PART II BASIC METHODOLOGIES FOR WORLD ECONOMY, TRADE AND TRANSIT ANALYSIS AND FORECASTING

PREFACE OF PART II

Part II will assist the SCA participants to understand how the Canal transit volume will be analyzed and forecast on a short-term basis. The basic concepts and methods will be explained so that all of the participants will acquire a basic knowledge and skills necessary for this task. The transit analysis and short-term forecast should be regarded as one of the major research tasks of the Economic Unit, and all of its staffmembers should become familiar with research porblems involved in this task.

In Chapter 1, a brief explanation is made on world environmental problems that are closely related to the Canal transit demand. In addition, the research procedure is shown as to how the analysis and forecast must be made on the transit volume of Suez Canal while referring to a system chart of the various factors that must be considered in the analysis. The system chart provided in this Chapter will be found useful for understanding how each of the problems are mutually related to other problems that are described in the succeeding Chapters.

In Chapter 2, the subject matter of how the world economy and trade should be analyzed and forecast is discussed. As general background information a brief description is given on the basic problems of the world economy such as GDP (Gross Domestic Products), demand and supply of energy and non-oil products (grain, iron ore and coal). In addition, world trade problems of oil and non-oil products is described. It must be recognized that oil will remain the major commodity item which will continuously affect the transit demand of the Canal in the long term, while trends in trade patterns of non-oil products will become a concern for the SCA in the short term.

On the basis of the general information provided in Chapter 1 and 2, in Chapter 3 explanations are given on the technical details of how the world sea-born trade will be analized. Treated in this Chapter are the origin and destination (O/D) matrix, forecasting methods such as the average factor method, Frator method and the like. It is advised that staff members of the Economic Unit become familiar with these methods, particularly with the Frator method.

In Chapter 4, basic statistical tools such as the linear regression and correlation analysis method is explained. These methods are commonly used for short-term forecasting analysis of various problems including the Canal transit volume. It is recommended that the Economic Unit's staff members acquire technical proficiency on how to use these tools. As for the long term forecasting analysis of the transit, more complex mathematical models will become necessary. They will be explained in later stages of the technical training program.

In Chapter 5, a technical procedure of how to assign trade flows to specific sea routes is described with special reference to the Suez Canal. In Chapter 6, a convoy system is described in which methods of calculation of the Canal capacity and transit time are indicated. A concept of a dynamic simulation method is also explained.

CHAPTER 1 INTRODUCTION

It is considered that the following jobs should be performed by the Economic Unit as a part of its functions.

(1) Analysis of the present Canal traffic

(2) Analysis of the changes in environs which will potentially affect Canal traffic

(3) Short term transit forecast of Canal traffic

Results of the analysis will be published by the Economic Unit and they will be used for Canal project identification and budget planning of the SCA. It is very important for the staff members of the Economic Unit to have a basic knowledge necessary for carring out these analyses and forecasts.

1.1 A System Chart for Analysis

The essential task in analysing and forecasting is to clarify the relationship that might exist between causes and effects of the objects under consideration. They are:

(1) changes in environments which will potentially affect Canal traffic and

(2) the Canal traffic volume.

A system chart for analyzing Canal traffic and short term transit forecasting is shown in Fig. 1.1.

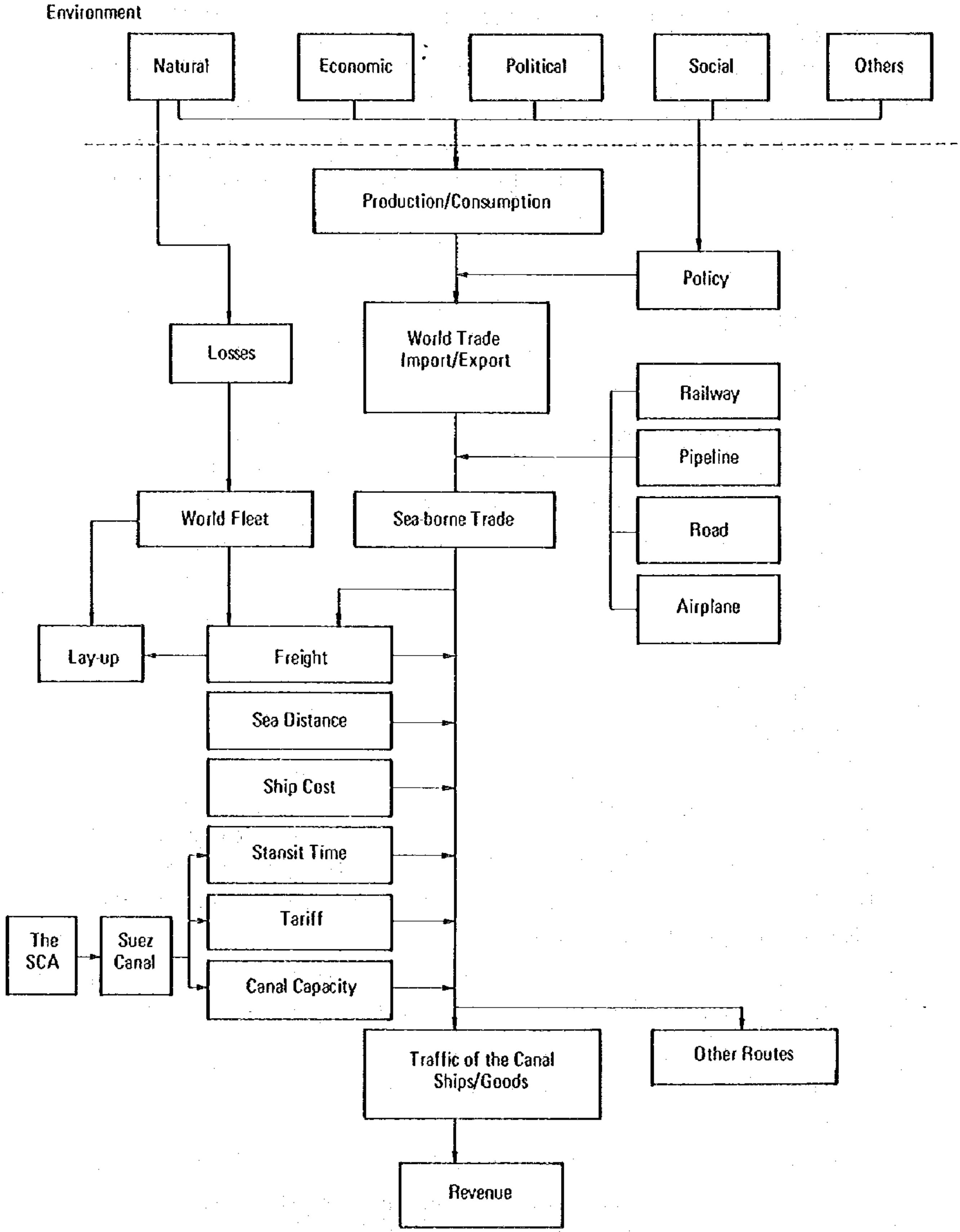


Fig. 1.1 A System Chart for Analysing Canal Traffic and Short Term Transit Forecasting

1.2 Causal Relationship between the Changes in the World and Traffic through the Canal

Causal relationship between environmental factors and Canal traffic is explained here according to the system chart shown in Fig. 1.1.

(1) Production and consumption of each country in the world is affected by its environmental changes. The environmental factors could be classified into the following groups.

1) Natural
2) Economic
3) Political
4) Social
5) Others

(2) The volume and pattern of world trade flow is determined by how production and consumption of goods are distributed in various regions. They are also affected by policy measures taken by governments of the world.

(3) Trade commodities are carried by various means of transportation such as:

1) Road
2) Rail
3) Pipeline
4) Airplane
5) Sea.

Shipping is the most important in the international carriage of goods. Trade made by sea is generally called as sea-borne trade. Construction of pipelines, railways, etc. will have affects on sea-borne trade. However, in the short term it could be assumed that there will be no change in the carriage capacities of these facilities.

(4) Freight rates will fluctuate according to the supply are demand condition. In other words, freight rates are determined by the relationship between:

1) the volume of goods to be carried by ship
and
2) available tonnage of the world fleet.

If the volume of goods to be transported increases and the tonnage of the world fleet is fixed, then the freight rate will increase.

(5) Route choice is made by considering the following factors such as:

1) Sea distance
2) Freight rate
3) Ship cost
4) Ship size
5) Tariff of the Suez Canal
6) Transit time of the Suez Canal.

The maximum number of ships which can transit the Canal is restricted by the Canal capacity.

(6) World fleet characteristics are affected by lay-up and losses. Shipbuilding is considered not to affect the world fleet characteristics in the time span of less than one year.

(7) The SCA could control the tariff, transit time, and capacity of the Canal, but they are also considered fixed in the short term analysis.

1.3 <u>Examples of Events Affecting the Traffic</u>

Examples of events which might potentially affect the traffic through the Canal are listed as follows:

(1) Growth of world economy
(2) Production of Egyptian cotton
(3) Japanese steel production
(4) Development of oil fields in the North Sea
(5) A poor harvest in USSR
(6) The demand for crude oil in Japan
(7) The demand for crude oil in the United States
(8) A housing construction plan started in the Arabian countries
(9) Production of crude oil in Alaska
(10) OPEC is going to hold a meeting and an oil price increase is expected
(11) The resident of the United States announces an energy conservation policy
(12) A rise in oil prices by OPEC countries
(13) Cold weather in North America
(14) ....
(15) ....

1.4 Summary of Procedures for Analysis and Short-term Forecasting

Procedures for short term forecasting of Canal traffic are briefly explained in this section.

The procedures of analysis and forecast are broken down into various methods and steps and technical details will be explained in the succeeding Chapters.

For analysis and short term forecasting of Canal traffic, a flow of the steps, starting from the analysis of "economic environment" and ending at the estimation of "Canal traffic" (Economic environment → Production/Consumption → World trade → Seaborne trade → Canal traffic) is of the highest importance.

Our purpose is to show how the analysis will be carried out according to the flow of the research steps and the procedures and models which are considered to closely represent the real world of sea-borne trade.

The system chart which was previously given is shown here again for explanation (Fig. 1.2).

In building mathematical models for short term forecasting, the factors listed in shaded blocks can be assumed to be constant and not variables of the models.

Freight rates, however, must occasionally be considered as variable even in short term forecasting.

It is suggested that a variety of mathematical models and procedures be employed for the analysis and short term forecasting of Canal traffic. These procedures are explained in the following paragraphs according to the order of simplicity of their procedures.

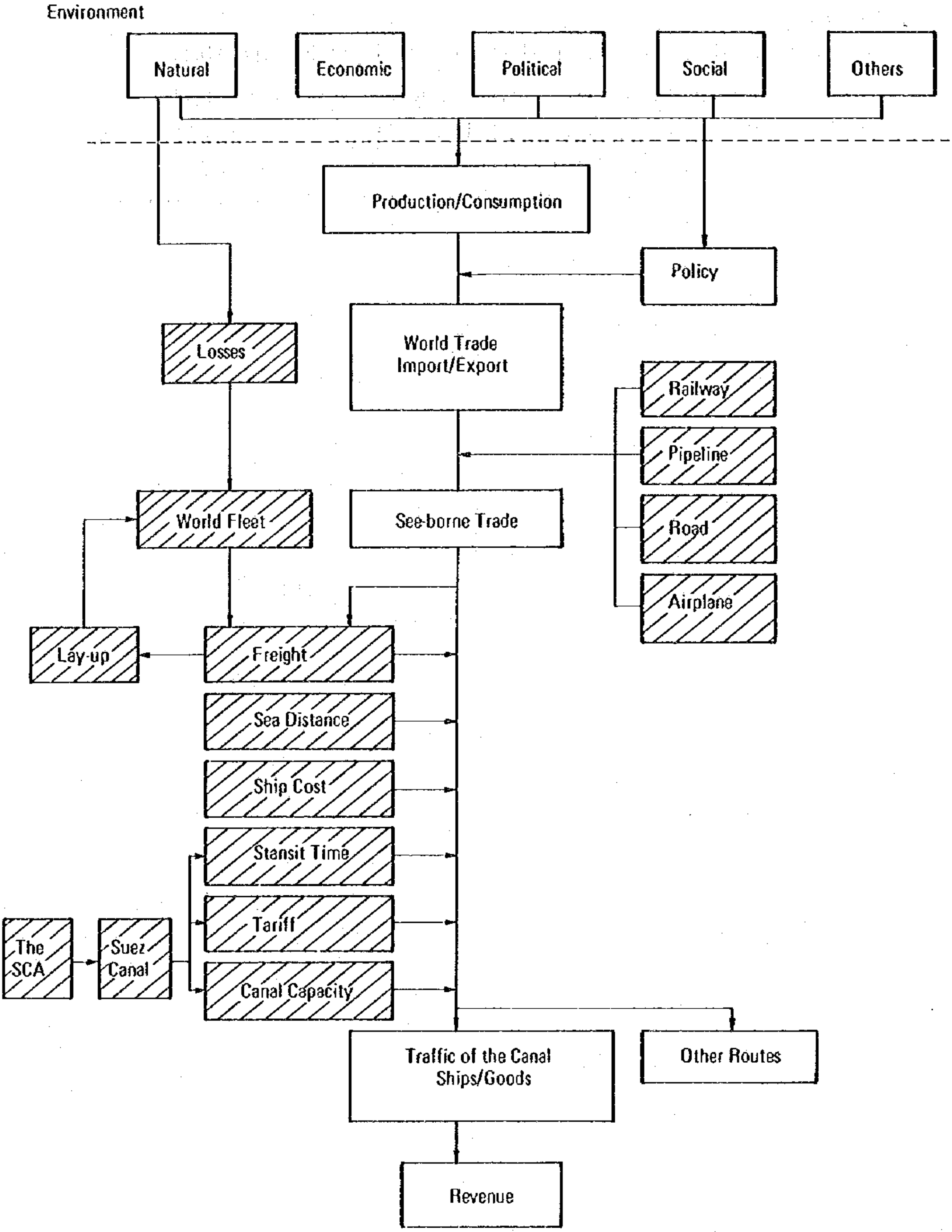


Fig. 1.2 A System Chart for Analysing Canal Traffic and Short Term Transit Forecasting

Procedure A

The simplest method by which past Canal traffic is extrapolated.

Traffic volume via the Canal is directly forecast by extrapolating the past value of the transit volume. Extrapolation will be made by a graphical method or by a regression method or just by using the growth rate. However, a separate forecast must be made for oil and non-oil products.

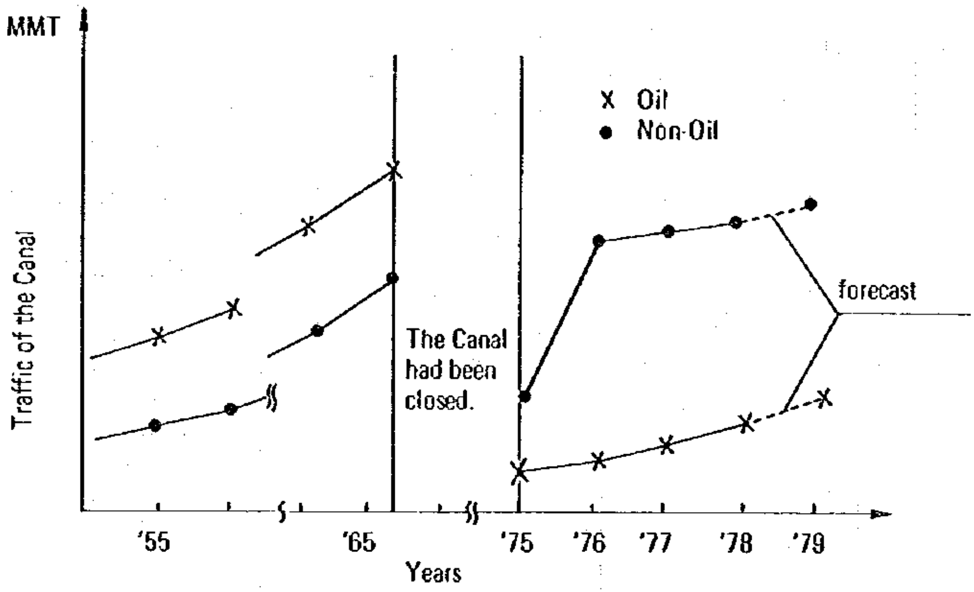


Fig. 1.3 Method of Extrapolation

Procedure B

The world seaborne movement for the following year is, first, forecast by extrapolating it's past value, or by regression analysis of relevant variables such as world seaborne trade volume and GDP indicator etc. The forecast value is to be multiplied by a coefficient which will represent the ratio of Canal traffic to the total seaborne movement. If the share for the Canal is predicted to be the same as that of this year, this year's ratio of Canal traffic to the world seaborne movement could be employed. However, the seaborne trade movement must be forecast by commodity such as oil and non-oil products.

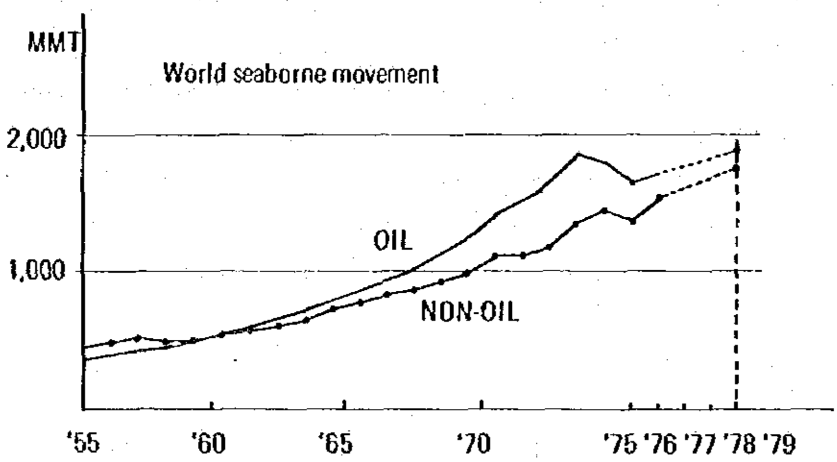


Fig. 1.4 Method of Trend Multiphication by Coefficient

Note: The forecast values of world seaforse movement for oil and non-oil products are multiplied by coefficients to estimate the traffic volume of the Canal.

Procedure C

Different forecasting procedures should be used for oil and non-oil products. The procedure of analysis for oil could be described in the simplest terms as follows;

1) world demand and supply of oil should be estimated first, and then
2) origin/destination pairs of sea-borne trade relevant to the Suez Canal must be selected
3) share of oil carried through the Canal should be estimated.

The same procedure could be used for non-oil products, but depending on the types of commodities, origin/destination pairs could be disregarded. It must be noted however that the procedure mentioned above is an simplified method and that more sophisticated methods must be used for the detailed analysis of the Canal transit volume by taking into consideration various factors such as ship costs, sea distance, freight rate etc. For rigorous analysis it is recommended that the "route choice model" be used in actual research work of the Economic Unit.

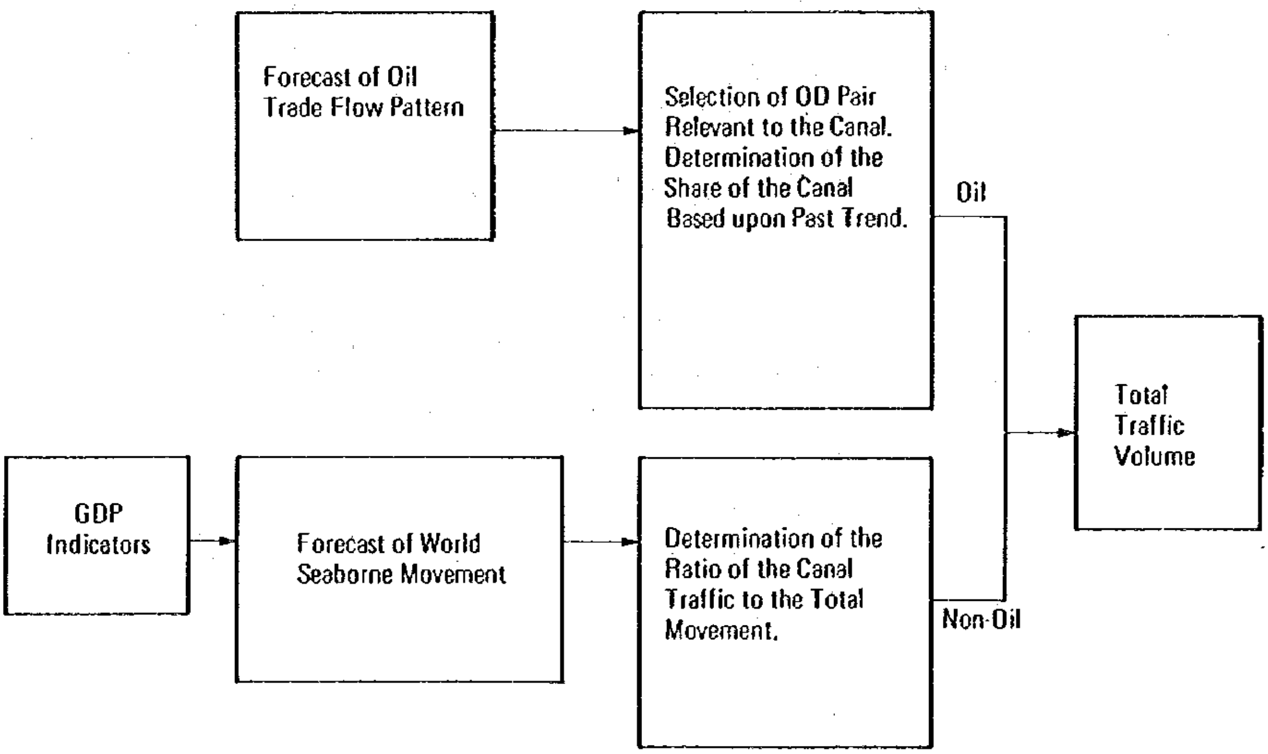


Fig. 1.4 Forecasting Steps of Procedure C

The number of ships transitting the Canal can be estimated simply by using a conversion ratio of the volume of commodity traffic to the number of ships.

The revenue of the SCA obtained from Canal traffic can also be estimated by using a conversion ratio of the volume of commodity traffic to the revenue.

Checks should be made as to whether the capacity of the Canal is sufficient for the traffic forecast.

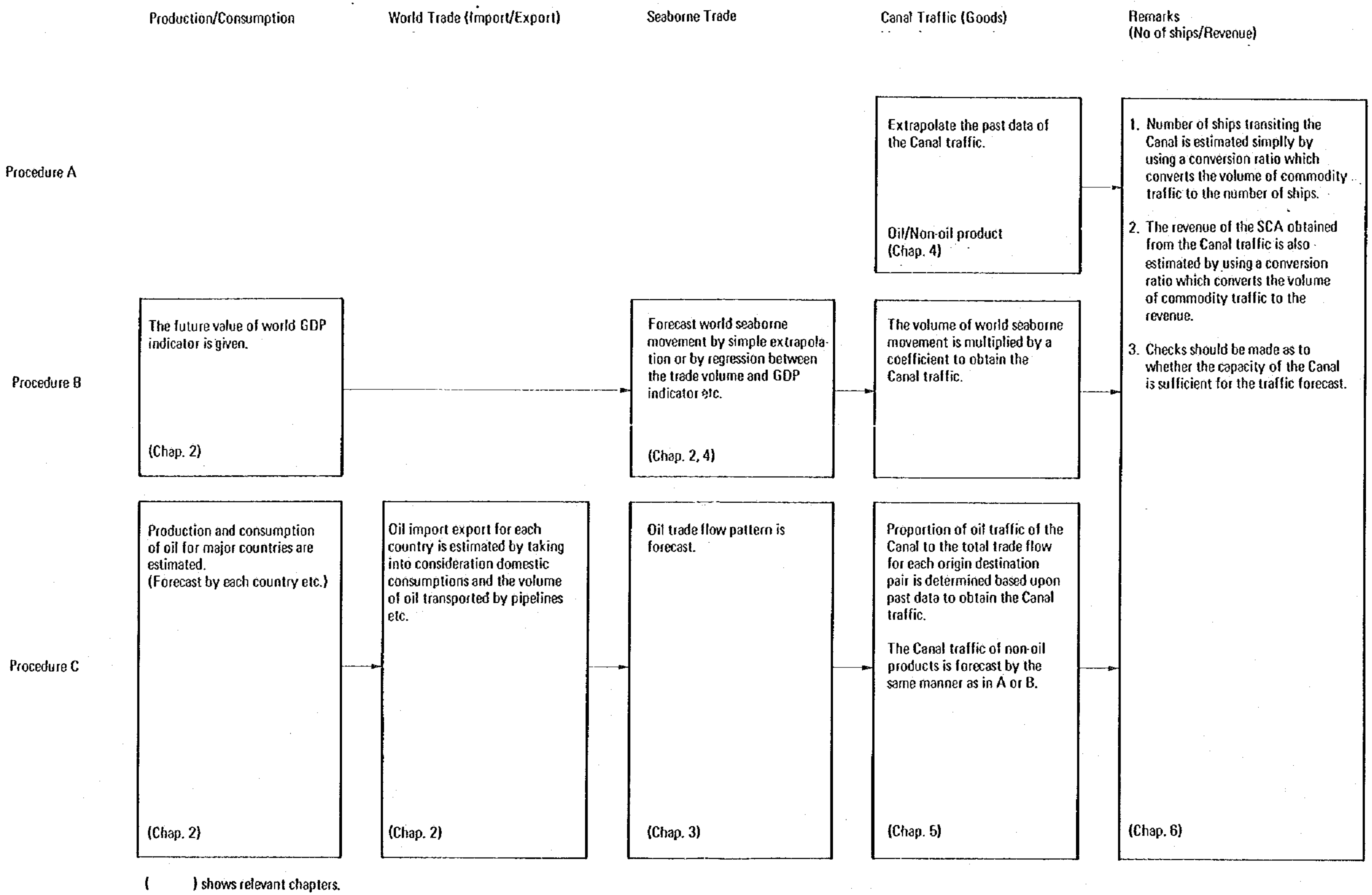


Fig. 1.5 Flow of Forecasting Steps

1.5 Exercises

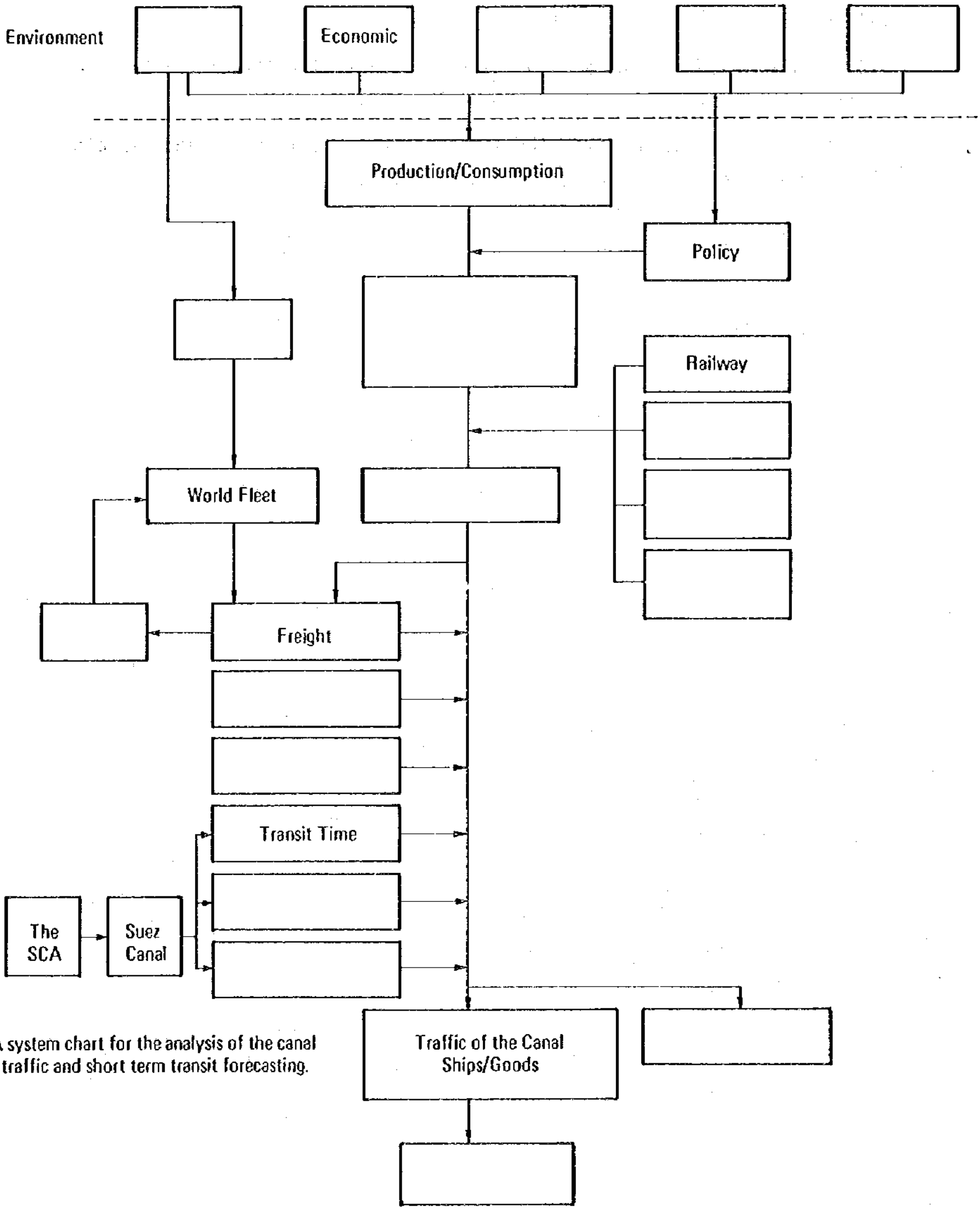
(1) Complete the System Chart.

(2) List up events which are supposed to potentially affect the traffic of the Suez Canal.

(3) Pick up some events from the lists shown in section 1-3 and explain the effect of the events on Suez Canal traffic.

Problem 1 Complete the System Chart

Name: ____________



A system chart for the analysis of the canal traffic and short term transit forecasting.

Problem 2 List up events which are supposed to potentially affect the traffic of the Suez Canal.

(1)

(2)

(3)

(4)

(5)

Problem 3 Pick up some events from the list shown in section 1.3 and explain the effect of the events on Suez Canal traffic.

(1) Event No.______

(2) Event No.______

(3) Event No.______

CHAPTER 2 WORLD ECONOMY AND TRADE ANALYSIS

2.1 General Remarks

The volume of trade flow is determined by the level of demand in consuming areas. For example, the volume of oil trade is dependent upon the total demand for energy along with the development of alternative sources of energy in consuming countries. The total demand for energy will depend upon gross domestic product and some other indicators of the economic development in those countries. That is the reason why world economy is studied in the present chapter. In this chapter, the term "world economy" means consumption/production of energy and some other selected products in the world.

The following are major terms under study in the chapter;

GDP growth in some selected countries and areas
sources and consumption of energy
non-oil products and
world trade of some of those above

The main emphasis is put on trend analysis and graphical presentation of them.

2.2 World Economy

2.2.1 GDP Growth

Table 2.1 shows the growth factors of Gross Domestic Products in some selected countries and areas. The percentage changes per annum from 1970 to 1977 are larger in North America (Canada and U.S.A.) and Japan than in OECD-Europe.

Table 2.2 shows the indicators of development (1970 base) in gross domestic product in OECD-total, North America, OECD-Europe and EEC.

Table 2.1 GDP Growth (percentage change at annual rates)

	1970–1977	1970–1974	1974–1977
Canada	4.7	6.0	2.9
USA	3.1	3.2	3.1
Japan	5.5	6.2	4.5
France	4.1	4.9	3.0
Germany	2.5	3.1	1.8
Italy	2.7	3.9	1.2
United Kongdom	1.8	2.8	0.6
OECD Total	3.4	3.9	2.8
North America	3.3	3.4	3.2
OECD-Europe	3.0	4.0	1.8
EEC	2.9	3.7	1.7

Calculated from Gross Domestic Product, Main economic indicators, OECD, Aug., 1978, which is shown at 1970 prices and 1970 exchange rates.

Table 2.2 GDP Development (1970=100)

	1972	1973	1974	1975	1976	1977
OECD Total	109.5	116.2	116.5	115.9	121.9	126.5
North America	109.1	115.3	114.2	113.3	119.9	125.5
OECD-Europe	108.2	114.4	116.8	115.5	120.5	123.1
EEC	107.6	113.8	115.7	113.8	119.2	121.8

Calculated from the same source as Table 2.1

2.2.2 Source and Consumption of Energy

(1) Energy Source

We have various sources of energy. They are usually grouped into oil, natural gas, solid fuels, waterpower and nuclear. There are other sources; wind power, geothermal energy, solar energy and so on. However, they may be considered a negligible share of the total in the near future.

(2) Oil and Natural Gas Reserves

World "published proven" reserves at the end of 1977 are shown in Table 2.3 (excluding the oil content of shale and tar sand). We have reserves of 88.6 thousand million tonnes of oil and 71.4 trillion cubic meters of natural gas in the world. It is remarkable that more than half of the world published proven oil is held in the Middle East area (55.9%). As for natural gas reserves, U.S.S.R. has a more than a one-third share (36.5%) of the total and the Middle East has 28.5%.

Note that proven crude oil reserves are generally taken to mean the volume of oil remaining in the ground which geological and engineering information indicate, with reasonable certainty, to be recoverable in the future from known reservoirs under existing economic and operating conditions and that the relationship between proven reserves and total in places varies according to local conditions and can vary in time with economic and technological changes.

Table 2.3 World "Published and Proved" Reserves of Oil and Natural Gas at the End of 1977

Country/Area	OIL			NATURAL GAS		
	Thousand Million Tonnes	Share of Total	Thousand Million Barrels	Trillion* Cubic Feet	Share of Total	Trillion* Cubic Metres
U.S.A.	4.6	5.4%	35.5	208.8	8.3%	5.9
Canada	1.0	1.2%	7.9	59.5	2.4%	1.7
Total North America	5.6	6.6%	43.4	268.3	10.7%	7.6
Latin America	5.7	6.2%	40.4	108.6	4.3%	3.1
Total Western Hemisphere	11.3	12.8%	83.8	376.9	15.0%	10.7
Western Europe	3.7	4.2%	27.2	138.7	5.5%	3.9
Middle East	49.7	55.9%	365.8	719.1	28.5%	20.4
Africa	7.9	9.0%	59.2	207.5	8.2%	5.9
U.S.S.R.	10.2	11.5%	75.0	920.0	36.5%	26.0
Eastern Europe	0.4	0.5%	3.0	10.0	0.4%	0.3
China	2.7	3.1%	20.0	25.0	1.0%	0.7
Other Eastern Hemisphere	2.7	3.0%	19.7	122.7	4.9%	3.5
Total Eastern Hemisphere	77.3	87.2%	569.9	2,143.0	85.0%	60.7
World (Excl. U.S.S.R., E. Europe & China)	75.3	84.9%	555.7	1,564.9	62.1%	44.4
World	88.6	100.0%	653.7	2,519.9	100.0%	71.4

Source: BP Statistical review of the world oil industry 1977.

*Trillion: 10^{12}; one million million.

(3) Oil Production

Cumulative production between 1857 and 1977 and reserves at the end of 1977 are shown in Fig. 2.1. The U.S.A. has the largest cumulative production in the last 120 years, the Middle East second largest and U.S.S.R., etc. third.

In the last 20 years, however, the Middle East has produced the largest volume, nearly 12 thousand million tons which is about 87% of its cumulative production in the last 120 years. The U.S.A. has produced, in the same period, 52% of the cumulative production in the last 120 years.

We can see that the Middle East has made a rapid increase in the production volume in recent years. Note that we can arrive at the total amount of oil discovered by adding cumulative production and reserves in Fig. 2.1.

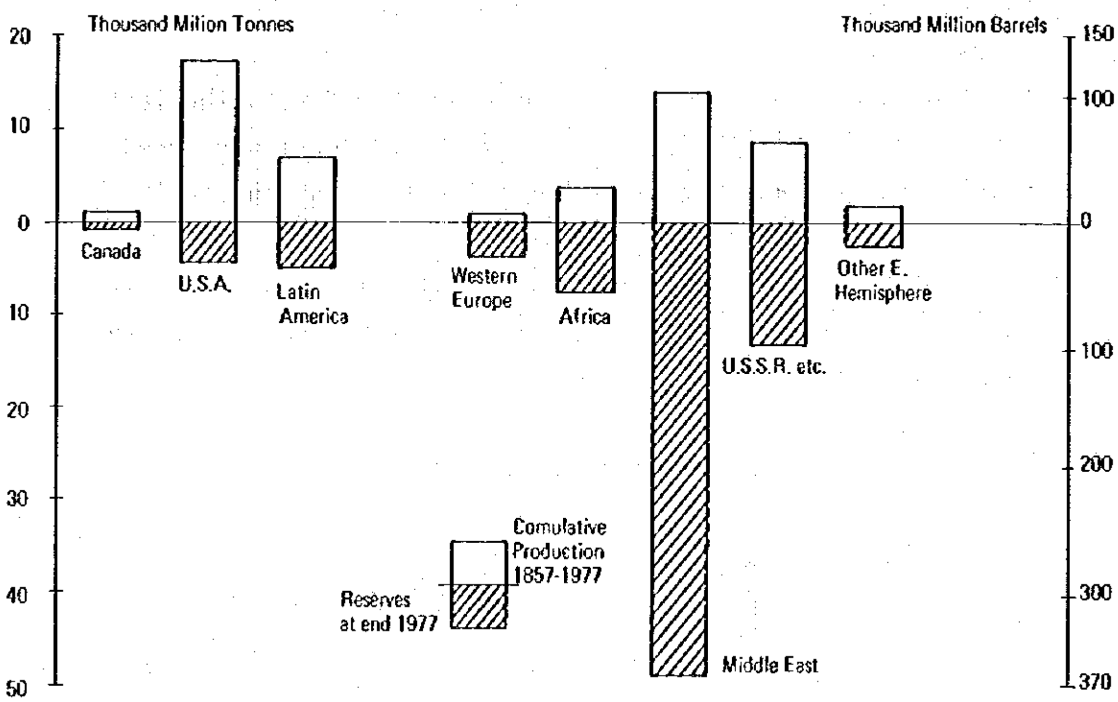


Fig. 2.1 Total Discovered Oil

Source : BP statistical review of the world oil industry 1977

World oil production in the last 11 years also shows a rapid increase in oil production in the Middle East (see B.P. Statistical Review) while the total western hemisphere (north and Latin America) remains at nearly constant production level for the period. Historical changes in the share of total production is shown in Fig. 2.2.

As a share of the total, the Middle East increased from 27% in 1967 to 36% in 1977, while the western hemisphere decreased from 44% to 26%.

Fig. 2.3 is a graphical representation of the trend in production volume in selected areas and countries; North America, Middle East and U.S.S.R.. The broken lines were obtained by assuming a linear relationship between production volume and time, though no test of significance of linear regression has been made.

Fig. 2.3 shows that

1) the Middle East has increased production rapidly in the last eleven years (1967-1977) and in 1977 the production reached nearly as twice as much as in North America, though in 1967 it was nearly at the same level,
2) as for the U.S.S.R., the yearly production line falls almost on the regression line, which means that the yearly increase is nearly fixed.

Note: Based on the data of B.P. Statistical Review

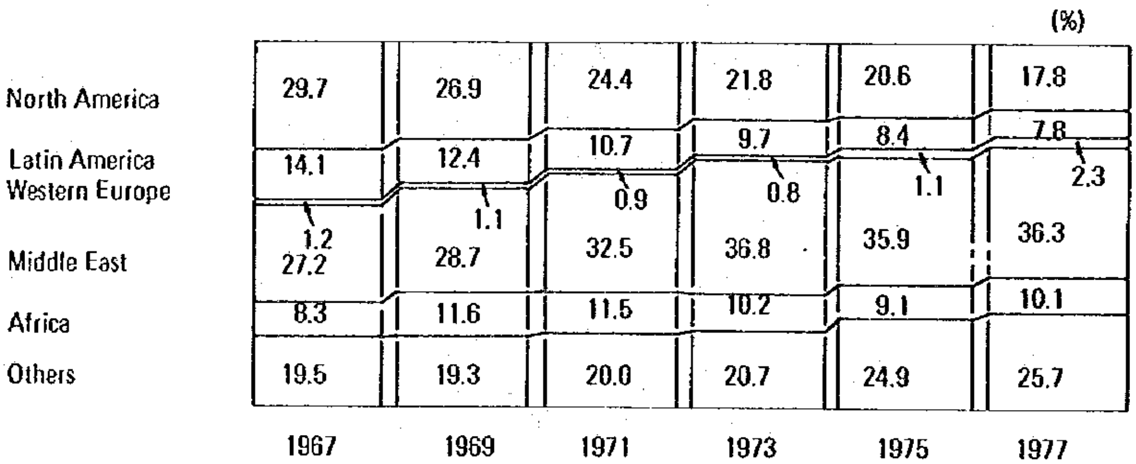


Fig. 2.2 Share of Total Oil Production

Note: Based on the data of B.P. Statistical Review

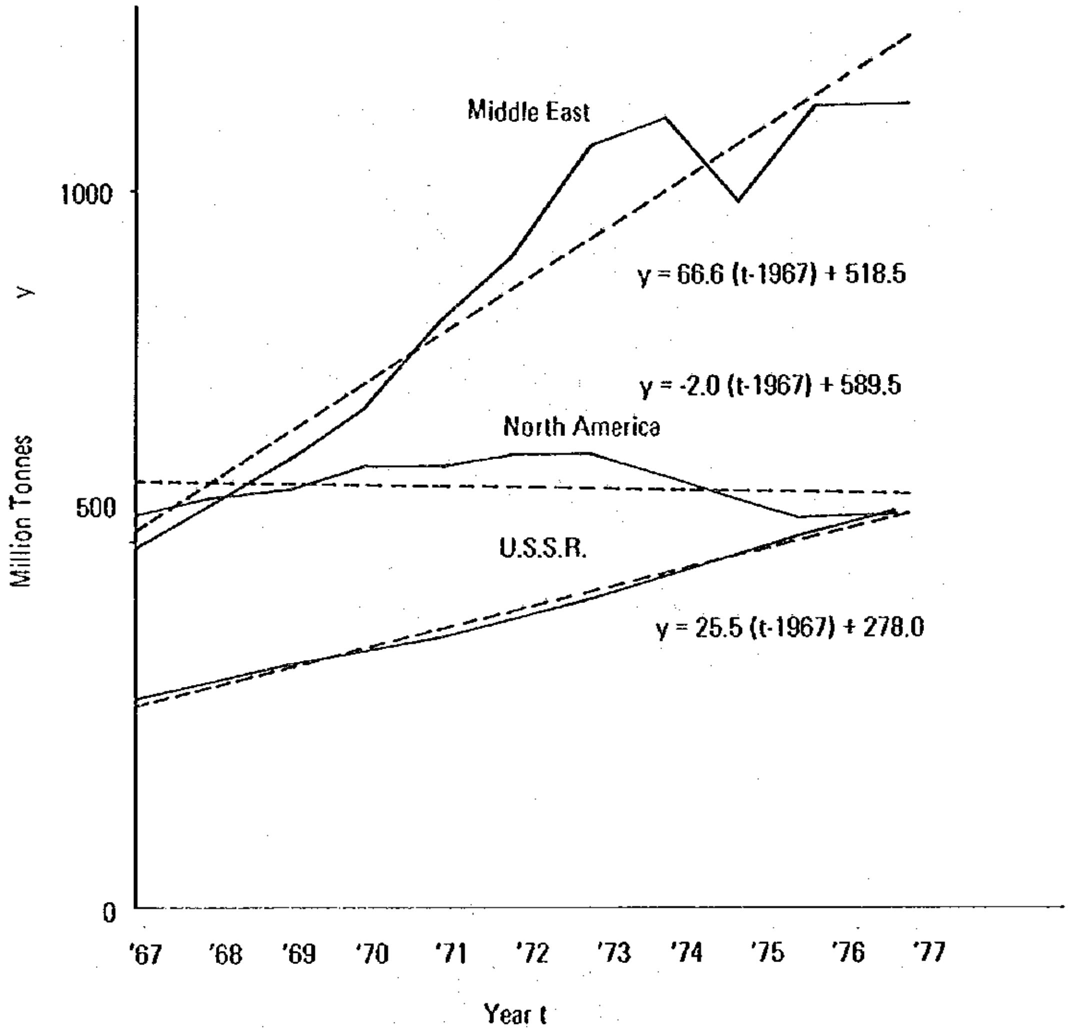


Fig. 2.3 Linear Regression of Oil Production on Time

A far more accurate short term forecast for oil production in the U.S.S.R. is expected.

3) North America has been stagnant in production, that is, the United States and Canada. The former decreased in production from 487.9 (Million tonnes) in 1967 to 465.5 in 1977, while the latter increased from 53.8 to 75.7 over the same period. (See B.P. Statistical Review).

(4) Energy Consumption

Primary energy consumption in the world is shown in B.P. Statistical Review.

In Fig. 2.4 can be seen the energy consumption per capita vs. gross domestic product per capita in two cross-sections, 1970 and 1976.

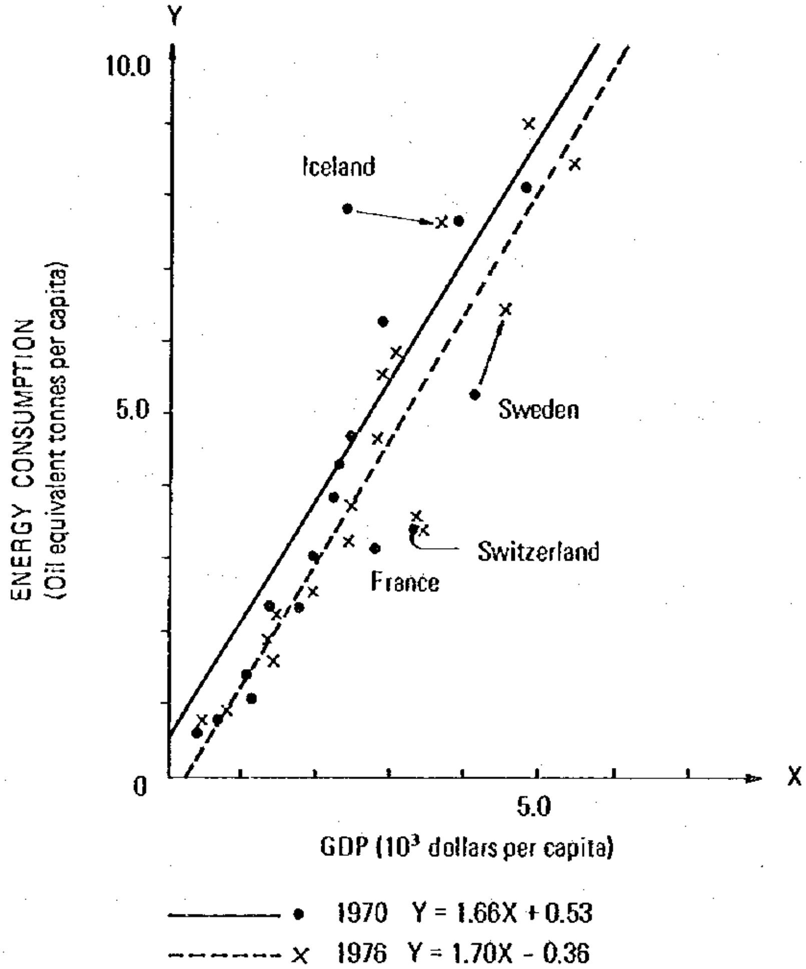


Fig. 2.4 Energy Consumption vs. GDP

The solid and broken lines were obtained through the method of least squares by assuming a linear relationship between energy consumption per capita and gross domestic product per capita in the year 1970 and 1976 respectively.

The correlation coefficients are 0.83 and 0.91, both of which, though no test of significance of the correlation coefficients has been done, are regarded large enough to assume a linear relationship between the two quantities.

The following is noteworthy:

1) The linear relationship is assumed to exist between energy consumption and gross domestic product (both, per capita).

2) The line of regression of energy consumption on gross domestic product may shift to the right in time, though it is not conclusive.

3) Though there are some isolated scattered points, for example, Iceland, France, Switzerland and Sweden, there seems to exist the possibility for us to make a short term forecast of energy consumption for a given gross domestic product and population. The reason why we have to say "short term" is that the shift, if any, of the regression line will be regarded as negligibly small in a short period.

(5) Energy Balance by Sources

The major sources of energy are grouped into oil, natural gas, solid fuels and waterpower/nuclear. Table 2.5 shows world energy consumption by source, and Table 2.6, the yearly change in percentage of consumption in the last ten and five years.

It is a remarkable fact that yearly changes in percentage of both oil and natural gas consumption in the last five years are nearly half of those in the last ten years, while those of solid and waterpower/nuclear are larger than those in the last ten years.

Table 2.5 World Energy Consumption by Source
(Million tonnes oil equivalent)

Source \ Year	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Oil	1769	1926	2097	2275	2399	2572	2773	2730	2701	2882	2972
Natural gas	755	822	903	955	1022	1040	1071	1102	1089	1139	1168
Solid fuels	1652	1729	1773	1801	1794	1790	1837	1870	1891	1965	2036
Waterpower/Nuclear	277	291	311	328	348	365	383	412	447	472	511
World*	4452	4768	5084	5358	5564	5768	6064	6115	6128	6458	6687

Source: BP statistical review of the world oil industry 1977

* : World does not necessarily coincide with the sum of sources because of rounding off.

Table 2.6 Yearly Change in Energy Consumption by Source

Source	1977 over 1967	1977 over 1972
Oil	5.3%	2.9%
Natural Gas	4.5%	2.3%
Solid Fuels	2.1%	2.6%
Waterpower/Nuclear	6.3%	7.0%
World	4.1%	3.0%

Source: BP statistical review of the world oil industry 1977

In the following a very primary short term forecast of energy balance by source is tried. The problem is to forecast the energy balance in the year 1980 provided that world energy consumption in three years from 1977 grows by the same yearly percentage change as in the last five years, that is, by 3.0% per annum.

1) World energy consumption grows to 7308 million tonnes oil equivalent in the year 1980.
2) Assuming that consumption of each source grows in three years from the year 1977 by the same change as given by the last column in Table 2.6, consumption of each source in 1980 grows to

Oil	3238	(million tonnes)
Natural Gas	1250	(million tonnes oil equivalent)
Solid Fuels	2199	
Waterpower/Nuclear....	626	
Total	7313	

3) The sum is 7313 million tonnes of oil equivalent, which is a little over the world forecast of 7308. Some adjustment is needed.
4) Noting that world consumption of 7308 should be fixed because it is a control total, the sum of 7313 is world adjusted. One way of convenient adjustment is to allocate the world 7308 in proportion to each consumption in the year 1980. By convenience way we have

Oil	3236	(44.3)
Natural Gas	1249	(17.1)
Solid Fuels	2197	(30.0)
Waterpower/Nuclear	626	(8.6)
	7308	(100)

where the figures in parenthesis mean the share of the total.

5) Table 2.7 shows the changes in the balance of world energy consumption by source.

However, we have to pay attention to the fact that the above process of forecasting the energy balance disregards any changes that may happen in economic and technological conditions.

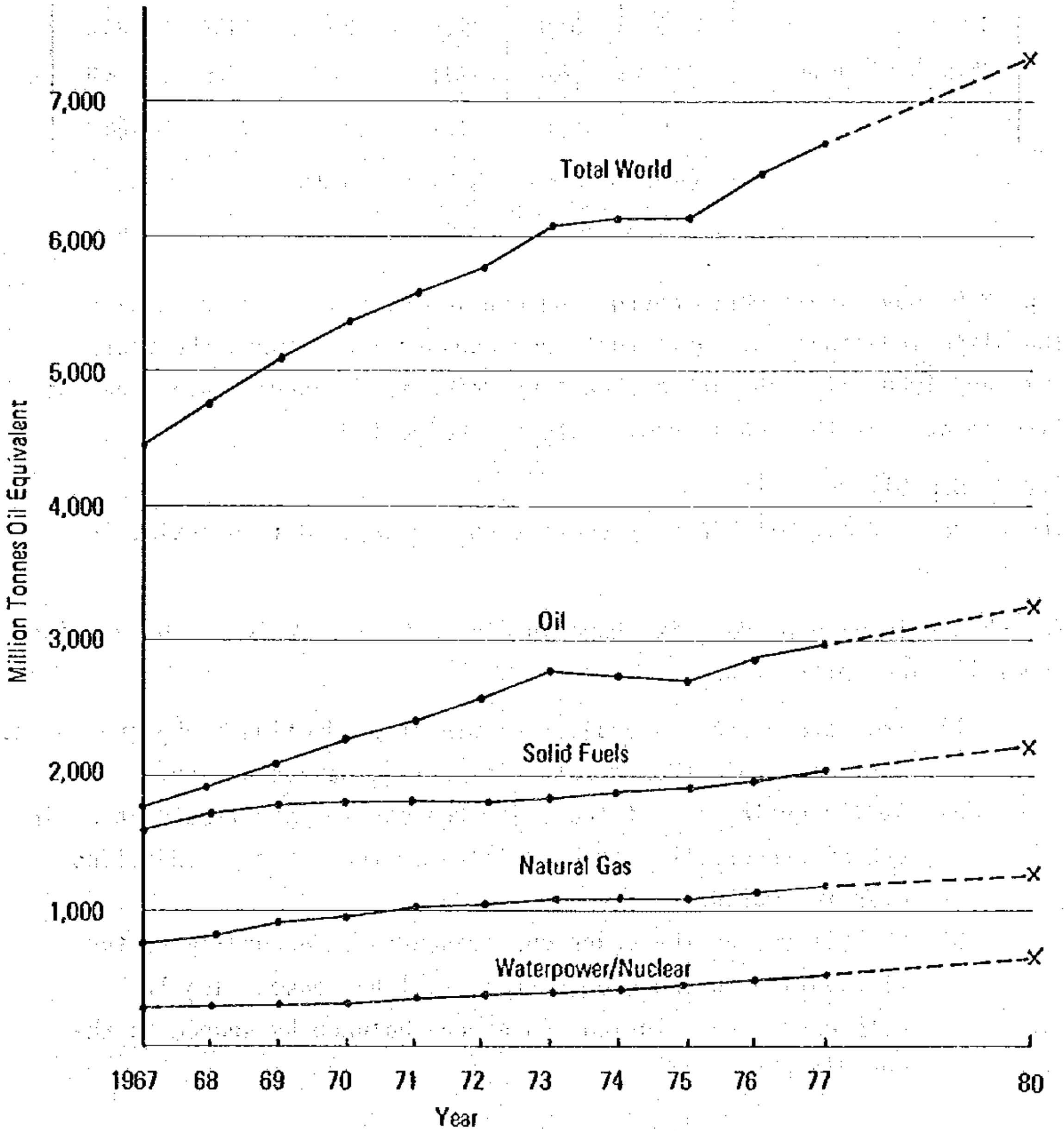


Fig. 2.5 World Energy Consumption by Source

Table 2.7 Short Term Forecast of World Energy Consumption by Source (Million tonnes oil equivalent)

Source	1972		1977		1980*	
Oil	2572	44.6%	2972	44.4%	3236	44.3%
Natural Gas	1040	18.0	1168	17.5	1249	17.1
Solid Fuels	1790	31.0	2036	30.4	2197	30.0
Waterpower/Nuclear	365	6.4	511	7.7	626	8.6
World	5768	100.0	6687	100.0	7308	100.0

*: Consumption forecast is shown in Fig. 2.5

Fig. 2.5 above shows world energy consumption by source forecast with the historical changes. Note that each consumption between the years 1977 and 1980 falls on each broken line which is an approximate straight line because of the small growth rate in the period.

2.2.3 Non-Oil Products

The products dealt with in this subsection are grouped into grain, iron ore and coal.

The change in each product is shown in Fig. 2.6, from which we have gained the following information:

1) Iron ore has the steadiest growth of production among the three. Coal and grain show a rather time-fluctuation growth.
2) As for grain, one of the major reasons for the flucturation in the growth process may be related to the weather conditions over the world.
3) Coal is one of the major energy sources. Accordingly, the fluctuation in the growth trend will be caused largely by both energy consumption and energy balance by source in the world/areas.

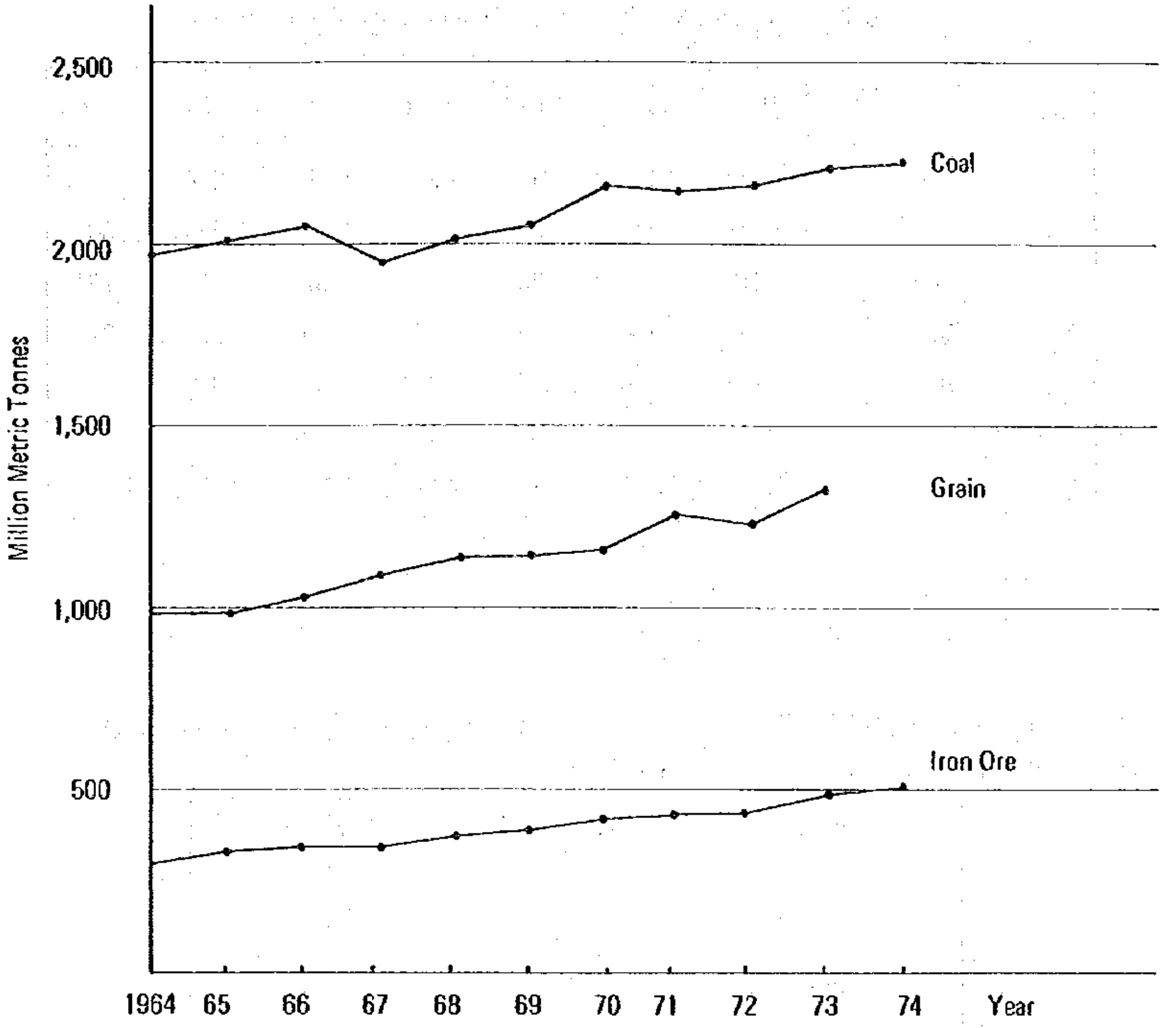


Fig. 2.6 World Selected Non-Oil Products

Table 2.8 World Selected Non-Oil Products Trend (Million Metric Tonnes)

Product \ Year	1964	1969	1970	1971	1972	1973	1974
Grain	977	1,143	1,161	1,258	1,232	1,328	
Wheat	277	314	318	354	347	377	360
Corn	216	267	262	306	305	311	294
Rice	265	296	309	309	296	324	322
Others*	219	266	272	289	284	316	
Iron Ore	301	387	424	430	440	485	508
Coal	1,966	2,051	2,164	2,140	2,162	2,208	2,227

Source: U.N. Statistical Yearbook

*: Including barley, oats, rye and soybeans.

Based on data in Table 2.8 , the annual average growth rates from the year 1964 to 1974 are shown as follows:

Product	1964 – 1974	1969 – 1974
Grain	3.5%*	3.8%*
Wheat	2.7	2.8
Corn	3.1	2.0
Rice	2.0	1.7
Others	4.1 *	4.4 *
Iron Ore	5.4	5.6
Coal	1.2	1.7

*: 1964 – 1973, 1969 – 1973 respectively

Assuming the average growth rate per annum between the years 1974 and 1978 to be the same as given in the last column obtained above, we have in the year 1978 the following products in million metric tonnes;

Grain	1,600
Iron Ore	631
Coal	2,383

Note, however, that (1) grain products are likely to suffer from unseasonable weather conditions resulting in a larger products variance and (2) the conditions of world energy consumption and balance by source have to be taken into consideration in forecasting the coal product.

2.3 World Trade

2.3.1 Oil

The changes in the share of exports from and imports to country/area are shown in Figs. 2.7 (1) and (2), respectively, which are based on the data of B.P. Statistical Review, P. 30.

From Fig. 2.7 some information is obtained on the share of total export and import of oil;

1) The Middle East's, West Africa's and South East Asia's each share has been expanding since the year 1967. The three areas have expanded the sum of their share from about 56% in the year 1967 to 71% in 1977. It is especially noticeable that West Africa and South East Asia have rapidly expanded their share, from 2.5% in 1967 to 7% and from 2.2% to 5% respectively.
2) North and Latin America's and North Africa's share of exports have been on the decline, among the three Latin America's has declined most rapidly. Various reasons may exist for these declinations; decrease in its own oil production, increase in its domestic oil consumption, increase in oil production in country/area within a shorter hauling distance from the major consuming country/area and oil prices and so on.
3) U.S.S.R., Eastern Europe and China have been rather stagnant in their export share.
4) As for imports, the United States of America's share has rapidly expanded, especially in the last five years. On the other hand, Western Europe's share has declined from 51% in the year 1967 to 38% in 1977. The Western European declination of share is remarkable especially in the last five years. Japan and the rest of the world have both been rather stagnant.
5) One of the reasons why the Western European share of oil import has declined sharply, especially in the last five years, may be because of the development of oil production in its own area (See B.P. Statistical Review).

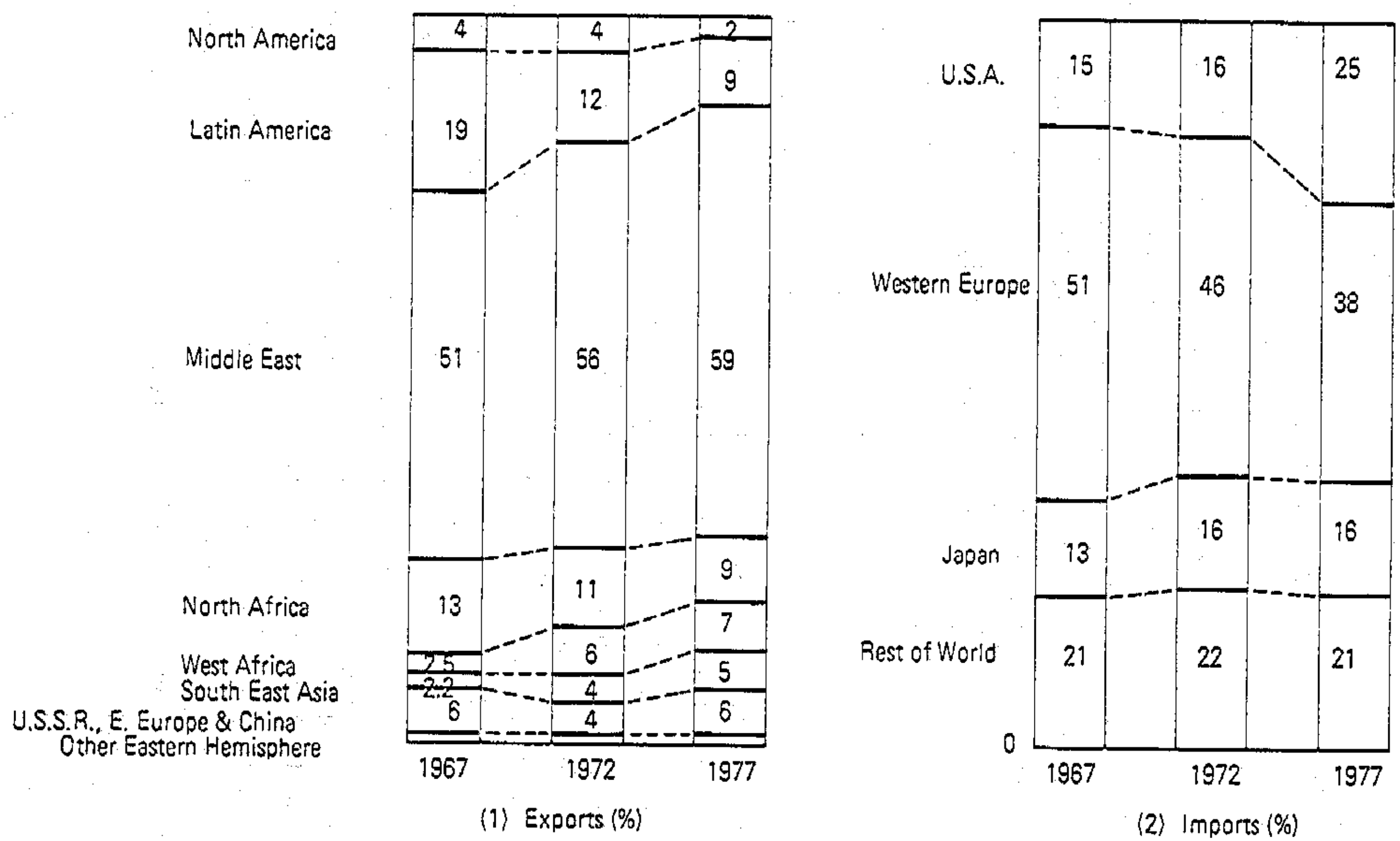


Fig. 2.7 Export and Import Share Trend

Source: Derived from BP Statistical review of the world oil industry 1977

Inter-country/area oil movements are dependent essentially on the world energy consumption and balance by source, which in turn is influenced by the conditions of inter-country/area oil movements. The relationship between them is regarded as rather complicated.

Anyway, Exports from and imports to country/area are correspondent to the marginal distributions of the Origin-Destination table showing inter-country/area oil movements. Oil exports from and imports to country/area are shown by the values placed in the right hand column and the bottom row in the OD-table, respectively. Each element in the OD-table, except for the right hand column and row, means the oil movement between two countries/areas.

2.3.2 Non Oil Product

(1) Grain Trade

The trend is shown in Table 2.9 and Fig. 2.8. Total exports seem to increase with a certain oscillatory fluctuation. Wheat and Wheat Meal export has a trend pattern analogous to the total.

The Wheat and Wheat Meal Share declined in total grain exports, from 62% in the year 1963/64 to 46% in 1973/74. The exports of others expanded from 38% to 54%.

In total grain exports the annual average growth rate is 4.7% in the ten years from 1963/64 to 1973/74, and that of wheat and wheat meal is 1.6% over the same period. Accordingly, the exports of others grew at a larger rate in the period.

Attention should be paid to the fluctuation around the average trend of growth as seen in Fig. 2.8. One of the reasons for the fluctuation is considered to be the unseasonable weather conditions in the producing country/area. In a sense, as accurate forecast of grain products and exports/imports is largely dependent on weather forecasting over the world.

Table 2.10 shows the shares of major exporting countries and the shares of major importing countries areas.

In the year 1973/74, North America exported about 64% of total grain exports, and Western Europe about two-thirds of total imports. Egypt and Japan are both importing countries.

Table 2.9 World Grain Trade in Selected Years

Products \ Year*	Million Metric Tonnes		
	Imports		
	1963/1964	1968/1969	1973/1974
Wheat & Wheat Meal	53.8 (62)	42.7 (52)	63.7 (46)
Others **	32.8 (38)	38.9 (48)	75.3 (54)
Total	86.6 (100)	81.6 (100)	139.0 (100)
	Exports		
Wheat & Wheat Meal	55.2 (62)	43.7 (53)	64.7 (46)
Others **	33.2 (38)	39.1 (47)	76.0 (54)
Total	88.4 (100)	82.8 (100)	140.7 (100)

Source: Compiled from FAO World Grain Trade Statistics
*: from July to June
**: including rye, barley, oats, corn and others.

Table 2.10 Share of Major Exporting and Importing Countries/Areas 1973/74

Export		Import	
Country	%	Country/Area	%
U.S.A.	53.8	Western Europe	35.1
Canada	10.4	Japan	14.0
France	13.3	India	3.4
Australia	5.2	China	5.5
Argentina	6.8	U.S.S.R.	7.4
Rest of World	10.5	Egypt	2.6
		Rest of World	32.0
World	100.0	World	100.0

Source: Derived from data in FAO World Grain Trade Statistics

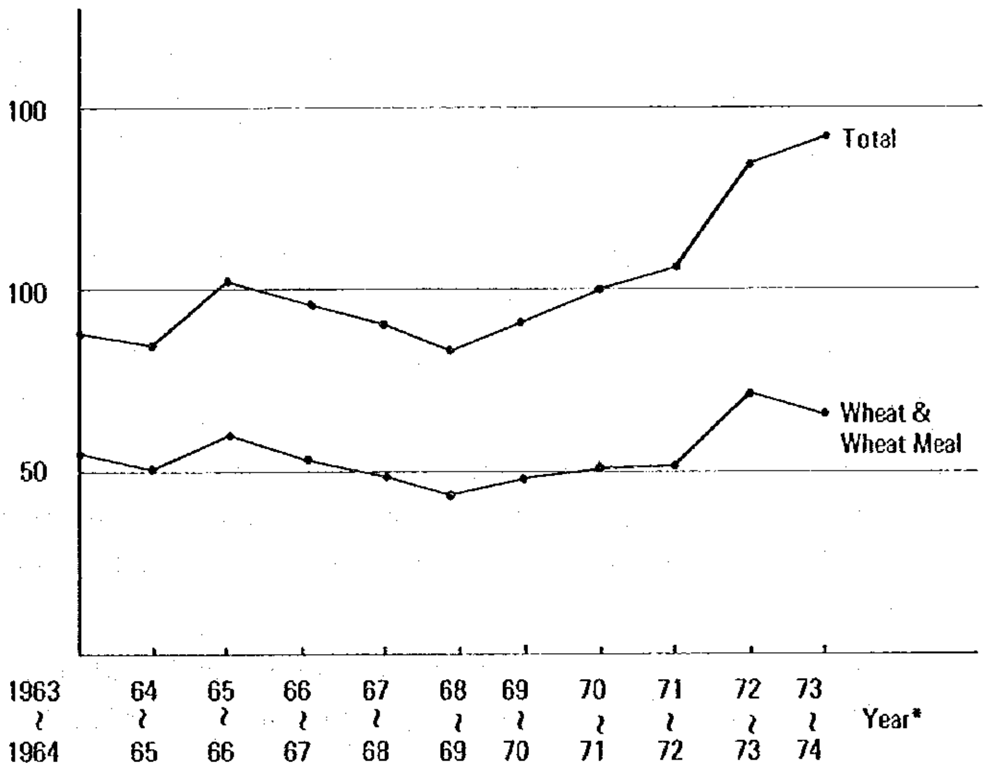


Fig. 2.8 World Grain Export Trend

Source: FAO World Grain Trade Statistics
*; from July to June

(2) Other Trade

This includes coal, iron ore and other non-oil products. No analysis of them, however, is made here because we have studied some methodologies of general outlook on world trade. Some parts of them will be referred to in other chapters, for example, as seaborne trade.

2.4 Exercises

(1) Calculate the annual average percentage change in GDP of OECD total and EEC in the year 1977 over 1973, using the data in Table 2.2 and logarithm table.

(2) Find when the world crude oil reserves at end 1977 (Table 2.3) will be exhausted, in each of the following cases

1) the world oil production grows at an annual rate of 3.1% after 1977, while no additional reserves are recoverable
2) after 1977 the oil production continues to grow at an annual rate of 5.3% with added annual reserves of 1.0%.

(3) Using the method of least squares, find the value of the parameters a and b for the following equation

$$y = a\,(t - 1967) + b$$

where

y = oil production in the total South East Asia area at year t

t = 1967, 1968, ..., 1977

Notice: Appendix 2.1 is available

(4) Using the same method as above, find the linear regression line of energy consumption per cpita (y) on the GDP per capita (x), based on the data at year 1970 in Appendix 2.6 excluding the data for Iceland, Sweden and Switzerland.

(5) 1) Plot the same data (x_i, y_i) as used above in the x-y plan
2) Lay down the linear regression line obtained in exercise 4 in the plane
3) Calculate the correlation coefficient between x and y to compare with the corresponding one shown at the bottom of Appendix 2.6. Notice: Use the formula

r (correlation coefficient between x and y)

$$= \Sigma (x_i - \bar{x})(y_i - \bar{y})/[\Sigma(x_i-\bar{x})^2]^{1/2} [\Sigma(y_i-\bar{y})^2]^{1/2}$$

or

$$= [\Sigma x_i y_i - n\bar{x}\bar{y}]/[\Sigma x_i^2 - n\bar{x}^2]^{1/2} [\Sigma y_i^2 - n\bar{y}^2]^{1/2}$$

where

x_i = per capita GDP of sample country i in 1970

y_i = per capita energy consumption of sample country i in 1970

$\bar{x},\bar{y}$ = sample means of x_i, y_i

n = sample size (in the present case, n=14)

(6) Following the method in pp. 78 - 79, try to forecast the energy balance in the year 1981 assuming that after 1977 world energy consumption grows at an annual rate of 2.5% and each source continues to be consumed at an annual rate as shown in the last column of Table 2.6.

(7) Using the world oil consumption in 1981 as forecast above, fill up the marginal column and row of the table showing inter-country/area oil movement in 1981 assuming that (1) the ratio of world oil exports or imports to the world oil consumption* is the same as in 1977, (2) each country's/area's share of world oil exports and imports is also the same as in 1977 (Appendix 2.5).

* nearly equal to the production

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CHAPTER 3 SEABORNE TRADE ANALYSIS

3.1 Introduction

Knowledge of world seaborne trade movements is the most important factor in the analysis of maritime transport. Cargo produced and loaded in each country is carried from origin and destination in a ship. It is especially useful for us to perceive quantities and commodities of seaborne trade.

Many statistical books or yearbooks show the movement of commodities in the world by unit in metric tons, ton-kilometers and ton-miles. It is necessary to notice the cargo of seaborne trade, i.e., important commodities such as crude oil, oil products, grain, coal, and iron ore, as these commodities are characteristics of ship utilization for the reasons of low transport cost.

The total quantity of seaborne trade by commodities and regions is also an important factor. This shows the state of movement of commodities in the world. If a matrix called an origin destination table is tabulated on commodities, it clearly shows the commodity movement from origin to destination. In addition, an origin destination matrix is the most fundamental method often used to forecast the cargo demand. And if the structure characteristics on commodity movement between zones are grasped, it is possible to forecast world seaborne trade in the future.

By the way, it is also important to forecast the quantity of cargo produced and loaded in the future. In this chapter linear regression analysis is explained to forecast cargo demand.

Finally, the growth and iteration method is explained to converge the future pattern of world seaborne trade.

3.2 World Seaborne Trade Analysis

The world seaborne trade demand for each year can be seen by referring to the statistical data from yearbooks. And if a graph by commodities is made, the yearly change can be read. It is important to obtain useful information.

3.3 World Seaborne Trade by Commodities

Natural resources are produced in certain parts of the world. Therefore, there are producing and consuming countries. Generally speaking, it is said that two types of countries exist, i.e., producing and consuming.

Then, movement is generated to carry the commodity from origin to destination. World seaborne trade is mainly taken up with natural resources and materials. Crude oil, oil products, coal and iron ore play as especially important role in world seaborne trade. These cargoes depend on maritime transport.

The movement of such commodities varies with the changes in trade, technological innovation and oil crises. World seaborne trade may decrease or increase for these reasons, and maritime transport is affected by world affairs.

3.4 Origin Destination Matrix and Analysis

3.4.1 Origin Destination Matrix

Cargoes are carried from one place to another in a ship, aircraft or other vehicles. Places which produce and attract cargoes are called origin and destination, respectively. The combination of origin and destination represents the quantity of cargo from origin to destination.

An origin and destination matrix is defined as a matrix which indicates the quantity of cargo that is carried between regions by a transport means within a period.

Table 3.1 shows an origin destination matrix.
The notations in Table 3.1 are as follows:

- i: origin zone
- j: destination zone
- T_{ij}: the quantity of cargo from origin zone i to destination zone j
- A_j: the total quantity of cargo attracted in zone j.
- B_i: the total quantity of cargo produced in zone i.
- T: the total quantity of cargo under study

In general the origin and destination is in the same zone in the origin destination matrix, i.e., m=n. This is called a square origin destination matrix. In this case the elements on the diagonal in the origin destination matrix shows a quantity of cargo within a zone and the residual elements of the quantity of cargo between zones. This origin destination matrix is shown in the urban transportation survey.

But a restangular origin destination matrix is made in maritime transportation, since the origin destination zones are different countries. Therefore, a rectangular origin destination matrix is used in the following sections.

Table 3.1 Origin Destination Matrix

O \ D	1	2	· · ·	j	· · ·	n	$\sum_j T_{ij}$
1	T_{11}	T_{12}	· · ·	T_{1j}	· · ·	T_{1n}	B_1
2	T_{21}	T_{22}	· · ·	T_{2j}	· · ·	T_{2n}	B_2
·	·	·		·		·	·
·	·	·		·		·	·
·	·	·		·		·	·
i	T_{i1}	T_{i2}	· · ·	T_{ij}	· · ·	T_{in}	B_i
·	·	·		·		·	·
·	·	·		·		·	·
·	·	·		·		·	·
m	T_{m1}	T_{m2}	· · ·	T_{mj}	· · ·	T_{mn}	B_m
$\sum_i T_{ij}$	A_1	A_2	· · ·	A_j	· · ·	A_n	T

A rectangular origin destination matrix is made by regions, cargoes and transport means.

3.4.2 Analysis of Origin Destination Matrix

The normalized method is the simplest method for analysis of the origin destination matrix. This is called a normalized origin destination matrix. The normalized origin destination matrix is defined as a matrix made by multiplying all the figures in the origin destination matrix obtained in practice by C/T. C is arbitrary. If C is chosen as 100 or 1000, all the elements in the normalized origin destination matrix show units in per cent or per mill, respectively.

The normalized origin destination matrix is a method that makes a clear structure of transport between regions and cargo.

Mathematically it can be expressed as follows:

Table 3.2 Normalized Origin Destination Matrix

O \ D	1	2	· · · · · ·	j	· · · · ·	n	$\sum_j t_{ij}$
1	t_{11}	t_{12}	· · · · · ·	t_{1j}	· · · · ·	t_{1n}	b_1
2	t_{21}	t_{22}	· · · · · ·	t_{2j}	· · · · ·	t_{2n}	b_2
·	·	·		·		·	·
·	·	·		·		·	·
·	·	·		·		·	·
i	t_{i1}	t_{i2}	· · · · · ·	t_{ij}	· · · · ·	t_{in}	b_i
·	·	·		·		·	·
·	·	·		·		·	·
·	·	·		·		·	·
m	t_{m1}	t_{m2}	· · · · · ·	t_{mj}	· · · · ·	t_{mn}	b_m
$\sum_i t_{ij}$	a_1	a_2	· · · · · ·	a_j	· · · · ·	a_n	t

$$t_{ij} = C \cdot \frac{T_{ij}}{T} \qquad (3\text{-}1)$$

$$a_j = C \cdot \frac{A_j}{T} \qquad (3\text{-}2)$$

$$b_i = C \cdot \frac{B_i}{T} \qquad (3\text{-}3)$$

$$t = C \cdot \frac{T}{T} = C \qquad (3\text{-}4)$$

Table 3.2 shows a normalized origin destination matrix.

3.5 Seaborne Trade Demand Forecasting

When the total quantity of cargo produced and attracted, or gross future cargo by region is forecast, variables concerning the transport quantity are used for making a model. An econometric model is usually used to forecast the seaborne trade demand.

First of all, the real change in the transport quantity is analyzed by data, and a model is made to show the change of transport quantity.

Secondly, the transport quantity in the future is forecast by substituting a forecast value into explanatory variable in the model.

A forecast value of an explanatory variable is necessary with this method.

In general the forecast equation is represented as follows:

$$f = g(X_1, X_2, \ldots, X_n) \qquad (3\text{-}5)$$

where f: dependent variable.

g: the function of $X_1, X_2, \ldots, X_n$.

$X_i (i=1,2,\ldots,n)$: the explanatory variable.

For simplicity, it assumes that the equation is linear as follows:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + \ldots + a_n X_n \qquad (3\text{-}6)$$

where y: the dependent variable.

$X_i (i=1,2,\ldots,n)$: the independent variable relating to socio-economic characteristics.

$a_i (i=1,2,\ldots,n)$: the coefficients of the respective independent variable.

a_0: a constant included to represent that portion of the value of y not explained by the independent variables.

In a typical regression analysis, the given data relates to the present-day values of the dependent variable y and the independent variables X_1 to X_n, for all regions under study. The statistical technique of the least squares fitting process is applied to determine those values of the regression coefficients a_1 to a_n and the constant a_0 which best fit the given data.

The following equations are an econometric model most often used to forecast demand in all kinds of fields.

$$Y = a + b \cdot X \qquad (3\text{-}7)$$

$$\log Y = a + b \cdot X \qquad (3\text{-}8)$$

where Y: dependent variable
X: independent variable
b: coefficient
a: constant

These are called structural equations in economics.
This is applied to forecast demand in the same manner.

3.6 Cargo Distribution Forecasting

Cargo distribution is an important part of the transportation planning process which relates to a given quantity of cargo origins for every zone under study, to a given quantity of cargo destinations located within the other zones. It is not necessarily concerned with the means of transportation used for a given movement, nor the routes which could be taken to complete this movement. Rather, it is concerned with establishing the links between a number of zones for which cargo generation calculations have previously been made.

Mathematical procedures tend to fall into two main groups.

(1) Growth factor methods — in which growth factors are applied to present-day interzonal movements.

(2) Iteration method — in which iterations are applied to present-day interzonal movements.

3.6.1 Constant-Factor Method

Future origin destination forecasting is obtained by multiplying an observed value of cargo distribution during a survey period by a constant-factor. The formulation can be expressed as follows:

$$T_{ij} = k \cdot T_{ij} \qquad (3\text{-}9)$$

where $\bar{T}_{ij}$: future quantity of cargo from zone i to zone j.
T_{ij}: present quantity of cargo from zone i to zone j.
k : constant-factor.

The constant-factor in the equation (3-9) has to be equal to a value of the future quantity of cargo $\bar{T}$ divided by the present quantity of cargo T, i.e.,

$$k = \frac{\overline{T}}{T} \qquad (3\text{-}10)$$

Because the future value of cargo in an origin destination matrix must be held as the following relation:

$$\sum_{j=1}^{n} \sum_{i=1}^{m} \overline{T}_{ij} = \overline{T} \qquad (3\text{-}11)$$

If equation (3-9) is substituted into equation (3-11),

$$\sum_{j=1}^{n} \sum_{i=1}^{m} k \cdot T_{ij} = \overline{T} \qquad (3\text{-}12)$$

Therefore,

$$k \sum_{j=1}^{n} \sum_{i=1}^{m} T_{ij} = \overline{T} \qquad (3\text{-}13)$$

i.e., the following equation holds:

$$k \cdot T = \overline{T} \qquad (3\text{-}14)$$

The constant-factor method is calculated for the entire zones under study. If a future origin destination matrix holds the same structure of the present origin destination matrix, it is available to forecast future cargo distribution.

This is applied to the normalized origin destination in the same manner.

3.6.2 Constant-Factor Method by Origins

This method is calculated for future cargo distribution by origins. Mathematically the formulation can be expressed as follows:

$$\begin{aligned} \overline{T}_{1j} &= p_1 \cdot T_{1j} \\ \overline{T}_{2j} &= p_2 \cdot T_{2j} \\ &\vdots \\ \overline{T}_{mj} &= p_m \cdot T_{mj} \end{aligned} \qquad (3\text{-}15)$$

where

$$p_1 = \frac{\overline{B}_1}{B_1}, \; p_2 = \frac{\overline{B}_2}{B_2}, \; \ldots\ldots\ldots\ldots, \; p_m = \frac{\overline{B}_m}{B_m} .$$

This method assumes that the constitution ratio of transport quantity by origins is constant in the future.

The constitution ratio of transport quantity by origins is represented with t_{ij}^* as follows:

$$t_{ij}^* = \frac{T_{ij}}{B_i} \qquad (3\text{-}16)$$

If this future value is $t_{ij}^{*'}$ and is equal to t_{ij}^*, the following equation holds:

$$t_{ij}^{*'} = t_{ij}^{*} \qquad (3\text{-}17)$$

Therefore,

$$\frac{T_{ij}'}{B_i'} = \frac{T_{ij}}{B_i} \qquad (3\text{-}18)$$

where T_{ij}': future quantity of cargo from zone i to zone j.

B_i : future total quantity of cargo in origin i.

On the other hand,

$$B_i' = p_i \cdot B_i \qquad (3\text{-}19)$$

If the equation (3-19) is substituted into the equation (3-18),

$$T_{ij}' = p_i \cdot T_{ij} \qquad (3\text{-}20)$$

where T_{ij}' is unknown.

Then, T_{ij}' replaces with $\overline{T}_{ij}$, i.e.,

$$\overline{T}_{ij} = T_{ij}' \qquad (3\text{-}21)$$

From the equations (3-19) and (3-21), the following equation is obtained:

$$\overline{T}_{ij} = p_i \cdot T_{ij} \qquad (3\text{-}22)$$

3.6.3 Constant-Factor Method by Destinations

This method is calculated for future cargo distribution by destinations. Mathematically the fomulation can be expressed as follows:

$$\left.\begin{array}{l} \overline{T}_{i1} = q_1 \cdot T_{i1} \\ \overline{T}_{i2} = q_2 \cdot T_{i2} \\ \quad\vdots \\ \overline{T}_{in} = q_n \cdot T_{in} \end{array}\right\} \qquad (3\text{-}23)$$

where

$$q_1 = \frac{\overline{A}_1}{A_1},\ q_2 = \frac{\overline{A}_2}{A_2},\ \ldots\ldots\ldots\ldots\ldots,\ q_n = \frac{\overline{A}_n}{A_n}.$$

This method assumes that the constitution ratio of transport quantity by destinations is constant in the future.

The constitution ratio of transport quantity by destinations can be expressed with t_{ij}^{**} as follows:

$$t_{ij}^{**} = \frac{T_{ij}}{A_j} \qquad (3\text{-}24)$$

If this future value is $t_{ij}^{**'}$ and is equal to t_{ij}^{**}, the following equation holds.

$$t_{ij}^{**} = t_{ij}^{**} \qquad (3\text{-}25)$$

Therefore,

$$\frac{T'_{ij}}{A'_j} = \frac{T_{ij}}{A_j} \qquad (3\text{-}26)$$

where T'_{ij}: future quantity of cargo from zone i to zone j.

A_j': future total quantity of cargo in destination j.

On the other hand,

$$A'_i = q_j A_j \qquad (3\text{-}27)$$

If the equation (3-27) is substituted into the equation (3-26), the following equation holds:

$$T'_{ij} = q_j T_{ij} \qquad (3\text{-}28)$$

where T'_{ij} is unknown.

Then, T_{ij} replaces with $\overline{T}_{ij}$, i.e.,

$$\overline{T}_{ij} = T'_{ij} \qquad (3\text{-}29)$$

From the equation (3-27) and (3-29), the following equation is obtained:

$$\overline{T}_{ij} = q_j T_{ij} \qquad (3\text{-}30)$$

3.7 Iteration Method

3.7.1 Furness Method

This method was proposed by K.P. Furness in 1962 for calculating future traffic.

The first step in this method is as follows:

$$T_{ij}^{(1)} = T_{ij} \frac{\overline{B}_i}{\sum_{j=1}^{n} T_{ij}} \qquad (3\text{-}31)$$

where $\overline{B}_i$: future total quantity of cargo in origin i.

The second step is the following procedure:

$$T_{ij}^{(2)} = T_{ij}^{(1)} \frac{\overline{A}_j}{\sum_{i=1}^{m} T_{ij}^{(1)}} \qquad (3\text{-}32)$$

where A_j: future total quantity of cargo in destination i.

The third step is carried out in the same manner as the first step:

$$T_{ij}^{(3)} = T_{ij}^{(2)} \frac{\overline{B}_i}{\sum_{j=1}^{n} T_{ij}^{(2)}} \qquad (3\text{-}33)$$

A modified value is obtained by this modification.

The fourth step is carried out in the same manner as the second step:

$$T_{ij}^{(4)} = T_{ij}^{(3)} \frac{\overline{A}_j}{\sum_{i=1}^{m} T_{ij}^{(3)}} \qquad (3\text{-}34)$$

The same procedure continues.

In general, the modified value of cargo distribution at step (2S-1) is as follows:

$$T_{ij}^{(2s-1)} = T_{ij}^{(2s-2)} \frac{\overline{B}_i}{\sum_{j=1}^{n} T_{ij}^{(2s-1)}} \qquad (3\text{-}35)$$

And the modified value of cargo distribution at step (2s) is as follows:

$$T_{ij}^{(2s)} = T_{ij}^{(2s-1)} \frac{\overline{A}_j}{\sum_{i=1}^{m} T_{ij}^{(2s-1)}} \qquad (3\text{-}36)$$

As a result of the modification, when the modified values of cargo distribution at step r, i.e., the total modified quantity of cargo distribution by origins and destinations are equal to the future total quantity of cargo by origins and destinations, respectively, the calculations for modification are stopped, i.e.,

$$\sum_{j=1}^{n} \bar{T}_{ij}^{(r)} \fallingdotseq \bar{B}_i \qquad (3\text{-}37)$$

$$\sum_{i=1}^{m} \bar{T}_{ij}^{(r)} \fallingdotseq \bar{A}_j \qquad (3\text{-}38)$$

Then, the modified values of cargo distribution are used for the future quantity of cargo from origin i to destination j:

$$\bar{T}_{ij} = \bar{T}_{ij}^{(r)} \qquad (3\text{-}39)$$

3.7.2 Average-Factor Method

The modified quantity of cargo distribution at the first step is computed in the following manner:

$$\left.\begin{aligned} \bar{T}_{ij}^{(1)} &= \frac{1}{2} T_{ij} \left[\frac{\bar{B}_i}{B_i} + \frac{\bar{A}_j}{A_j} \right] \\ B_i &= \sum_{j=1}^{n} T_{ij} \; , \; A_j = \sum_{i=1}^{m} T_{ij} \end{aligned}\right\} \qquad (3\text{-}40)$$

The second step is carried out in the same as the first step.

$$\left.\begin{aligned} \bar{T}_{ij}^{(2)} &= \frac{1}{2} \bar{T}_{ij}^{(1)} \left[\frac{\bar{B}_i}{\bar{B}_i^{(1)}} + \frac{\bar{A}_j}{\bar{A}_j^{(1)}} \right] \\ \bar{B}_i &= \sum_{j=1}^{n} \bar{T}_{ij}^{(1)} \; , \; \bar{A}_j = \sum_{i=1}^{m} \bar{T}_{ij}^{(1)} \end{aligned}\right\} \qquad (3\text{-}41)$$

In general, the step s is as follows:

$$\left.\begin{aligned} \bar{T}_{ij}^{(s)} &= \frac{1}{2} \bar{T}_{ij}^{(s-1)} \left[\frac{\bar{B}_i}{\bar{B}_i^{(s-1)}} + \frac{\bar{A}_j}{\bar{A}_j^{(s-1)}} \right] \\ \bar{B}_i^{(s-1)} &= \sum_{j=1}^{n} \bar{T}_{ij}^{(s-1)} \; , \; \bar{A}_j^{(s-1)} = \sum_{i=1}^{m} \bar{T}_{ij}^{(s-1)} \end{aligned}\right\} \qquad (3\text{-}42)$$

The process of iteration is continued until the new average-factors approximate to unity.

Then, if the following equations hold, the process of iteration is stopped.

$$\sum_{j=1}^{n} T_{ij}^{(s)} \doteqdot \bar{B}_i \qquad (3\text{-}43)$$

$$\sum_{i=1}^{m} T_{ij}^{(s)} \doteqdot \bar{A}_j \qquad (3\text{-}44)$$

The modified quantity of cargo distribution is the future quantity of cargo from origin i to destination j.

3.7.3 Frator Method

The first step is as follows:

$$T_{ij}^{(1)} = T_{ij}\frac{\bar{B}_i}{B_i}\ \frac{\bar{A}_j}{A_j}\left[\frac{\sum_{j=1}^{n} T_{ij}}{\sum_{j=1}^{n}\left(\frac{\bar{A}_j}{A_j}\right) T_{ij}} + \frac{\sum_{i=1}^{m} T_{ij}}{\sum_{i=1}^{m}\left(\frac{\bar{B}_i}{B_i}\right) T_{ij}}\right]\frac{1}{2} \qquad (3\text{-}45)$$

$$B_i = \sum_{j=1}^{n} T_{ij}\ ,\quad A_j = \sum_{i=1}^{m} T_{ij}$$

In general the modified quantity of cargo distribution at step s is as follows:

$$T_{ij}^{(s)} = T_{ij}^{(s-1)}\ \frac{\bar{B}_i}{B_i^{(s-1)}}\ \frac{\bar{A}_j}{A_j^{(s-1)}} \times \left[\frac{\sum_{j=1}^{n} T_{ij}^{(s-1)}}{\sum_{j=1}^{n}\left(\frac{\bar{A}_j}{A^{(s-1)}}\right) T_{ij}^{(s-1)}} + \frac{\sum_{i=1}^{m} T_{ij}^{(s-1)}}{\sum_{i=1}^{m}\left(\frac{\bar{B}_i}{B_i^{(s-1)}}\right) T_{ij}^{(s-1)}}\right] \times \frac{1}{2} \qquad (3\text{-}46)$$

where

$$B_i^{(s-1)} = \sum_{j=1}^{n} T_{ij}^{(s-1)}\ ,\quad A_j^{(s-1)} = \sum_{i=1}^{m} T_{ij}^{(s-1)}\ .$$

If the following equations hold, the process of iteration is stopped.

$$\sum_{j=1}^{n} T_{ij}^{(s)} \doteqdot \bar{B}_i \qquad (3\text{-}47)$$

$$\sum_{i=1}^{m} T_{ij}^{(s)} \doteqdot \bar{A}_j \qquad (3\text{-}48)$$

As a result of the modification, when the modified values of cargo distribution at step r, i.e., the total modified quantity of cargo distribution by origins and destinations are equal to the future total quantity of cargo by origins and destinations, respectively, the calculations for modification are stopped, i.e.,

$$\sum_{j=1}^{n} \bar{T}_{ij}^{(r)} \fallingdotseq \bar{B}_i \tag{3-37}$$

$$\sum_{i=1}^{m} \bar{T}_{ij}^{(r)} \fallingdotseq \bar{A}_j \tag{3-38}$$

Then, the modified values of cargo distribution are used for the future quantity of cargo from origin i to destination j:

$$\bar{T}_{ij} = \bar{T}_{ij}^{(r)} \tag{3-39}$$

3.7.2 Average-Factor Method

The modified quantity of cargo distribution at the first step is computed in the following manner:

$$\left.\begin{aligned} \bar{T}_{ij}^{(1)} &= \frac{1}{2} T_{ij} \left[\frac{\bar{B}_i}{B_i} + \frac{\bar{A}_j}{A_j} \right] \\ B_i &= \sum_{j=1}^{n} T_{ij} , \quad A_j = \sum_{i=1}^{m} T_{ij} \end{aligned}\right\} \tag{3-40}$$

The second step is carried out in the same as the first step.

$$\left.\begin{aligned} \bar{T}_{ij}^{(2)} &= \frac{1}{2} \bar{T}_{ij}^{(1)} \left[\frac{\bar{B}_i}{\bar{B}_i^{(1)}} + \frac{\bar{A}_j}{\bar{A}_j^{(1)}} \right] \\ \bar{B}_i &= \sum_{j=1}^{n} \bar{T}_{ij}^{(1)} , \quad \bar{A}_j = \sum_{i=1}^{m} \bar{T}_{ij}^{(1)} \end{aligned}\right\} \tag{3-41}$$

In general, the step s is as follows:

$$\left.\begin{aligned} \bar{T}_{ij}^{(s)} &= \frac{1}{2} \bar{T}_{ij}^{(s-1)} \left[\frac{\bar{B}_i}{\bar{B}_i^{(s-1)}} + \frac{\bar{A}_j}{\bar{A}_j^{(s-1)}} \right] \\ \bar{B}_i^{(s-1)} &= \sum_{j=1}^{n} \bar{T}_{ij}^{(s-1)} , \quad \bar{A}_j^{(s-1)} = \sum_{i=1}^{m} \bar{T}_{ij}^{(s-1)} \end{aligned}\right\} \tag{3-42}$$

The process of iteration is continued until the new average-factors approximate to unity.

Then, if the following equations hold, the process of iteration is stopped.

$$\sum_{j=1}^{n} \bar{T}_{ij}^{(s)} \doteqdot \bar{B}_i \qquad (3\text{-}43)$$

$$\sum_{i=1}^{m} \bar{T}_{ij}^{(s)} \doteqdot \bar{A}_j \qquad (3\text{-}44)$$

The modified quantity of cargo distribution is the future quantity of cargo from origin i to destination j.

3.7.3 Frator Method

The first step is as follows:

$$\bar{T}_{ij}^{(1)} = T_{ij} \frac{\bar{B}_i}{B_i} \frac{\bar{A}_j}{A_j} \left[\frac{\sum_{j=1}^{n} T_{ij}}{\sum_{j=1}^{n} \left(\frac{\bar{A}_j}{A_j}\right) T_{ij}} + \frac{\sum_{i=1}^{m} T_{ij}}{\sum_{i=1}^{m} \left(\frac{\bar{B}_i}{B_i}\right) T_{ij}} \right] \frac{1}{2} \qquad (3\text{-}45)$$

$$B_i = \sum_{j=1}^{n} T_{ij} \;, \quad A_j = \sum_{i=1}^{m} T_{ij}$$

In general the modified quantity of cargo distribution at step s is as follows:

$$\bar{T}_{ij}^{(s)} = \bar{T}_{ij}^{(s-1)} \frac{\bar{B}_i}{\bar{B}_i^{(s-1)}} \frac{\bar{A}_j}{\bar{A}_j^{(s-1)}} \times \left[\frac{\sum_{j=1}^{n} \bar{T}_{ij}^{(s-1)}}{\sum_{j=1}^{n} \left(\frac{\bar{A}_j}{\bar{A}^{(s-1)}}\right) \bar{T}_{ij}^{(s-1)}} + \frac{\sum_{i=1}^{m} \bar{T}_{ij}^{(s-1)}}{\sum_{i=1}^{m} \left(\frac{\bar{B}_i}{\bar{B}_i^{(s-1)}}\right) \bar{T}_{ij}^{(s-1)}} \right] \times \frac{1}{2} \qquad (3\text{-}46)$$

where

$$\bar{B}_i^{(s-1)} = \sum_{j=1}^{n} \bar{T}_{ij}^{(s-1)} \;, \quad \bar{A}_j^{(s-1)} = \sum_{i=1}^{m} \bar{T}_{ij}^{(s-1)} \;.$$

If the following equations hold, the process of iteration is stopped.

$$\sum_{j=1}^{n} \bar{T}_{ij}^{(s)} \doteqdot \bar{B}_i \qquad (3\text{-}47)$$

$$\sum_{i=1}^{m} \bar{T}_{ij}^{(s)} \doteqdot \bar{A}_j \qquad (3\text{-}48)$$

Then, the modified quantity of cargo distribution is the future quantity of cargo from origin i to destination j.

3.7.4 Detroit Method

The first step is as follows:

$$T_{ij}^{(1)} = T_{ij} \frac{\overline{B}_i}{B_i} \cdot \frac{\overline{A}_j}{A_j} \cdot \frac{T}{\overline{T}} \qquad (3\text{-}49)$$

The second step is as follows:

$$T_{ij}^{(2)} = T_{ij}^{(1)} \cdot \frac{\overline{B}_i}{\overline{B}_i^{(1)}} \cdot \frac{\overline{A}_j}{\overline{A}_j^{(1)}} \cdot \frac{\overline{T}^{(1)}}{\overline{T}} \qquad (3\text{-}50)$$

In general the process of iteration at step s is as follows:

$$T_{ij}^{(s)} = T_{ij}^{(s-1)} \cdot \frac{\overline{B}_i}{\overline{B}_i^{(s-1)}} \cdot \frac{\overline{A}_j}{\overline{A}_j^{(s-1)}} \cdot \frac{\overline{T}^{(s-1)}}{\overline{T}} \qquad (3\text{-}51)$$

where

$$\overline{B}_i^{(s-1)} = \sum_{j=1}^{n} T_{ij}^{(s-1)} \quad , \quad \overline{A}_j^{(s-1)} = \sum_{i=1}^{m} T_{ij}^{(s-1)} \quad , \quad \overline{T}^{(s-1)} = \sum_{i=1}^{m} \overline{B}_i^{(s-1)}$$

The process of iteration is continued until the ratio of $\overline{B}_i/B_i^{(s)}$, $\overline{A}_j/A_j^{(s)}$ and $\overline{T}^{(s)}/\overline{T}$ converges to unity.

3.8 Exercises

(1) Calculate a normalized origin destination matrix of crude oil seaborne trade for the year 1976.

(2) Plot the total volume of seaborne oil trade for each year given below and forecast the volume for the year 1980 on the graph by linear extrapolation.

Then calculate k value.

1974	1100.0	million metric tons.
1975	1258.8	
1976	1417.5	

Make a normalized origin destination matrix for the year 1980 with the k.

(3) Calculate an origin destination matrix for the year 1980.

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CHAPTER 4 REGRESSION AND CORRELATION ANALYSIS AND ITS APPLICATION TO THE TRAFFIC ANALYSIS OF THE SUEZ CANAL

4.1 Introduction

Various analyses can be implemented to develop the planning and design of the Suez Canal using various types of information. In order to attain the basic information for transit analysis of the Suez Canal as the first stage, the regression and correlation analysis methods can be applied to obtain many characteristics of goods and ship movement through the Suez Canal.

In this paper, the mathematical methods and techniques are stated briefly, and then some exercises are prepared to utilize them to obtain effective information from existing data.

4.2 Basic Formulation of Linear Regression

When pairwise data for two variables, say X and Y, are plotted on a two-dimensional graph, the possible value of one variable, for example, Y, may depend on the other variable X. For this reason, it would be inappropriate to analyze the data, say for Y (for example, in determining the mean and variance of Y), without due consideration of X. In the case of Fig. 1, we observe that there is a general tendency for the value of Y to increase with increasing values of X (X may be deterministic or random). Hence the mean value of Y will also increase with increasing values of X; the actual values of Y, of course, may not always increase with increasing values of X. In general the mean value of Y will depend on the value of X. Suppose that this relationship is linear; that is,

$$E\ (Y|X)_{X=x} = \alpha + \beta x \qquad (4\text{-}1)$$

where α and β are constants, and the variance of Y may be independent or a function of x. This is known as the linear regression of Y on X.

Conceivably, there could be many straight lines, depending on the values of α and β, that might qualify as the mean-value function of Y in the light of the data. The best line may be the one that passes through the data points with the least error. To obtain this we see from Fig. 1 that the difference between each observed value and the straight line $y_i' = \alpha+\beta x_i$ is $|y_i-y_i'|$. Therefore the line with the least total error can be obtained by minimizing the sum of the squared errors -- that is,

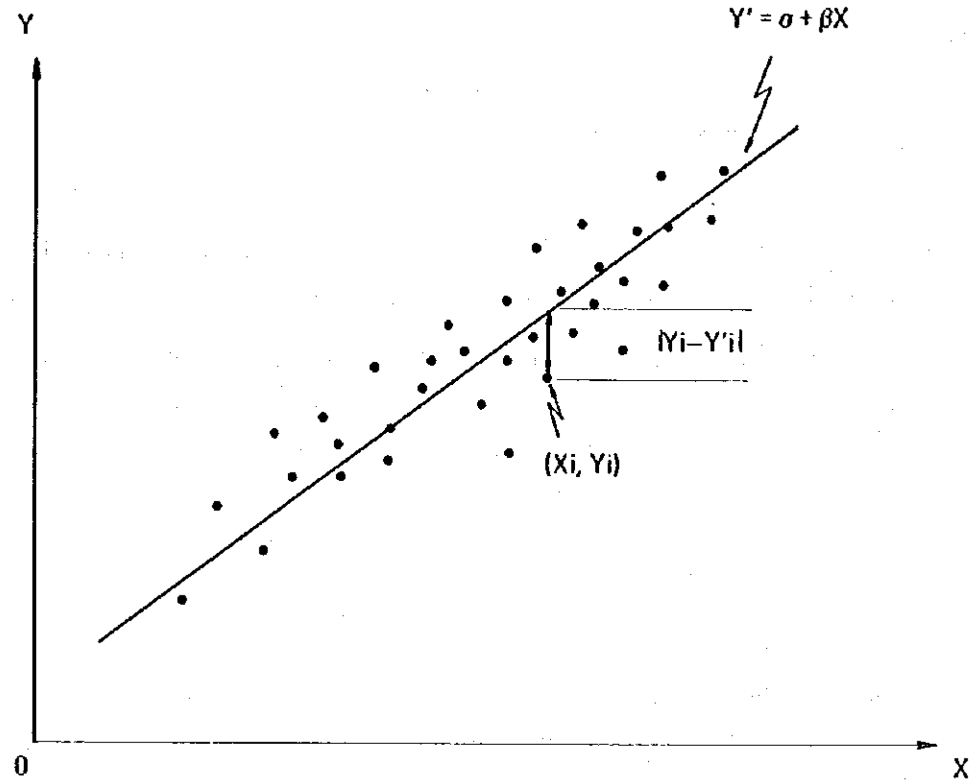


Fig. 4.1 Linear Regression Analysis of Data for Two Variables

by minimizing

$$\delta^2 = \sum_{i=1}^{n} (y_i' - y_i)^2 = \sum_{i=1}^{n} (y_i - \alpha - \beta x_i)^2$$

to obtain α and β, where n is the number of data points. This is known as the method of least squares, which leads to the following;

$$\frac{\partial \delta^2}{\partial \alpha} = \sum_{i=1}^{n} 2\,(y_i - \alpha - \beta x_i)(-1) = 0$$

$$\frac{\partial \delta^2}{\partial \beta} = \sum_{i=1}^{n} 2\,(y_i - \alpha - \beta x_i)(-x_i) = 0$$

From which the least-squares estimates of α and β are as follows;

$$\hat{\alpha} = \frac{1}{n} \Sigma y_i - \frac{\hat{\beta}}{n} \Sigma x_i = \bar{y} - \hat{\beta}\bar{x} \qquad (4\text{-}2)$$

and

$$\hat{\beta} = \frac{\Sigma x_i y_i - n\bar{x}\bar{y}}{\Sigma x_i^2 - n\bar{x}^2} = \frac{\Sigma (x_i - \bar{x})(y_i - \bar{y})}{\Sigma (x_i - \bar{x})^2} \qquad (4\text{-}3)$$

where $\Sigma = \sum_{i=1}^{n}$

Therefore the least-squares' regression line is

$$E(Y|x) = \hat{\alpha} + \hat{\beta}x \qquad (4\text{-}4)$$

It should be emphasized that, strictly speaking, this regression line is valid only over the range of values of x for which data had been observed.

Equation (4-1) and (4-2) are referred to as a regression of Y on X. If X and Y are both random variables, we may also obtain the least-squares regression of X on Y using the same procedure; in this latter case, we would obtain the regression equation for $E(X|y)$. In general, this is a different linear equation from that of $E(Y|x)$; the two regression lines, however, always intersect at $(\bar{x}, \bar{y})$.

Since the general trend is accounted for through the regression line of Eq. (4-4), the variance about this line is the measure of dispersion of interest, which is a conditional variance $Var(Y|x)$. For the case where the conditional variance $Var(Y|x)$ is assumed to be constant within the range of x of interest, an unbiased estimate of this variance is

$$S_{Y|x}^{2} = \frac{1}{n-2}\sum_{i=1}^{n}(y_i-y_i')^2$$

$$= \frac{1}{n-2}\left[\sum_{i=1}^{n}(y_i-\bar{y})^2 - \hat{\beta}^2\sum_{i=1}^{n}(x_i-\bar{x})^2\right] \qquad (4\text{-}5)$$

Observe that this is

$$S_{y|x}^{2} = \frac{\delta^2}{n-2}$$

Thus, the corresponding conditional standard deviation is $S_{Y|x}$.

The coefficients $\hat{\alpha}$ and $\hat{\beta}$, and $S_{Y|x}^2$, are estimates of the respective true values of α, β, and $Var(Y|x)$. Confidence intervals may also be established on the basis of available data. For this purpose, if assuming that Y has a normal distribution about the regression line $E(Y|x)$ for all values on x, then $\hat{\alpha}$ and $\hat{\beta}$ individually follow the t-distribution. In such a case, the regression values

$$E(Y|x) = \hat{\alpha} + \hat{\beta}x$$

will also be t-distributed. On these bases, the required confidence intervals can be determined. It is worth nothing here that these intervals for α, β, $E(Y|x)$, and $Var(Y|x)$ will decrease with increasing n.

The physical effect of linear regression of Y on X can be measured by the reduction of the original variance of Y, S_Y^2, resulting from taking into account the general trend with X. This reduction is represented by,

$$r^2 = 1 - \frac{S^2 y|x}{S_{Y^2}} \qquad (4\text{-}6)$$

where

$$S_Y^2 = \frac{1}{n-1} \sum_{i=1}^{n} (y_i - \bar{y})^2$$

is the sample variance of Y. It will be shown later that (for large n) r is approximately equal to a point estimate of the correlation coefficient.

*** In the above, the regression method for the linear regression with constant variance is stated from the practical view point, but there are various types of regression methods other than this linear regression with a constant variance. Those methods such as a linear regression with a nonconstant variance, nonlinear regression and multiple linear regression and so on are advanced and complicated mathematically but very useful, it would be better to learn them after this program.

4.3 Correlation Analysis

The study of the degree of linear interrelation between random variables is called correlation analysis. Recall that in regression analysis we are interested in predicting the value of a variable (or estimating associated probability) for given values of variables. However, the accuracy of a linear prediction will depend on the correlation between variables.

Mathematically the correlation between two random variables X and Y is measured by the correlation coefficient defined as below;

$$\rho = \frac{Cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

Based on a set of observed values of X and Y, the correlation coefficient may be estimated by

$$\hat{\rho} = \frac{1}{n-1} \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{S_x S_y} = \frac{1}{n-1} \frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{S_x S_y} \qquad (4\text{-}7)$$

where $\bar{x}$, $\bar{y}$, Sx, and Sy are, respectively, the sample means and sample standard deviations of X and Y. The value of $\hat{\rho}$ also ranges from -1 to +1 and is a measure of the strength of linear relationship between the two variables X and Y. If the estimate $\hat{\rho}$ is close to +1 or -1, there is a strong linear relationship between X and Y, linear regression analysis may be carried out to obtain the regression equations. On the other hand, if $\hat{\rho} \simeq o$ this would indicate a lack of linear relationship between the variables.

From Eqs. (4-3) and (4-7) it can be shown that

$$\hat{\rho} = \frac{\Sigma(x_i-\bar{x})(y_i-\bar{y})}{\Sigma(x_i-\bar{x})^2} \cdot \frac{S_x}{S_y}$$

$$= \hat{\beta} \frac{Sx}{Sy} \quad (4\text{-}8)$$

This is a useful relationship between the estimate of ρ and the regression coefficient $\hat{\beta}$. Furthermore, by substituting Eq. (4-8) into Eq. (4-5) we obtain

$$\mathrm{Var}(Y|x) = \frac{1}{n-2} [\Sigma(y_i-\bar{y})^2 - \hat{\rho}^2 \frac{S_y^2}{S_x^2} \Sigma(x_i-\bar{x})^2]$$

$$= \frac{n-1}{n-2} S_y^2 (1-\hat{\rho}^2) \quad (4\text{-}9)$$

from which we also have

$$\hat{\rho}^2 = 1 - \frac{n-2}{n-1} \frac{S_{Y|x}^2}{S_{y^2}} \quad (4\text{-}10)$$

which is equal to r^2 of Eq. (4-6) for large n. On this basis, therefore, we can say that the larger the value of $|\hat{\rho}|$ the greater will be the reduction in the variance when the trend between the variables is taken into account, and hence the more accurate will be the prediction based on the regression equation.

4.4 Estimation of Characteristics of Goods and Ships through the Suez Canal

In the methodology of planning and design of the Suez Canal, estimates of characteristics of goods and ship movement concerned with Suez Canal in the future would have an important place in the planning and the design system to determine the dimensions and the scale of the Suez Canal.

After constituting the process in the methodology, it will become necessary to estimate various characteristics of goods and ships to proceed with the process. But at this stage we can not have confirmation which factors are necessary or not, then some way to utilize statistical data to the process of planning and the design method of Suez Canal can only be stated here.

We can forecast certain characteristics in the future by the linear regression analysis of time-series data. There will be some examples shown of forecasting by this method in the following included exercise.

In the planning process, we often meet the requirement of estimation or forecast of a certain characteristic which indicates as an increasing or decreasing value corresponding to its development. In this case, utilizing those values as a time-series data we can apply the linear regression method defining the time t as X and the characteristic as Y of the model stated above.

Example 1.

The development of the world dry bulk carrier fleet from 1973 to 1978 is shown in the following table. The linear regression line of ore carriers is computed as $y = 11104+146.3\ t$ and correlation coefficient is computed as 0.6303.

Exercise: Compute the linear regression line of other dry bulk carriers by computing its correlation coefficient. (Please refer to Development of the World Dry Bulk Carrier Fleet in 1973-1978 "Shipping Statistics and Economics" H.P. Drewry (Shipping Consultants) Ltd.

Example 2.

The cost of maintenance of the facility increases according to the period being used as in the following data. Computing the linear regression line we obtain the line c=0.015+0.0517 t and its correlation coefficient is computed as 0.813.

Period being used (t)	6	8	14	14	18	20	20	24	28	30
Cost of maintenance (c) (million yen)	0.28	0.58	0.50	0.83	0.71	1.01	1.29	1.50	1.29	1.58

Exercise: Complete the computational tableau of this example.

4.5 Exercises

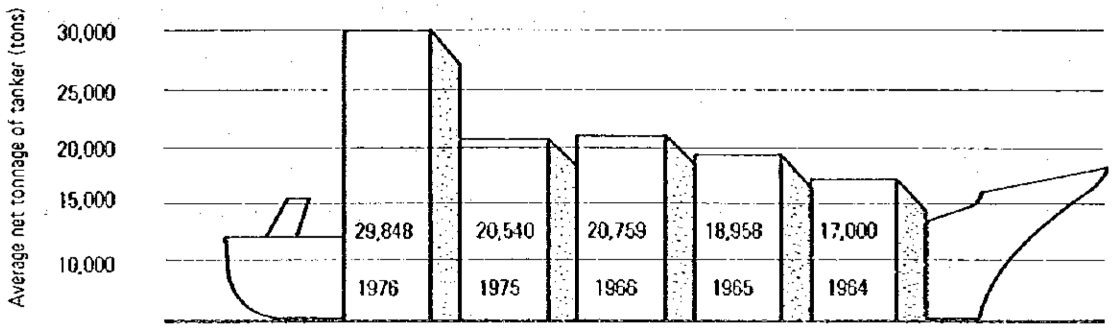
(1) In table 1, we have some time-series data of world international seaborne trade. Compute the linear regression line to forecast characteristics of international seaborne trade in the future.

Table 1 Development of World International Seaborne Trade

Year	Dry Carco		Oil		Total	
	Million Metric Tons	Per Cent increase/Decrease over Previous Year	Million Metric Tons	Per Cent Increase/Decrease over Previous Year	Million Metric Tons	Per Cent Increase/Decrease over Previous Year
1950	300	..	225	..	525	..
1951	360	20	255	13	615	17
1952	350	– 3	285	12	635	3
1953	360	3	295	4	655	3
1954	390	8	320	8	710	8
1955	450	15	350	9	800	13
1956	490	9	390	11	880	10
1957	510	4	420	8	930	6
1958	480	– 6	440	5	920	– 1
1959	490	2	480	9	970	5
1960	540	10	540	13	1,080	11
1961	570	6	580	7	1,150	6
1962	600	5	650	12	1,250	9
1963	640	7	710	9	1,350	8
1964	720	13	790	11	1,510	12
1965	780	8	860	9	1,640	9
1966	830	6	940	9	1,760	7
1967	860	4	1,010	7	1,870	6
1968	930	8	1,130	12	2,060	10
1969	990	6	1,260	11	2,250	9
1970	1,110	12	1,420	13	2,530	12
1971	1,120	1	1,520	7	2,640	4
1972	1,180	5	1,650	9	2,830	7
1973	1,350	14	1,865	13	3,215	14
1974	1,450	7	1,800	– 3	3,250	1
1975	1,380	– 5	1,640	– 9	3,020	7
1976	1,540	12	1,710	4	3,250	8

Note: Excluding international cargoes loaded at ports of the Great Lakes and St. Lawrence system for unloading at ports of the same system. Including imports into Netherland Antilles and Trinidad for refining and re-export. These figures are the average of loaded and unloaded quantities.
Courch: United Nations Monthly Bulletin of Statistics

(2) In the Suez Canal yearly report, the following time-series data on the average net tonnage per tanker evolved in the period from 1964-1966 was shown as in the following figure. Aiming to forecast such a characteristic in the future, compute the linear regression line using these data.



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CHAPTER 5 ESTIMATION OF CANAL TRAFFIC

5.1 Introduction

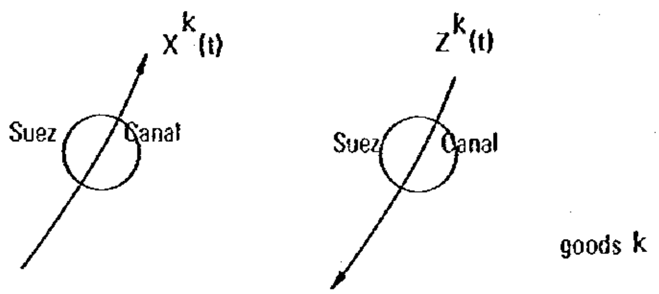
To estimate Canal traffic in the first step we have to estimate the international seaborne trade flow among countries and consider the international economic and political conditions. Utilising information from the world trade flow analysis, we have to prepare origin-destination tables for each type of goods in order to analyse the movement of goods or ships among significant ports of the world.

After obtaining OD tables for each type of goods, we have to consider their shipping route from origin to destination and whether they utilize the Suez Canal or not.

In this paper, several ways to analyse this assignment problem as to the possible shipping routes are discussed.

5.2 Estimation of Suez Canal Traffic without Analysing Assignment Problem

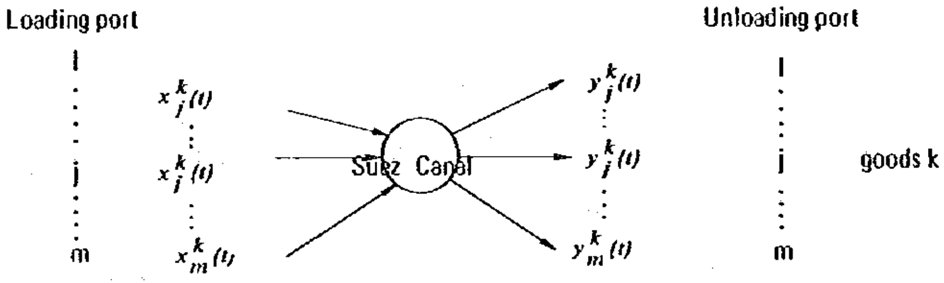
The Suez Canal Authority publishes a yearly report incorporating much information concerned with Suez Canal traffic and goods movement. We can forecast several characteristics utilizing these data in the following manner without using the techniques for the assignment problem.



The amount of each type of goods movement in two directions (northbound and southbound) can be found in the yearly report. Let's define them as $x^k(t)$ and $y^k(t)$ respectively and applying the regression method we can obtain the forecast $x^k(t^*)$ and $y^k(t^*)$ at time t^*.

Then the sum of them, $x^k(t^*)+y^k(t^*)$ would be the total volume of the goods k movement. But this forecast can not explain the mechanisms of world trade flow, and sometimes a problem of the accuracy of the forecast arises.

Considering these situations and the many problems encountered, we can advance in this manner to forecast more precisely. Let's define $x_i^k(t)$ and $y_i^k(t)$ as the loading amount of goods k and unloading amount of goods k in the northbound direction.



Each $x_i^k(t)$ and $y_i^k(t)$ at time t can be analysed at the phase of world trade flow, and supposing that $x_i^k(t^*)$ and $y_i^k(t^*)$ can be forecast with a certain degree of accuracy through the statistical structural analysis, we can forecast the total amount of goods in the northbound direction through the Suez Canal, and in the same way also analyse the influence of the economical and political conditions.

5.3 Assignment of Goods or Ships

After obtaining an OD table for each type of goods, we generally assign the goods to possible shipping routes of forecast the goods movement through the Suez Canal under a certain criterion. In this case two types of ways can be applied; the first way is to estimate the amount of movement on each shipping route utilizing the existing shipping route pattern (proportion) called the present pattern, assuming that the existing shipping route pattern between origin and destination could not change in the future.

On the other hand, the second way recognizes this future change and utilizes the mechanism of route choice behavior. Depending on the manner of description (recognition) of route choice behavior, several methods exist. In the following a brief explanation is given on these methods.

(1) Present Pattern Method

Let's define the amount of goods k which are loaded at origin i and are unloaded at destination j as S_{ij}^{k} in the future, and also let's define the proportion of shipping goods k by the existing route as $p_t^k(i_1j)(t=1, 2, \ldots, T;$ the number of existing shipping routes).

Applying the present pattern, we can forecast the future amount of goods k assigned to each of the routes $x_t^k(i,j)$ by the following equation:

$$x_t^k(i,j) = p_t^k(i,j)\cdot S_{ij}^k \quad (t=1,2,\ldots,T)$$

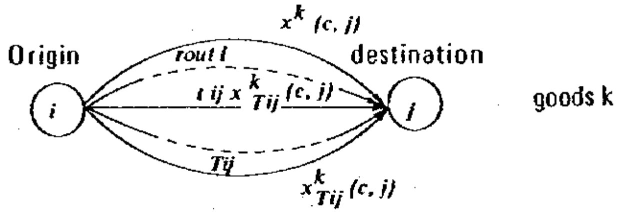
(2) Assignment Problem

The Assignment Problem can be formulated as follows under a certain supposition on a criterion of route choice for goods k:

Minimize $\quad Z^k = f^k(x_{tij}^k(i,j): i,j=1,2,\ldots,n,\ tij=1,2,\ldots,Tij)$

Subject To

$$\begin{cases} \sum_{tij=1}^{Tij} x_{tij}^k(i,j) = S_{ij}^k \\ \\ x_{tij}^k(i,j) \geqq o \quad \text{for all } (i,j) \end{cases}$$



In this case the objective function is very important and various types of objective functions are considered. The most simple type of objective function is composed of time elements. If this assignment problem considers only the passing time through the Suez Canal and other shipping time including loading and unloading time, we can define the total shipping time as τ_{tij} and formulate the objective function by

$$Z^k = \sum_{tij=1}^{Tij} \tau_{tij}\, x_{tij}^k(i,j)$$

Of course each τ_{tij} could be easily computed using all existing data.

The model is formulated as a mathematical programming model. But in total time minimization, this model is called the shortest route assignment model because all assignments are implemented only to the shortest time route among possible shipping routes.

When we consider the restrictions such as the capacity of the Suez Canal, loading and unloading ports and so on, we have to solve the mathematical programming problem (in the above case linear programming). But a sufficient and a feasible solution can be obtain in the following manner:

1) Separate the amount of goods between origin and destination into several parts.
2) Assign one part of the separated amount to the shortest shipping route.
3) Checking the feasibility with the constraints, implement a feasible assignment to another part of the separated amount to the shortest possible shipping route. Repeat this process until assignment finishes.

The change in the objective function sometimes needs another assignment method. But according to the manner in formulation of the objective function we can apply the same method. For example, in the case of total cost minimization; if the objective function is formulated as follows:

$$Z^k = \sum_{tij=1}^{Tij} C_{tij}\, x^k_{tij}\ (i,j)$$

the same method can be applied. And if the cost function is a non-linear function of $x^k_{tij}(i,j)$ the same method to obtain approximated solutions can also be applied.

5.4 Algorithm to Obtain the Solution

As stated before, the problem of assignment to shipping routes can be solved by the mathematical programming technique, for example LP, under the formulation shown above. But by utilizing the dynamic programming technique we can find the solution more easily. In the following the technique is set out with a simple example.

The figure shows 6 ports, and the characteristic of each arc between ports is defined as a criterion in order to evaluate the shipping between them. In this case let's assume that we set the criterion by shipping cost and they are shown on each arc respectively.

The OD-table of maritime transportation by shipping is forecast as the following:

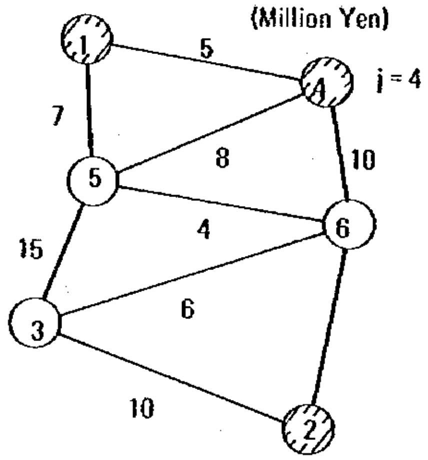
OD-Table

Restination / Origin	1	2	3	4	5	6
1	–	50	30	80	40	80
2	20	–	50	40	70	30
3	80	30	–	60	20	10
4	50	10	70	–	100	20
5	90	80	70	60	–	90
6	30	20	10	40	80	–

(x 10^3 ton)

Shipping Network

i = 1



$c^{(1)}_{ij} = c^{(1)}_{14} = 5$

$c^{(1)}_{ij}$

As the first step we have to find the minimum cost route between ports i and j for all pairs of (i,j) by the following procedure: Defining the cost as $c^{(1)}_{ij}$ where $c^{(1)}_{ij}$ is the cost from i to j with shipping on only one arc. (It means the direct shipping from port i to port j, and if there exists such an arc as (i,j) it is assigned ∞.) Using this cost matrix we compute $c^{(2)}$ by the following equation

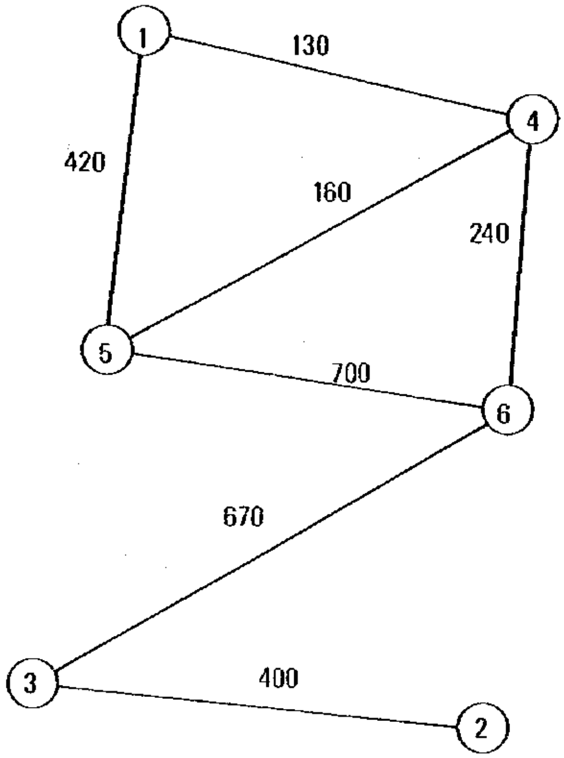
$$c^{(2)}_{ij} = \min_{k} \{ c^{(1)}_{ik} + c^{(1)}_{ij} \} , \quad c^{(2)} = (c^{(2)}_{ij})$$

where $c^{(2)}_{ij}$ shows the minimum route cost of a route which consists of less than two arcs. In the same manner we continue to compute $c^{(4)}$, $c^{(8)}$, ... and obtain $c^{(2m)}$. This computation finishes when either $c^{(m)} = c^{(2m)}$ or $m \geq n-1$ is satisfied. When the finishing condition is satisfied all the minimum cost routes are found.

Using the information obtained through the computing procedure we can find the all the minimum cost routes. And after finding them we assign the goods (or ship) to the according OD-table.

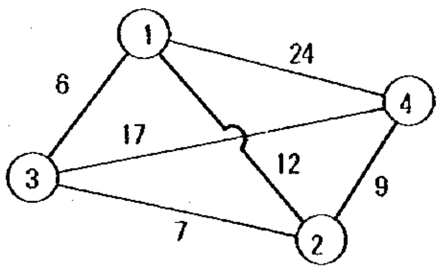
The result of computation can be shown as the following figure.

The number on the arc shows the shipping amount assigned.



5.5 Exercises

(1) Compute all minimum routes to the shipping network shown below.



(2) Assign goods shown in the OD-table given below

OD-Table

Destination (port)

Origin (port)	1	2	3	4
1	–	50	10	80
2	30	–	40	30
3	70	20	–	40
4	20	90	50	10

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CHAPTER 6 CONVOY SYSTEM

6.1 Characteristics of the Present Suez Canal (Appendix: Fig. 6.1)

(1) Length:

162.5 km from Port-Said to Port-Tewfik

(2) By-pass:

1) East branch of Port-Said By-pass
   2.15 km from 3.0 km to 5.10 km
2) East branch of Ballah By-pass
   9.15 km from 51.1 km to 60.3 km
3) East branch of Kabret By-pass
   7.144 km from 114.96 km to 122.10 km

(3) Speed Limit

Type of Vessel	Navigation speed	Minimum distance between vessels
Tanker more than 18 kilo tons	12 km/hr	3 km or 15 min.
Tanker less than 18 kilo tons	13 km/hr	2 km or 10 min.
Other ships	14 km/hr	1 km or 5 min.

(4) Tonnage Limit

Up to 60 kilo tons fully loaded.
Up to 250 kilo tons in ballast.

(5) Development Program

1st stage: expand water-section from 1,870 m^2 to 3,700 m^2 to raise permissible draught from 38 to 53 feet and to allow transit of 150 kilo ton D.W. tanker.

2nd stage: expand water-section to 5,000 m^2 to allow for a draught of 67 feet, 260 kilo ton tanker.

(6) Time Schedule

Northbound convoy leaves Port-Tewfik at 5 a.m.

1st southbound convoy leaves Port-Said at 11 p.m. of the last day and has to anchor in the Kabret By-pass.

2nd southbound convoy leaves Port-Said at 7 a.m. of the last day and has to anchor in the Ballah By-pass.

(7) Improving Plan

1) Various convoy patterns must be tried out in order to speed up the overall transit operation and increase the capacity of the Canal.

2) Various controlled operating cycle times must be tried out in order to accommodate random arrivals.

3) New electronic and computer technology must be used to:

   (i) monitor the arrival pattern of ships at each port.

   (ii) sense the position of the head and tail ship of each convoy and the speed of each ship.

   (iii) simulate by computer the expected transit pattern and evaluate any difference between actual condition and planned one.

   (iv) simulate an emergency operation by displaying the actual situation.

4) Good communications and modern equipment combined with strict radiotelephone procedures are recommended.

6.2 Arrival Patterns of Ships at Port-Said and Port-Tewfik (Appendix: Fig. 6.2)

Arrival Time

- time interval is negative exponential in form.
- pattern of ship arrival is normally random, and arrival process follows the poisson distribution.
- mean number of daily arrival is;

  27.48 ships per day ..... southbound } can be assumed by
  25.58 ships per day ..... northbound } normal distribution

6.3 Time Interval between Ships

This depends on the number and the type of ships;

- time span of the convoy 164-288 min. (20 ships) } southbound
  24- 41 min. (5 ships)
  143-184 min. (20 ships) } northbound
  84-125 min. (5 ships)
- average interval = $\frac{Y}{X-1}$, Y: time span, X: number of ships

6.4 Canal Capacity

	Loaded	Ballast	Total
(1) • in 1980, the number of southbound ships	8,367	5,680	14,047
• in 1980, the number of northbound ships	7,648	871	8,519

(2) • Suez Canal would soon be congested with the present layout.

the number of ships per year (day)

	1977	1980	1985	1990
Southbound	10,137 (27.7)	14,047 (38.5)	15,385 (42.1)	18,420 (50.5)
Northbound	9,546 (26.2)	8,519 (23.3)	9,780 (26.8)	10,542 (28.9)
Total	(53.9)	(61.8)	(68.9)	(78.4)

(3) • Factors for increasing the effective utilization capacity

a. construct additional by-pass

b. increase the duration of the operating cycle time

c. increase the size or number of convoys

d. increase the transit speed and reduce ship separation

(4) • Definition of canal capacity

a. maximum number of transits possible during 24 hours

b. maximum tonnage of transits possible during 24 hours

Maximum number depends on the mix of ships, clearance between ships, speeds and properties of the total transit.

General Cargo Ship (GCS) is decided as a reference ship which transit the Canal at a constant speed of 14 km/hr at a constant interval of 10 minutes.

(5) • Maximum capacity of existing layout (Appendix: Fig. 6.3)

Configulation	Capacity	Maximum utilization factor
one convoy per day	76 ships	52.7%
two convoys per day	60 ships	41.6%
three convoys per day	78 ships	54.1%

The above values are estimated under the following assumption; perfect navigation control, perfect transit completion within 24 hours, 50% travelling north and 50% travelling south.

(6) • Effect of additional by-pass (Appendix: Fig. 6.4 and Fig. 6.5)
Port-Fouad By-pass (0-17 km): for reducing congestion, disturbance to vessels berthed.
Deversoir By-pass (93-122 km): as mooring area for VLCC in a northbound convoy.
Timsah By-pass (73-86 km): as storage capacity for 20 GCS in southbound convoy.

	Capacity	Maximum utilization factor
basic layout (3 convoys)	78 ships	54.1%
addition of Port-Fouad	84	58.3%
addition of Port-Fouad and Deversoir	90	62.5%
addition of Port-Fouad and Timsah	98	68.0%

(7) Operating cycle time

Capacity of the Canal in 24 hours: $24 \times \frac{60}{10} = 144$ GCS

Capacity of 2 convoy pattern: $\frac{144xn}{n} - \frac{144-60}{n} = 144 - \frac{84}{n}$

Capacity of 3 convoy pattern: $\frac{144xn}{n} - \frac{144-78}{n} = 144 - \frac{66}{n}$

so that, n must be, $144 - \frac{84}{n} \geqq 0$ $n \geqq 0.58$ day $\doteqdot$ 14 hours

where 84 is the loss capacity of a two convoy pattern.

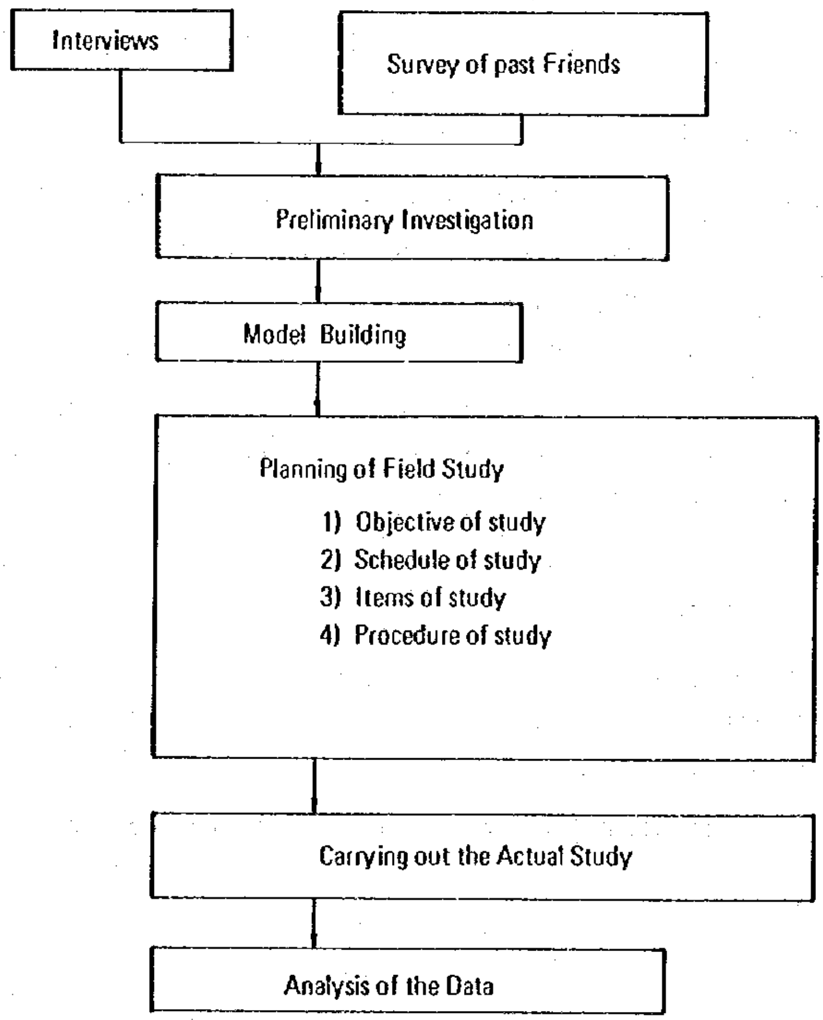
6.5 Analysis of Convoy Navigation in the Suez Canal: Static Analysis by Operation Diagram, Dynamic Analysis by Monte-Carlo Simulation

Analysis of convoy navigation through the Canal could be carried out either by a static analysis of an operation diagram or by a dynamic analysis employing the Monte-Carlo simulation.

Either pseudo random numbers or arithmetic random numbers are used for the Monte-Carlo simulation.

The former is usually generated by the logical operation of numbers and the latter is generated by the middle-sequence method or by using a linear recurrence relation formula.

Procedures of a field study and system simulation are shown below.



Procedure of Field Study

Fig. 6.1

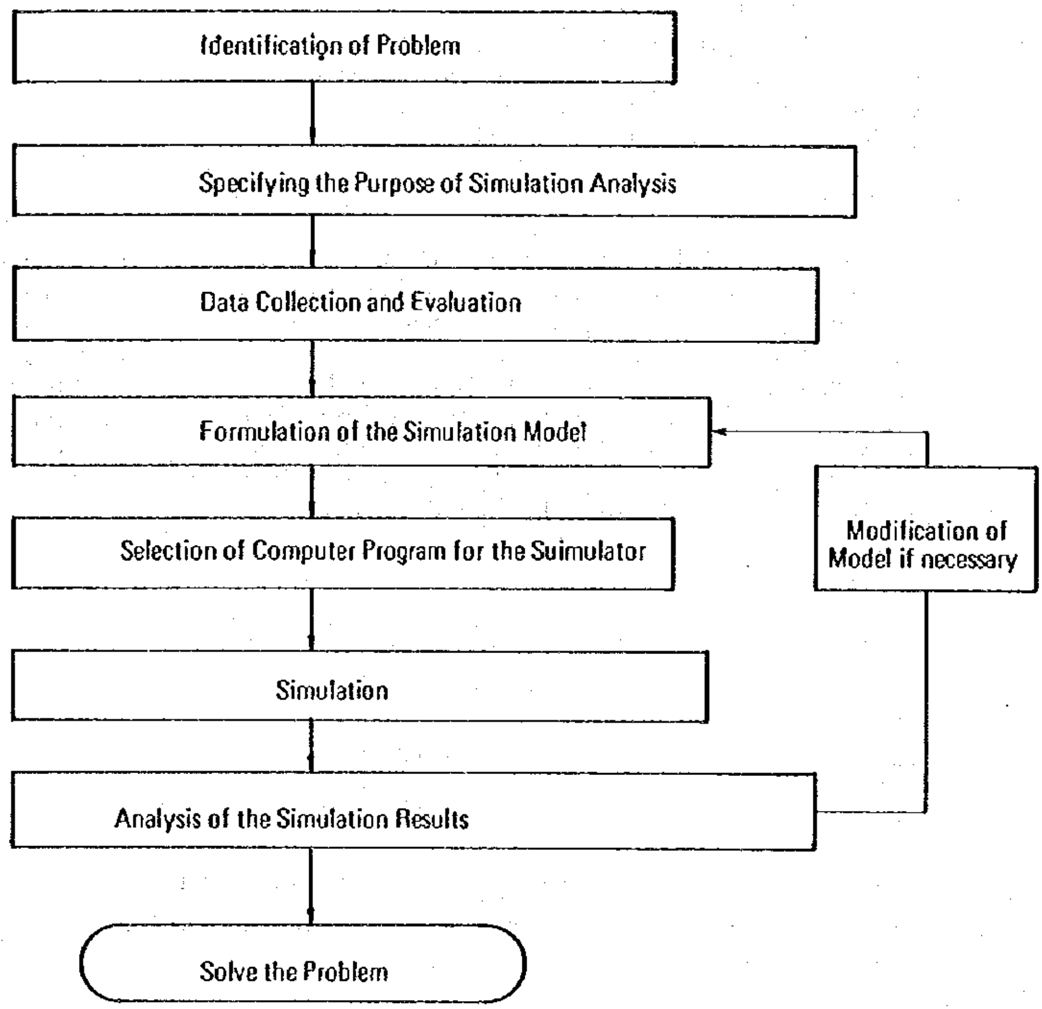


Fig. 6.2 Procedure of System Simulation

(1) Probabilistic phenomena

Arrival time interval, Navigation speed,
Navigation interval, Tonnage of ships.

(2) Suez Canal Traffic Simulation by S.M.I. Mansour (Appendix: Fig. 6.6)

1) Parameter of simulation

a. length of each convoy
b. starting time of each convoy
c. delay time of each convoy in by-pass
d. Navigation speed of each convoy
e. time clearance of each ship

2) Input data

a. average speed of northbound (V_3)	12.5 km/hr
b. average speed of first southbound (V_1)	14 km/hr
c. average speed of second southbound (V_2)	15 km/hr
d. storage capacity of Ballah By-pass	19 vessels
e. Storage capacity of Great Bitter Lake	no limitation
f. average time clearance of northbound (C_3)	15 minutes
g. average time clearance of first southbound (C_1)	10 minutes
h. average time clearance of second southbound(C_2)	5 minutes
i. number of ships in northbound convoy	

3) Simulation case

Case 1: $V_1 = V_2 = V_3 = 14$, $C_1 = C_2 = C_3 = 10$,

$DT_2 = DT_4 = DT_6 = 40$

Case 2: $V_1 = 14$, $V_2 = 15$, $V_3 = 12.5$

$C_1 = 10$, $C_2 = 5$, $C_3 = 15$

Case 3: Case 2 plus addition of Port-Fouad By-pass

Case 4: Case 2 plus 36 hours and 48 hours operation cycle time

4) Output data

a. number of ships in each convoy : Ni
b. transit time of each convoy : TTi
c. total transit time of each convoy: TT ($= \Sigma$ TTi)
d. delay time of each convoy : WLi i

5) Simulation results

Case 2; if Ballah By-pass storage become 35, the canal capacity increases from 66 to 82.

Case 3; maximum capacity increase 66 to 81

Case 4; if cycle time is 36 hours, maximum capacity increases from 66 to 138, and if 48 hours, 210.

(3) Procedure to make a operation diagram

1) Assumption

a. operating cycle time
b. departure time of 1st southbound convoy at Port-Said
c. arrival time of northbound convoy at Port-Said
d. navigation speed of each convoy
e. time clearance of each convoy
f. safety time interval at each by-pass

2) Procedure in the case of 2 convoys

1. draw the head line of southbound convoy (SBC) from Port-Said to Kabret By-pass
2. draw the tail line of northbound convoy (NBC) from Port-Tewfik to Port-Said
3. draw the tail line of SBC from Port-Tewfik back to Kabret By-pass
4. draw the head line of SBC from Kabret By-pass to Port-Tewfik
5. draw the tail line of SBC from Port-Said to Kabret By-pass
6. draw the head line of NBC from Port Tewfik to Port-Said
7. calculate the number of ships in each convoy

6.6 Exercises

(1) Make an operation diagram under the following conditions, and calculate a capacity

. V_1 = 14, V_2 = 14, V_3 = 14 km/hr

. $C_1 = C_2 = C_3$ = 10 min.

. operating cycle time = 24 hours

. time clearance at each by-pass = 0 min.

. navigation priority is given to northbound convoy

. 2 by-passes (Ballah and Kabret)

. capacity of Kabret By-pass is 19 ships

. 3 convoys (2 southbound and 1 northbound)

(2) Make a simulation model of canal navigation considering the randomness of ship arrival, navigation speed and clearance interval of each ship (refer to the lecture in the morning).

Appendix: REFERENCE

[1] Samir Mohamed Ibrahim MANSOUR, Queuing and Traffic Simulation in the Suez Canal, Thesis submitted to Cairo University for a Master of Cience Degree, May (1978)

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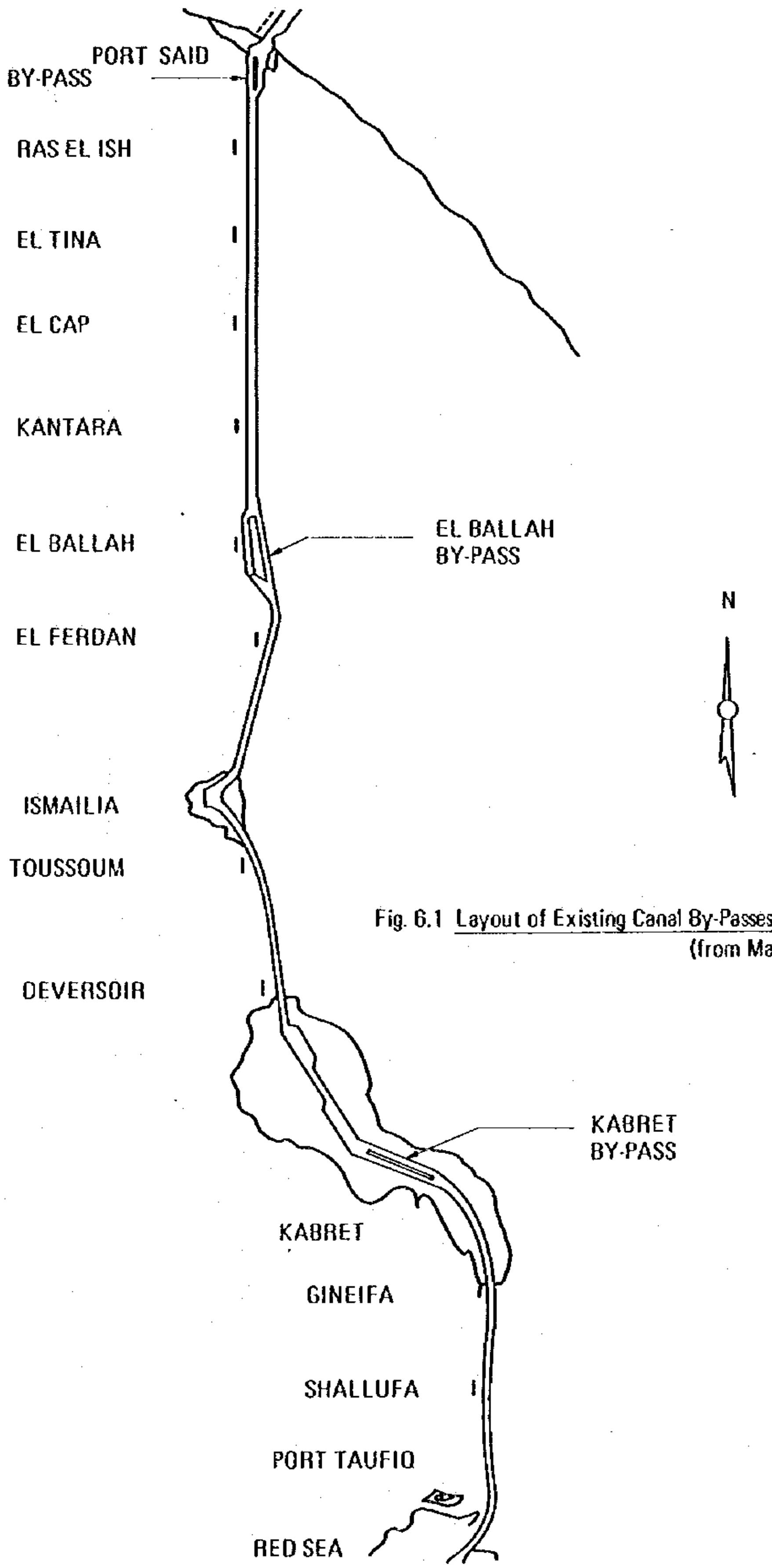


Fig. 6.1 Layout of Existing Canal By-Passes
(from Mansour [1])

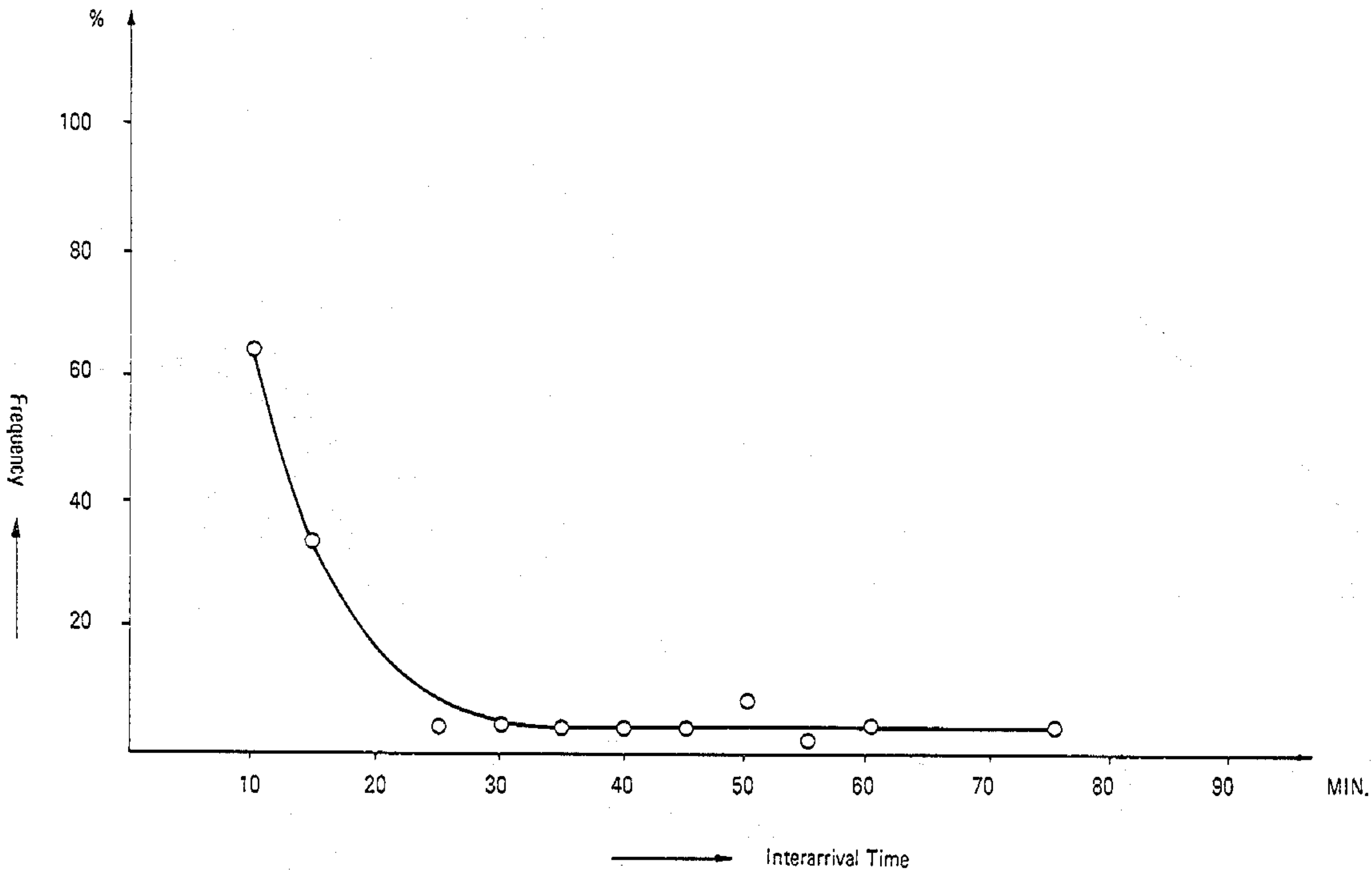


Fig. 6.2 Distribution of Interarrival Time (from Mansour [1])

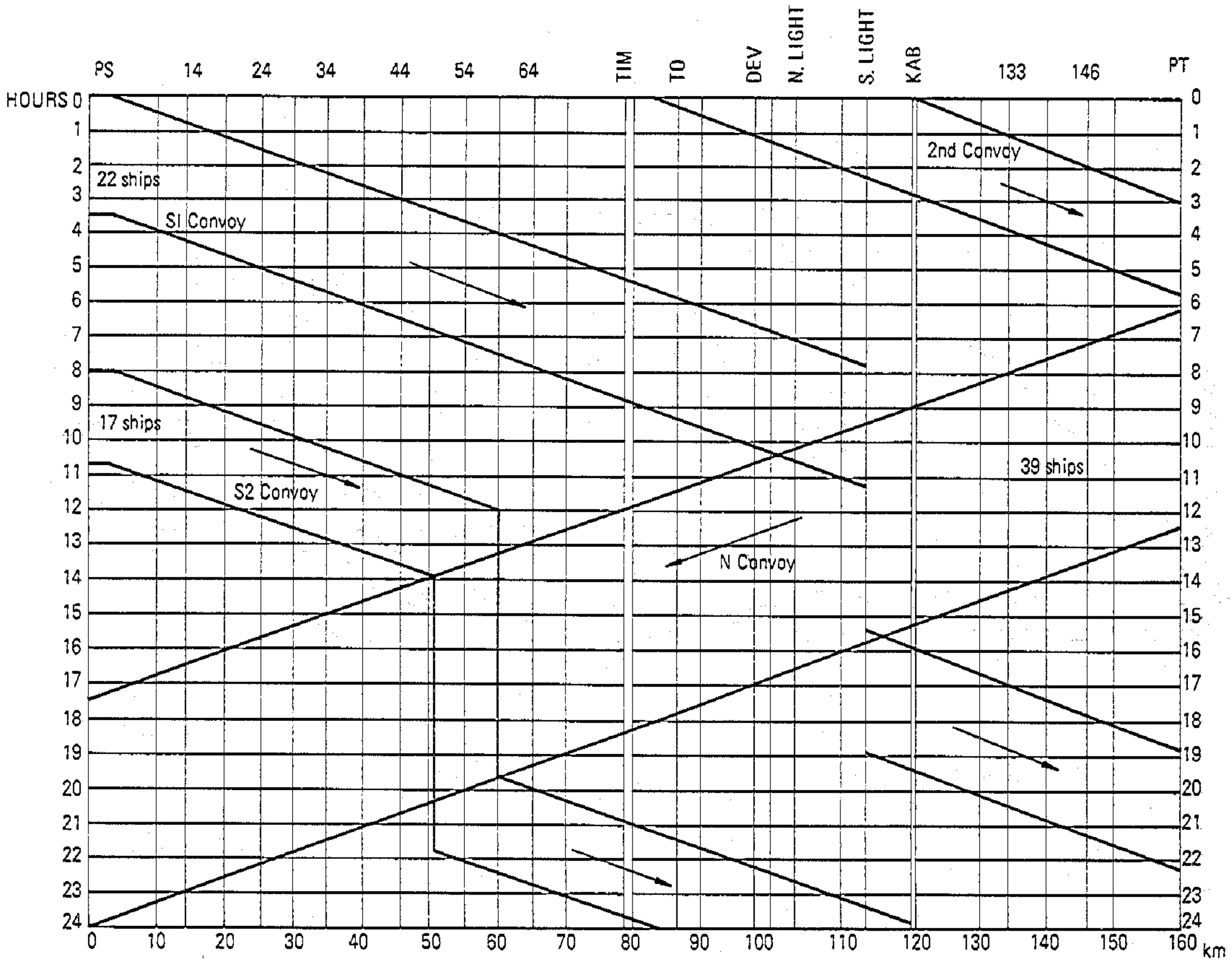


Fig. 6.3 Maximum Capacity of Present Canal 3 Convoy Per Day (from Mansour [1])

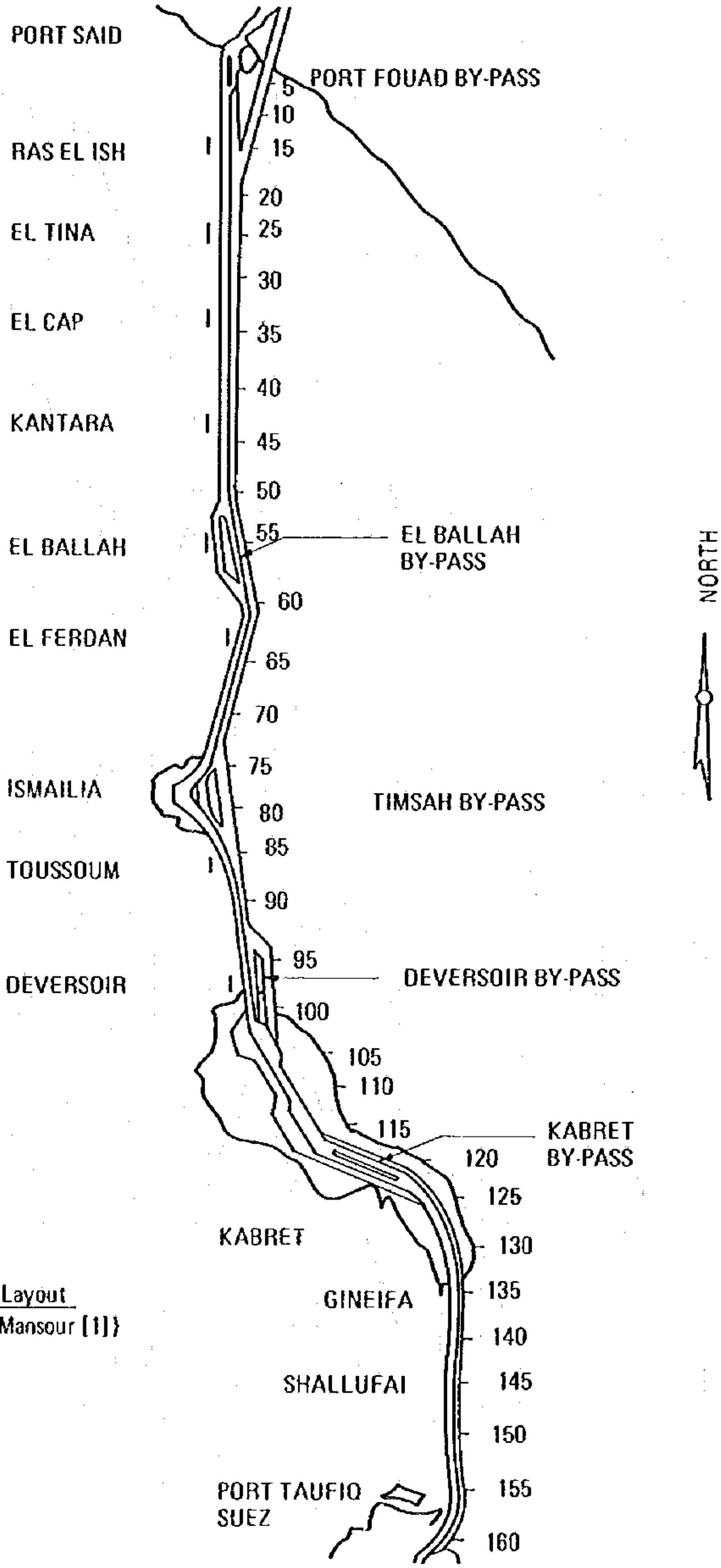


Fig. 6.4 By-Passes Layout
(from Mansour [1])

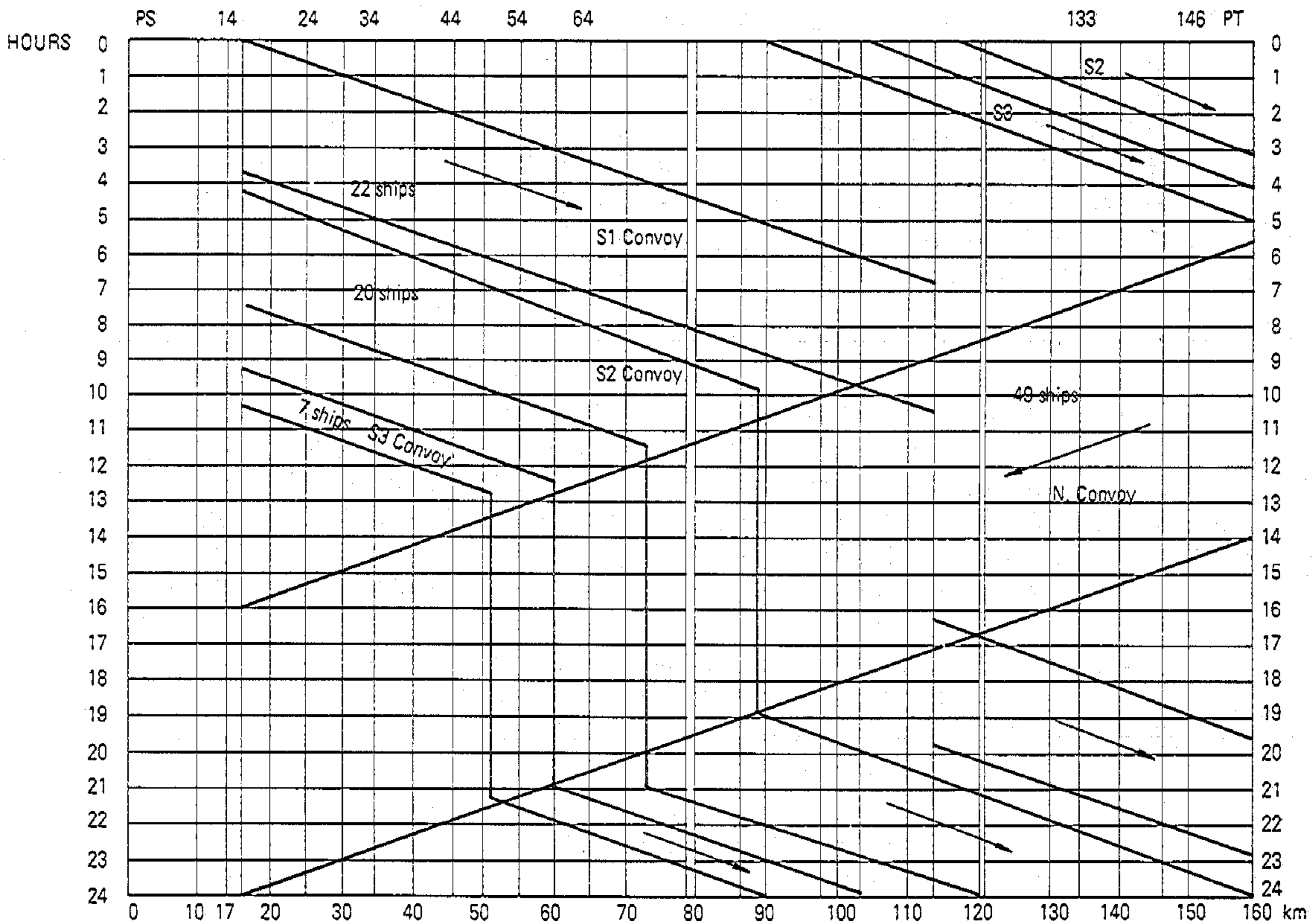
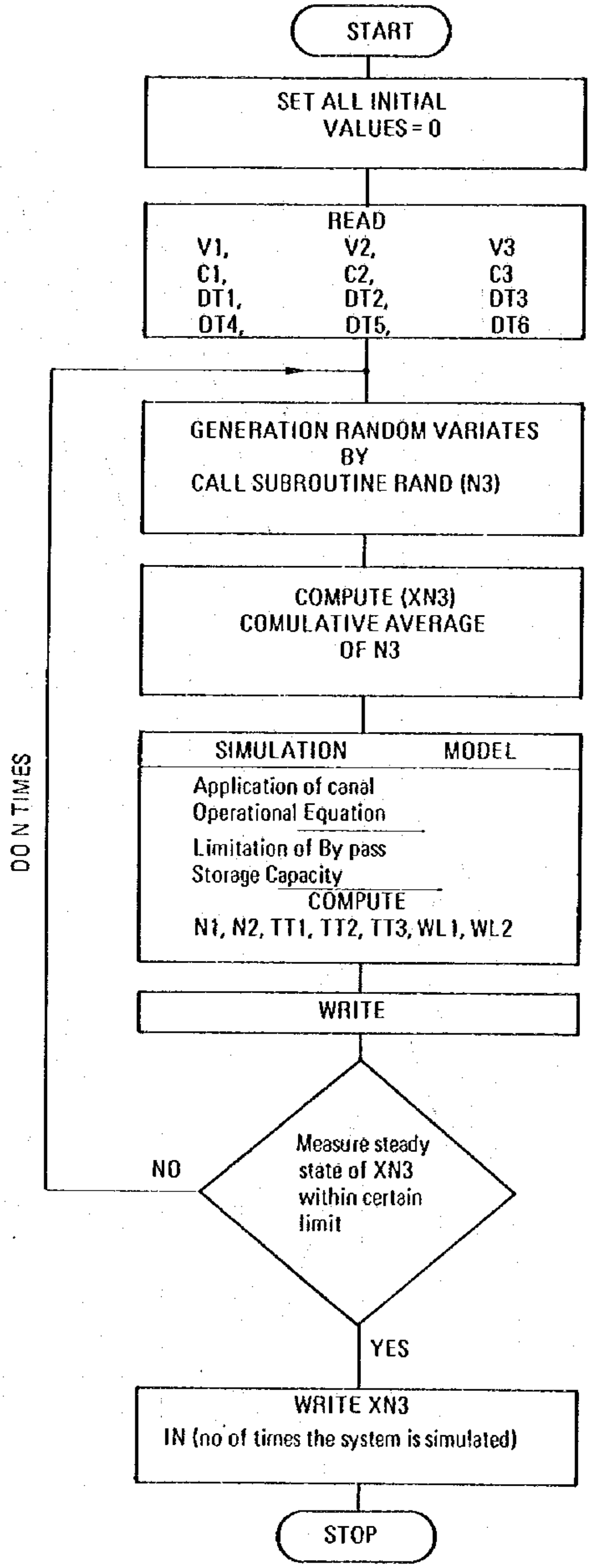


Fig. 6.5 Capacity of the Canal Addition of Port Fouad and Timsah By-Passes (from Mansour [1])



Vi: average speed of convoy i

Ci: average time clearance of each vessel in convoy i

DT1: safety time interval of northbound at Great Bitter Lake

DT2: safety time interval of southbound at Great Bitter Lake

DT3: safety time interval of northbound at Ballash By-pass

DT4: safety time interval of southbound at Ballah By-pass

DT5: safety time interval at Port-Said

DT6: safety time interval at Port-Tewfik

N3: number of ships in the northbound convoy

N1: number of ships in the first southbound convoy

N2: number of ships in the second southbound convoy

TTi: transit time of convoy i

WLi: delay time of convoy i

Fig. 6.6 Flow Chart for Suez Canal Traffic Simulation Model Program (from Mansour [1])

PART III SPECIAL LECTURE: ON SYSTEMS ANALYSIS

Systems analysis seeks to deal with problems by methodologically exploring cost, time, and effectiveness as an integral whole. The means for doing this is the formal consideration of alternatives, assumptions, criteria, and risk inherent in any acceptable choice. It is implicit that the problems to be attacked are complex and not trivial; also, that the time horizon is generally not immediate, but intermediate to long-range. The problems are also characterized as being only partly quantitative. Formality becomes less and less rigorous (mathematically - oriented) as the problems become less subject to quantification.

The first task of problem solving is to define the set of objects to be analyzed. A set of objects taken as a whole comprises an alternative. Evaluation of alternatives is the means of selecting solutions or objectives. A single solution may have many alternative problem-solving routines. Alternatives may or may not have quantifiable aspects. For example, the alternative numbers of men or numbers of pieces of equipment are quantifiable. Type of market, extent of market domination, or location of market may only be partly quantifiable. Alternatives imply the ability to make a choice between two or more acceptable solutions. The content of alternatives are the terms under which one choice may be made.

Assumptions are statements of supposition concerning the state of an object, attribute, or relationship. Suppositions are hypotheses or postulates. When the supposition is false, the assumption is false, and the condition of the problem is contradictory. Assumptions are used to deal with difficult realities that tend to upset a problem-solving routine. When assumptions do not change the level of risk or alter the cost-effectiveness relationship of an alternative they are useful, essential parts of a problem. Assumptions place a burden of consistency on the analyst. An assumption infers the existence of a fact, not known with certainty, from the known existence of other facts.

A criterion is the means by which an alternative is measured or chosen. A criterion enables the analyst to show consistency in his preference selection. The criterion will illustrate the relative achievement of an alternative in terms of other yardsticks, such as time, cost, or effectiveness. A criterion is a standard by which a judgement can be made about the relative merits of a choice.

Risk is the measure of potential exposure to system failure. His risk may also be characterized by low statistical probability, although precise measures of risk are not always quantifiable. In complex, quantitative-qualitative problems, the term used to describe risk is uncertainty.
In this use, the term uncertainty refers to the relative likelihood of an event actually occurring. Risk or uncertainty may manifest itself throughout the problem-solving exercise. Risks are increased, for example, if criteria are intrinsically incapable of measuring that which is being measured. Risk is also increased if an assumption, accepted as true, turns out to be false. Risk can emerge as the predominant characteristic of an alternative that has been chosen through miscalculation of an input-output-feedback error. The relationships to be explored are shown in Fig. 1-1.

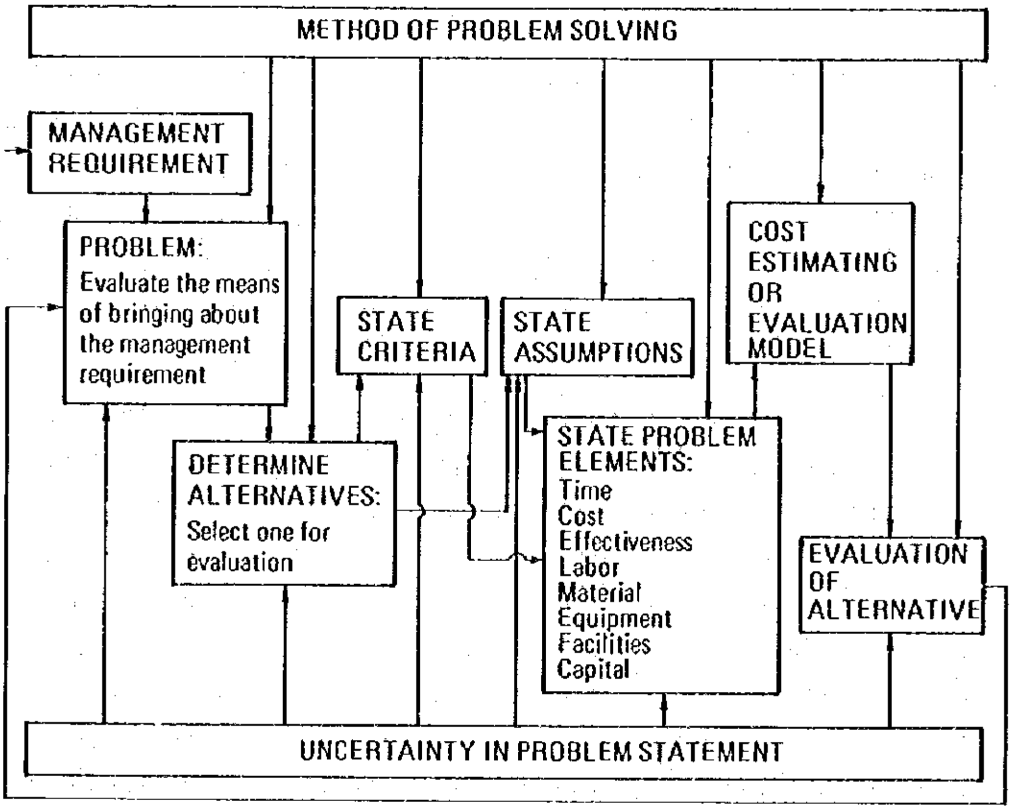


Fig. 1.1

Management (a system purchaser) conceives a requirement based upon an existing state. This state is to be changed, based upon some proposed state that is known qualitatively, if not quantitatively. The question is how to bring about the proposed change. The problem is to evaluate the means by which the change may be brought about.

Assuming there are acceptable alternatives, each is evaluated, one at a time. For each alternative, there are a number of assumptions. These are stated and their basis defined, since they may increase risk, and hence dominate the estimates derived. The elements of each alternative are stated next, examining for each element (labor, material, equipment, facilities, capital, etc.) the time, cost, and effectiveness dimension.

These values are then introduced into a cost estimating or evaluation model. The model is assumed to be objective and free of bias in its objects, attributes, and relationships. Thus, it becomes a useful arbiter of choice where quantifiable elements are under consideration. Operation of the model delivers an evaluation. The process is then repeated for additional alternatives.

Selecting Alternative

An alternative is defined as an opportunity to choose among more than one possible option. To be considered an alternative must be an acceptable, potential solution of a stated problem. Among alternatives, it is assumed that all are comparable, or to the degree that they are not, their differences are recognized. Alternatives, under this definition, may have differences of degree or differences in kind.

Alternatives are of two general forms: functional difference (a difference of kind), or operationally difference (a difference of degree)

Alternatives are evaluated for their total resources, cost, and profit impact.

Selection of alternatives for evaluation are assumed to include deliberately the company's capacities and capabilities (personnel, facilities, equipment restrictions, budget, cost restrictions, etc.).

The time restriction of an alternative may be integrated with other factors. For example: The time available may be inadequate for research and development, tooling, production, or marketing and sales. Time may also be insufficient in terms of product effectiveness.

Alternatives should reflect the inherent sensitivity of their components to one of the principal objects of the system.

Alternatives should be formulated that are capable of significantly reflecting the inherent costs of an action.

Alternatives may be set up to maximize, minimize, or optimize the effectiveness of a system.

Identifying Assumptions

The goal in problem solving is to make as few assumptions as possible. Each assumption tends to become a location of weakness, since it is not demonstrable. An assumption may be eliminated after the solution has been determined, because it becomes a redundant condition to the problem. Sometimes, however, the solution may be hedged through the assumption.

In these instances, they do not serve the problem solver or the system purchaser.

The relationship of objectives, alternatives, and assumptions is illustrated in Fig. 1-2

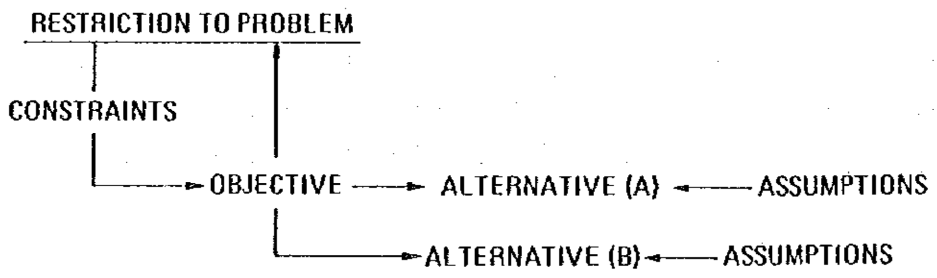


Fig. 1.2

Stating Criteria

Criteria are set by the system purchaser or the problem solver. These are the means by which alternative solutions are evaluated. The relationship of the elements of the problem-solving method, which includes the application of alternatives, assumptions, and criteria, may be illustrated as in Fig.1-3 where the time-cost-effectiveness evaluation model translates the alternative into a solution. The application of the criterion makes it possible to accept or reject a certain number of solutions. Those that are acceptable may be compared in order to select a solution that is dominant or superior. Note that the criterion is drawn from the problem restriction, providing the means of judging the solution. The criterion is a dimension of the objective, creating the thread of consistency in the evaluation process. Acceptable solutions are not ready for discard yet. The relative risk inherent in each acceptable solution must be evaluated.

Assessing Risk

Systems analysis is concerned with a

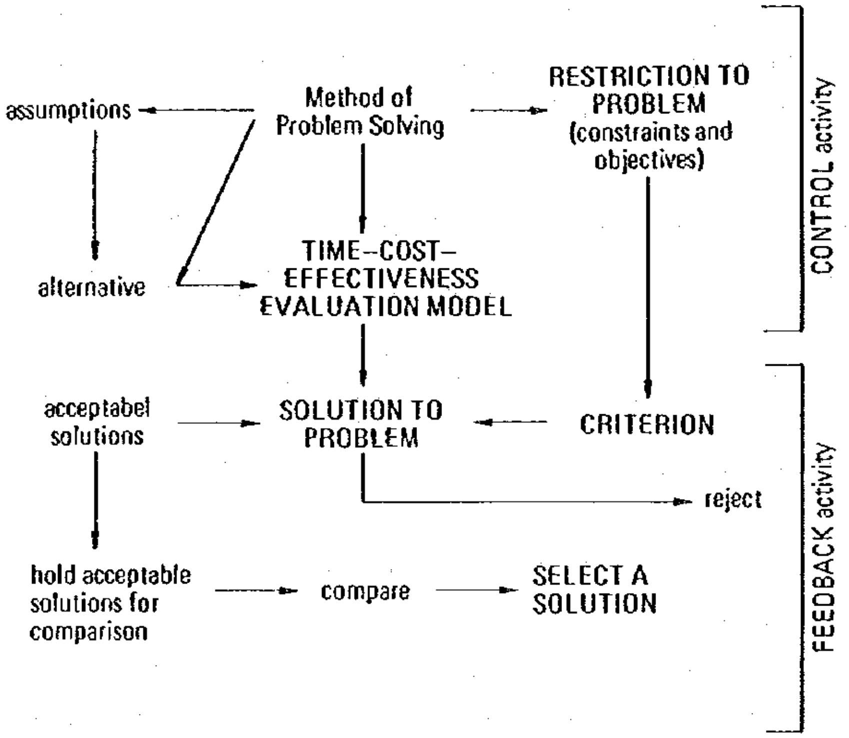


Fig. 1.3

class of problems outside the short range of day-to-day activity. The more distant in time the problem is, the more difficult is to assess the risk inherent in a given solution with precision. In evaluating alternatives, each has its own measure of risk. Each must be judged by direct or indirect measurements that are criteria of system performance. The key to this assessment lies in the comparability of judgements. Each solution must be of the same kind and must be judged in the same manner. The goal is to assess alternative solutions systematically by determining the sensitivity of each problem parameter tested over the range of values (rather than the single points). Each problem parameter represents some aspect of the performance of the system.

Alternatives and Trade-offs

Trade-off is the term that describes how objects and attributes are methodically manipulated to determine the full range of system characteristics. Trade-off may be defined as the exchange of one set of values, derived from the relationship of a set of objects and attributes, for another set that is to be similarly valued.

In Summary

The procedure of problem solving in public works has been as follows:

(1) Discussion of problem solving in the environment of public works.
(2) Review of the basic system concepts.
(3) Examination of the feedback-control phenomena in problem solving.
(4) Discussion of the methodological elements of problem solving.
(5) Examination of relationships among system components in problem solving.

The initial task was to review problem solving from a number of standpoints. The characteristics of typical problems were explored. The significant differences between problems that can be solved quantitatively were compared to problems that are not completely mathematical, but quantitative-qualitative. These latter problems were termed the ill-structured problems in which we were primarily interested. They tend to be wide in scope, difficult, and complex. They invariably involve the use of both men and machines at different levels of effectiveness. The selection and presentation of problems, data, and solutions illustrated practical difficulties the executive problem solver encounters in bringing his work into focus for management.

The next task was to understand the broad, system concepts that apply to the problems under study. The phenomena characterized as system were presented to show the range of applications that utilize a common approach to problem solving. The system itself was defined functionally and operationally. Man-machine systems were defined and explored in a number of contexts. There was discussion of the attributes that differentiate men from machines, describing the areas in which their functions are uniquely complementary.

Feedback and control were explored in conjunction with their problem-solving role in man-machine systems. The activities that define feedback and control were described in depth by defining problem solving and exploring output models. The output model, test of correspondence, and intervention model were presented to show that problem solving in ill-structured systems may be attacked through a method that has structure, rather than an informal, procedural method.

The elements of problems were defined and organized, first functionally, then operationally. The formulation of problems and objectives was analyzed within this context. Problem solving was characterized as the process of iterating a feedback-control. The critical elements of feedback and control were explored, in turn.

The alternatives, assumptions, criteria, and risks inherent in a course of time, cost, and system effectiveness were briefly discussed. Each of these elements were defined as possible criteria of system design and their influence on the choice of alternatives was explored. The essence of selecting a course of action was seen as a trade-off. Problems were defined as solved through a process of optimizing the content of alternatives.

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No. 4

EXERCISES FOR TRANSIT FORECASTING AND PROJECT EVALUATION

NO.4 EXERCISES FOR TRANSIT FORECAST AND PROJECT EVALUATION

PREFACE

This No.4 curriculum text is a compact compilation of the detailed texts on the subject of "Exercises For Transit Forecast And Project Evaluation" to be distributed in advance to the participants of the Suez Canal Authority for the training program in Japan which will be held on December 4-15, 1978 at Mitsubishi Research Institute.

The present training text is prepared for the SCA participants to be used as an introductory guidebook of II-2: Transit Forecasting Methods and Project Evaluation, TASK II: Systems Analysis which was defined in the Inception Report On the Technical Cooperation Program To the Economic Planning Unit, submitted to the SCA in July 1978.

In this textbook covered at the introductory level are: 1) basic concepts and methods of feasibility study, 2) forecast methods of seaborne trade, 3) transit forecasting methods, 4) basic concepts and methods of evaluation of the Canal capacity and 5) methods of project evaluation. These subject matters are described in this textbook so as to assist the participants to understand how the "systems analysis methods" should be used to tackle the Economic Unit's research task of transit forecast and project evaluation. However, it must be noted that the present training textbook is mainly concerned with the essentials and fundamentals of the concepts and methods relating to forecast and project evaluation. A detailed textbook will be prepared later for the second stage of the training program.

The present textbook is set out according to the following objectives and principles: 1) all of the SCA participants will become sufficiently exposed to practical problems involved in transit forecast and project evaluation; 2) theoretical knowledge and technical methods will be learnt through problem exercises and 3) the participants will be given orientation as to what they have to do at later stages of the technical training program.

However, it must be understood that the present training text is written as a lecture notebook so that the explanations provided on each of the subject matters are made as briefly as possible and a more detailed explanation will be provided during the lecture sessions.

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During the lecture sessions, a special lecture will be delivered by Professor S. Myojin of Okayama University on some of the basic forecasting methods.

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CHAPTER 1 INTRODUCTION TO FEASIBILITY STUDY

1.1 Systems Approach to the Feasibility Study

The main objective of the feasibility study on the Suez Canal development is to determine the best programme among various alternative developing schemes for the Canal, where the alternatives include a project of maintaining the present Canal situation.

For this purpose, the feasibility of each scheme is tested from the viewpoints of technology and economics, and each scheme is evaluated. According to the results of the evaluation, the best programme of the expansion schemes for the Canal is determined.

In this section, the outline of the methodology underlying the study is briefly described. In the remainder of this section, a summary of its main features is presented and in the succeeding sections each feature is discussed in turn.

The feasibility study consists of the following phases.

(a) Setting various expansion schemes for the Suez Canal

(b) Forecasting Canal traffic

In this phase, there are eight stages required for the forecasting:

(i) seaborne trade flows;
(ii) world fleet characteristics;
(iii) ship costs and sea distances;
(iv) route costs;
(v) route choice;
(vi) fleet mix relevant to the Suez Canal;
(vii) Traffic capable of using the Canal;
(viii) actual Canal traffic

(c) Project evaluation

In this phase, there are at least two analyses to be carried out:

(i) economic evaluation (cost-benefit analysis);
(ii) financial analysis.

Figure 1.1 is a schematic diagram of the feasibility study and shows the way in which the phases listed above are interrelated.

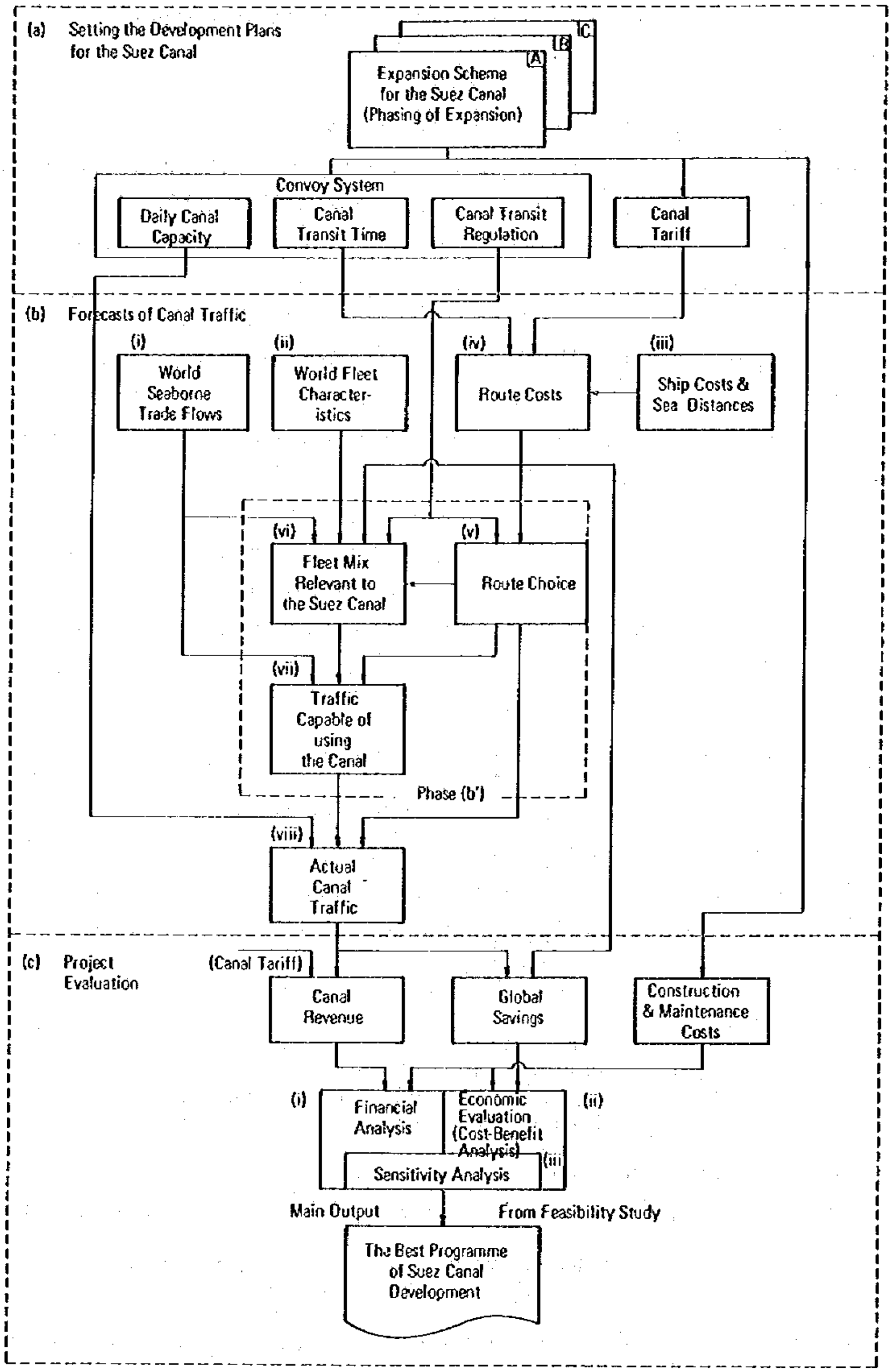


Fig. 1-1 Schematic Diagram of Feasibility Study

1.2 Setting Various Expansion Schemes for the Suez Canal

Each expansion scheme is defined in terms of depth, width, existence of by-passes, convoy system and other characteristics of the Canal. The phasing of expansion is also to be set in the scheme.

The data described above is used to determine Canal daily capacity, Canal transit time and Canal transit regulation in each year of the forecasts for each expansion scheme. These factors are used in the forecast phase. Canal tariff is also to be set in this phase, but the level of Canal tariff will be modified in the succeeding phases from the viewpoint of Canal revenue.

1.3 Forecasting Canal Traffic

(1) Seaborne Trade Flows

Firstly, commodities and areas (origin and destination zones) are categorised. The classification of both commodity and area should be made so that it minimises the necessary input information while at the same time keeping important characteristics for determining the proportion of each trade that will use the Suez Canal.

In order to forecast the long-term seaborne trade flows for each commodity, it is necessary that the following forecasts should be carried out in turn for each commodity.

1) Production and consumption in each zone
These are forecast based upon the forecasts of GDP and others.
2) Import and export of each zone
3) Trade flows between each pair of zones
Trade flow forecast is carried out by using the present trade flow pattern, distances between each zone and imports and exports of each zone.
Note: This work is necessary only for the O/D pairs where distance savings would be accrued from transitting the Suez Canal instead of taking the Cape Route.
4) Seaborne trade flows
In the case of crude oil, it is necessary that the seaborne trade flow should be forecast by subtracting the volume of crude oil movement through pipelines from the trade flow given in the previous paragraph.

(2) World Fleet Characteristics

Vessel sizes and types are to be categorised in order to forecast Canal traffic.

The proportion of vessels within a particular size category that can transit the Suez Canal, is determined. In addition, the following transit conditions should be taken into account in the case of oil tankers.

1) fully laden
2) partly laden
3) in ballast
4) transit not possible, either laden or in ballast

In the case of oil tankers, the main output from this stage is the proportion of vessels falling into each of the transit conditions for each size category of vessels under each of the various transit regulations. The total number of vessels in the world is also forecast for each vessel category.

(3) Ship Costs and Sea Distances

Three main categories of ship cost are identified:

1) capital costs
2) fixed operating costs
3) voyage costs

Each component cost of the above are input to the route cost stage together with sea distances.

(4) Route Costs

The route cost stage is used to calculate the cost of shipping one ton of cargo on each trade flow and in each type of vessel that may be relevant to the Canal. Shipping costs are calculated for each trade flow both for the route using the Canal and also for the Cape route. In the case of oil and oil products, three different route costs are calculated.

1) via the Canal both laden and in ballast;
2) via the Canal in ballast but not laden;
3) not via the Canal either laden or in ballast.

(5) Route Choice

The route choice stage is used to determine the proportion of tonnage using the Canal for each category of vessels on each trade flow. The proportion of that tonnage for which vessels of that category return in ballast through the Canal is also determined.

In the case of crude oil tankers and dry bulk carriers, probabilistic methods are often used to determine the proportion of tonnage using the Canal route.

In the case of vessels other than crude oil and dry bulk carriers, the analysis of route choice is carried out in a rather simpler way.

The output from this stage is as follows:

Output from Route Choice Stage			
	Trade Flow from	[ ] to [ ]	
	Vessel Type	[ ]	
	Vessel Size	[ ]	
		Proportion	
(1) via the Suez Canal		[ ]	%
(2) via the Cape		[ ]	%
Total		100	%

(6) Fleet Mix Relevant to the Suez Canal

The fleet mix stage is used to estimate the future mix of crude oil carriers by size on each trade flow for each year of the forecasts.
The tanker fleet mix stage is divided into two sub-stages. In the first, a minimum percentage of the tonnage on each trade flow, which will not be affected by the expansion of the Canal, is allocated to each vessel size group. The second sub-stage allocates the remaining tonnage on each trade flow on the basis of the cheapest cost per cargo ton within a maximum percentage of using vessels for each size group.

(7) Traffic Capable of Using the Canal

In this stage, the traffic which wishes to use the Canal in the absence of a daily capacity constraint, is determined. The following data is used to carry out the calculation:

1) the forecast trade flows;
2) the fleet mix on each trade flow;
3) the proportion of tonnage using the Canal for each category of vessel on each trade flow.

By combining the outputs from the route choice stage with the fleet mix on each trade flow, the volume of traffic capable of using the Canal can be determined.

As the stages from (5) to (7) are closely interrelated and include very complicated processes, the following simplified method of traffic forecasting might be used in the introductory feasibility study.

The outline of the forecast method is shown as a schematic diagram in Figure 1.2. There are four stages and each stage is explained in turn below.

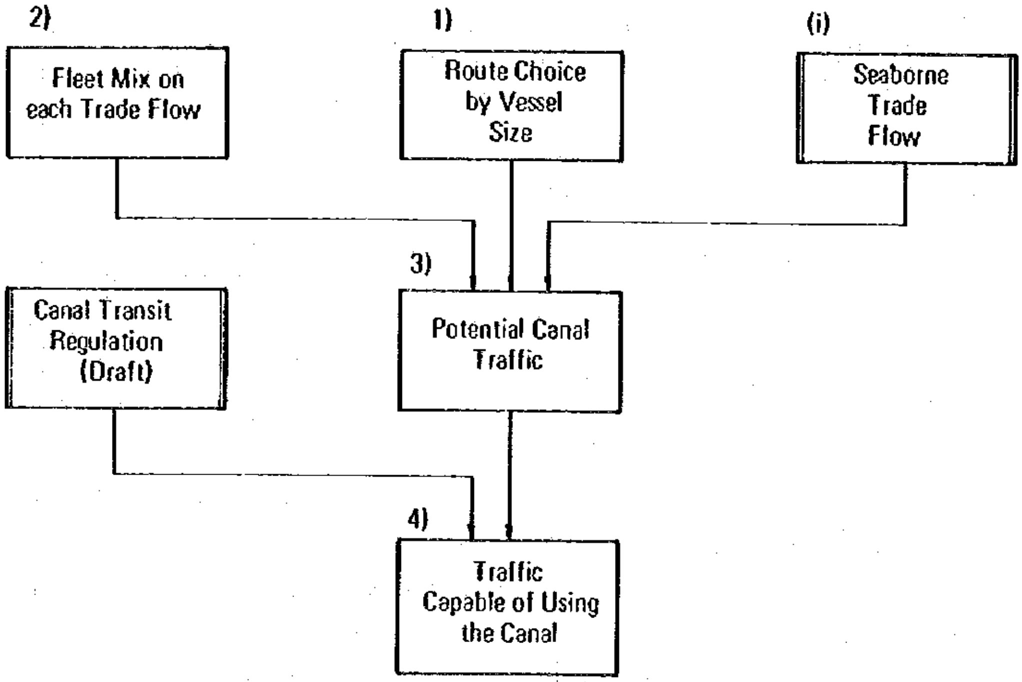


Fig. 1.2 Schematic Diagram of Simplified Forecast Method

1) Route choice by vessel size
In this stage, the proportion choosing the Suez route is calculated based upon the cost difference between the cost via Suez and via the Cape. The result derived from the cost differences is hereafter called the cost-derived proportion.

2) Fleet mix on each trade flow
The future fleet mix on each trade flow is forecast on the basis of the present fleet mix and future trends. This stage is a free-standing stage not directly linked to any other portion of the study. The proportion of each size and each type of vessel is determined on each trade flow.

3) Potential Canal traffic
The traffic which wishes to use the Canal in the absence of a draft constraint, is calculated. The following information is used to carry out the calculation:

a) the forecast trade flows;
b) the fleet mix on each trade flow;
c) the choice of route derived on the basis of route costs for each category of vessel on each trade flow.

4) Traffic capable of using the Canal
Potential Canal traffic and Canal transit regulations (draft constraint) are used to determine the traffic of vessels that are physically able to transit the Canal either fully laden, partly laden, or in ballast (see Figure 1.3).

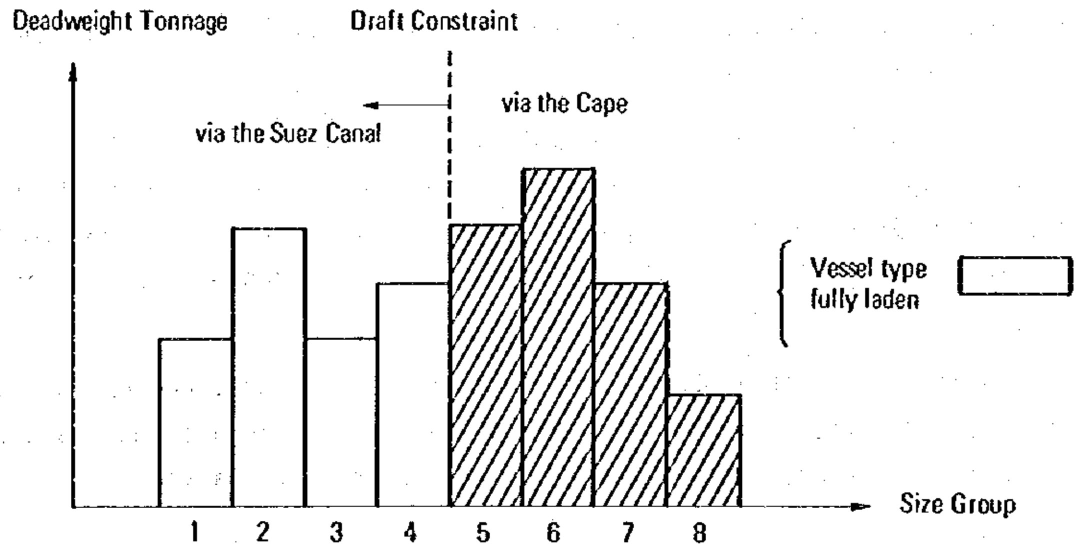


Fig. 1.3 Draft Constraint

(8) Actual Canal Traffic

The Canal traffic figures obtained in the preceding stage have to be adjusted so that they are consistent with the daily capacity of the expansion scheme under evaluation. This adjustment of traffic is carried out as follows:

1) evaluated the daily capacity and check whether the Canal can meet the demand.
2) if the Canal has insufficient capacity to meet the demand, the transits whose savings in time by using the Canal are small, are reduced until the Canal can meet the demand.

1.4 Project Evaluation

The economic and financial evaluation of different expansion schemes for the Suez Canal is a complex process requiring a wide range of knowledge. The comparative evaluation of different expansion schemes cannot be measured according to one simple criterion.

In this phase, therefore, it is necessary that both the methods of cost/benefit analysis and financial analysis should be employed. Since there is considerable uncertainty regarding many of the basic assumptions adopted, sensitivity analysis should also be used both in the economic and financial evaluations.

At the beginning of this phase, construction, maintenance, and operation costs are estimated. At the same time, Canal revenue is also estimated. These cost and revenue data are used in the succeeding analyses.

(1) Economic Evaluation

Economic Evaluation has an another name, Cost-benefit analysis and it has two different important viewpoints: Egyptian Economy and World Economy. From the viewpoint of Egyptian economy, the main benefits derived from the projects are the increment in Canal revenues. From the viewpoint of World economy, the main benefits of the projects are the sum of the increments of Canal revenues which is distributed to the Egyptian Economy and the cost savings in shipping accrued from the shortened distance due to the Canal development, which is at first gained by the ship operaters and later might redistributed to the whole world economy. Hence the sum of the two kinds of benefits mentioned above can be called the Global Benefits.

Economic analysis calculates a stream of net cash flow of each project, which is composed of benefits and cost streams. Those benefits and cost should be evaluated by the "real economic prices" which reflect the true economic scarcity, instead of the current prices. The internal rate of return and a net present worth are calculated for the cash flow stream derived from each project.

(2) Financial Analysis

The purpose of the financial analysis stage is to evaluate the cash flow streams attributable to each expansion scheme from the viewpoint of SCA.

The cost schedule is determined by using data on construction and operating costs and financing terms in order to calculate the schedule of cash payments that must be made by the SCA.

The financial analysis is carried out by using the annual revenue estimates and the schedule of costs in order to calculate a stream of net cash flows. The stream represents those cash flows that will be paid or received directly by the SCA and therefore includes tax, the payment of interest and subsidies.

(3) Sensitivity Analysis

Since there is considerable uncertainty regarding many of the basic assumptions adopted, sensitivity analysis is used to test the robustness of the results on alternative expansion schemes which will be affected by changes in the following factors:

1) trade flows;
2) fleet mix;
3) tariff levels;
4) freight rates and costs;
5) inflation rates (for financial analysis only)
6) discount rates;
7) construction costs;
8) delays in construction.

According to the results from those analyses described above, comparative evaluation is made for various alternative expansion schemes. Then, the best programme for the Suez Canal development including a "project of maintaining the present Canal situation" is determined.

1.5 Exercises

Answer the following questions:

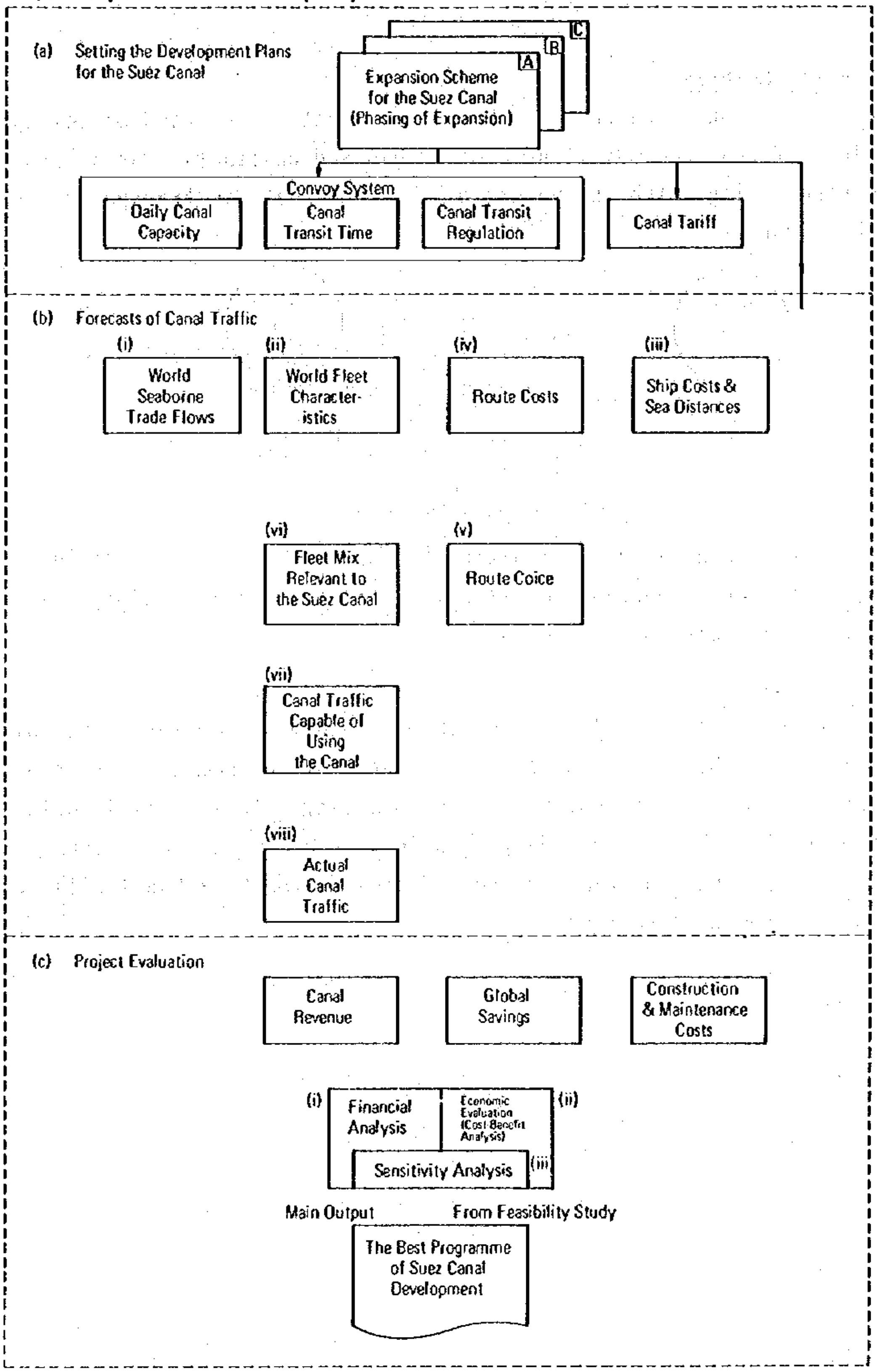
(1) Why should long-term forecasts be carried out in the feasibility study?

(2) Why are the cost-benefit analysis, financial analysis and sensitivity analysis required in the phase of project evaluation?

What are the differences between cost-benefit analysis and financial analysis?

(3) Complete the chart of feasibility study

(3) Complete the Chart of Feasibility Study



CHAPTER 2 FORECASTS OF SEABORNE TRADE FLOWS

2.1 General Remarks

The trade flow can be represented by five elements: the kind of commodity, the volume of that commodity, name of origin and destination area and the time period during which the volume of that commodity is transported as shown by Figure 2.1.

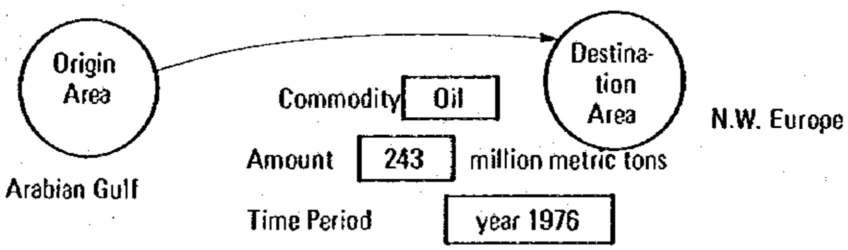


Fig. 2.1 Definition of Trade Flow

Because there are numerous commodities and numerous places of origin/destination, it is very important for an efficient study to adequately classify commodity and origin/destination area.

(1) Commodities

The proper commodity classification depends mainly on the International Statistics available, the degree of importance of the commodity to the Suez Canal and the means of transporting the commodity. It is very important to keep the total number of commodity groupings to a minimum for economy of analysis. The important kinds of commodities to the Suez Canal will be discussed in the next section.

(2) Origin/Destinations

The origin/destination zoning needs careful consideration on, International Statistics availability, the importance of the route to the Suez Canal, the way in which individual ports can be grouped into an effectively single route. It is also important to keep the total number of zones to a minimum for economy of analysis.

(3) Amount of Trade Flow

The amount of trade flow is expressed in million metric tons per annum in the case of long-term forecasts.

As a result of the discussion described above, the annual trade flow of commodity k from zone i to zone j can be denoted by T_k (i, j). Generally, the trade flows T_k (i, j) are expressed as a table for each commodity. This table is called as OD table (Origin/Destination table), and an example of an OD table is shown as Table 2.1.

Table 2.1 An Example of an OD Table

Commodity [k] Year [ ]

to / from	Zone j= 1	2	3	4	5	6	Total
Zone i=1							
2					(*)		
3							
4							
5							
6							
Total							

(million metric tons)

[The marked element (*) is the cell for $T_k(2, 5)$]

Suppose that we devide commodities into eleven groups and O/D region into twenty-four zones, we would have 6,336 factors (commodities x origin zones x destination zones) to predict for each year of the forecasts. Although this is quite a large number, many of the factors are equal to zero or negligibly small. Therefore, the number of factors which we must forecast is not so large.

2.2 Important Commodities to the Suez Canal

Oil is more important than other kinds of commodities for the Suez Canal Authority. Oil shipment will compose a main source of additional marginal Canal revenue derived from the different expansion schemes that are described below.

For each category of commodities, the volume of seaborne trade potentially available for Suez Canal transits in 1976 was estimated by picking up the O/D pairs that would save distance by transiting the Suez Canal instead of taking the Cape route. The proportion of the estimated volume for each commodity is shown in Table 2.2. On the other hand, the actual volume of seaborne trade through the Canal in 1976 for each commodity is available from the Suez Canal Annual Report. The proportion of the actual volume for each commodity can be compared with the estimated one as shown in Table 2.2.

Table 2.2 Commodity Structures of Seaborne Trade (1976)

Commodity	Seaborne Trade in the World (percentage)	Seaborne Trade Relevant to the Suez Canal (percentage)	Actual Seaborne Trade via the Suez Canal (percentage)
Crude Oil and Oil Products	50.5%	84.3%	28.8%
Iron Ore	8.9%	2.5%	7.8%
Coal	3.8%	0.8%	0.6%
Grain	4.4%	0.8%	6.7%
Others	32.7%	11.6%	56.1%
Total	100.0%	100.0%	100.0%

The oil share of all trade potentially available for Suez transits is 84.0%. This figure contrasts with 28.8% for the oil share of the actual trades through the Canal.

The proportions using the Canal are estimated to be 5.2% and 68.4% respectively for oil and non-oil as shown in Table 2-3.

Table 2.3 Proportions Using the Canal in 1976

Commodity	Trade Volume		Proportion using the Canal
	Total (Potential)	Through the Canal (Actual)	
Oil	646 (10^6 tons)	33.9 (10^6 tons)	5.2%
Non-Oil	123 (10^6 tons)	83.9 (10^5 tons)	68.4%

In 1976, therefore, Canal oil traffic accounted for only 5% of all inter-area oil movements potentially available for Suez transits. Canal non-oil traffic, however, accounted for about 70% of non-oil movements relevant to the Canal. The reason why the oil trade proportion using the Suez Canal is very small, is mainly due to the changes in tanker fleet structure experienced since the Canal was closed. The closure of the Canal gave an impetus to the construction of very large crude carriers aimed at achieving the maximum economies of scale on the long route around the Cape. Because of this, the present proportion of the fleet capable of loaded voyages through the Canal with its current 38-foot draft restriction has decreased dramatically since 1966. Only 16.5% of the fleet is now under the 60,000 DWT limit for transiting the Canal fully laden, as compared to 77.2% in 1966.

As explained above, oil is most important for the Suez Canal, therefore, detailed forecast studies must pay attention to oil movements. For other commodities except oil, simpler methods of forecasting might be employed.

Commodity structure of world seaborne trade (1965-1977) is shown in Table 2.4. The share of crude oil and oil products has been over 50% since 1970.

Table 2.4 World Seaborne Trade, 1965 – 1977

Year	Total Trade Estimate (In million metric tonnes)	Commodities					
		Crude Oil	Oil Products	Iron Ore	Coal	Grain	Other Estimate
1965	1,638	33.7%	10.7%	9.3%	3.6%	5.0%	37.7%
1966	1,772	34.2	11.0	8.6	3.4	5.2	37.5
1967	1,864	36.6	10.4	8.8	3.6	4.5	36.7
1968	2,041	37.6	10.1	9.2	3.6	3.8	35.6
1969	2,237	38.9	9.3	9.6	3.7	3.2	35.3
1970	2,481	40.1	9.9	10.0	4.1	3.6	32.4
1971	2,575	41.5	9.6	9.7	3.7	3.5	32.0
1972	2,762	42.9	9.4	8.9	3.5	3.9	31.4
1973	3,120	43.8	8.8	9.6	3.3	4.5	30.1
1974	3,247	41.9	8.1	10.1	3.7	4.0	32.2
1975	3,043	41.4	7.7	9.6	4.2	4.5	32.7
1976	3,320	42.7	7.8	8.9	3.8	4.4	32.4
1977 (est.)	3,421	43.3	8.2	8.3	3.7	4.2	32.7

Note: Attention is drawn to the figures for Grain which include sorghum and soya beans (in addition to wheat, maize, barley, oats and rye) for the entire period.

Source: Fearnley and Eger's Chartering Co., Ltd., Review 1977.

2.3 Methodology of Forecasts

The basic procedure of long-term forecasting of seaborne trade flows is mainly divided into the following six components:

1) scenario of world economic development;
2) consumption and production;
3) imports and exports;
4) world trade flows;
5) inter-area trade flows relevant to the Suez Canal;
6) seaborne trade flows relevant to the Suez Canal.

Figure 2.2 is schematic diagram of the long-term forecasting procedure. Note how the components listed above are inter-related.

The outline of the methodology underlying the long-term forecasts is briefly described in this section. In the remainder of this section, each component is explained in turn.

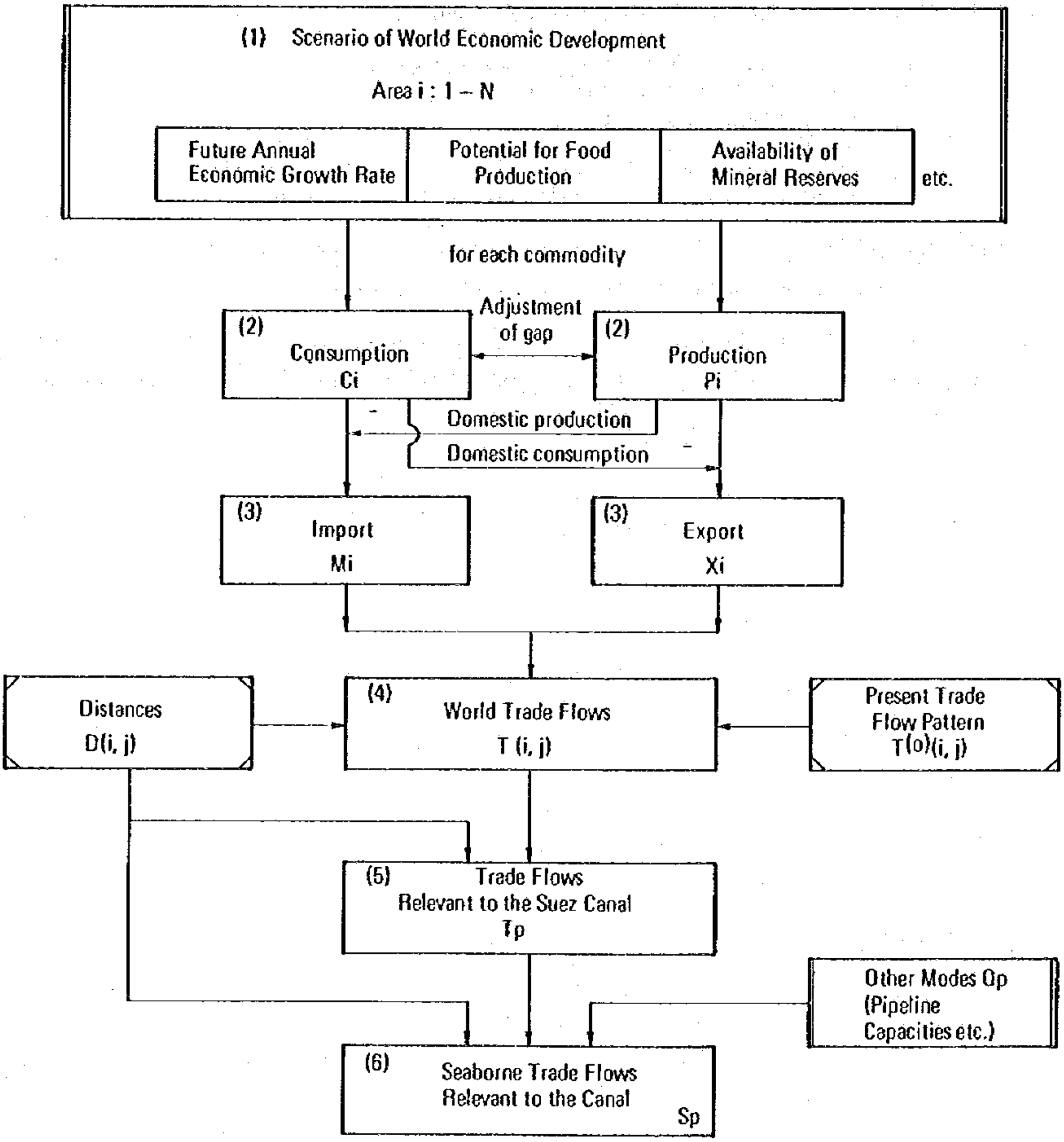


Fig. 2.2 Outline of Forecasts

(1) Scenario of World Economic Development

In the case of long-term forecasts, it is necessary to choose a set of well-defined hypotheses concerning the evolution of the economic environment for each area. If several equiprobable possibilities should be retained, a scenario is made to incorporate each set of hypotheses.

In order to set a scenario considerable use will be made of existing forecasts available from various organizations such as the United Nations and OECD. From the comparison among the various forecasts, several sets of scenarios must be extracted. The extracted scenarios have to include one which will be considered as the most probable and others which will be derived from fundamentally different hypotheses.

A scenario consists of many factors. The most important factor is the GDP (Gross Domestic Product) annual growth rate for each area. GRi denotes the GDP annual growth rate of area i. In addition to GRi, it is necessary to determine all explanatory variables, the potential for food production, the availability of mineral reserves, OPEC behavior, important discoveries of oil and natural gas, a slowing-down of nuclear projects, etc.

In the succeeding parts of this section, the methods of forecasting trade flows will be explained in turn. The methods to be described below can be applied for each commodity.

(2) Consumption and Production of Commodity

Consumption in area i is denoted by Ci. Ci is often assumed to be dependent on the GRi (GDP growth rate of area i) and the elasticity (consumption growth rate/GDP growth rate, e_i) of area i. The following equation is the most popular one representing the relationship between C, GR and e:

$$C_i^n = C_i^o \cdot (1 + e_i \cdot GRi)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}1)$$

where C_i^o: consumption in area i of the base year,

C_i^n: consumption in area i of the n-th year.

GRi and e_i have been already determined in the scenario stage.

In the case of energy consumption, oil consumption in area i is forecast by taking into account the availability of alternative energy sources in that area.

Production capability in area i (Pi) is forecast by taking into account oil reserve, coal reserve, and other constraints. After forecasting production capabilities, total consumption is compared to total production capability and the following modification is made.

If $\sum_{i=1}^{N} Ci \leq \sum_{i=1}^{N} Pi$, Pi is modified so that

$\sum_{i=1}^{N} Pi$ is equal to $\sum_{i=1}^{N} Ci$.

If $\sum_{i=1}^{N} Ci > \sum_{i=1}^{N} Pi$, Ci is modified so that

$\sum_{i=1}^{N} Ci$ is equal to $\sum_{i=1}^{N} Pi$

(3) Import and Export

Import to area i (Mi) and export from area i (Xi) are forecast by the following equations.

$$Mi = \begin{cases} Ci-Pi, & \text{if Ci is greater than Pi.} \\ 0, & \text{otherwise} \end{cases}$$
$$Xi = \begin{cases} 0, & \text{if Ci is greater than Pi.} \\ Pi-Ci, & \text{otherwise.} \end{cases} \qquad \text{............(2-2)}$$

(4) World Trade Flows of Commodity

Trade flows between areas are forecast based upon the data of imports, exports, present trade flow pattern and the distances between areas. Various methods have been developed and applied. Among them, the FRATOR method which is explained below is one of the most famous methods in forecasting the trade flow pattern.

FRATOR method

The data which will be used in the FRATOR method is as follows:

$T^{(o)}(i, j)$: present trade flow from area i to area j.

$X^{(o)}(i)$: present total exports from area i.

$M^{(o)}(j)$: present total imports to area j.

$$X^{(o)}(i) = \sum_{j=1}^{N} T^{(o)}(i, j) \text{ ....(2-3)}$$

$$M^{(o)}(j) = \sum_{j=1}^{N} T^{(o)}(i, j) \text{ ....(2-4)}$$

$X(i)$: future total exports from area i.

$M(j)$: future total imports to area j.

The forecast of future trade flows ($T(i, j)$) is carried out through the following steps by using the above data.

1) First approximation $T^{(1)}(i, j)$

The following growth factors are calculated as shown below.

$$F^{(o)}(i) = X(i)/X^{(o)}(i) \quad \text{.........................} \quad (2\text{-}5)$$

$$G^{(o)}(j) = M(j)/M^{(o)}(j) \quad \text{.........................} \quad (2\text{-}6)$$

The first approximations $T^{(1)}(i, j)$ are obtained by the equation.

$$T^{(1)}(i, j) = T^{(o)}(i, j) \cdot F^{(o)}(i) \cdot G^{(o)}(j) \cdot \frac{U^{(o)}(i) + V^{(o)}(j)}{2}$$

$$\text{.........................} \quad (2\text{-}7)$$

where,

$$U^{(o)}(i) = X^{(o)}(i)/[\sum_{j=1}^{N} (T^{(o)}(i, j) \cdot G^{(o)}(j))] \quad \text{....} \quad (2\text{-}8)$$

$$V^{(o)}(j) = M^{(o)}(j)/[\sum_{i=1}^{N} (T^{(o)}(i, j) \cdot F^{(o)}(i))] \quad \text{....} \quad (2\text{-}9)$$

2) Second approximation $T^{(2)}(i, j)$

$$X^{(1)}(i) = \sum_{j=1}^{N} T^{(1)}(i, j) \quad \text{........................} \quad (2\text{-}10)$$

$$M^{(1)}(j) = \sum_{i=1}^{N} T^{(1)}(i, j) \quad \text{........................} \quad (2\text{-}11)$$

$$F^{(1)}(i) = X(i)/X^{(1)}(i) \quad \text{........................} \quad (2\text{-}12)$$

$$G^{(1)}(j) = M(j)/M^{(1)}(j) \quad \text{........................} \quad (2\text{-}13)$$

$$U^{(1)}(i) = X^{(1)}(i)/[\sum_{J=1}^{N} (T^{(1)}(i, j) \cdot G^{(1)}(j))] \quad \text{.....} \quad (2\text{-}14)$$

$$V^{(1)}(j) = M^{(1)}(j)/[\sum_{i=1}^{N} (T^{(1)}(i, j) \cdot F^{(1)}(i))] \quad \text{.....} \quad (2\text{-}15)$$

$$T^{(2)}(i, j) = T^{(1)}(i, j) \cdot F^{(1)}(i) \cdot G^{(1)}(j) \cdot \frac{U^{(1)}(i) + V^{(1)}(j)}{2}$$

$$\text{........................} \quad (2\text{-}16)$$

3) k-th approximation $T^{(k)}(i, j)$

$$T^{(k)}(i, j) = T^{(k-1)}(i, j) \cdot F^{(k-1)}(i) \cdot G^{(k-1)}(j) \cdot \frac{U^{(k-1)}(i) + V^{(k-1)}(j)}{2} \quad \text{............ (2-17)}$$

Iterative calculation is finished when all of $F^{(k)}(i)$, $G^{(k)}(j)$, $U^{(k)}(i)$, and $V^{(k)}(j)$ converge to unity.

When employing a Gravity Model, distance data between each pair of areas are also used to forecast the trade flows.
By the methods described above, future trade flows T(i, j) are forecast.

(5) Inter-Area Trade Flows Relevant to the Suez Canal

The distance data is used to extract the origin/destination pairs (p) which are potentially available for Suez transits. After that extraction, the trade flows relevant to the Suez Canal (T_p) are determined.

(6) Seaborne Trade Flows Relevant to the Suez Canal

For each OD pair (p) relevant to the Canal, the share of the seaborne trade is estimated by taking into account the following information.

Other transportation modes available for the trade
Distance between each OD pair
Category of commodity
etc.

In the case of crude oil trade, the future pipeline capacities relevant to the extracted OD pairs are used to forecast the seaborne trade flows. (S_p)

$$S_p = T_p - Q_p \quad \text{.................................. (2-18)}$$

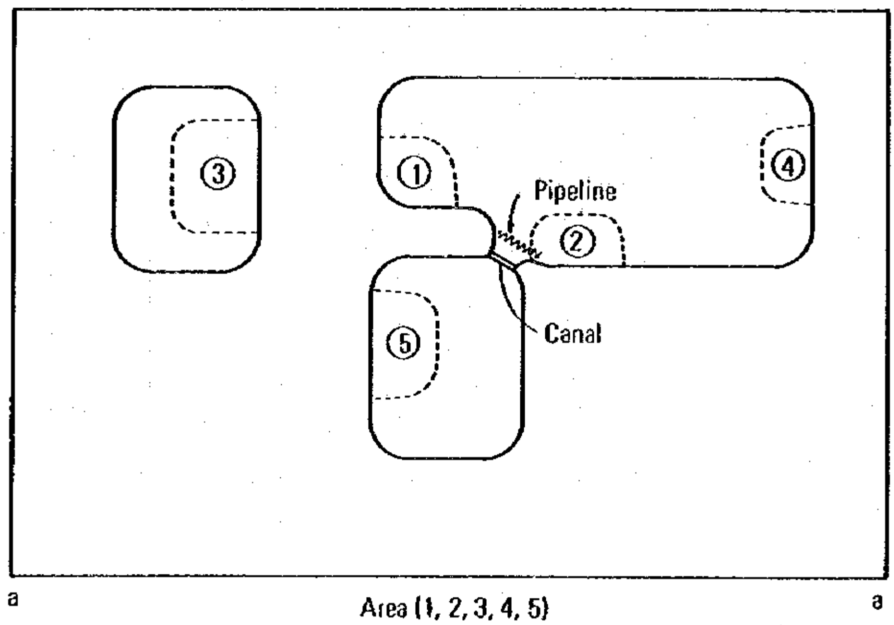
where Q_p is the pipeline capacity of the O-D pair p.

2.4 Exercises

Forecast the crude oil seaborne trade flows of the year 1985, based upon the following data.

(1) Five areas in the world shown below.

MAP



Area (1, 2, 3, 4, 5)

(2) Sea distance table (symmetric)

(   ): via the Canal

O \ D	Area 1	2	3	4	5
Area 1		6000 (1500)	1500	10000 (5500)	1500
2			7000 (3000)	4000	4500 (3500)
3				4000 (7000)	2500
4					6000 (5500)
5					

(in miles)

(3) Present trade flows (1975)

in million metric tons

O \ D	1	2	3	4	5	Export
1	0	0	0	0	0	0
2	400	0	300	400	0	1100
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	50	0	40	10	0	100
Import	450	0	340	410	0	1200

Pipeline capacity (2 1) is 50 million metric tons in 1975.

(4) Production and consumption in 1975

Area	1975		Growth Rate of GDP (1975/1985)	Elasticity (1975/1985)	1975	
	Produc-tion	Consump-tion			Import	Export
1	150	600	3%	0.9	450	0
2	1150	50	9%	1.1	0	1100
3	700	1040	3%	0.9	340	0
4	0	410	6%	0.9	410	0
5	150	50	7%	1.0	0	100

(5) Production capability in 1985

Area	Production Capability
1	200
2	1700
3	800
4	0
5	400
Total	3100

Q1. Calculate the seaborne trade flows which were potentially available for the canal in 1975.

Origin	Destination	Volume
Total		

Q2. Calculate the future consumption in each area

(1985)

Area	Consumption
1	
2	
3	
4	
5	
Total	

Q3. Calculate the future production in each area by using the following equation.

$$Pi = \frac{(\text{Production capability})i}{\sum_{j=1}^{5} (\text{Production capability})j} \times \left[\sum_{j=1}^{5} (\text{Consumption})j \right]$$

(1985)

Area	Production
1	
2	
3	
4	
5	
Total	

Q4. Calculate the future import and export for each area

Area	1985	
	Import	Export
1		
2		
3		
4		
5		
Total		

Q5. Forecast the future trade flows (OD table) by using the FRATOR method.
(Calculate $T^{(k)}$ until $|F^{(k)}-1.0| \leqq 0.01$ & $|G^{(k)}-1.0| \leqq 0.01$ for all i)

$T^{(1)}(i, j)$

O \ D	1	2	3	4	5	Export
1	0					
2		0				
3			0			
4				0		
5					0	
Import						

$T^{(2)}(i, j)$

O \ D	1	2	3	4	5	Export
1	0					
2		0				
3			0			
4				0		
5					0	
Import						

$T^{(3)}(i, j)$

O \ D	1	2	3	4	5	Export
1	0					
2		0				
3			0			
4				0		
5					0	
Import						

Q6. Calculate the future seaborne trade flows which are potentially available for the Canal in 1985.
(Pipeline capacity (② → ①) is assumed to be 150 million metric tons.)

(1985)

Origin	Destination	Volume
Total		

CHAPTER 3 TRANSIT FORECAST

3.1 Introduction

This chapter aims at analyzing the forecasting process of Suez Canal transits.

It is assumed that seaborne trade flow is already determined. Therefore the problem is how to distribute it between the relevant routes and vessel size categories.

This distribution depends upon the shipping cost per cargo ton, and this cost also is assumed to be given. This section, therefore, focuses on the general procedure of forecast and methodology of cargo tonnage distribution between routes and size categories.

3.2 Method of Approach

The forecasting process is separated into the following six phases.

(1) Trade flows: Trade flows are expressed in annual tonnage that is transported from one region (called origin) to another (called destination). These trade flows are the original source for the ships movement.

(2) World fleet characteristics: The size of vessels which would transit through the Suez Canal is important to the revenue of the Suez Canal Authority. And the fleet mix of the Canal transit, and the proportions of size categories depends upon the world fleet mix, the transit regulations of the Canal and the limitations of ports.

(3) Shipping costs: Shipping costs are composed of various kinds of elements that are grouped into capital costs and operating costs. The route choice and fleet choice, which route to choose and which size category of vessel to choose, are based on the shipping costs.

(4) Distribution model: This model is used to determine how the tonnage of the given OD seaborne trade flow will be distributed between different routes and vessels of different size. And both distributions are based on the comparisons of shipping costs and the market condition of vessels that may have effects on shipping costs.

(5) Canal traffic: The distribution model mentioned above allocates the tonnage of a given OD seaborne trade flow to each route and each size of vessel. The Canal transit tonnage of both cargo and ships are determined through the following two stages. Firstly, the Canal transit tonnage of

cargo and ships are calculated without the Canal regulations (potential traffic) and secondly, the potential tonnage is adjusted according to the regulations (actual traffic).

(6) Revenue: The Canal transit fee is decided as a unified rate with respect to vessel size and its rate depends on the vessel type and loading condition. Therefore the number of transits through the Canal with their size categories and their loading condition are used to calculate the revenue by the Canal.

Figure 3.1 is a schematic diagram showing how the forecasting steps progress while each trade flow pair is given.

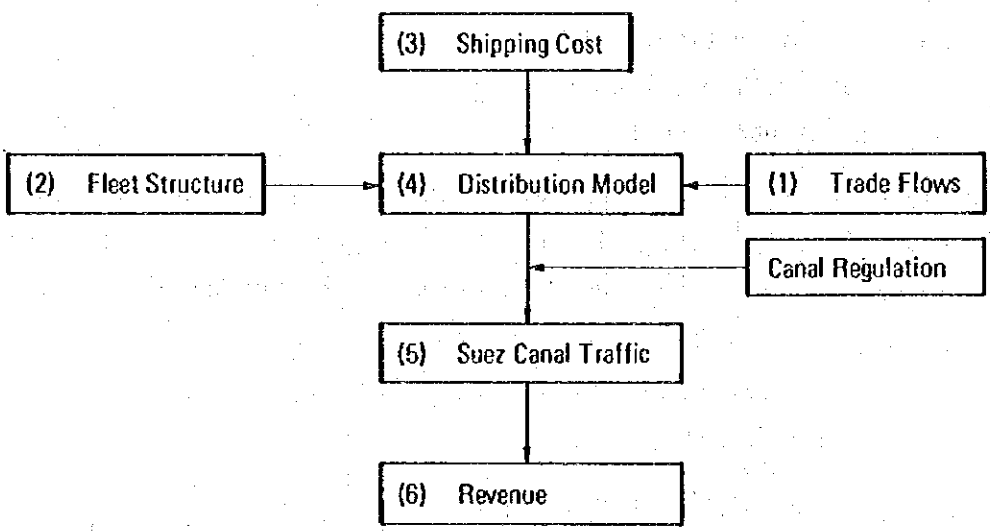


Fig. 3.1 Interrelation among Forecasting Phases

3.3 Shipping Costs

Shipping costs are the most important factors in determining the procedures when the trade flows are divided into the relevant routes and sizes of vessels.

Annual shipping costs per ship are divided into two main components, capital costs and operating costs.

$$C = C_k + C_o$$

C : shipping costs per cargo ton

C_k: capital cost

C_o: operating cost

These two costs are composed of the following factors respectively and the equations show the relationship between them.

$C_k = P_r\ (1+E)(R_d + R_r + R_i)$

P_r: contract price

E : fitting out expense ratio

R_d: depreciation rate

R_r: interest

R_i: insurance rate

$C_o = B_k + P_t + C_r + M_s + A_a + L_b + R_p$

B_k: bunker consumption charge

P_t: port charge

C_r: crew expense

M_s: miscellaneous

A_d: administration cost

L_b: lubricating oil cost

R_p: maintenance cost

It is useful for us to divide these costs per ship by the annual transportation volume and to obtain the value of the cost per cargo ton. The cost per cargo ton is expressed as the linear function of the voyage distance.

$C_p = a + bd$

d : transportation (voyage) distance

a, b : coefficients

$$a = \left[\frac{(cP_r+C_r+M_s+A_d+L_b+R_p)\cdot(D_t+D_o)}{D_a} + (D_t + D_o)\cdot B_2\cdot P_b + T_t + T_o\right]\cdot \frac{1}{D_W\cdot R}$$

$$b = \left(\frac{cP_r+C_r+M_s+A_d+L_b+R_p}{D_a} + B_1 P_b\right)\cdot\left(\frac{1}{S_1} + \frac{1}{S_2}\right)\cdot\frac{1}{24}\cdot\frac{1}{D_W\ R}$$

c : constant

D_t: loading time (days/voyage)

D_o: unloading time (days/voyage)

B_1: bunker oil consumption in voyage (t/day)

B_2: bunker oil consumption at anchor (t/day)

P_b: bunker oil price ($/t)

T_t: loading cost ($/operation)

T_o: unloading cost ($/operation)

S_1: laden ship speed

S_2: ship speed in ballast