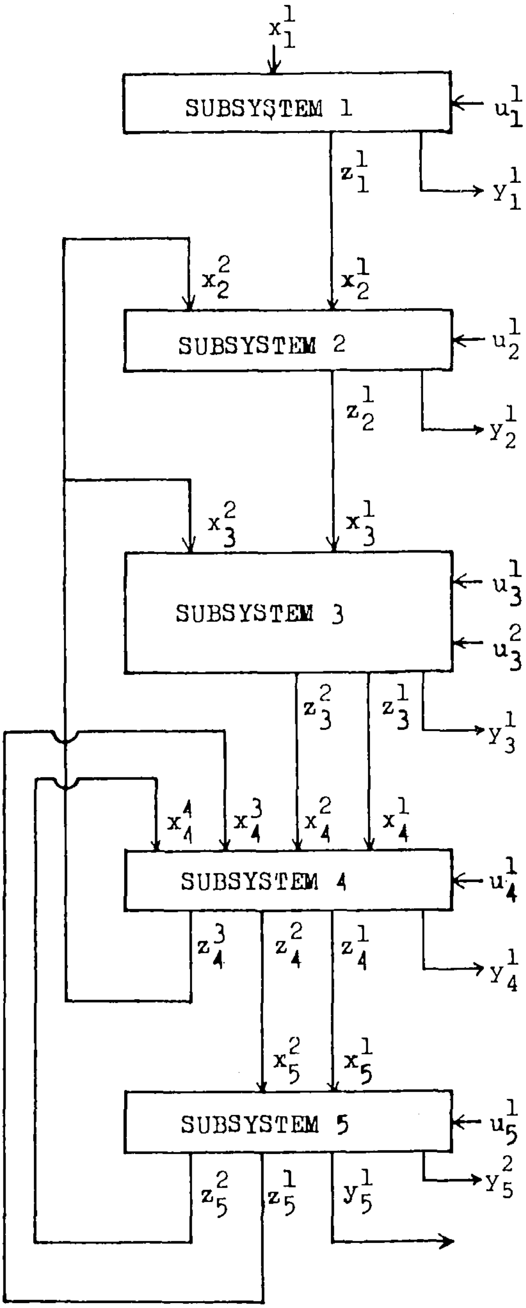
The volume of cargoes estimated at "i" and "j" are to be incorporated into the calculation of transport costs necessary for each route.

Volumes, numbers, capacity, speed of necessary equipment and facilities are to be incorporated accordingly, as variations, thereby to simulate the possible status of the operation of such facilities and equipment. Operation time as well as idle time are to be calculated.

(Fig. 3.2). The model is also intended to express the total cost by adding up each of subtotal costs necessary for constituent sub-systems.

By adjusting the levels of each variation, the model must be so designed to represent the exact situation of the operation of the system. However, there has to be some compromise as to the setting of the reasonable depths of the simulation with providing a permissible allowance in each model, in order to attain a simplification in the model, without which the simulation shall

Fig. 3.2 – Subsystems and Variables of Intercontinental Transportation System



Note; x,u: input variables, and y,z: output variables.

be hampered by endless series of calculations or combinations.

Every possible consideration should be provided, utilizing the methods of mathematical divisions and analysis in order to attain possible proper answers.

Many studies under the above principle have been developed to suit the requirements applicable to every component.

Models of the International Marine Container Transportation System

Many models aimed mainly at the economic optimization of the international marine container transportation system have been developed, and they can be divided into four categories. These are:

i) Network Models

Models in this category aim to determine the transportation routes, location of container terminals, and the size of terminal facilities. This type of model is regarded as the applied model of the "Warehouse Location Model" or "Plant Location Model". Mathematical techniques used in modeling the system consist of linear programming or transformed linear programming (mixed integer Programming), which involves fixed costs of terminals. [7,8] Näslund obtained the optimal ship size, number of ships, number of ports of call, and quantity of commodities handled at each port for the case of integrated marine container transportation system with full ships and fractional ships, between Sweden and the United Kingdom and European Continent. This kind of model is useful for obtaining general information about the international marine container transportation system. [9]

ii) Optimum Size Determination Models of Terminal Facilities

Models in this category aim to analyze the behavior of the arrival of commodities transported from inland regions, and that of ships on sea, and to determine the optimal number of berths in container terminals. This type of study has been used widely as a size determination model of port facilities for many years. [10-13] Queuing theories, such as M/M/S or M/E /S types, is often used as a method to analyze the system. Further, a bulk queuing theory has been employed, in which the arrival of container ships in ports is regarded as a bulk arrival. [14] In addition, many simulation models were developed to analyze the behavior of the system in more detail. [15,16]

iii) Thorough Transportation System Models

Models in this category refer to the "multiple link transportation system". [3] The transportation process from origin to destination is regarded as a multiple link transportation system, which contains in it many links (transport equipment units perform their shuttle activities in links) and nodes (transport equipment units transfer or store the commodities at nodes). (Fig. 2.1).

Hence, if the number of links contained in the transportation system, arrangement of links (parallel or in series), the number of transport equipments operating in each link, operating behavior of transport equipments in each link, relative size of commodities transported at one time by each transport equipment unit, and storage capacity at nodes, are regarded as parameters of the system, it becomes possible to clarify the behavior of the entire transportation system and to quantify the productivity or effectiveness of the transportation system.

These kinds of studies were performed intensively at the University of California in the United States of America, and the influences that each parameter has upon the productivity and effectiveness of the transportation system were shown through simulation techniques. [17,18] With regard to handling operations in the container terminals, many studies, which regard the operations as a two-link transportation system, have been carried out, based on the cyclic type of queuing theory, in order to estimate the port time of container ships. [19]

*iv) Many other applications of mathematical optimization techniques have been studied, taking note of the characteristics of cost-function and constraints of the marine container transportation system consisting of three principal subsystems, namely, land transport, sea transport, and port interface, and afterward explained positively that the cost-function and constraints of the system are described by posynomials, and obtained ship size, ship speed and terminal capacity by the use of geometric programming. [20] P. Wilmes and E. Frankel regarded the function of ports as a part of the transportation system from origin to destination and presented various type of models. [21] Continuous simulation models were also developed to examine the behavior of the container transportation network under a given demand [22]

Design of the International Marine Container Transportation System in Japan

To design an optimal marine container transportation system between Japan and foreign countries, an analysis based both on the network model shown in Fig. 3.1 and the multiple link transportation model shown in Fig. 3.2 has been performed. [6] Total cost C, of the system is given as

$$C = C_i + C_t + C_o$$

where

C_i: inland transport cost
C_t: terminal cost, and
C_o: cost related to ships and containers.

To calculate actual cost, the total system is divided into many subsystems and the consistency of the entire system is maintained by connecting each subsystem with many intermediate variables. (Fig. 3.3). At the same time, ship size and the port handling system are also determined. Tokyo Bay, Osaka Bay and Ise Bay are adopted as sites proposed for container terminals. As a result of the calculation, the following became evident.

i) Optimum Number of Gantry Cranes

The number of gantry cranes is an indispensable factor for the calculation of terminal cost and it greatly affects the time required for loading and unloading containers, with eventual impact on the marine transport cost. For this reason, it is essential to determine the optimum number of gantry cranes from the standpoint of economic efficiency. Results of a study in this connection are shown in Fig. 3.4. The relative cost shown in the figure includes capital costs on investments for gantry crane and cargo handling equipment in yard and ships at berth, and the operational costs, as well as day charges of container ships.

This figure represents the results to be obtained when the cargo handling method in the yard is to be the straddle carrier system, and the number of carriers is to be three per gantry crane. Based on this chart, the optimum number of gantry cranes form an economic point of view is considered to be two for container ships with a capacity of 700, 1,000 and 1,500 containers, three for ships with a capacity of 1,800 containers and four for ships with a capacity of 2,000 containers.

ii) Terminal Cost

Annual Terminal costs calculated for the Japan-North American Atlantic Coast route are shown in Table 3.2. It is evident that the terminal cost decreases in proportion to the increase in ship size.

iii) Marine Transport Cost (Costs related to ships and number of containers)

Marine transport cost in the case of one port in Japan is shown in Fig. 3.5. The figure shows a case in which the terminal is located in the Tokyo Bay area. From this figure, it is evident that the difference in transport cost depending on ship size is quite clear for the North American Pacific Coast route and European route.

Fig. 3.6 shows the composition of marine transport

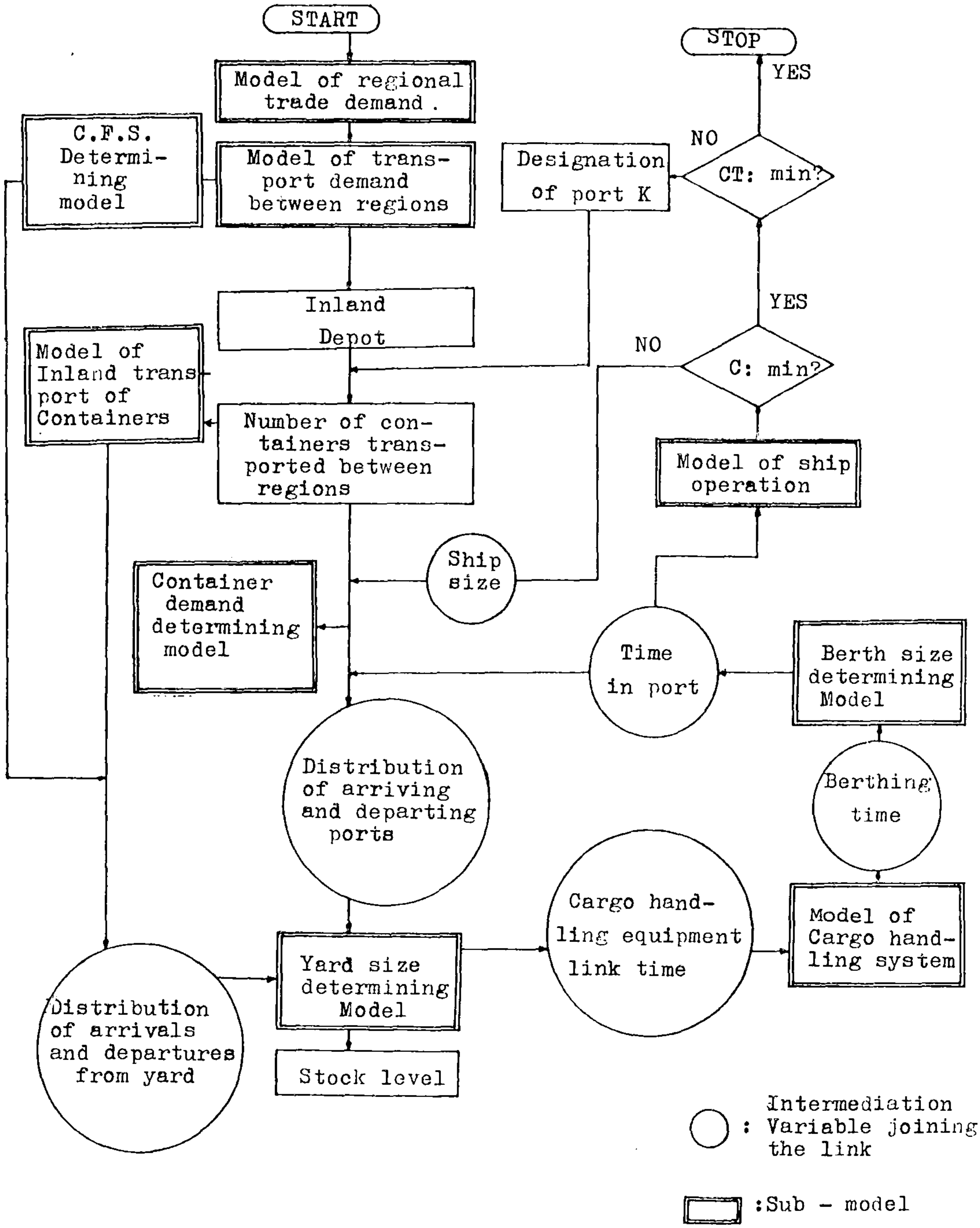


Fig. 3.3 – Flow Chart of the International Marine Container Transportation System

costs, by item, for North American Atlantic Coast service. According to this chart the capital cost on investments for ships and container is relatively large, thus suggesting the importance of efficient utilization of ships and containers. As the increase of ship speed results in a sharp increase of fuel expenses, this calculation shows some results which make the merits of larger ships some what doubtful. This is indicative of the need for a thorough study in relation to ship speed in order to fully realize the scale merit.

Table 3.2 – Annual Terminal Cost (100 million yen)

Bale capacity	Facility cost	Equipment cost	Labor cost	Operating cost	Others	Terminal cost
700	36	22.9	6.9	0.8	6.1	71.9
1000	36	22.9	6.9	0.8	6.1	71.9
1500	31.5	11.5	3.5	0.8	3.1	50.3
1800	31.5	8.9	2.7	0.8	2.5	46.4
2000	31.5	11.5	3.5	0.8	3.1	50.3

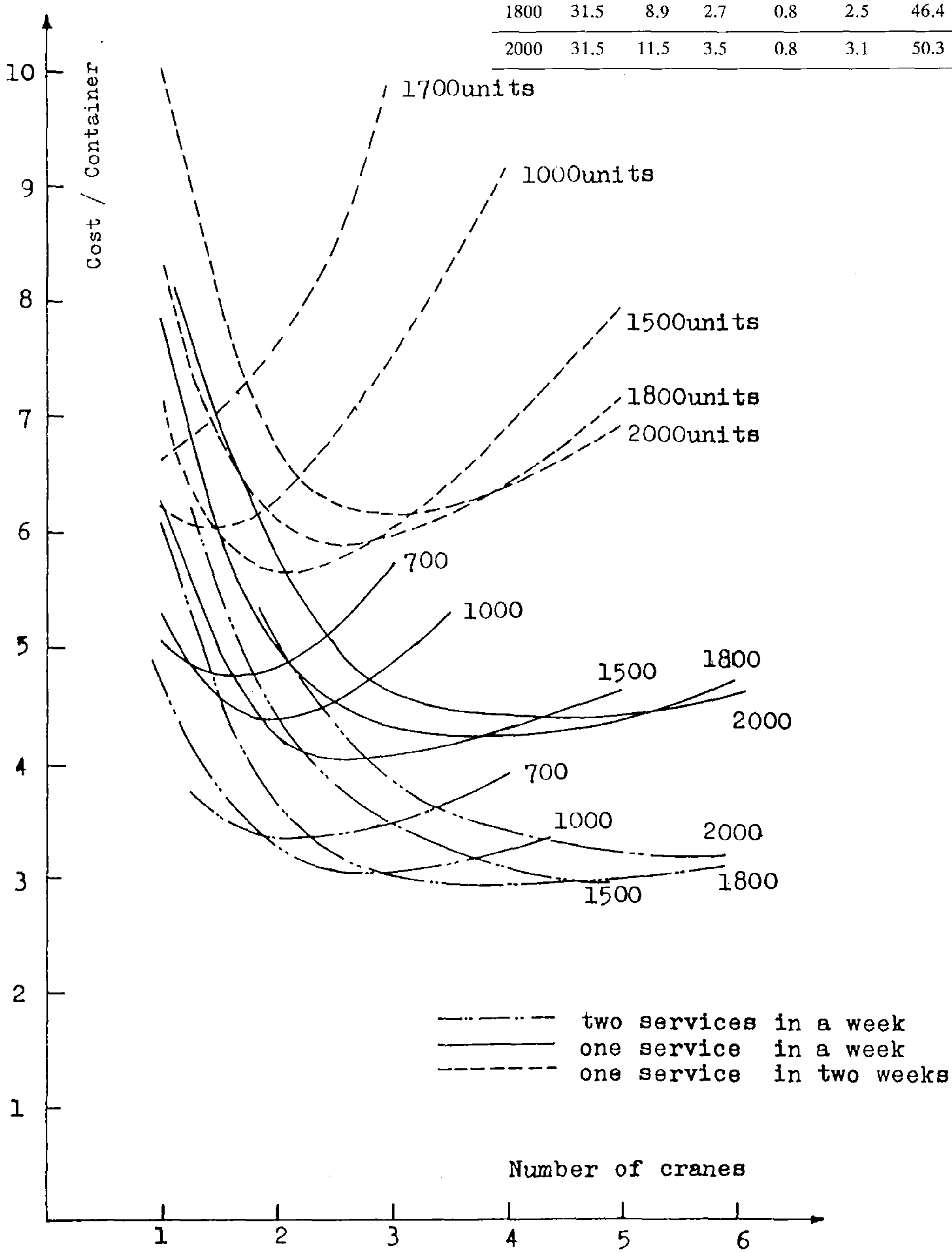


Fig. 3.4 – Physical Distribution Cost in Terminal

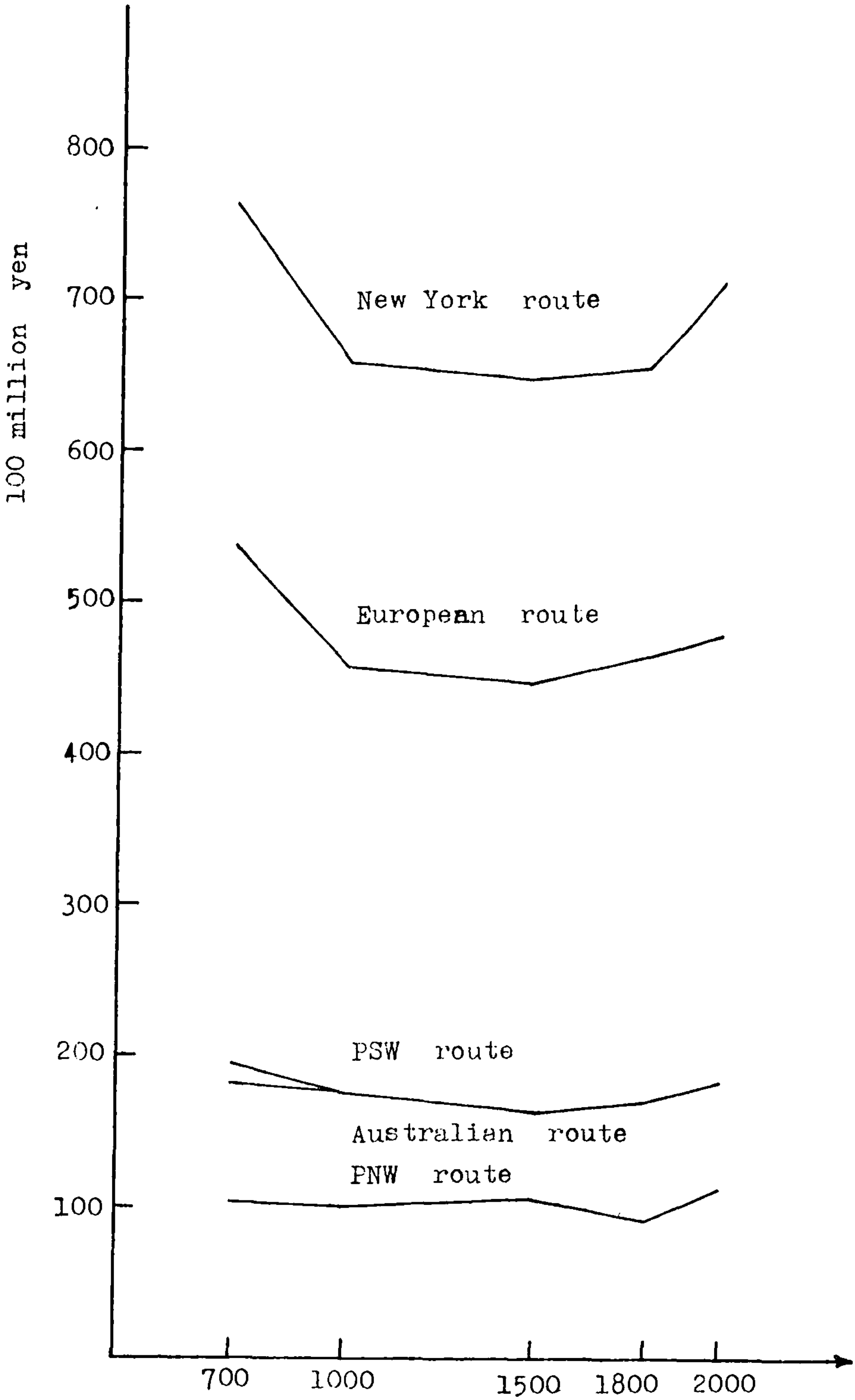


Fig. 3.5 – Annual Costs Related to Ships and Containers

iv) A Study of Total Cost

From the results of calculation in the above model, it is apparent that if the amount of containerized commodities imported to and exported from Japan is rather small, and only one container port is constructed in Japan, then the development of Nagoya Port, which is located in the middle of Japan, is the most advantageous. On the other hand, if the amount of intercontinental marine container transportation is rather large, the development of Kita-Kyushu and Niigata in southern and northern Japan, respectively, are also needed.

Furthermore, by analysis of the above model, it becomes possible to specify the decision variables, such as number of berths needed in each container port, and number of cranes per berth, quantity of handling equipment in the container yard, and number of ships in each route, when the total cost of the intercontinental marine transportation system is minimized. Due to the efficiency advantage of plural servers (berths), joint use of berths is enforced.

In Japan, in response to the progress of containerization in the intercontinental marine transportation system, Keihin (Tokoy Bay) Port Development Authority and Hanshin (Osaka Bay) Port Development Authority were founded in Tokyo and and Kobe, respectively, in October, 1967. They constructed a number of container

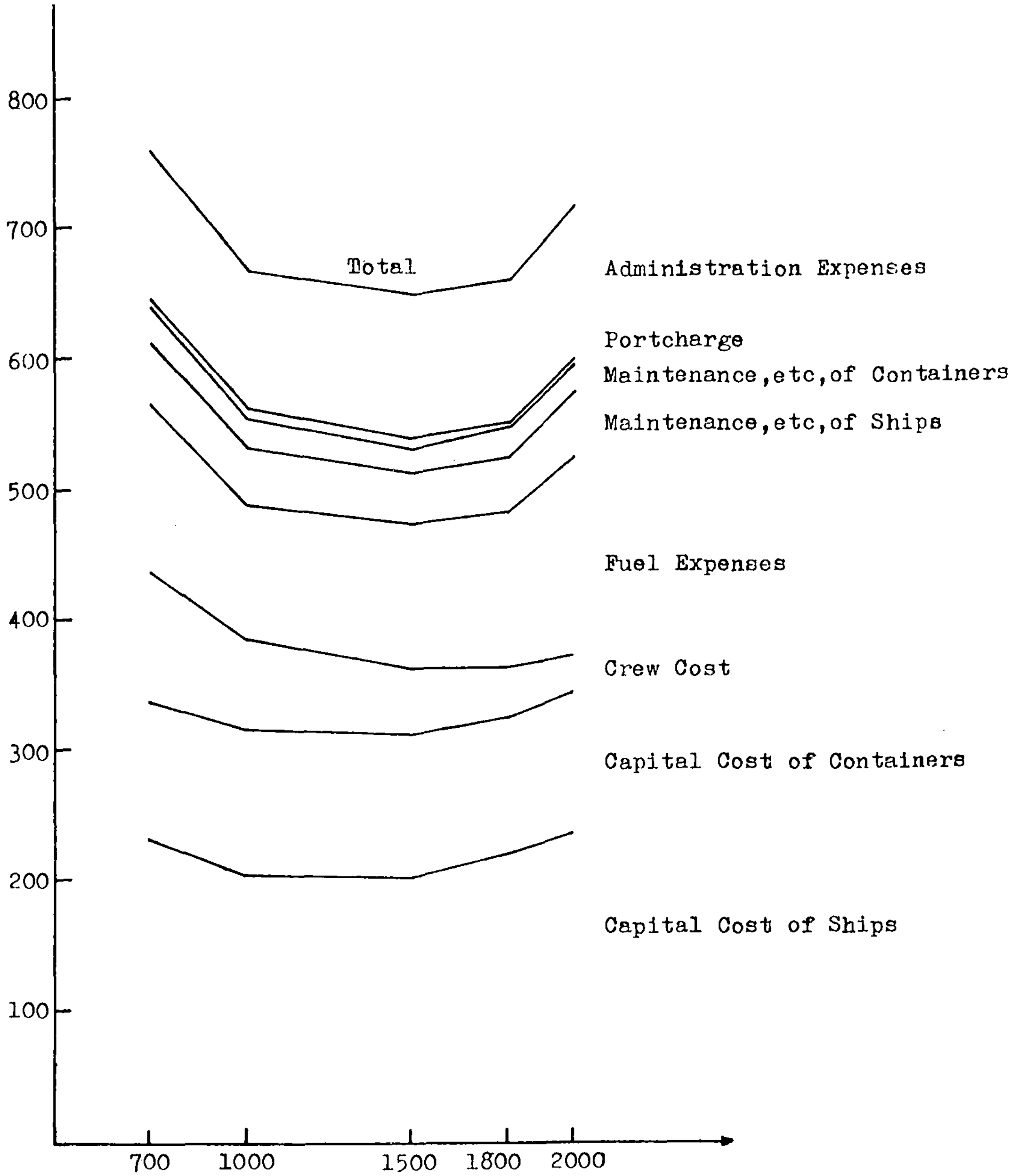


Fig. 3.6 – Composition of Annual Costs Related to Ships and Containers

berths with a depth of 12 m. in Tokyo Bay and Osaka Bay, which had typical Japanese liner ports. At the same time, institutions that manage and administer the operation of ships and the usage of port facilities were introduced. The introduction of these institutions may be regarded as a proper policy when considering the future increase of containerized commodities and the results obtained from the above models.

In fact, construction of container terminals was demanded at Shimizu, Nagoya, and Kita-Kyushu, in addition to the above ports, and this construction was carried out. These ports were constructed as the result of the strong demand in each region, but are also significant as feeder-service ports in Japan.

As of January 1976, 324 full-container ships belonging to 111 shipping companies and having a total capacity of 390,000 containers (20 ft.) have been put on 13 principal intercontinental lines and are involved in intercontinental marine transportation.[23] (Table 3.3).

Table 3.3 – Full-Container Ships in the World (1976. 1.1)

Route	No. of Companies	No. of Ships	G/T	20 ft. Container Capacity	Increase from 1975. 1.1 (*: decrease) No. of Ships	G/T	20 ft. Container Capacity
Far East/ West Coast North America	15	75	1,647,325	88,355	*1	86,669	10,775
Far East/ East Coast North America	12	51	1,147,258	63,803	12	63,803	15,984
Europe/ Far East	15	33	1,470,531	65,359	9	65,359	13,985
Medit./ Far East	6	11	276,361	14,356	*1	14,356	*581
Far East/ Australia	13	18	304,887	15,541	4	15,541	3,814
Europe/ East Coast North America	12	43	813,191	44,453	*3	44,453	2,761
Medit./ East Coast North America	6	28	444,924	25,828	2	25,828	3,514
Gulf/ Europe	2	8	220,453	12,856	0	12,856	730
Europe/ Great Lakes	6	12	127,114	6,120	*1	6,120	*548
Australia/ North America	6	18	306,842	17,803	*4	17,803	2,826
Gulf/ Persian Gulf	–	–	–	–	*1	–	*528
Europe/ West Coast North America	3	4	78,564	4,642	0	4,642	1,202
Europe Australia	15	24	547,273	32,570	2	32,570	2,012
Total	111	324	7,384,723	391,68618	18	424,487	50,294

FUTURE PROBLEMS

To improve the intercontinental marine transportation system, many responsible authorities in various countries have made bold policy-decisions. These developments have been collectively termed a "transportation revolution".

Further, many studies have been promoted for the development of new transport techniques and the planning of new transportation systems, which enable these policies to be put into practice. Standardization of the unit size of commodities, for example, is recognized as a highly useful method for increasing transport efficiency, but it may not necessarily be universally agreed upon because economic conditions and trading customs differ from country to country.

Furthermore, legal and institutional adjustment, such as the revision of the standards of road design of each country to those of the international marine transportation system, coordination of shipping interests with land carriage interests on an international scale, free establishment of feeder-service ports in each country, and amendment of many international stipulations on transport, are all lagging.

The reasons are found in the fact that each management authority in the intercontinental marine transportation system has a different history of progress and has a different view toward the future. It is important, therefore, for future studies to consider the response of each country and each management authority in the intercontinental transportation system from the viewpoint of global optimization of the world economy.

There are some unexplored aspects in the past studies on the designing of the intercontinental marine transportation system into which further studies are very necessary. They are:

a. Problems of regional community

b. Consideration on the length of time for an estimation of a project

c. Treatment of uncertainty

d. Adjustment of the total evaluation and subdivision

These factors are closely interrelated and some further studies must be made to achieve comprehensive analysis.

As to the problems of regional community, the following questions will be raised:

a. Improvement in the intercontinental marine transportation system will inevitably affect the labour conditions

b. Improvement of economical efficiency cannot be the only reason to justify cooperation from the labourers

c. Innovations or improvement sometimes bring forth the reduction of revenues to a community and discourage the investment to the port

d. Shortage in the funds might cause the provision of preventative measures against traffic congestion on roads, air and water pollution which might lead to the destruction of the environment

e. Acquisition and exclusive use of lands for the system might disturb the possibility of the land utilization by people of the community

f. Sophisticated improvements might not always beneficial to the improvement of social conditions of developing countries or regions.

Therefore, every possible consideration must be taken into account, such as regional specialities, as guidelines for the evaluation of standard or infrastructure. Considerations shall have to be expanded not only from the containerization but also to ro/ro, LASH, SEABEE systems for its combined use.

Secondly, the concept of time in the planning of the transportation system is important. To satisfy a given transportation demand, a huge investment in transportation systems is needed, and the investment, in turn, gives rise to further demand. This fact implies that the concept of "elasticity" in economics is essential for the study of transportation systems. Transportation systems designed over a long period of time are quite different from those designed over a short period of time.

Generally speaking, the former system may easily enjoy the scale merit (the merit of accumulation) of the system in future. Investments aimed at future scale merits, however, often involve risks resulting from the uncertainties involved in estimating future conditions. Hence, except for cases in which the present value of capital is quite lower than its future value, large investments will be made only with considerable hesitation. [24] To resolve this problem, studies concerning the timing of investments are being undertaken. [25,26]

Thirdly, there exists the problem of the evaluation of transportation systems. Formerly, in the evaluation of transportation systems, the economic evaluation method, which is based on cost-benefit analysis, was prominent; but the use of that method alone is not satisfactory. [1,27/ 29] Some problems referred to in the first item are closely related to the natural and social environments in the port regions.

It is possible to calculate these quantities in terms of economic units (such as dollars) and to include them within the category of economic evaluation (e.g. protection cost and compensation of public nuisance) to a certain extent, but the method has its limits. [30]

Hence, an integrated evaluation method, which estimates the trade offs among multiple objectives aimed at by changes in the transportation system, must be developed. Moreover, a methodology must be sought for the reallocation of benefits derived from changes in the intercontinental transportation system to those who suffer damages as a result of those changes. [31] In this way, people will be able to enjoy fairly the benefits derived from improvement of transportation systems. Those problems will be of utmost importance for many decision makers who manage the intercontinental marine transportation system.

Studies concerned with the above mentioned problems have been undertaken only recently and have not reached the stage of practical application. These problems, however, demand early solutions and those who wish to develop the intercontinental marine transport system must challenge them bravely.

CONCLUSIONS

In the field of intercontinental transportation, the tendency for the greater part of commodities to depend upon marine transportation will not change, even if the share of air transportation continues to grow. In the last ten years, especially, remarkable changes have taken place in marine transportation. The most typical changes are specialization of bulky commodities and containerization of general cargoes. The steps that authorities concerned with intercontinental marine transportation have made to adapt to the changes are as follows: thorough understanding of the total transportation system; specialization of transport method; standardization or unitization of the size of transport commodities; enlargement and speed-up of ships and transport equipment; and the introduction of automation and comprehensive information into the transportation system.

Many studies have been undertaken with regard to the above mentioned aspects of the intercontinental marine transportation system. These studies take a great many approaches, ranging from very large scale ("macro") analyses, to very small scale ("micro") analyses. These studies generally employed the criteria of economic evaluation, based on cost-benefit analysis, and they succeeded in providing much information about the optimum design of the transportation system.

Not all problems contained in the intercontinental marine transportation system, however, have been solved by these studies. The results obtained by these studies proved that many more problems exist for the optimization of the international marine transportation system beyond the situation of each management authority and each country in the world. These problems include not only technical and economical ones, but also socio-economic conditions, trading customs, and other factors in each country.

Many social and environmental problems have been created, such as those relating to port labor and seamen, [32] the financial problems of port authorities and environmental problems in urban regions. Further, design of the intercontinental marine transportation system requires a huge investment and the decisions with regard to timing are also very important. This problem relates to the investigation and resolution of uncertainties involved in estimating the future merits and demerits of investment.

Finally, the need to establish an integrated evaluation method for transportation systems is apparent in light of the above mentioned factors. The method must be not merely a technical and economic one, but a comprehensive one agreed upon by each country, each region, and each management authority in the world. Furthermore, a methodology on decentralization must be sought for the fair reallocation of benefits derived from improvement in the intercontinental marine transportation system. As the approaches to the study of these kinds of problems have thus far been inadequate, it is hoped that they may be resolved through international, interdisciplinary studies.

If the world is at peace, all countries in the world will desire interdependence with each other, and free and stable trade with other countries will continue. Improvements in the intercontinental marine transportation system will contribute to the betterment of international relations, and produce quantitative and qualitative rises in the production and consumption activities of each country. Japan is one of the countries that can grow only under such international conditions.

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