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thesis entitled

SHIP TRAFFIC SIMULATION AND PORT INVESTMENT
OPTIMIZATION FOR LAGOS PORT COMPLEX IN NIGERIA

presented by

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has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Civil Engineering

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Date July 31, 1979

SHIP TRAFFIC SIMULATION AND PORT INVESTMENT OPTIMIZATION FOR LAGOS PORT COMPLEX IN NIGERIA

By

Samuel Kingsley Nnama

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Civil and Sanitary Engineering

ABSTRACT

SHIP TRAFFIC SIMULATION AND PORT INVESTMENT OPTIMIZATION FOR LAGOS PORT COMPLEX IN NIGERIA

By

Samuel Kingsley Nnama

The objectives of this dissertation are three fold; first to analyze and simulate the ship queuing problem at Lagos port. Secondly the research will prepare an annual cost analysis of various logistical port subsystems. Thirdly an optimization program will be employed to establish a sound criteria for port investments.

To achieve the first objective, the Chi-square statistical technique was employed to test the ship arrival and service distribution. Ship arrivals at the port follow a Poisson distribution while service fits a negative exponential distribution. A Fortran program was written to simulate the ship queuing process and print ship delay parameters and queue length.

The optimization program was employed to determine the optimum combination of port resources considering total thoroughput and total cost to the port under specific time constraints.

In general, this dissertation focuses on the problem of port congestion in developing countries. The overall approach is to analyze the port problems by relating it to national economic growth and other multi-modal transportation systems. Hence the author carried out a detailed discussion of multi-modal transportation networks in Nigeria.

However the methodology adopted in this research can be applied to any general cargo port both in developed and developing countries. As each general cargo port has unique morphology and service policy care should be taken in identification of traffic variables and logistical subsystems.

DEDICATED TO THE MEMORY

OF

MY FATHER AND MOTHER

CHIEF JOSHUA ORJI NNAMA
THE OFLOZOR IV OF NIBO, NIGERIA

AND

MRS. SELINA MGBAFOR NNAMA
THE ORIMILI I OF NIBO, NIGERIA

In recognition of your singular courage to break with established palace tradition in 1919. You chose to become missionaries. In four decades you established numerous schools and churches in several towns in both the upper Niger provinces and the impregnable Delta provinces. By doing this you unveiled the blanket of darkness and brought light to millions of less privileged people. It was in recognition of these services that you were nominated as a life member of the Niger Anglican Synod and the Niger Mother's Union respectively. Your example of princely humility has been unprecedented in the Niger Diocesse.

On behalf of your six children may I express our gratitude for the great price you paid for our education and up bringing. We have always counted your benevolence, honesty, steadfastness and calm composure as our greatest heritage.

ACKNOWLEDGEMENTS

I wish to express my gratitude to all the members of my Ph.D. guidance committee. Dr. William C. Taylor has been particularly helpful from the initial process of proposal development to the completion of this research. He shared the challenging problems of this dissertation with the author. His ideas provided direction when all hopes were lost. Dr. James Brogan in addition to serving on my guidance committee was my major supervisor as a graduate research assistant. The projects provided immense training for me. Dr. James Brogan also followed this research with special interest. I am grateful to him for useful ideas in developing the research structure. Dr. George Wagenheim has been my major advisor in areas of system logistics. He was instrumental in developing an operations research orientation to this problem. Dr. Gail Blomquist was readily available to make contributions on research problems. His advice helped me to determine the scope of the study. I am grateful to the entire members of my Ph.D. guidance committee for their numerous contributions which cannot be mentioned.

My gratitude also go to Chief and Mrs. Godwin Nnama, the Managing Director of NNAMA Shipping Lines, Inc. (NTL), for providing me with a scholarship up to graduation from the University of Nigeria Engineering School. The summer job experience I earned in the NTL introduced me to the logistics of ship traffic and cargo flow. My twin brother, Emmanuel and his wife Mercy deserve my special gratitude for their encouragement and support during the difficult days of this research. Emmanuel as the Assistant Chief Port engineer for Lagos port was instrumental for quick data collection and operations survey forms circulation. I will also use this opportunity to thank my sister Dinah and my brother Joshua for their contributions to my education. The Rev. Beford Nnama, my immediate senior brother deserves a special gratitude for his numerous contributions and encouragement at various stages of my education.

My wife Ihuoma has shown unlimited devotion and understanding during the field studies and the entire period of this research. She has been a tower of strength during my period of grief. I share this accomplishment equally with her. The birth of my son Ifeanyi Sam Jr. generated a new vigor in me therefore he equally deserves a special mention. I owe unlimited gratitude to Ihuoma and Sam Jr.

I wish to thank the General Manager of the Nigerian Port Authority, Alhaji Bamanga M. Tukur for his cooperation and authorization of this study. I am also grateful to numerous officials of the Nigerian Port Authority who were involved in various aspects of data collection and operations survey. Finally I wish to thank Brigadier Benjamin Adekunle (former military commandant of the port of Lagos and former commander of Nigeria Elite Commando Division) for useful discussions on the past and present problems facing the port of Lagos. Brigadier Benjamin Adelkunle lead a successful military campaign to decongest the port of Lagos in 1970. He is reputed as one of Africa's leading military logisticians and tacticians. His interest in this research has been special and I wish to thank him for this.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

1.1 Introduction

The international demand for shipping services is based on the economic law of supply and demand. Developing countries export agricultural products, timber, minerals and crude oil to the industrialized countries in return for processed food, drugs, manufactured goods, equipment and military hardware. This trend in international commerce creates a two directional logistical flow. Ocean shipping provides the dominant mode for movement of goods between nations. Seventy-eight percent of the total tonnage in the world trade are moved by merchant marines. Airlines move .5% of the total tonnage. The balance of 21.5% are moved by overland carriers rail and truck lines between contiguous countries. (1)

Ocean shipping is dominant because of the following major comparative advantages:

> Ocean liners and tankers have tremendous freight capacity (20,000 - 60,000 tons). A large liner of 60,000 tons moves six times the freight accommodated by a train load of 66 cars.
>
> Shipping freight rates are very low. The average revenue per ton mile for all modes in international trade is shown below
>
> Ocean liners - .2¢ per ton mile.
> Rail - 1.3¢ per ton mile.
> Air - 29.9¢ per ton mile. (2)

The tendency is for shippers to move only costly inventory (e.g. jewelry, watches) by air.

Since the rail lines are limited by the geographical dispersal of the continents, ocean liners are expected to remain the dominant mode for providing international trade. This view is substantiated by the fact that both international trade and ocean shipping are growing at almost the same rate. Between 1950 and 1970 world trade value increased by an annual rate of 5.42% while annual waterborne tonnage increased by 4.67%. (3) It follows that the smooth flow of goods will require the development of well equipped national ports. This need is even greater in developing countries because of the dependent nature of their economy on imported goods.

Developing Countries: Developing countries generate 41.0% of the world seaborne trade. (4) In recent times earnings from crude oil exports have bolstered national foreign exchange reserves. This has created a favorable balance of payment position for some developing countries. The result is that the level of import rises. This trend is expected because imports are a function of exports (i.e. input-output model). As those increases occur, port logistical subsystems (e.g. berths, shorehandling equipment, warehouses) become inadequate to handle the increasing number and types of ships. A common result is port congestion and ship queueing.

This implies that port planning and development should be tied to the economic growth of developing countries. Planning of ports must be carried out as a long term measure and not just an ad hoc project. The objective of this research is to analyze the planning requirements at the port of Lagos.

1.2 Overview of Nigerian Economy

An overview of Nigeria's economy is important to highlight the impact of economic growth on the port of Lagos. The Nigerian economy has been growing very rapidly since 1960 when she gained independence from British Administration. The discovery of petroleum onshore and offshore in 1957 was an economic landmark. Higher prices of oil in world market increased Nigeria's foreign exchange holdings. The gross domestic product jumped from $3.3 billion in 1960 to $4.8 billion in 1970. (5)

In addition to the petroleum increases, agricultural and manufacturing sectors have been growing at the average of 4% per year. The emphasis are on mechanized agriculture and large scale farming. Intermediate industries are being established for the processing of agricultural products and manufacturing of durable goods.

Governmental service is the highest growth area, with an annual growth rate of 30%. (6) The Government policy is to provide better education and health services to the people. This entails construction of numerous physical infrastructures to accommodate the expansion. These increased Government service activities have an upward multiplier effect on the national economy. Employment is increased in all sectors and a boom is created in the construction industries. Thus with more public and private spending the quantity and quality of imports is increasing.

In total, the Nigerian GNP has been growing at an annual rate of 10.0%. (7) This rate is significantly high for a developing country. It has many desirable features, but it is accompanied by a major problem, i.e. modification of physical infrastructures to accommodate the congestion created by such growth. National ports are examples of such infrastructures which must be developed to service increasing numbers of ships and to handle higher import and export freight tonnage.

1.3 Ocean Ports in Nigeria

Figure (1.1) illustrates the location of Nigerian seaports. The major seaports are Lagos and Port Harcourt, which together handle about 60% of the total freight tonnage. These two ports are general commodity ports and are equipped with specialized terminals for handling refined bulk products. The port of Lagos is dominant because Lagos is both the commercial center and administrative capital of Nigeria. This port is also a gateway to the densely populated Western States. Port Harcourt is a natural sheltered deepwater port. It services the oil rich delta region.

Burutu, Calabar, Warri, Sapele, Koko and Degema are minor ports located on inland channels which require regular dredging. The following table indicates the type and percentage of total freight tonnage (import and export) handled by each port. The port of Bonny is a specialized port developed to handle only crude oil shipments. The crude oil terminal is located to service ocean tankers directly. On the other hand, the minor ports of Sapele, Warri and Koko are inland river ports which are influenced by seasonal variation of channel depth. In low water (between December 1st and April 30th) the Benin and Warri rivers are 15 feet deep. (8) This means that only medium liners (20,000 tons) can safely navigate the channels.

Table (1-1). OCEAN PORTS OF NIGERIA

(9)

PORTS	% of Total Tonnage	No. of Berths	Remarks
Major Ports			
LAGOS	50	39	Major General Commodity Port
PORT HARCOURT	10	12	General Commodity
Minor Ports			
Sapele	1.5	3	General Commodity
Warri	2.0	3	General Commodity
Burutu	2.0	3	General Commodity
Calabar	2.0	3	General Commodity
Degema	1.0	2	Palm Oil Port
Bonny	30.0	6	Crude Oil Port
Koko	1.5	3	General Commodity

In conclusion, the ports of Lagos, Port Harcourt and Calabar are more suitable for major expansion because of year round deep approach channels (25 feet) and shipper preference because of their location.

1.4 The Existing Problem and Scope of the Study

The port of Lagos was built by the British administration in the early twenties. Nigeria's exports prior to 1957 were mainly agricultural products (cocoa, palm oil, groundnuts, rubber and timber, etc.). With the production of oil the national balance of payment position became more favorable. This economic boom resulted in greater government and private spending which required higher import levels.

In 1964 the port of Lagos handled imports of .99 million ton; ten years later import tonnage through the port increased to 2.29 million. (10) In this time the physical facilities at the port did not expand much. The number of berths became inadequate for the increasing number of ships calling on the port of Lagos. An average of ten ships a day arrived at the port of Lagos despite the fact that all 14 berths were occupied 95% of the time. (11)

Ship service times at berth were very long; it took an average of 10 days to off load and reload a ship. The delay was caused by lack of modern shorehandling equipment (e.g. cranes, fork lifts, roll on roll off steel structures, elevator conveyor belts). Warehousing space was not adequate to provide for increased freight-tonnage. This situation required that vessels (except container ships) had to wait until warehousing space was available. Harbor masters were unwilling to discharge cargo outside warehouses because of the high degree of pilferage associated with the port of Lagos. In the rainy tropical climate probability of damage is high to uncontainerized cargo.

Since all port facilities in Nigeria are government owned and operated, there was no opportunity for private investments to increase the logistical subsystem within the port complex.

Another bottleneck was the lack of efficient multi-modal freight terminals for the flow of goods in and out of the port system. Lagos port was designed as a railway port but train operations were irregular due to the lack of rail units allocated to port operations. The trucking industry dominated freight movement in and out of the port. This mode hauls 80% (12) of the total import freight leaving the port complex. It is apparent that this mode does not meet the high capacity required by port operations. One thousand trucks are required to move freight offloaded from an average liner of 20,000 tons.

The overall results of these structural and technical inadequacies can be summarized as follows: (13)

- Delay in ship waiting time within the queue. Average delays in 1975 was as high as 60 days.
- High berth occupancy rate. All 14 berths were occupied 95% of the time in 1975.
- Delay in ship service time at the berth. An average of 10 days was required to offload and onload a ship.
- Ship cluster off the coast of Nigeria. In July 1975 ships in the queue numbered 230.
- Due to high berth occupancy rates express ships were forced to wait for one or two days. Demurage on express ships are as high as $3500.00 a day.

1.5 Economic Justification for the Study

In 1975 a cluster of 230 ships waited an average of 60 days before berthing. The Government was worried because of the economic impacts of this situation. The average cost of demurage for general cargo ships was $2500.00 with some ships' demurage as high as $3000.00. (14) The total annual dollar cost of demurage can be estimated as follows:

Total Cost	=	$C_d \times T \times N$
where C_d	=	Daily Average Demurage fee for one ship in the queue.
T	=	number of days a ship stays in the queue before berthing.
N	=	total number of ships which entered Lagos port in 1975.
Total Demurage Cost	=	$2500 x 60 x 4000
		$600,000,000

This figure represents 14.5% of the national foreign exchange holdings in 1975. It is evident that port demurage is draining the national reserve. The government, in an effort to capture some of the demurage charges, increased import and export duties. The shippers in turn increased unit cost of goods sold to consumers. This situation created inflationary pressure on the economy. To rescue the market situation, the government enacted price control laws. These laws were not very successful because many dealers resorted to black market sales.

In-transit damages occur to some commodities due to long ship waiting times and rainy tropical weather. In 1974 four ship loads of cement valued at about $2 million spoiled while the carriers were in the queue for over 60 days. (15) The building industry suffered tremendously because of a lack of construction materials. Government construction projects (e.g. schools, hospitals, factories) were delayed. Individual home builders had to abandon construction due to high costs of materials. In general port congestion created a downward multiplier effect on the economy. Unemployment and inflation increased due to the slump in the construction industry which is a major employment sector.

Regional Influences: Port congestion in Nigeria has great regional influence on landlocked countries like Chad and the Niger Republic. These two countries direct 40% and 60%, respectively, of their export and import freight via Lagos. It is evident that these countries are also affected by congestion at the port of Lagos. The port of Lagos is a regional port and an important node center for the movement of import and export commodities.

In July 1975 an agreement was negotiated between Nigeria and Ghana allowing ships bound for the port of Lagos to discharge their freight in Ghana's port of Accra. (16) Truck lines would complete the service by hauling the goods from Accra to Lagos a distance of 300 miles. This arrangement had specific problems; first Ghana demanded exchange of crude oil in return for these services. Another agreement was signed with the Republic of Benin to enable overland shipment through its territory. Overland shipments did not work as efficiently as expected because of the tariffs associated with international shipments and in-transit losses.

Improvements

In September 1977 the Nigerian Government completed the 'Tin Can' extension of the Lagos Port complex. This improvement provided ten extra berths with modern shore handling equipment and warehouses. (17) It is apparent that this improvement will reduce ship waiting and service time but the following questions remain unanswered:

- What was the relative contribution of inadequate berths and poor service facilities at the old and new berths to ship delay and cost?
- What is the optimum number of berths to meet the demand for shipping services in the next 20 years.
- What logistical subsystems should be combined to achieve a flow rate that will minimize total ship delay?
- What multi-modal systems are necessary for goods movement into and outside the port system?
- What is the cost effectiveness of alternative port investments (e.g. new berths, port handling equipment, multi-modal transfer facilities, rail road yard).

The 'Tin Can Creek' port extension was capital intensive, total cost were as high as $350 million. (18) However, this expansion was merely an ad hoc measure to meet the challenge of port congestion. The Nigerian Port Authority deserves credit for this improvement which averted a total failure. There is still a great need for further logistical and engineering analyses aimed at increasing the flow rate of goods and reducing ship delay. There is also a need to tie port development with the economic growth of the country.

Figure (1.1). NIGERIAN PORTS AND COSTAL CREEKS

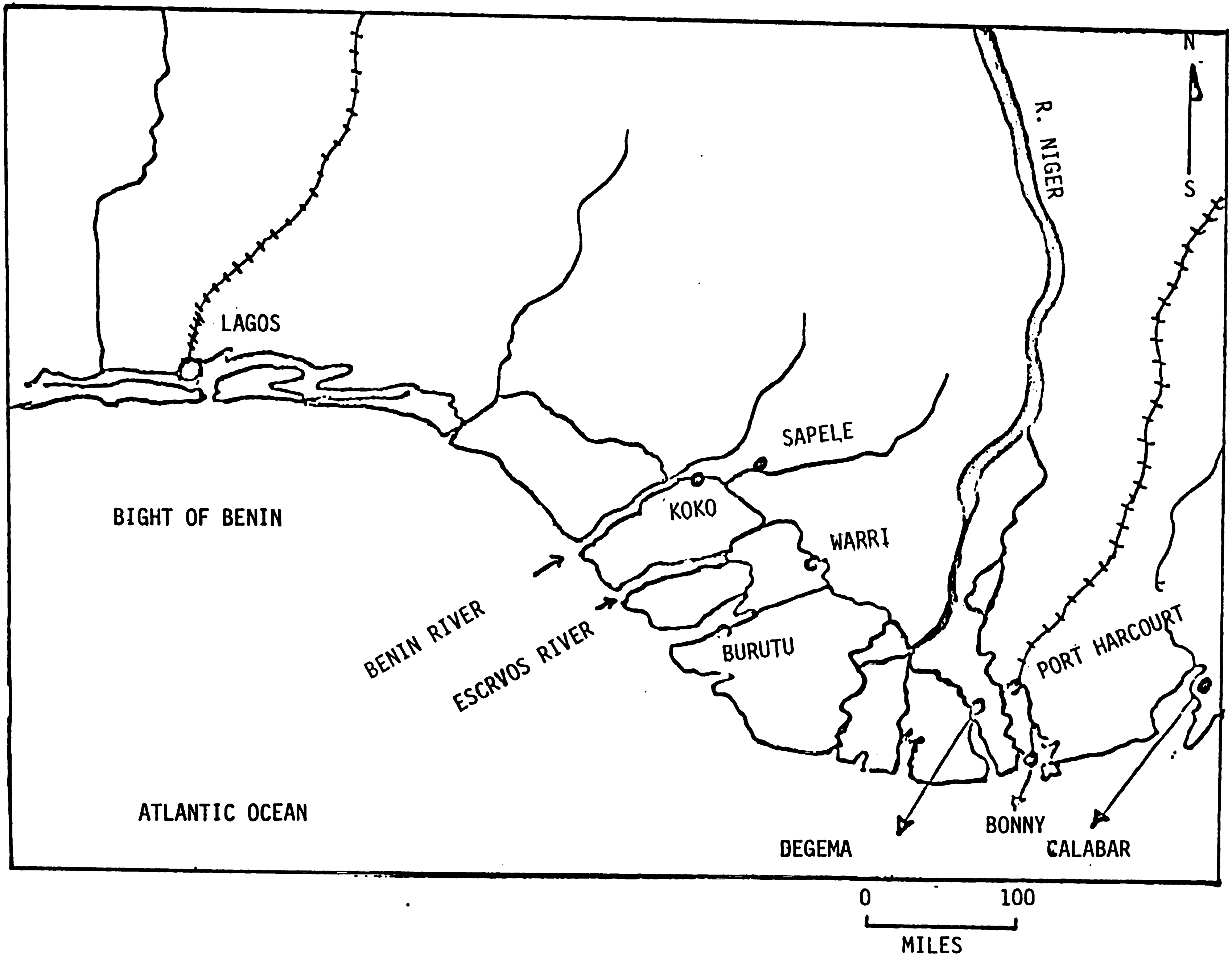
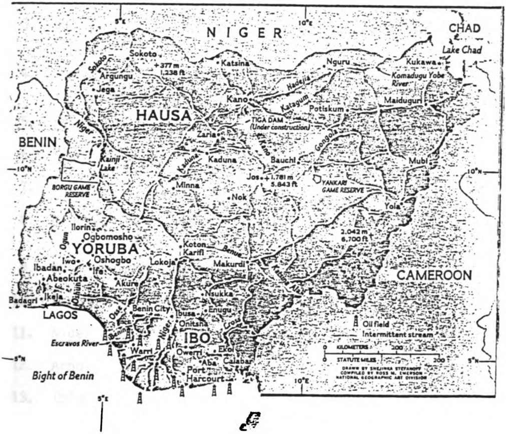


Figure (1.2). MAP OF AFRICA

Figure (1.3). MAJOR ECONOMIC RESOURCES OF NIGERIA



Source: National Geographic Magazine. March 4, 1979.
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CHAPTER II

NIGERIAN ECONOMY AND POPULATION GROWTH TRENDS

2.1 (a) Gross Domestic Product

Nigerian economic growth has four distinct historical phases:

- Colonial era 1900-1959
- Independence era 1960-1966
- Civil war era 1967-1970
- Post war oil boom 1970

In the colonial era the economy of Nigeria depended heavily on primary products and cheap solid minerals. Major agricultural exports were cocoa, palm oil, groundnut and rubber. Nigeria was rated as the third world's largest exporter of cocoa in 1950, and the third largest world exporter of tin ore. However, in that era, net foreign exchange earning were less than ₦2.00 billion (1) naira because of the unstable prices of agricultural products in the world market--particularly the price of cocoa.

In the independence era 1960-1966 Nigeria's Gross domestic product jumped from ₦ 2.2 to ₦ 3.5 billion valued at current factor price (see table 2-1). This represents a growth rate of 59.1%. This rapid growth rate is significant because it illustrates the impact of petroleum exports on the Nigerian economy. Higher earnings from oil and gas bolstered Nigerian foreign exchange holdings. As indicated by table 2-1 between 1960-1966 the GDP increased by 40%. Hence in the independence era the Nigerian economy was transformed from a primarily agrarian based economy to an oil based economy.

The Nigerian civil war (1967-1970) precipated a remarkable decline on the economy. In effect it created a downward multiplier on the national economy. The oil rich Eastern States, which contain 70% of the oil producing wells, were disturbed by the war; oil production temporarily ceased and some oil installations were damaged. Agricultural exports from the war affected areas were blockaded by naval operations and key industries were shut down. The aggregate effect of the civil war was to deflate the economy to the 1962 levels. The 1967 GDP was ₦2,752 million which is approximately equal to the 1962 GDP (see table 2-1). Hence the country lost five years of growth.

Table 2-1. GROSS DOMESTIC PRODUCT

	At Current Factor Cost (₦ Million)	At 1962 Factor Cost (₦ Million)
1960/61	2,247.4	2,493.4
1961/62	2,359.6	2,492.2
1962/63	2,597.6	2,597.6
1963/64	2,745.8	2,825.6
1964/65	2,894.4	2,947.6
1965/66	3,110.0	3,146.8
1966/67	3,374.8	3,044.8
1967/68*	2,752.6	2,572.2
1968/69*	2.656.2	2,543.8
1969/70*	3,505.0	3,205.8

*Civil war years

Source: Nigerian Statistical Year Book 1972.

In any economy this situation would be described as a major setback, considering not only the decline but the opportunity loss of development which would have occurred. To Nigeria it was the price for National unity.

The post war oil boom started in 1970. Increased oil production of 1.5 (2) million barrels a day generated increased revenues. The

GDP increased again to ₦ 3,504 million naira at the end of 1970. The second national plan projected economic growth from 1970-1974 at an average growth rate of 6.6% (2) per annum (see table 2-2). The third national plan (see table 2-3) was even more optimistic projecting a growth rate of 9.8% per annum at current prices. It now appears that these predictions were overly optimistic.

In 1975/76 Nigerian foreign reserves stood steadily at ₦ 3.7 billion. In 1977 this reserve declined to ₦ 3.0 billion (3) due to high dependence on foreign imports of equipment and manufactured goods. Even though exports in 1977 increased to ₦ 8 billion, imports also increased to ₦ 7 billion. This situation yields ₦ 1.3 billion surplus but when remittances, dividends, repatriations and services such as shipping insurance are considered a balance of payment deficit of ₦ 600 million was incurred. The above figures indicate that despite the oil revenue, the cost of equipment and other manufactured materials necessary for building an economic infrastructure are still considerable.

In the fiscal year of 1978/79 the estimated gross revenue for the entire country is estimated at ₦ 6.826 billion. The federal retained earnings is estimated at ₦ 5.2 billion while total recurrent expenditure is predicted to fall to ₦ 2.8 billion, about 10% less than the ₦ 3.1 billion for the 1977/78 (4) year. These estimates are in line with new government policy objectives:

(i) to re-order Government priorities so as to ensure efficient utilization of the limited resources;

(ii) reduction in Government spending;

(iii) to diversify our resource base and avoid lop-sided reliance on the oil sector;

Table 2-2. SECOND NATIONAL PLAN

G.D.P. PROJECTIONS

	At Current Factor Cost (₦ Million)	At Constant 1962 Factor Cost (₦ Million)
1970/71	3,485.8	3,171.2
1971/72	3,756.4	3,371.8
1972/73	4,111.0	3,639.4
1973/74	4,561.8	3,986.6

Source: Federal Republic of Nigeria: Second National Development Plan 1970-1974. Federal Ministry of Information, Lagos, 1970.

Table 2-3. THIRD NATIONAL PLAN

G.D.P. PROJECTIONS

At Current Factor Cost (₦ Million)

1974/75	1975/76	1976/77	1977/78	1978/79	1979/80
7,507.6	8,151.6	8,873.8	9,738.0	10,769.2	11,957.0

Source: Federal Republic of Nigeria: Guidelines for the Third National Development Plan 1975-1980. Federal Ministry of Economic Development and Reconstruction, Lagos, 1973.

(iv) to fight the present high rate of inflation with renewed vigor;

(v) re-distribution of income to arrest apparent social polarization;

(vi) to protect, encourage and increase local industrial production;

(vii) to relieve the pressure on our external account by influencing the volume, structure and direction of our imports, while placing more emphasis on the non oil sector of our export trade.

These objectives are indicative of major economic problems which Nigeria and many developing countries are facing. In the Nigerian situation the Head of State emphasized the major economic problems (5) "namely, shortage of essential commodities, inflation, a substantial rise in government expenditure occasioned by a determined development drive, an inequitable income distribution, unsatisfactory growth in agriculture and industrial output, inordinate crave for imported luxury items, overdependence on the oil sector for which there has been a declining contribution resulting in a widening disparity between Government resources and commitments, and balance of payment pressures."

In summary, these problems and policy objectives illustrate the present economic setting. There is then a greater need for consolidation of regulatory measures which conserve resources by minimizing excess government and private spending. Higher taxes for imported luxury goods, such as costly cars, has been successful in reducing the volume of import of goods in this category.

In order to understand the various economic problems, it is necessary to analyze the major economic sectors:

2.1 (b) Development by Sectors

(i) Agriculture: Historically agriculture has been the dominant sector of Nigerian economy. Oil production and export recently forced agriculture to the second place in national GDP contribution. Over 80% (6) of the total population are employed in farming with 10% of this figure engaged in subsistent farming. The total land area is 91.2 (7) million hectares but only 68.4 million of this area are cultivatable. However, only 34 million hectares are cultivated at present. There are limitations due to lack of access roads linking major population centers with remote farms. In addition 39% of the entire land area is tropical forest and out of this 18% are forest and wild life reserves. The principal cash crops include groundnut, millet, maize and soya beans. As indicated by table (2-4) the overall agricultural production growth rate is low. The output has been declining on the aggregate and deficit situations are experienced for major food items. As a consequence, agricultural contribution to the GPD has been declining at an alarming rate. In 1960 it generated 64.1% of GDP, in 1969 it dropped to 47.7% and in 1974 it reached a nadir of 44.2% (see table 2-5).

Thus agriculture in Nigeria is experiencing numerous problems similar to that found in most developing countries of Asia, Africa and Latin America. A summary of the major problems are presented below:

- Lack of adequate degree of mechanization to keep up with the population growth rate and consequent increase in food consumption.
- Migration of youths from rural to the urban areas thereby depleting farm labor sources.

Table (2-4). COMPARISON OF PROJECTED FOOD SUPPLY AND DEMAND.
('000)

Commodity	1968-69 Base Year Supplies	Compound Annual Trend Rate of Growth of	Projected Demand	1975 Projected Supply	Surplus or Deficit	Projected Demand	1980 Projected Supply	Surplus or Deficit
a1 Maize	831.883	2.4	1,034.030	982.112	- 51.918	1,200.407	1,105.759	- 94.648
a2 Millet	1,909.213	0.5	2,273.152	1,977.045	-296.107	2,754.994	2,026.967	- 728.027
a3 Sorghum	2,985.106	-0.3	3,710.487	2,922.981	-787.506	4,307.508	2,879.398	-1,428.110
a4 Rice	333.964	10.4	455.861	667.548	+211.687	555.716	1,094.782	+ 539.066
a5 Wheat	27.684	6.4	46.205	24.973	- 21.232	61.375	34.215	- 27.160
b1 Cassava	7,521.667	2.5	8,439.310	8,940.899	+501.589	9,183.955	10,115.806	+ 931.851
b4 Yams	7,239.028	-0.2	822.189	7,138.288	-983.901	8,838.853	7,067.189	-1,771.660
b5 Coco Yams	802.173	2.5	900.038	953.532	+ 53.494	979.453	1,078.833	+ 99.384
b6 Plantain	1,250.559	2.5	1,403.127	1,486.523	+ 83.396	1,526.933	1,680.760	+ 153.827
c1 Groundnut	263.139	-0.5	311.293	254.065	- 57.228	350.501	247.777	- 102.724
c2 Beans (Cowpea)	430.709	5.7	509.529	634.905	+125.376	573.704	837.690	+ 263.986
c3 Soya Beans	38.914	5.7	46.035	57.363	+ 11.328	51.833	75.684	+ 23.851
d1 Melon Seeds	52.510	2.5	62.119	62.416	+ 0.297	69.943	70.616	+ 0.673
d2 Benni Seeds	30.185	2.5	45.173	45.391	+ 0.218	50.862	51.356	+ 0.494
e1 Vegetables	1,164.067	3.5	1,388.951	1,481.018	-107.933	1,937.007	1,758.986	- 178.021
e2 Fruits	133.989	3.5	191.068	170.472	- 20.596	237.830	202.467	- 35.363
f1 Palm Oil	535.954	-0.2	698.884	528.496	-107.388	832.337	523.231	- 309.106
f2 Groundnut Oil	29.776	-0.2	33.828	29.362	- 9.466	46.242	29.070	- 17.172
f3 Melon Seed Oil	89.033	2.5	11.649	10.620	- 1.620	13.879	12.016	- 1.857

Source: Federal Republic of Nigeria: Guidelines for the Third National Development Plan 1975-1980. Federal Ministry of Economic Development and Reconstruction, Lagos, 1973.

Table (2-5). COMPOSITION OF GROSS DOMESTIC PRODUCT
At 1962-1963 Factor Cost (%)

	SECTOR	1960/61	61/62	62/63	63/64	64/65	65/66	66/67	67/68*	68/69*	69/70*	70/71	71/72	72/73	73/74
1.	Agriculture	64.1	62.2	61.8	61.5	58.7	55.4	52.0	52.8	52.6	47.7	51.1	49.0	46.7	44.2
2.	Mining (Incl. Oil)	1.2	1.7	2.1	2.1	2.7	4.8	6.9	6.4	3.3	7.9	6.0	7.9	10.3	13.4
3.	Manufacturing	4.8	5.2	5.6	6.0	6.1	7.0	7.3	7.4	7.9	8.2	10.2	10.9	11.7	12.4
4.	Electricity and Water	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.6	0.7	0.6	0.8	0.8	0.8	0.8
5.	Building and Construction	4.0	4.2	4.3	4.2	4.3	5.2	5.3	5.3	4.6	4.4	5.0	5.1	5.1	5.0
6.	Distribution	12.7	12.4	12.0	12.8	13.5	13.3	12.8	12.9	13.1	12.8	12.2	11.8	11.3	10.7
7.	Transport	4.1	4.7	4.4	4.2	4.5	4.1	4.0	3.9	4.4	3.6	3.3	3.1	3.0	2.9
8.	Communication	0.4	0.4	0.5	0.5	0.5	0.6	.06	.05	0.5	0.4	0.6	0.6	0.6	0.6
9.	General Government	3.2	3.1	3.0	2.8	3.0	3.1	3.3	3.3	5.5	7.5	3.3	3.2	3.1	2.9
10.	Education	2.6	2.8	3.0	2.9	3.2	3.1	3.6	3.5	3.6	3.3	3.2	3.2	3.2	3.1
11.	Health	0.5	0.6	0.6	0.5	0.9	0.7	0.9	0.8	0.7	0.8	0.7	0.6	0.7	0.7
12.	Other Services	2.0	2.3	2.2	2.0	2.1	2.3	2.7	2.7	3.1	2.8	3.6	3.5	3.4	3.3

Source: Nigerian Statistical Year Book 1975.

*Nigerian Civil War Years.

- Poor feeder transportation systems required to connect remote farms to the market areas with high population concentration.
- Land tenure system--particularly in southern Nigeria. This system involves ownership of small parcels of land by individual farmers which hinders the benefits of large scale farming.
- Over 10% of the arable land require irrigation systems which are capital intensive.
- Crop diseases and pests create major problems in the semi-arid areas of the country.
- Federal and State spending in agriculture have not been sufficient to transform additional labor intensive farms to mechanized high output farms.

The government acknowledges the existence of these problems; as evidenced by the policy on agriculture as expressed in the third national plan:

"The conclusion to be drawn is that at the present rate of growth of supplies Nigeria will not be able to feed it's people in the next decade unless there is a radical departure from existing attitudes to investment in Agriculture."

As a response to the above observation in the 1978 national budget a total of ₦ 2.2 billion was allocated to agriculture identifying it as the main single activity. A total of ₦ 39.00 million was allocated for the development of irrigation networks in the following river basins: Sokoto-Rima, Chad Basin and Funtua agricultural project. Twenty four thousand tonnes of wheat, 30,000 tons of rice and 3000 tonnes of cotton (8) will be produced in these areas respectively. Four other River development authorities have been established.

Mechanized farming cannot be achieved by government spending alone. The private sector has a great part to play. Hence there is a need for Nigerian farmers to form cooperatives to enjoy economies of scale due to large scale farming. The Agricultural development bank should modify its existing tight loan credit qualification terms. This will make it easier for middle income farmers to obtain funds for improving their farms. There is also a need to develop feeder transportation systems to provide access to remote farms by linking them with urban markets. This will induce flow from areas of surplus to areas of scarcity. Individual farmers should be given incentives through reasonable prices. The present system whereby Government owned Marketing boards set prices without adequate farmer participation provides no motivation to cultivate. This is one reason why 34 million hectares out of 64 (9) million hectares of cultivatable land are farmed. If more hectares of land are brought under cultivation, the present food shortages should never occur.

In 1970 food imports were valued at ₦ 19 million. (10) This trend will continue to be upward unless mechanization of agriculture is carried out extensively. Extreme restriction of the import of food items is not feasible unless domestic production can keep up with growing demand. Food import restrictions will only generate inflationary trend on the economy. Because of all the infrastructure and policy changes required to increase agricultural production, port planning should continue to be based on a rising or at least stable volume of imports.

2.1 (b)

(ii) Oil Sector: The production of oil in Nigeria transformed Nigerian economy from a purely agrarian base to an energy exporting economy. Nigeria joined the powerful OPEC organization, and in 1971 became the ninth largest world oil producer with a daily output of 1.68 (11) million barrels.

In 1973 production increased to 2.3 million (12) bpd. (i.e. close to Libya which was the highest producer in Africa). By 1974 Nigerian daily oil production was 2.4 million (13) bpd. of high priced low sulphur crude. This figure represented 6.7% of the total OPEC output.

The Nigerian Government is aware that effective participation in oil production is indispensable in national planning. The Federal government acquired 55% (14) of the stock in all major oil producing companies operating in Nigeria. The Nigerian national oil corporation was empowered to monitor and supervise the operation of these foreign firms. The Federal Ministry of Petroleum and Energy Resources has the responsibility of regulating all oil drilling and the issuing of permits.

In 1976 the National Oil Corporation and the Federal Ministry of Petroleum and Energy were merged to resolve conflicts of authority and to ensure consolidation of efforts. This new body in charge of Nigeria's oil production is known as Nigerian National Petroleum Development Corporation (NNDC). The creation of this organization is significant for two major reasons:

- It emphasized the fact that Nigeria intends to take control of this major economic sector.
- It also represents a major effort by a developing country to develop indigenous skilled manpower to meet the demands of such an intensive technology and high capital industry.

Nigeria, like most other countries of the OPEC, has the problem of identifying the extent of its oil reserve. An expert predicted that Nigerian reserves may last for (14-16) years (15) at the present production of 3 million barrels per day. It is not easy to predict Nigeria's reserves because 50% of the country is unmapped for mineral analysis. The fact that oil was discovered around Lake Chad basin in an indicator that oil may be found in Northern Nigeria. The areas adjacent to Lake Chad basin has the same geographical fault as parts of Northern Nigeria. As a result of the 1974 oil crisis the price per barrel jumped from $4.29 to $14.69. This increased the contribution of the oil sector to 80% (16) of the total foreign exchange earnings. An additional $500 million dollars was generated in 1974. Higher earnings from petroleum export created a favorable balance of payment as high as ₦ 3.1 billion in 1975. Proceeds from the oil sector provides 75% of the funds proposed for the implementation of the third national development plan. Tables (2-6) and (2-7) emphasize the importance of oil in Nigeria's export trade. In 1972 the oil exports accounted for 87.2% of the export revenue. Agricultural products contributed only 10.9%. The dependency on oil has grown to 90% by December 1976.

Natural gas plants are not yet available to process Nigeria's gas reserves. Hence 56 (17) million cubit meters of gas are flared per year. This represents a great loss to the national economy. Priority should be given to construction of a natural gas liquification plan to maximize oil revenue and to conserve irreplacable resources.

It appears that port planning should be based on a constant production of 3 million barrels per day over the next ten years. Government control appears to be strong enough to assume this level of production.

Table (2-6). EXPORTS OF PRINCIPAL COMMODITIES
(₦ '000)

	1968	1969	1970	1971	1972
Petroleum Products	73,998	172,022	509,790	953,032	1,156,960
Cocoa	103,482	105,192	133,074	143,114	101,134
Groundnuts	75,906	71,758	43,458	25,020	19,134
Raw Cotton	6,534	6,712	13,123	11,094	606
Palm Kernels	20,346	19,512	21,740	25,916	15,668
Palm Oil	284	866	1,134	3,388	246
Rubber	12,622	19,288	17,568	12,402	7,350
Sub-Total: Agr.	219,174	223,328	230,106	220,934	144,138
Timber, Logs and Wood	7,116	10,324	6,206	5,288	6,330
Tin Ore	14	12	4	-	-
Tin Metal	27,428	27,850	33,202	24,812	19,124
Columbite	1,154	1,270	1,950	1,116	1,070
Sub-Total: Min.	28,596	29,132	35,156	25,928	20,198
TOTAL:	328,884	534,806	681,258	1,204,512	1,327,626
% of Total Exports	79.7	83.5	89.1	94.0	94.7
Percentage by Commodity Group:					
Petroleum Products	22.5	39.6	65.3	79.1	87.2
Agricultural Products	66.6	51.4	29.4	18.3	10.9
Forestry Products	2.2	2.4	0.8	0.4	0.5
Mining Products	8.7	6.7	4.5	2.2	1.5
TOTAL:	100.0	100.0	100.0	100.0	100.0

Source: Federal Republic of Nigeria: Economic Indicators, Vol. 9, No. 3, March 1973. Lagos, Nigeria.

Table (2-7). AGRICULTURAL EXPORTS
('000 tons)

	1965	1966	1967	1968	1969	1970	1971	1972
Groundnuts	520	582	549	648	525	291	136	105
Groundnut Oil	92	106	72	111	101	90	43	42
Groundnut Cake	115	135	133	174	171	163	96	105
Sub-Total:	727	823	754	933	797	545	275	254
Cocoa	259	193	248	209	173	196	271	277
Palm Oil	152	145	16	3	8	8	20	2
Palm Kernel	n.a.	n.a.	n.a.	n.a.	41	34	30	(24)
Benni Seed	21	25	3	14	16	12	7	(2)
Hides and Skins	9	8	8	6	10	5	4	4
Cotton Raw	14	15	34	14	14	28	22	1
Cotton Seed	71	n.a.	n.a.	n.a.	43	97	98	40
Rubber	69	71	49	52	56	58	50	41
Timber, Plywood	20	19	13	12	12	9	8	7
Coffee	1	n.a.	n.a.	n.a.	5	3	4	(4)
Shea Nuts	26	n.a.	n.a.	n.a.	23	16	11	(12)
Cocoa processed*	n.a.	n.a.	n.a.	n.a.	21	19	13	(18)

*Power, butter, cake ( ) estimate based on half year data n.a. not available

Source: Federal Republic of Nigeria: <u>Economic Indicators</u>, Vol. 9, No. 3, March 1973. Lagos, Nigeria.

2.1 (c)

(iii) Other Sectors: The manufacturing sector has been growing at the rate of 5% (18) per year. The emphasis is on establishing secondary industries for the processing of agricultural products and manufacture of durable goods. Two car assembly plants were established in Lagos and Kaduna under a joint participation program between Volkswagen of Germany and Pegeout of France. However these plants are of intermediate scale and jointly produce only 5% of the total automobile demand.

Four major cement factories are located in Sokoto, Nkalagu, Calabar and Ewekoro. These factories jointly produce 40% of the total cement used in the country. At present there is no major National Iron and Steel Industry; the Nigerian steel authority is still at the recruiting and planning stage. Hence like most developing countries Nigeria relies heavily on foreign countries for the supply of cars, equipment and construction materials. The manufacturing sector is lagging behind the GDP which is growing at 10%. This situation is due to the lack of sufficient capital in industries. Government spending alone will not be sufficient to achieve an adequate growth level in the industrial sector. The second major problem is the shortage of intermediate technicians and engineers.

Government services is the highest growth area. This sector is growing at an annual rate of 30%. (19) The government policy is to provide better health and educational services to the people. In pursuance of these objectives universal primary education (UPE) was introduced in 1976. Physical infrastructures to accommodate this program doubled government spending in education to ₦ 779,362,610 in

Table (2-8). ALLOCATIONS UNDER RECURRENT BUDGET

Ministries/Departments	Allocation
State House/Dodan Barracks	₦ 1,440,510
Cabinet Office	₦ 41,631,210
Police	₦ 127,625,850
Police Service Commission	₦ 141,420
Agriculture, rural development	₦ 19,711,170
Audit	₦ 1,360,000
Aviation	₦ 20,608,620
Co-operatives and supply	₦ 2,225,400
Communications	₦ 380,500
Defence	₦ 597,857,007
Economic development and reconstruction	₦ 27,714,430
Education	₦ 779,362,610
Establishments and service matters	₦ 19,332,280
External affairs	₦ 32,589,990
Finance	₦ 52,093,830
Health	₦ 81,090,350
Industries	₦ 4,406,100
Information	₦ 62,542,160
Internal affairs	₦ 45,332,220
Judicial	₦ 2,624,240
Justice	₦ 2,463,060
Labour	₦ 48,281,370
Mines and power	₦ 6,770,140
National science and technology Development agency	₦ 30,450,000
Nigerian National Petroleum Corporation	₦ 9,920,000
Public Complaints Commission	₦ 2,259,340
Public Service Commission	₦ 1,711,760
Trade	₦ 8,167,280
Transport	₦ 8,785,770
Water resources	₦ 2,193,620
Works	₦ 92,248,180
Federal Electoral Commission	₦ 9,942,070
Non-statutory appropriations	₦ 174,037,000
Consolidated Revenue Fund	₦ 454,002,217
Contingencies	₦ 28,777,296
TOTAL	₦ 2,800,000,000

Source: His Excellency General Obasanjo: Budget Speech 1978. Federal Ministry of Information, Lagos, Nigeria.

1978. Hence education was allocated 28% of the recurrent national budget, making it the largest government service activity. Figure (2-1) illustrates recurrent government spending in major service areas. Defense and police account for 26% of the recurrent budget thereby ranking second to education. Health and Works services have 2.9% and 3.3% of the total budget funds. Agriculture which is the second dominant economic sector was allocated only .7% of the recurrent budget. Industry is the lowest on the ladder with .12% of the recurrent budget.

2.1 (c). Population

In 1952, 1962 and 1963 population census were taken in Nigeria. Table (2-9) indicates the national population estimates between 1963 and 1968. (20) The 1962 population figures were controversial because of allegations of irregularities. Hence in 1963 Nigeria had to go through the costly exercises of a second count. When 1952 figures are matched with 1963 figures, a growth rate of 6.2% per year is obtained. This growth rate is not credible because it is far higher than the United Nations estimates of population growth for Africa (2.5-3%). This error is due to the fact that the 1952 figures were undercounted while the 1963 figures were high due to double counting in some parts of the country.

United Nations statistics put the growth rate of Nigeria's population at 2.5% per annum. The Federal Ministry of Transport developed a reliable forecast of Nigerian population based on UN and National Institute of Social and Economic Research (NISER) growth indices. Table (2-9) indicates that Nigerian population in 1985 will reach 96.5 million.

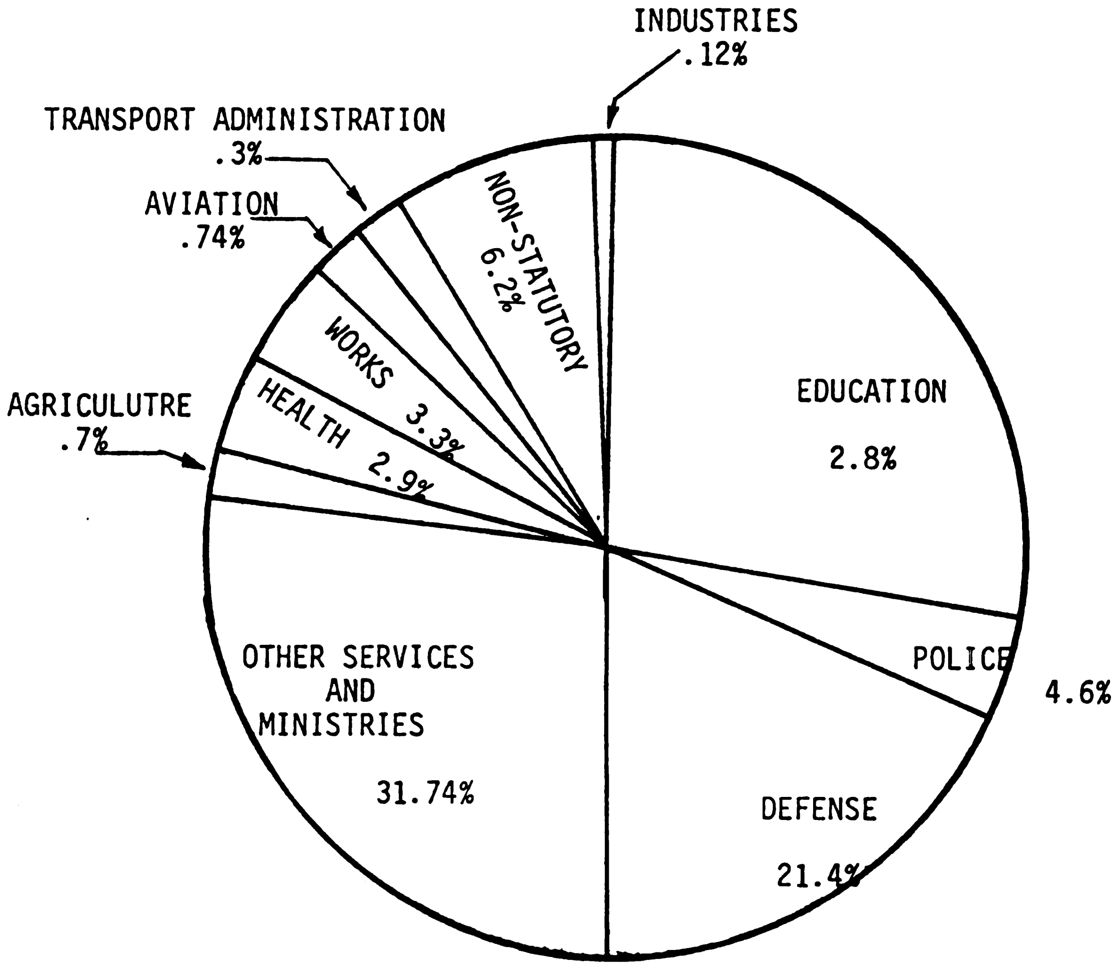


Figure (2-1). % ALLOCATION UNDER RECURRENT BUDGET 1978.

Prepared with data from National Budget 1978 (see Table 2-8).

Table (2-9). POPULATION ESTIMATES
('000)

	1963	1965	1970	1975	1980	1985
Urban	8,907	10,009	13,508	17,242	21,753	28,816
Rural	46,765	48,494	52,682	57,829	63,488	69,715
TOTAL	55,672	58,503	66,190	75,071	85,241	96,531

Source: Tranport Planning Unit MOT: Unpublished Records, Lagos, Nigeria.

Table (2-10). POPULATION GROWTH RATES
(% average per annum)

	1963-65	1965-70	1970-75	1975-80	1980-85
Urban	6.0	6.2	5.0	4.7	4.3
Rural	1.8	1.7	1.9	1.9	1.9
TOTAL	2.5	2.5	2.5	2.5	2.5

Source: Transport Planning Unit MOT: Unpublished Records, Lagos, Nigeria.

For the 1985 population, the urban and rural distribution are expected to be 27.8% and 72.2%, respectively. Nigeria's demography has shown a high population growth rate and increasing urbanization. Table (2-10) shows that the urban population is increasing by 5% per annum while the rural population is growing at 1.9% per annum. Hence there is marked evidence of labor migration from the rural to urban areas. The youths make up 80% of these job immigrants. This shift in labor force is a major problem facing agriculture in Nigeria, which is still labor intensive.

Population densities have considerable variations. Table (2-11) indicates that Lagos State is the most highly urbanized with a population density of 800 persons per square Km. The Former East Central State ranks next to Lagos State with a distribution of 300-377 persons per square Km. As indicated in tables (2-11) and Figure (2-10) the most sparsely populated states are North Eastern, North Western, Kwara and Benue-Plateau. In these states, rural population densities are under 50 persons per square km. As illustrated in Figure (2-10) the port of Lagos provides a gateway to the densely populated Lagos and Western States in particular. The second ranking port of Port Harcourt serves the densely populated Eastern States. These areas are not the only markets served by these ports but are the nearest.

2.2 Multi-Modal Transportation Systems

2.2 (a) Objectives and Policies

Transportation systems are indispensable physical infrastructures for economic development. In fact the development process depends, to a very large extent, on the efficiency of a country's transportation

Table (2-11). POPULATION DENSITIES BY STATE

STATE	Area (sq. Km)	Persons Per Square Kilometer 1963	1970	1975	1980	1985
North Eastern	272,726	29	34	39	44	49
Benue Plateau	100,826	40	45	51	58	66
North Western	168,720	34	40	45	51	58
Kwara	74,260	32	37	42	47	52
Western	75,369	126	157	180	205	234
Lagos	3,577	404	592	785	1,041	1,377
Mid-Western	38,648	66	75	83	92	100
East Central	29,909	242	277	305	337	370
Rivers	18,091	85	102	113	125	136
South Eastern	28,363	128	147	162	179	196
Kano	43,072	134	160	182	207	235
North Central	70,209	58	68	78	90	103
TOTAL	923,770	60	72	81	92	104

Source: Transport Planning Unit MOT: Unpublished Records, Lagos, Nigeria.

network. Modern economic theory holds that new transportation systems induce flow of goods and services which otherwise would not occur. (21) In developing countries such as Nigeria the need for efficient transportation systems is even greater due to the rapid growth of the economy (10% per annum). In the Third National Development Plan the Federal Government of Nigeria acknowledged the importance of efficient transportation systems in these terms:

> "Nigeria's transportation objectives have been stated since early 1960, in general terms as aimed at co-ordinated development, economic efficiency and, by implication, the support of national interests like the opening up and binding together of this vast nation. These objectives are as relevant and valid today as they were when first explicitly set down in 1965."

In pursuance of these objectives the Second National Development Plan emphasized transportation capital investments. Between 1970-1974 ₦ 485.2 (22) million or 23.7% of total public investment was injected into the transportation sector annually. This expenditure summed up to ₦ 1,025.4 million by the end of the second development period. By 1974 capital expenditures in transportation topped the list followed by other service areas like education (13.5%), agriculture (10.5%) and health (5.2%).

Public Investments by Modes

Table (2-12A) and Figure (2-2) illustrate the proportion of public investment allocated to each mode. Roads took the lion's share with 68.5% of the total capital investment. Railroads had only 9.0% while ports and airways got 7.4% and 10.6% respectively. An analysis of each of the modes is essential to assess the strengths and weaknesses of the above investment policy.

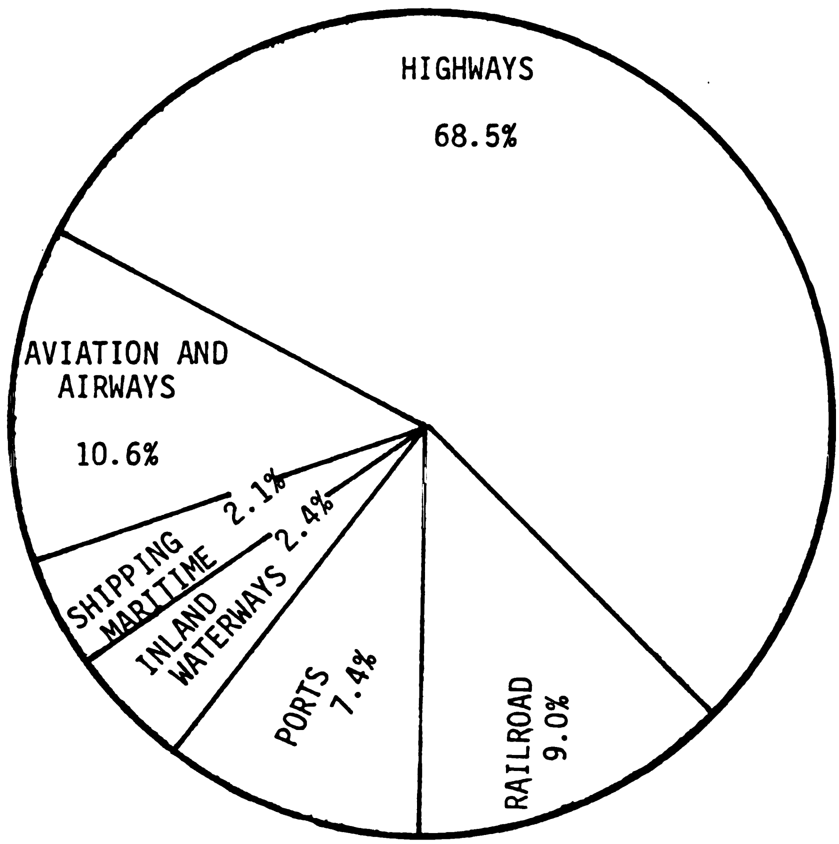


Figure (2-2). TOTAL INVESTMENT IN TRANSPORTATION BY FEDERAL AND STATE GOVERNMENTS OF NIGERIA, 1974.

prepared with data from Table (2-12)

Table (2-12A). TOTAL INVESTMENT IN TRANSPORT SECTOR
BY ALL GOVERNMENTS
1970-74

	Amount of Investment ₦ Million	Proportion of Investment %
Roads:		
--Total:	332.6	68.5
--Federal	187.7	38.7
--All States	144.9	29.8
Railway	43.7	9.0
Ports	36.0	7.4
Civil Aviation	27.6	5.7
Airways	23.7	4.9
Inland Waterways:		
--Total:	11.4	2.4
--Federal	5.4	1.1
--All States	6.1	1.3
Shipping	6.3	1.3
Maritime Service	0.5	0.1
	3.4	0.7
GRAND TOTAL:	485.2	100.0
FEDERAL	334.3	68.9
ALL STATES	150.9	31.1

Source: Federal Republic of Nigeria: Second National Development Plan 1970-1974. Federal Ministry of Information, Lagos, 1970.

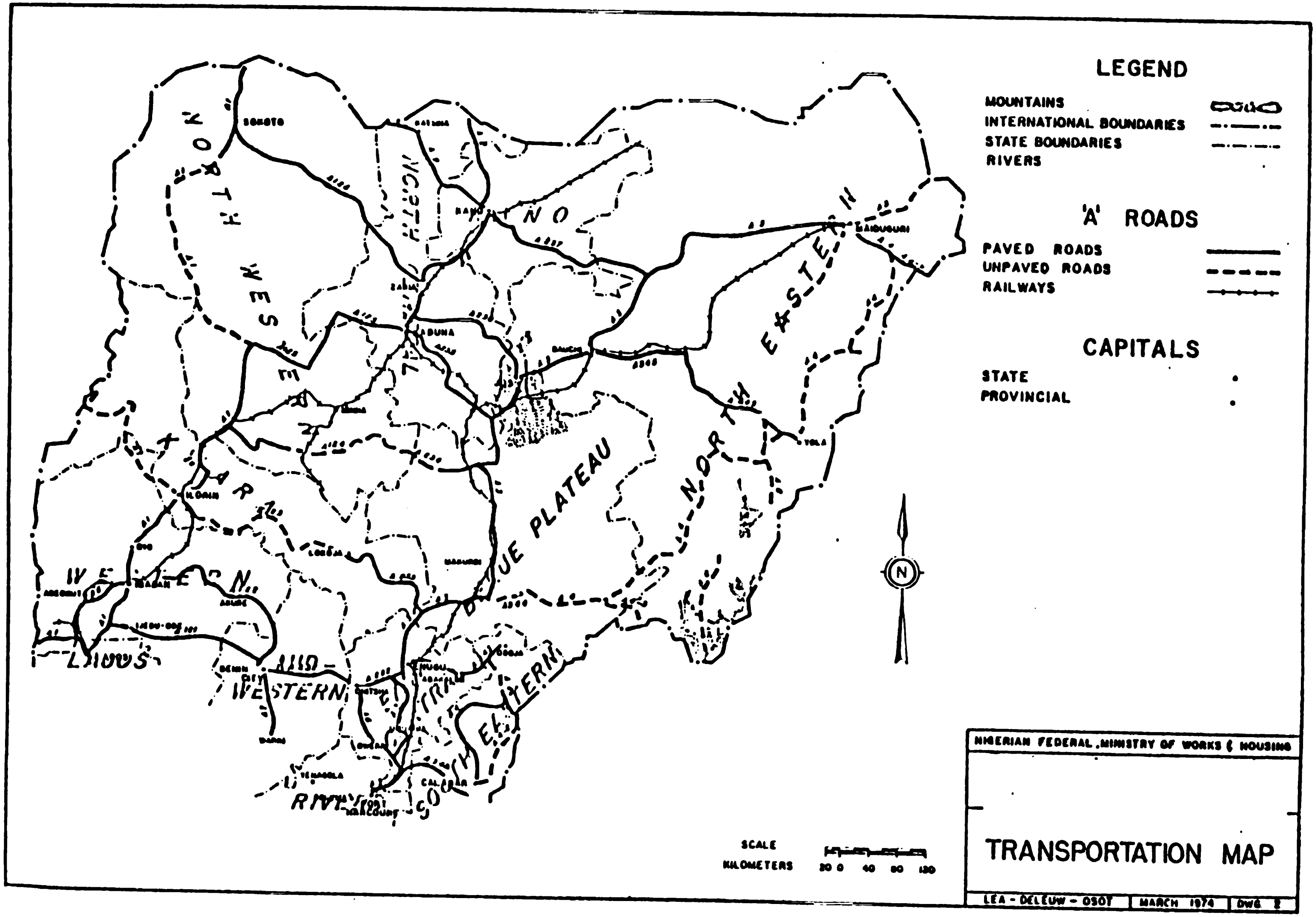
2.2 (b) The Highway Mode

In Nigeria, Federal and State governments emphasize road development more than any other mode. This emphasis is justified because the highway system is the primary mode for movement of passengers and freight. As illustrated in figure (2-11) the road networks penetrate the country more completely than rail or water. The highway systems are generally categorized as Trunk A, B and C. Traditionally the Federal government has been responsible for construction and maintenance of trunk A roads which link major cities (see figure 2-11). In 1975 the Federal government assumed responsibility for the trunk B roads from the States to facilitate coordinated planning and uniform development within the country. Roads in this category extend up to 16,000 Kms. (23) As of now the State governments are left with class C roads which link rural towns.

At the end of the Second National Development Plan in 1974 over 3000 (24) Kms of roadway have been built; indicating 75% performance in the projected program. By 1976, an additional 2570 Kms were completed. The third national plan is even more aggressive about road development in Nigeria; the plan identified 96,500 Kms (25) of road system. Out of this only 25% were to be tarred and the rest were earth roads. The ideas is to save money on low volume rural roads.

Trucking Industry: The trucking industry in Nigeria is one of the fastest growing sectors (10% per annum). The capital stock is provided mainly by independent owner operators. The government regulates the industry through the Ministry of Transport and the Nigerian

Figure (2-3). TRANSPORTATION MAP OF NIGERIA



Police. Regulation however is limited to safety requirements. Fare setting and route allocation are completely ignored. The result of this incomplete regulation is arbitrary setting of prices by individual operators. Movement of goods and services are hindered by unreasonable fares set by owner operators. Agricultural products are affected most because the cost of transportation absorbs the farmer's profit.

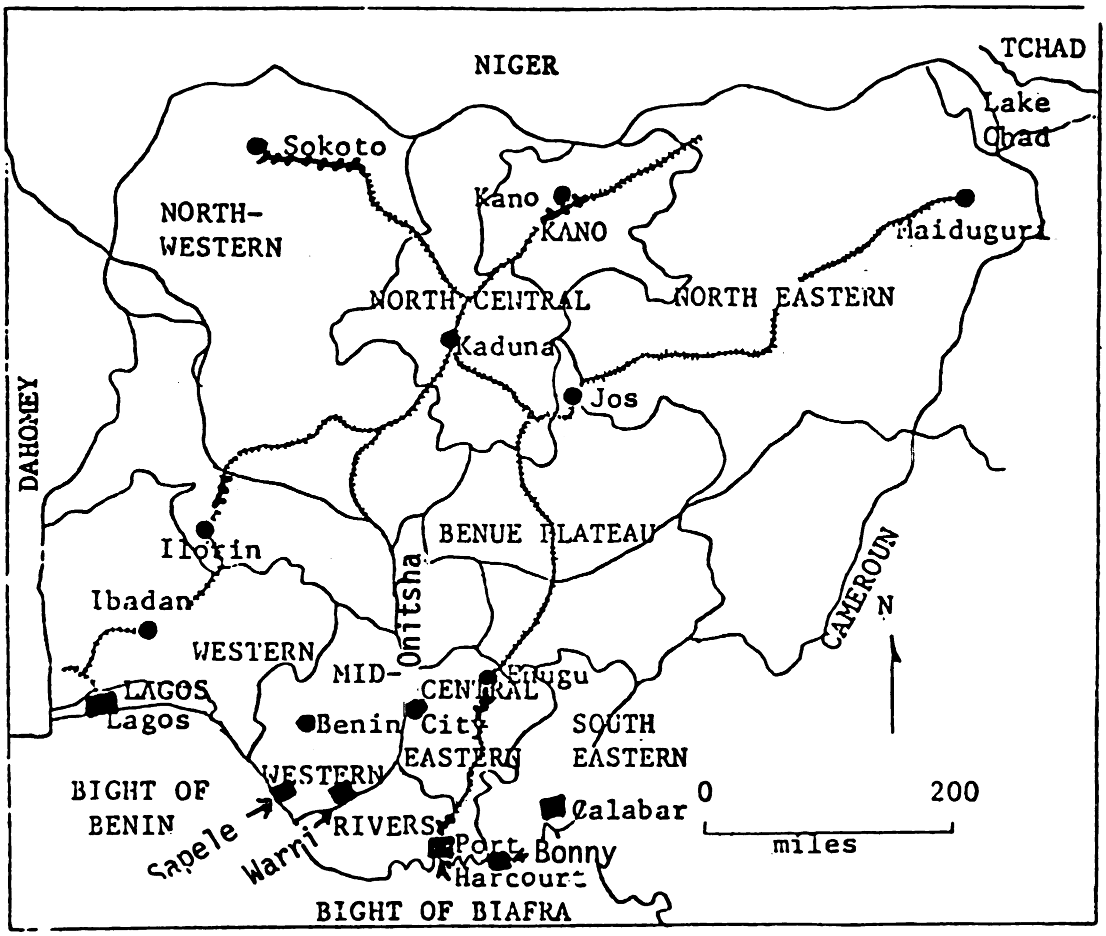
It is evident that efficient flow of goods and services cannot be achieved by providing only good highway systems. Economic regulation of carriers is as important as physical infrastructures. Nigeria Federal officials should consider fare and route regulation as enforced by the ICC in the United States.

2.2 (c) Nigerian Railway Corporation

As illustrated in Figure (2-4), Nigeria has 3,505 Km (26) of single rail track linking the two principal ports of Port Harcourt and Lagos. These tracks still retain the traditional 3'-6" guage (27) which were predominant, in many parts of the world, during the 1920's when these tracks were constructed. In fact the railways are outdated in terms of equipment, tracks and capacity. The track curvatures are numerous and in many locations bridges are old. The Railroad still relies on traditional signal systems and there are no automatic switching systems in the country. Scheduling is irregular because of rampant breakdowns and unavailability of both movement and power units.

The speed of delivery is very low because of track conditions and the age of the equipment. Trains average 40 Kms per hour, with frequent stops and unnecessary delay. As a result of these inadequacies, the Nigeria shippers prefer the trucks to rail service. As indicated

Figure (2-4). RAIL NETWORK IN NIGERIA



KEY

- ● Major Cities
- ■ Major Sea Ports
- ┼┼┼┼ Rail Lines

by table (2-12B) the Railroad traffic declined in both tonnage and monthly average length of haul between 1963 and 1972. Consequently the annual revenue declined from ₦ 32.6 million in the 1963/64 year to 24.5 in the 1971/72 year (i.e. a decline of 25% in 9 years). Since 1950 the Federal Government has stablized the railroad by providing both capital and operating subsidies. In 1972 NRC spent more than its revenues by 50%. With increasing costs incurred in other governmental services like education, works and health it is questionable whether the Federal government can continue to provide sufficient subsidy to the NRC.

In conclusion, the Nigerian railroad faces serious problems. The NRC runs a deficit each year in the face of sharp freight competition from the trucks. In 1958 850,000 tonnes of farm products moved by rail; in 1970 this declined to 350,000 tonnes (28) (indicating a loss of 59%). In 1961 passenger traffic stood at 11,000 per day; in 1974 it dipped to 4670 per day (indicating a drop of 58%). Operational deficits have been increasing. In 1973 the NRC losses totalled ₦ 21.8 million as against ₦ 33.1 million in 1974. (29) It is apparent that there is a need for the Federal government to inject funds into the NRC to phase out outdated 3'-6" track guages and purchase new rolling stock and power units. A new management is also needed to introduce modern techniques like programming, system scheduling and traffic co-ordination. The NRC needs to adopt a marketing orientation to ward off increasing competition by truckers. Improved shipper information and increased speed of delivery are essential in this direction.

Table (2-12B). NIGERIA RAILWAY PEFORMANCE

	1963-64	1971-72
Revenue for year (₦ million)	32.6	24.5
Monthly Average Paying Tonnage ('000)	2,154	1,107
Monthly Average Non-Paying Tonnage ('000)	360	81
Monthly Average Length of Haul (Km)	917	927
Average Kms. per day per Wagon in Stock	85	40
Average Kms. per day per Wagon in Traffic	93	43
Average Wagon Turn-Round Days	12.2	46
Engine Ksm. per Engine Failure: Steam	38,495	5,129
Diesel	22,896	11,252

Source: Nigerian Railway Corporation, Lagos, Nigeria

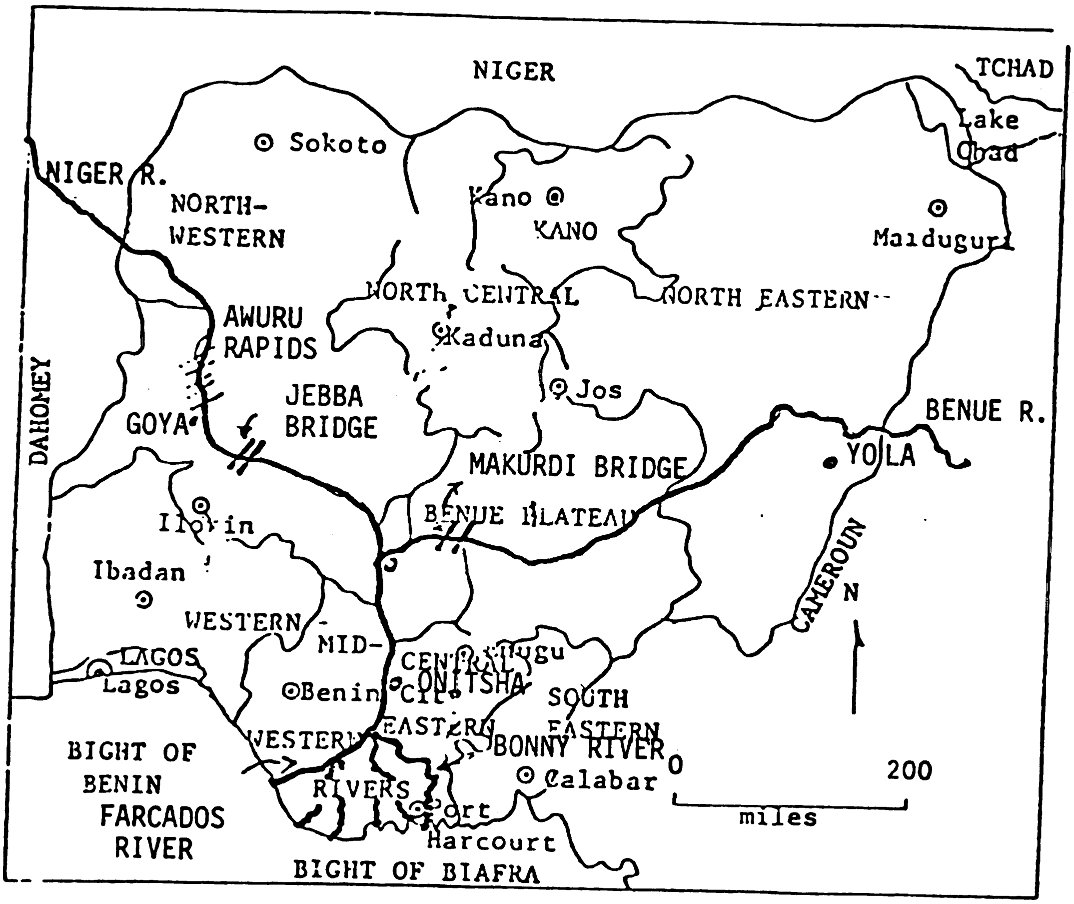
Finally the rail network needs to be extended to connect all principal seaports. As illustrated in map (2-4) the port of Calabar, which serves the South Eastern and North Eastern regions of Nigeria, still lacks a rail system. The river ports of Warri, Burutu, Sapele and Koko have no rail links. Functional planning requires integration of these ports into the rail system. In addition major commercial centers like Onitsha and Benin should be linked to the rail network. These new links would enable the NRC to provide complete service to the nation and the same time perhaps generate enough traffic to breakeven or even make a profit. In a country like Nigeria with 913,072 sq. miles the existing track length of 3,505 Kms. (.4 Km of track per 100 sq. miles) is far from adequate.

2.2 (d) River Transport

Nigeria takes its name from the River Niger which is the principal river in west Africa. It is the third longest river in Africa running for 2,600 miles and together with its tributary, the River Benue, drains about half a million square miles. On entering Nigeria the Niger receives the Sokoto and the Kaduna Rivers and other streams. At Lokoja the Niger forms a confluence with the river Benue, a river with an origin in the Cameronian mountains. The Benue enters Nigeria about 30 miles from Yola as shown in figure (2-5). Its main tributaries are the Gongola and the Donga Rivers.

After Lokoja the River Niger flows south; 5 miles from the market city of Onitsha it is joined by the Anambra River. At this point the

Figure (2-5). RIVER TRANSPORT MAP OF NIGERIA



Niger widens to 2 miles breadth and has a draught of 30'-50' (30) in the rainy season (June-July). The Niger continues its journey to the sea by breaking up into several small rivers. The main stream continues until it reaches the delta where it divides into fourteen main outlets to the sea as shown in fig. (2-5).

The more important outlets are the Bonny River and the Farcardos River. The Bonny River opens up a waterway which services the specialized oil port of Bonny. The Farcardos River is the gateway to the ports of Warri and Burutu.

As illustrated in figure (2-5) River Niger is navigable for river steamers up to Jebba. After Jebba there are problems of falls and rapids. Tugs of 1500 HP pull 3-4 barges of 500 ton as far as Goya and take only one 500 ton barge through the Awuru rapids. (31) Hence the Awuru rapids is the main impediment to navigation on the upper Niger; with depths as low as 10-15 feet (32) and tugs run the risk of running aground.

After Onitsha the lower Niger is navigable for the entire year. The draught is between 20-25 feet (33). until it divides into 14 delta rivers. Tugs of 1500 HP can effectively pull 3-5 barges of 500 tons. The main tributaries, the Bonny and Farcardos Rivers, are open all year. These rivers combined with coastal creeks are capable of taking 20,000 ton ships and medium size ocean tankers. However the extent of navigation is limited to short channels from the sea to the Warri River.

Traffic on the Niger River has been declining due to the lack of efficient equipment and funds required to revitalize inland water services. A River Transport Corporation was created in 1973 to investigate the feasibility of year-round navigation on the Niger river. This corporation was also empowered to operate vessels on the Niger. The corporation failed to deploy a single vessel on the Niger in a period of 5 years. It was a creation of three states and as such administration was difficult. The other lower Niger States declined to invest in such a venture. This situation is an indication of the fact that development of the Niger river cannot be handled by a group of states. It will require a Federal initiative to open this major waterway.

In recent times dams have been constructed at several points on the Niger. In Senegal a hydro-electric dam is under construction while in Nigeria the giant Kainji hydro dam was completed in 1968. These dams do not leave sufficient compensation water for navigation on the Niger.

Benue River

Traffic on the Benue has also declined. A number of factors contribute to this trend. First there are major impediments to navigation as indicated by table (2-13). Navigation up to Yola is possible for 3½ months of the year for vessels with draft of 2½ m. In the first 2 months draft of 4 m are available. Even during the navigation season temporary drops in water level delay navigation between Markudi and Yola. Secondly the channel is tortuous and rugged. As a result of this the length of tow is limited to 107 m maximum for single barges, 12 m wide or 76 m maximum length for double barges 23 m wide.

Table (2-14) indicates the total tonnage of traffic which the Benue River handled between 1950-1960. In 1950, at its peak, 50,000 tons were handled by all Benue river ports. In 1973, twenty-three years

Table (2-13). SAFE DRAUGHTS DURING ONE NAVIGATION SEASON ON THE BENUE RIVER.

Location	Km	June 1	June 15	July 1	July 15	August 1	August 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15
Niger Confluence	582												
		1.2/1.5	1.5/1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.8	1.2/0.9
Makurdi	821												
		n	n	n	1.2/1.5	1.8	1.8/1.5	2.0	2.0	1.8/1.5	1.5/0.9	n	n
Yola	1,429	n	n	n	n	1.2/1.8	1.2/1.8	1.8/2.0	1.8/2.0	1.8/1.5	1.5/0.9	n	n
Garua	1,564												

<u>Notes</u>: n = not navigable

$\frac{1.2}{1.5}$ = Safe draught varies between 1.2 and 1.5 meters

Draughts greater than 2 meters stated only as 2.0

Source: <u>Development of the Ports of Nigeria</u> 1970-1990 Ministry of Transport, Lagos, 1971.

Table (2-14). BENUE RIVERPORTS

THEIR FACILITIES AND TONNAGES

Port	Yearly Tonnages that used to be ('000t)	Covered Storage	Open Storage	Facilities
Makurdi	11	9	20	Manual to railway
Ibi	3	4	5.1	Manual
Lau	3	1.5	1.5	Manual
Numan	7	2.0	5.6	Manual
Yola	8	2.0	8.6	Manual
Garua	36	20	-	Quay, tank for petroleum, Manual and Mechanical

Source: Development of the Ports of Nigeria 1970-1990. Ministry of Transport, Lagos, 1971.

later, only 5000 tons were handled by these river ports. This is a decline of 90%. The main reasons for this decline are lack of new equipment for replacing old and unservicable barges and tugs, and vigorous rail and truck competition. By 1973 the major Benue River traffic; petroleum and fertilizer were being moved by trucks and motor tankers because of irregular service on the Benue.

The fare structure for the river shipments on the Benue and the Niger are also not competitive. Table (2-15) shows that river freight rates top rail and road for a major agricultural commodity like groundnut. For cotton lint and cotton seed the lower prices offered by river transport are not attractive enough to match the speed and dependability of trucking. In general there is great uncertainty about inland river navigation on both the Benue and the Niger.

2.2 (e) Air Transport

(i) International Airport: Nigeria has two international airports and ten other airports receiving domestic flights. Figure (2-6) illustrates the relative location of the external and internal airports. The line diagram describes the internal passenger and freight traffic flow. International airports are located at the suburbs of Lagos and Kano. These two airports have runway lengths and instrument control systems necessary to accommodate the takeoff and landing of a Boeing 747 or a C130 military cargo aircraft. Kano airport is strategically located at the cross roads of many African air-routes. It is a major air node for planes flying between London, Rome and Southern Africa. It also provides transfer and refueling services to planes destined to Ethiopia and the Middle East from other West African countries.

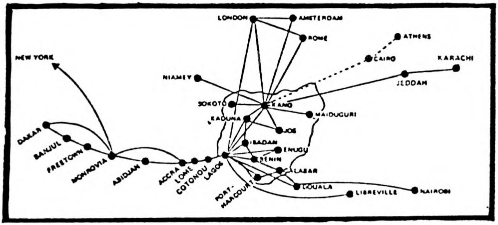
Table (2-15). FREIGHT RATES (in Naira) FOR SELECTED COMMODITIES FOR DIFFERENT TRANSPORTATION MODES

	Rail[1)]	Road[1)]	River[2)]
Groundnuts	169 ₦	158 ₦	186 ₦
Cotton Lint	246 ₦	242 ₦	119 ₦
Cotton Seed	148 ₦	158 ₦	142 ₦

1): Gombe to Port Harcourt

2): Numan to Warri/Burutu

Source: Nidan Consult: Feasibility Study for a Road Bridge Crossing the Benue River at Markurdi. Federal Ministry of Works, Lagos, Nigeria, 1972.



NIGERIA AIRWAYS

Figure (2-6). NIGERIAN AIRWAYS INTERNAL AND EXTERNAL FLIGHT ROUTES.

As a result of this strategic location Kano airport handles weekly arrivals and departures of 1000 aircrafts during the regular season. This demand does not consider the massive airlift operations during the Moslem pilgrimage to Mecca and Medina. In this period demand at Kano airport gets as high as 1,500 per week. (34)

Between 1970-1975 the freight traffic at Lagos airport doubled due to the heavy congestion at the Lagos seaport. Arrivals and departures climbed to 1,200 aircrafts per week. (35) Out of this figure 30% were freight service; creating tremendous storage and handling problems for which the airport was unprepared. In 1976 the government ordered auctioning of unclaimed goods in an attempt to decongest the warehouses.

This rapid growth in demand is an indication that long term planning is essential in national airport development; particularly in a developing country such as Nigeria. The freight congestion in Lagos airport demonstrates that with increasing seaport congestion Nigerian shippers will opt to pay the extra fare for air shipments. If this situation continues, the airport may eventually render a very poor level of service (i.e. freight service in particular). Hence multimodal planning is recommended in airport development.

(ii) Domestic Airports

The ten domestic airports are primarily used for inter-city passenger flights. The Nigerian Airways corporation, a Federal owned agency, has a monopoly on all internal passenger flights. It owns and operates a fleet of F-28 and Boeing 737 aircrafts. These two categories of crafts are deployed on internal routes while VC10 service external routes. Table (2-16) shows the arrival and departures for each of the internal airports in 1974. Kaduna tops the list with 96 flights followed by the oil city of Port Harcourt and the mining cities of Jos and Enugu. Kaduna is a regional airport servicing both the administrative city of Kaduna and the university of Zaria.

Between 1974-1977 internal air passenger demand increased by 30% (36) due to a higher standard of living and increased wages. As a result, Nigerian Airways has been unable to service more than 60% of the demand. Internal air ticket bookings must still be made one week in advance in cities like Enugu, Kaduna, Jos and Maidugiri. Airways management ateempted to solve this problem by deploying B-737 service on highly trafficed routes, e.g. Lagos-Kaduna-Kano, and Lagos-Enugu. Even though these planes added additional seats on these routes the problem still exists. The overall seat capacity of Nigerian Airways is still inadequate for the growing demand. The major problems of Nigerian Airways are lack of passenger capacity and inadequate route scheduling. Eight percent (37) of all the aircrafts are 35 seater F-28 with slightly less variable cost than the 55 seater Boeing 737. These F-28's do not have the capacity to meet the demand, and do not enjoy the economies of scale of the larger aircrafts.

2.3 Demand for Shipping Services in Nigeria

In any economy the demand for shipping services is dependent on the level of imports and exports. A favorable balance-of-trade in the external market is generated by high valued export commodities such as oil, solid minerals (like gold, copper, uranium) and manufactured goods. On the other hand, prices of agricultural commodities

Table (2-16). INTERNAL AIRPORTS

Airport	Scheduled Flight Arrivals and Departures per week	Type of Aircraft
Benin City	38	F 28*
Enugu	34	F 28 α 737
Port Harcourt	44	F 28
Calabar	16	F 28
Ibadan	34	F 28
Kaduna	96	F 28 α 737
Jos	40	F 28
Sokoto	6	F 28
Yola	12	F 28
Maiduguri	12	F 28

*F 28 -- 35 passenger jet aircraft.

Source: Nigerian Airways: Internal Flight Schedule Lagos, Nigeria.

fluctuate on the world market and yield less foreign exchange.

In general, Metaxas (38) held that the demand for shipping services depends on the following factors:

- Changes in international trade in terms of volume and structure.
- Geographical differentiation in world production and consumption of all types of goods (i.e. both agricultural and industrial).
- Demand levels for the commodities moved by ships at both countries of origin and destination.

In Nigeria the demand for shipping services is based on a favorable balance of payment generated by the oil sector. With this, service activities (e.g. construction, commerce, industrial, health and education) doubled between 1960 and 1975. In addition, higher personal income resulted in greater consumption of food and manufactured goods. The consumer price index jumped from 80.9 to 267.0 (39) between 1969 and 1976 (i.e. a period of only 7 years). This is an alarming increase of 230%.

The commercial sector of the economy increased import levels to meet this demand. On the aggregate, the increase in shipping demand is related to the growth in GDP. In 1964 when Nigeria's GDP was ₦ 2,894.8 million 5,636 (40) ships entered her ports, but in 1972 with GDP of ₦ 4,111.0 million 8824 ships entered her ports. Thus, as the GDP increased by 42% the number of ships increased by 57%.

A brief analysis of the structure of the shipping industry in Nigeria is essential for a clear understanding of this sector of the economy. The Nigerian Marketing Company is a Federal Government agency granted a monopoly for shipping and marketing of Nigeria's agricultural products. This company exports over 2 million tons of commodities annually. Other major firms include the United African Company, John Holt of England, Paterson Zochonis, Mandilas and A. G. Leventist. In recent times Nigerian owned private organizations like Henry Stephens Group and IBRU Organizations have become major forces to reckon with in the import and export business. This is due to the Nigerian Government indegenization Decree which granted trade concessions to Nigerian owned private organizations. However as of 1977, these firms still handle only (30-40%) of the total import trade moving into Nigeria (see Table (2-17)).

A disaggregate analysis of Nigerian import and export trade volume was carried out by NNEDECO. Their conclusions were that 10.5% of the trade volume were dry bulk cargo; .05% were liquid bulk and general cargo accounted for 89%. (41) This classification can be useful in forecasting the type of ships which will enter Nigerian ports. The Federal Inspector of shipping projected export and import tonnage to be 124 and 0.8 million long tons by 1980 (the end of the Third National Development Plan). The average size of general cargo ships entering Nigerian ports is 10,000 tons while the smallest oil tanker is 100,000 tons. This observation is in line with the trend in international shipping which emphasizes larger ships, as there are economies of scale involved, with the marginal increase in variable cost less than the marginal return from an increase in capacity.

Using these statistics a first order approximation of Nigeria's shipping demand by 1980 can be made.

Table (2-17). SHIPS ENTERING NIGERIAN PORTS BY PRODUCE SEASONS

Ports	1963-64		1964-65		1965-66		1966-67	
	No. of Ships	Net Reg. Tonnage	No. of Ships	Net Reg. Tonnage	No. of Ships	Net Reg. Tonnage	No. of Ships	Net Reg. Tonnage
Lagos	2,063	5,912,723	1,965	5,738,064	1,954	5,684,494	1,907	5,586,772
Port Harcourt	1,084	2,855,597	987	2,720,412	1,084	3,037,521	1,203	3,237,615
Minor Ports								
Sapele	345	865,411	281	750,677	287	--	327	905,898
Warri	161	424,929	150	402,413	198	758,276	299	570,603
Burutu	190	426,622	198	454,816	208	484,163	189	330,615
Calabar	173	419,732	169	369,491	186	545,057	191	357,495
Degema	40	80,072	33	78,614	32	368,029	25	71,978
Bonny	226	3,897,101	324	2,987,269	405	87,879	520	7,569,606
Koko	2	5,456	5	17,594	20	5,011,457	14	14,763
Total Minor Ports	1,137	6,029,251	1,160	5,060,874	1,336	7,248,147	1,495	9,820,950
Grand Total	4,284	14,797,671	4,112	13,539,350	4,374	16,025,023	4,632	18,645,345

Table (2-17). (continued)

Ports	1967-68		1968-69		19
	No. of Ships	Net Reg. Tonnage	No. of Ships	Net Reg. Tonnage	No. of Ships
Lagos	1,748	5,091,694	1,659	4,769,203	2,070
Port Harcourt	--	--	--	--	77
Minor Ports					
Sapele	218	501,165	264	556,651	243
Warri	124	234,259	203	464,487	195
Burutu	82	86,832	43	40,001	39
Calabar	--	--	72	73,395	110
Degema	--	--	--	--	--
Bonny	--	--	174	2,621,442	567
Koko	7	2,187	12	7,773	21
Total Minor Ports	431	824,443	768	3,763,749	1,175
Grand Totals	2,179	5,916,137	2,427	8,532,952	3,322

Source: Nigerian Port Authority: Annual Reports 1960-1976, Lagos.

The projected total export tonnage by 1980 is 124 million long tons. If the oil export tonnage is 15 million long tons, the dry bulk and general cargo tonnage will be 109 million long tons. This will require 10,900 general cargo ships of 10,000 long ton capacity and 150 100,000 ton tankers. This would represent an increase of 15% over the number of ships serviced in Nigerian ports in 1977.

Applying this traffic volume to a specific port like Lagos which handles 50% of the general cargo traffic entering Nigeria; 5450 ships will be serviced by Lagos port by 1980.

When shipping demand is related to specific ports as in table (2-17) one observes that the port of Lagos and Port Harcourt handle 50% and 25% of all ships cleared in Nigeria. However the specialized oil terminal port of Bonny is the second leading port in terms of total tonnage handled, servicing 55% of the net registered export tonnage from Nigeria. Figure (2-7) illustrates the ship traffic entering all Nigerian ports between 1963 and 1972. A fairly marked growth in traffic is observed between (1963-1967), the four years after independence. In the civil war period (1967 to 1969) the economy suffered a major set back. Consequently shipping traffic declined, reaching its ebb in 1969. In that same period the port of Port Harcourt, the second major port, was not operational because it was in the war affected area. As indicated by Figure (2-8) the port of Lagos moved 50% of the total tonnage and 90% of all the general cargo entering Nigeria. The oil port of Bonny and the river ports of Sapele, Warri and Burutu handled 50% of the total tonnage and 10% of the general commodity. In 1969 with Military air operations disrupting the river ports of Warri and Sapele, the port of

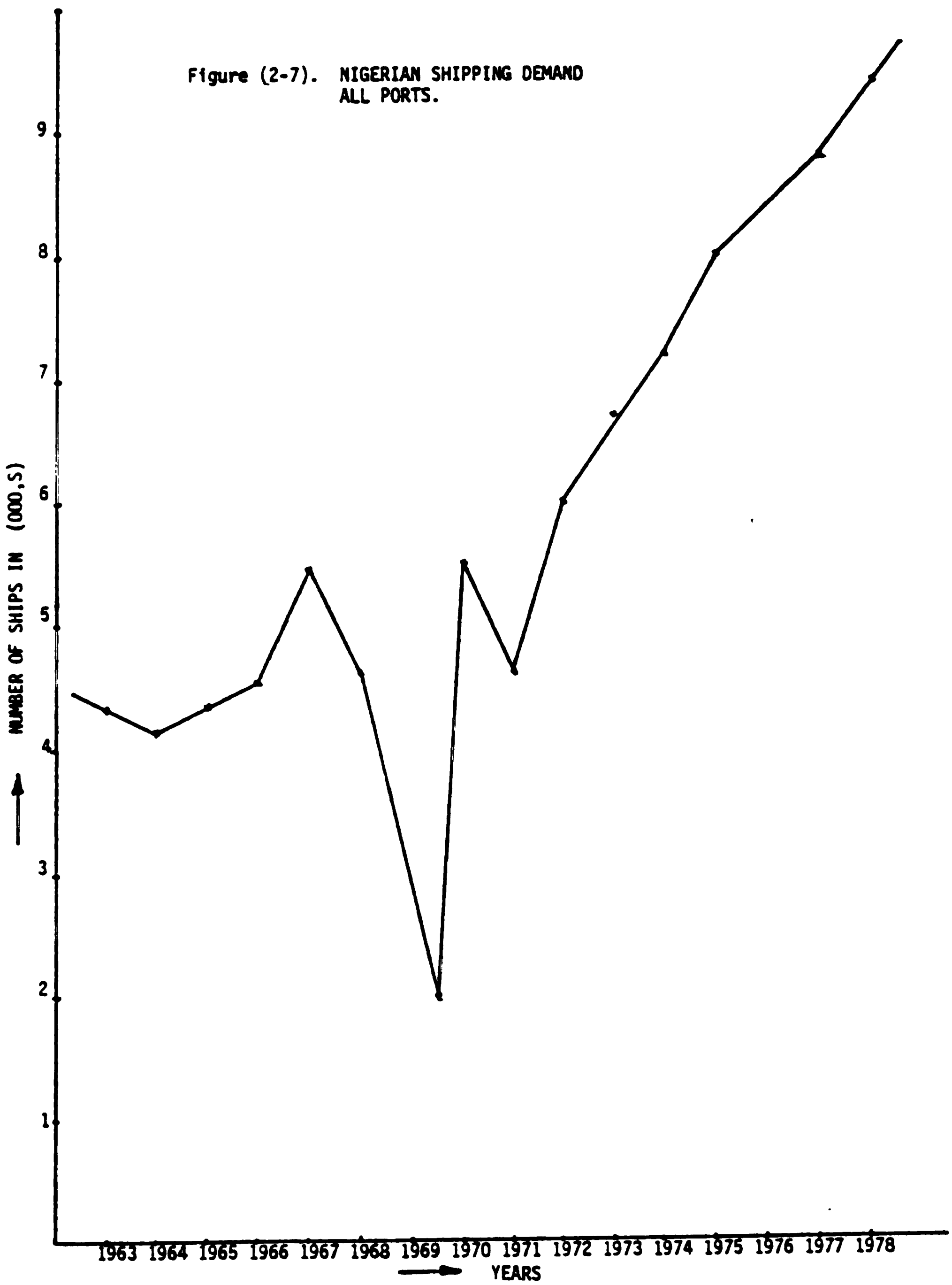


Figure (2-7). NIGERIAN SHIPPING DEMAND
ALL PORTS.
NUMBER OF SHIPS IN (000,S)
1
2
3
4
5
6
7
8
9
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978
YEARS

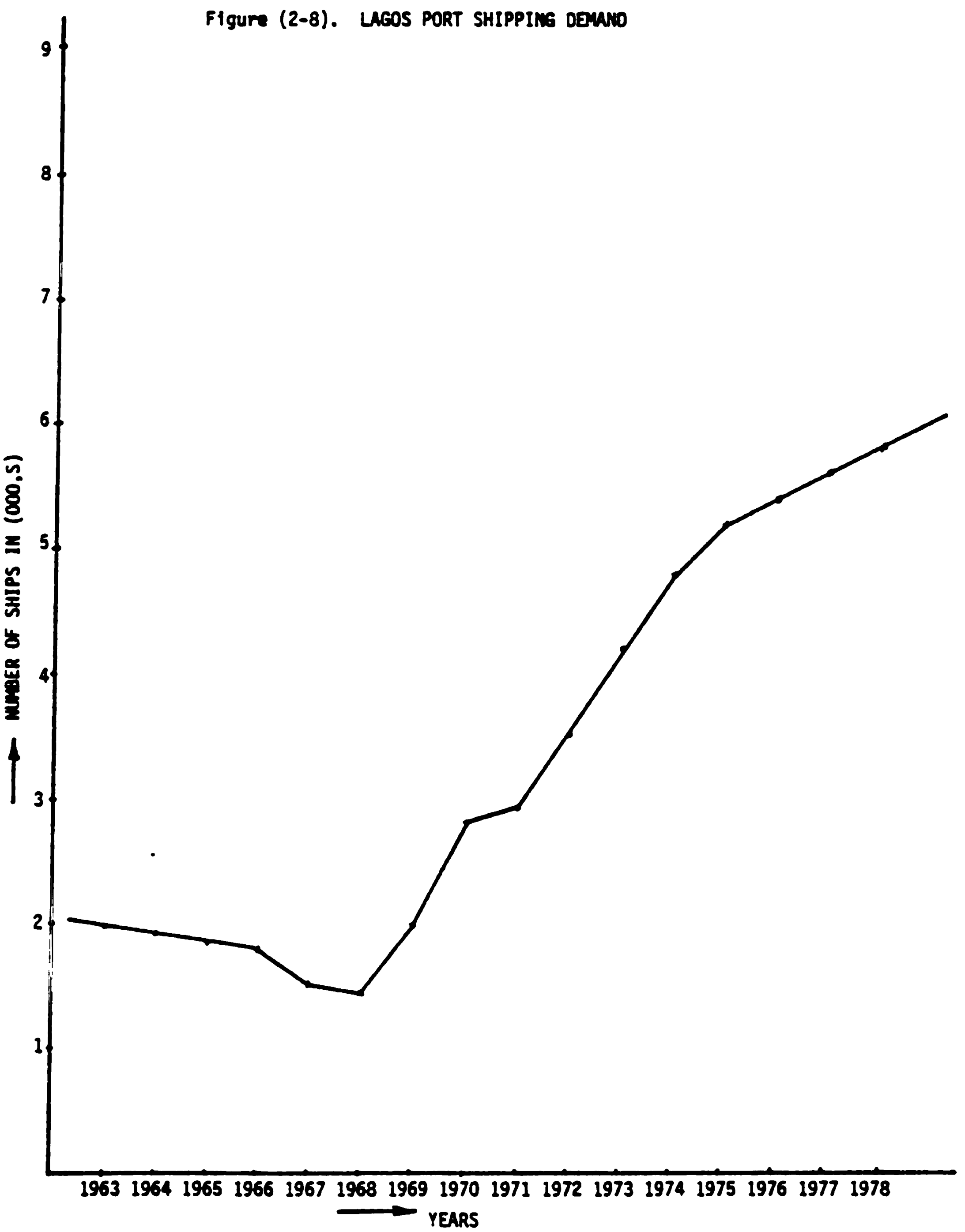


Figure (2-8). LAGOS PORT SHIPPING DEMAND
NUMBER OF SHIPS IN (000,S)
1
2
3
4
5
6
7
8
9
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978
YEARS

Lagos handled virtually all the general cargo. Hence the Lagos port ship traffic volume comes very close to the national volume. The minor difference is due to the tanker traffic at the port of Bonny (see figure (2-9)). In addition, the graph also indicates that in 1972 Lagos handled 60% of the growing ship traffic volume in Nigeria.

Seasonal Variations

Nigeria, like other countries of West Africa has two major seasons in a year. The dry season extends from October to April. The weather is generally warm and dry during this period. Temperature average in this season is about 85^{o}F. The rainy season starts in May and continues until September. In this period torrential rainfall occasionally disturbs dock activities like loading and unloading. Agricultural exports which are stored in open spaces have a higher probability of spoilage in this season than in the dry season. Variation in demand between the two seasons might be important in estimating peak demand for design purposes.

Table (2-18) illustrates the seasonal export and import trade volume. The Chi Square test was applied to the average volume of import and export to establish any significant variation at 95% confidence level (i.e. high enough for reliable conclusions). The test was carried out separately for export and import trade volumes respectively.

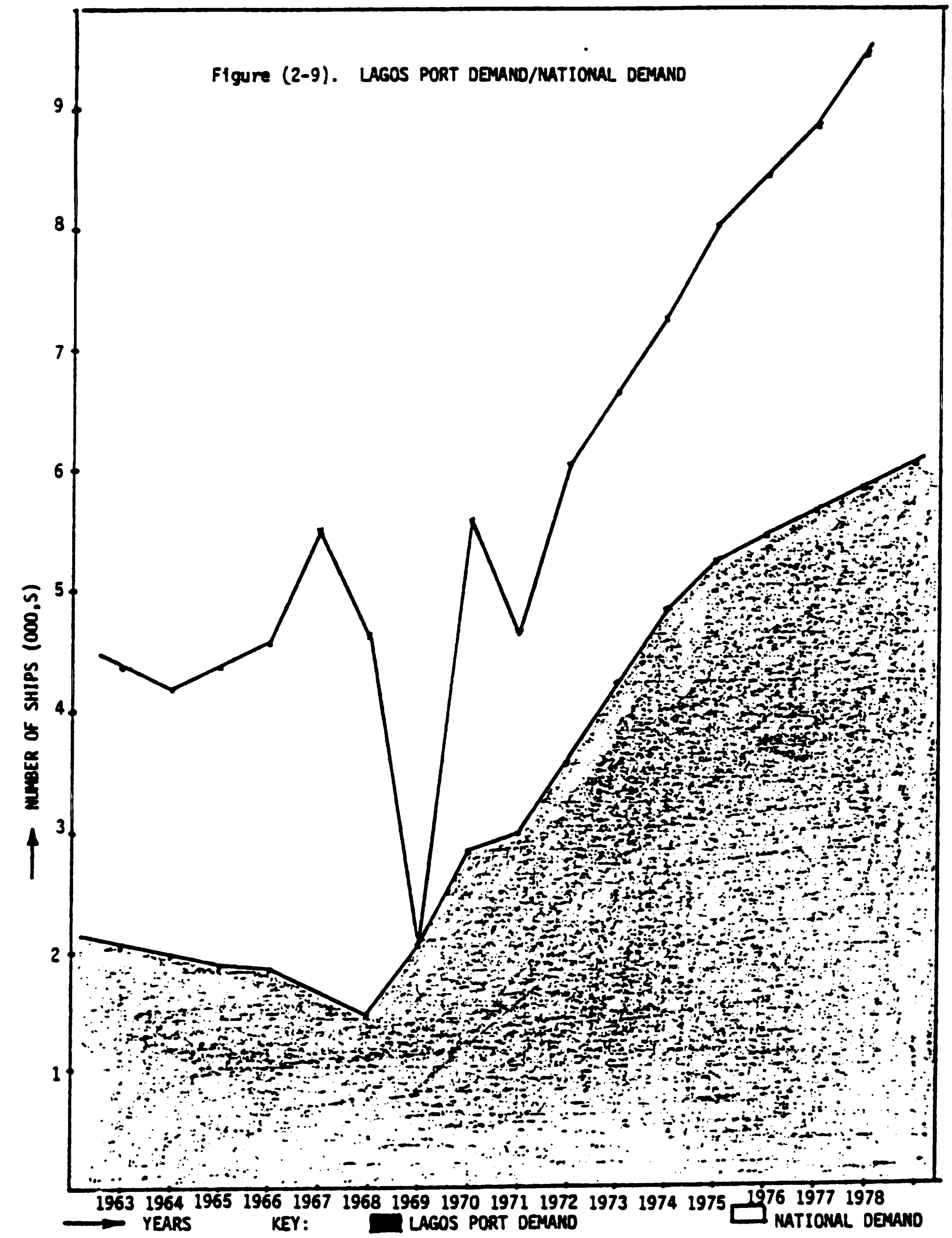


Figure (2-9). LAGOS PORT DEMAND/NATIONAL DEMAND
NUMBER OF SHIPS (000,S)
9
8
7
6
5
4
3
2
1
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978
YEARS
KEY:
LAGOS PORT DEMAND
NATIONAL DEMAND

Table (2-18). SEASONAL VARIATION OF NIGERIA'S EXPORT-IMPORT TRADE (₦ Million)

Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1960												
Exports	28.0	30.0	27.8	28.6	39.0	29.6	26.0	24.6	19.6	17.0	25.4	25.0
Imports	35.4	32.0	33.4	31.4	34.8	33.0	33.0	39.6	39.0	36.0	42.4	39.0
1963												
Exports	30.6	21.6	34.6	35.6	33.0	30.8	28.8	25.6	28.6	28.8	30.4	33.2
Imports	31.4	27.0	36.6	32.4	32.8	30.6	32.2	35.0	34.8	40.2	40.8	41.6
1965												
Exports	37.2	31.2	52.6	42.6	46.0	53.8	44.8	49.2	50.8	35.2	32.8	49.6
Imports	50.6	44.0	46.8	47.2	41.2	41.2	44.8	45.0	43.8	45.6	53.0	46.0
1970												
Exports	61.0	57.4	70.6	76.2	84.0	70.6	69.0	76.0	74.6	78.0	78.0	79.8
Imports	58.8	52.4	51.0	51.2	56.2	59.0	63.2	65.8	63.8	81.2	76.8	75.8
Average												
Exports	39.2	35.1	46.4	45.7	50.5	46.2	42.1	43.8	43.4	39.7	41.6	46.9
Imports	44.1	38.8	35.7	40.5	41.2	40.9	43.3	46.3	45.3	50.7	45.3	50.6
Total	83.3	73.9	82.1	86.2	91.7	87.1	85.4	87.1	88.7	90.4	86.9	97.5
Seasonal Weather Pattern	DRY SEASON					RAINY SEASON				DRY SEASON		

Source:

Table (2-19). AVERAGE SEASONAL IMPORT AND EXPORT TRADE

YEAR	DRY SEASON		RAINY SEASON	
	Import Average (₦ million)	Export Average (₦ million)	Import Average (₦ million)	Export Average (₦ million)
1960	35.7	26.0	35.9	27.8
1963	35.7	30.7	34.6	29.4
1965	47.6	47.2	46.5	48.9
1970	63.9	71.6	62.6	73.2

(Prepared from table 2-18)

(i) Applying X^2 test on seasonal import volume:

Dry Season Import Average	Rainy Season Import Average	$\frac{(Oi-E)^2}{E}$
35.7	35.9	.002
35.7	34.6	.03
47.6	46.5	.02
63.9	62.6	.02
		$\frac{(Oi-E)^2}{E}$ = .09

.·. $X^2_{0.05}$ confidence level with degree of freedom 3, X_o = 3.52 > .09

.·. $X_o > X^2$.

Hence there is no significant import variations during the dry and rainy seasons.

(ii) Applying X^2 test on seasonal export data:

Dry Season Export Average (₦ million)	Rainy Season Export Average (₦ million)	$\frac{(Oi-E)^2}{E}$
26.0	27.8	.12
30.7	29.4	.05
47.2	48.9	.06
71.6	73.2	.03
		$\frac{(Oi-E)^2}{E}$ = .262

.·. $X^2_{0.05}$ confidence level with degree of freedom 3,

X_o = .352 > X^2 > .262

.·. there is no significant variation between the volume of dry and rainy season exports.

Hence there is no significant seasonal variations during the dry and rainy season.

The result of the X^2 test is contrary to general expectation that the rainy season affects export and import activities. This analysis confirms that any disruption in these activities (e.g. loading and unloading of ships) is merely temporary and of no signficance in affecting aggregate seasonal export and import levels.

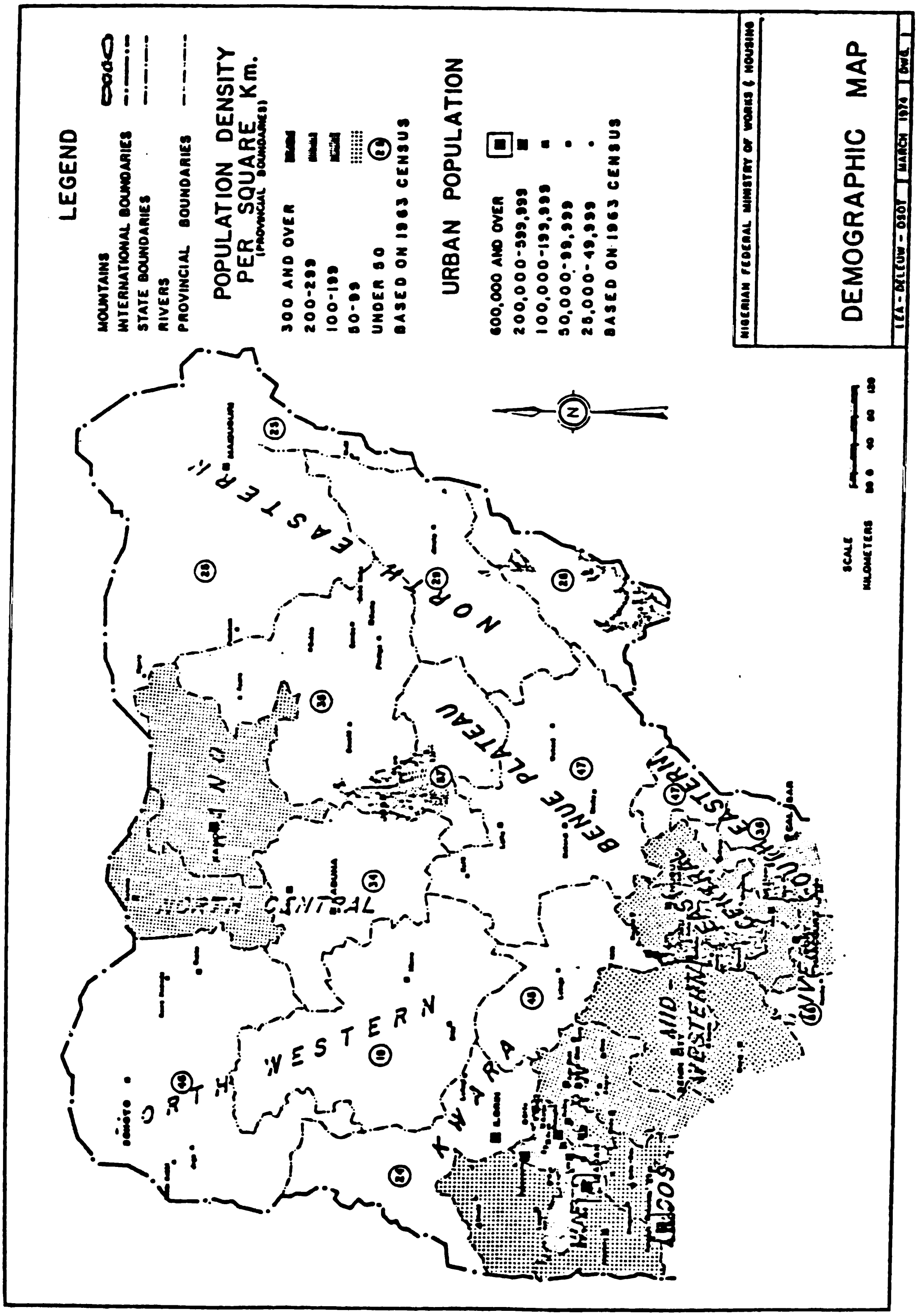
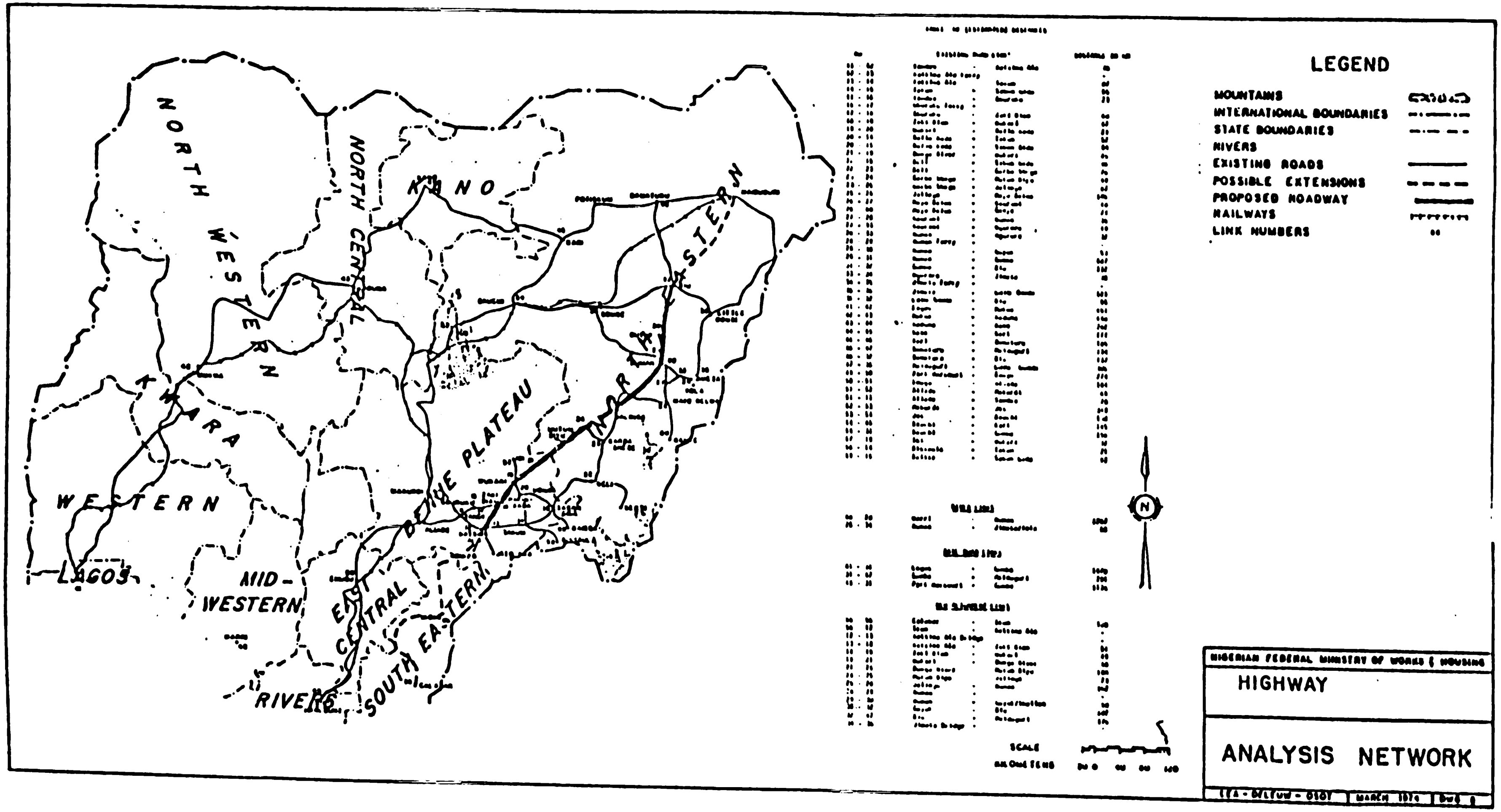


Figure (2-10). DEMOGRAPHIC MAP OF NIGERIA

Figure (2-11). ROAD MAP OF NIGERIA.



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CHAPTER III

LITERATURE REVIEW OF CURRENT TRENDS IN PORT PLANNING AND ANALYSIS

3.1

The state of the art in port planning and analysis is very much in a state of flux, with no specific model or class of model gaining universal acceptance. Instead, there are proponents for each of three distinct models:

a) Analytic models

b) Simulation models

c) Economic models

In many ways these models are complementary to each other and are often used for different aspects of port planning. Prior to selecting a model to analyze the Port of Lagos, review of each category will highlight the state of the art in port analysis and investment optimization.

3.1 (a) Analytic Models. The early application of analytic models was at specialized and single purpose ports. (1) These models considered only problems dealing with ship to berth interface (i.e. ship delay and berth occupancy). In most of these studies, queueing theory was the main technique for determination of waiting time and average ship service time. Assumptions regarding ship arrivals and service distribution can be classified into three main types. (2)

(i) Poisson arrivals and exponential service times, N station models (M/M/C) queue models.

(ii) Poisson arrivals, Kth order Erlang service times, N station models (M/EK/C models).

(iii) Ships were assumed to have independently distributed inter-arrival times, i.e. following general A(t) probability distribution. Service times follow a general G(t) distribution. N station models applying Pollaczeck-Khintehine formula.

There is some controversy regarding the accuracy of the above assumptions. A majority of scholars argue that ship arrivals can be described by a Poisson distribution (i.e. $P(x) = \frac{e^{-M}M^x}{x!}$ x = 0, 1, 2...). (3) This distribution describes the occurrence of random events x in terms of the mean number of occurrence of these events M. Proponents of the use of Poisson arrivals include Omtvedt who analyzed ship traffic at the Mediterranean port of Haifa, (4) and Da Silva (5) and Nicolaou (6) who in separate studies also reached these conclusions for the port of Lisbon and Cyprus. Jones and Blunden (7) identified a Poisson arrival distribution in the port of Bangkok. In 1969 the United Nations' Conference on Trade and Development (UNCTAD) (8) reached the same conclusions after analysis of data from the port of Casablanca.

Gooneratne and Buckley (9) argue that the assumption of Poisson ship arrivals over estimated port congestion in port Kembla--an Australian bulk port. However they did not present statistical data to show that any other distribution provided a better fit than the Poisson. The authors were vague about applying their conclusions to general cargo ports. The schedule of bulk vessels (e.g. oil tankers) are much more rigid than that of general cargo vessels and tramp ships. Therefore, the conclusions of Gooneratne and Buckley probably cannot be applied to general cargo and multi-purpose ports.

Cox and Smith (10) expressed the same view as Gooneratne and Buckley. In order to advance their premise they developed a "Discouragement" model which assumes that the ship arrival rate

$\lambda(n)$ is inversely proportional to the number (n) of ships in the queueing system, i.e.

$$\lambda(n) = \frac{\lambda(0)}{n + 1}$$

They held that this model gives a more accurate prediction of total ship delay than the widely accepted Poisson arrival distribution. As in the previous study, these authors failed to provide any evidence that the Poisson distribution did not fit the arrivals or that any other proposed distribution did fit the data. This study was also on the analysis of bulk ports, and thus may not be applicable to general cargo ports.

In such a situation, random arrivals may be disturbed by effective ship control regulations during periods of congestion. Ships destined to the port may be diverted to other bulk ports. It is only in such a circumstance that the arrival rate can be inversely related to the number of ships in the queueing system. Diversion of general cargo ships is difficult due to shipper preferences and custom complications. The experience of Lagos port between 1974-1975 (see Chapter I) confirms that the vessel arrival rate does not necessarily depend on the number of ships in the system. Instead the arrival rate at a general cargo port is a function of the volume of import and export trade that moves through the port.

The pattern and distribution of ship service times is another area of controversy. Ship service time is defined as the time the ship occupies the berth, transit time to and from berth and the idle time at the head of the queue. A number of scholars argue that the negative exponential distribution accurately describes ship service time.

Another group of scholars hold that the Erlang distribution provides the best fit for ship service time. Using this definition it is possible to examine the negative exponential and Erlang distribution formula (as shown in Figure 3-1).

(i) The negative exponential distribution is given by $f(t) = qe^{-qt}$ where q is the mean flow rate/per time period (t).

(ii) The Erlang distribution is described by

$$f(t) = \frac{(qa)^a}{(a-1)!} t^{a-1} e^{-aqt} \qquad a = 1, 2...$$

Where the mean flow rate $q = \bar{t}^{\,-1}$, t = unit time

Where a and (a-1) are the fractions of the total volume of ships in the two subdistributions (i.e. free flowing and constrained ships).

Equations (i) and (ii) above indicate that the negative exponential distribution approximates the Erlang distribution of (a = 1) type. This means that the two distributions can be applied as alternates for this case. However, the Erlang distribution of higher orders ($a = 2, 3... \infty$) accommodate ship service times for all cases between randomness (a = 1), to complete uniformity ($a = \infty$).

In a dynamic system such as a general cargo port uniformity is not generally attainable. Hence, the negative exponential distribution (Erlang a = 1) are frequently used. Erlangian distributions of higher orders (a = 2, 3) have been applied in port studies by Gooneratne and Buckley. (11) These authors contend that the predicted delay is greater than observed values when the negative exponential distribution is used.

In the study of Port Kembla, Gooneratne and Buckley noted that there was a marked difference between observed and predicted service

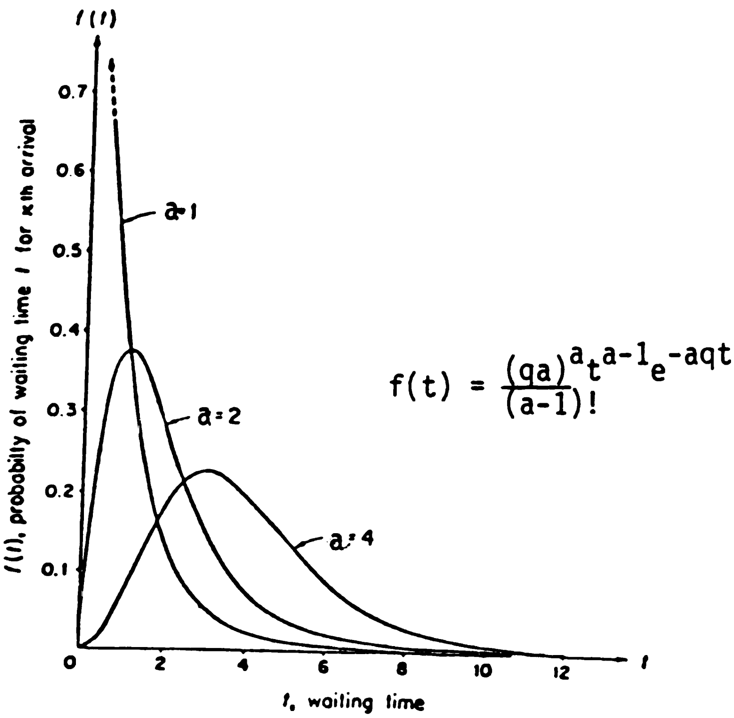

Figure (3-1). POISSON AND ERLANG DISTRIBUTION CURVES

Source: Wohl and Martin: Traffic Systems Analysis for Engineers and Planners. McGraw-Hill, New York.

times. They proposed that this difference was related to the level of berth occupancy (P). When $P < 0.5$ the "Discouragement" model provided reliable results. For values of $P > 0.5$ the observed service times were below the predicted values (based on the model $\lambda(n) = \frac{\lambda(0)}{n+1}$). This model assumes that higher berth occupancy levels tends to decrease ship service time. When the port logistical systems are operating at full capacity it is difficult to obtain significant increases in service rate from higher berth occupancy rates ($P > 0.5$). A minor increase in service rate may be obtained by more effective control of the longshoremen by supervisors. The application of the "Discouragement" model cannot be generalized because Gooneratne and Buckley studied only bulk ports. The service factors in a general or multi-purpose port are different from those of a bulk port.

In general, analytic models can be derived which effectively describe ship arrival and service patterns for a single port. This is a very important technique in the determination of ship waiting and service time, which are major cost functions in port studies.

However, analytical models have their limitations as tools for studying port economics. For example, most analytic models fail to include all of the variables which affect port operation. Many variables have to be unduly restricted to construct these models. Because of these restrictions, analytic models, when applied to a complex problem, often yield inaccurate results, and conclusions derived from these analytic models may have low confidence levels.

3.1 (b) Simulation Model. Computer technology made possible the use of simulation models in the analysis of many real life problems. In complex projects like ports, simulation models enable planners to look at the total port system. The objective of the model is to describe the entire port operation rather than any subsystem. It considers the entire system to be made up of dynamic logistical subsystems (e.g. transfer equipment, warehousing space, berths, pilotage and multimodal terminals).

One of the models developed to study ports is the Seaport Model. Figure (3-2) shows the model concept. The port control model is an input-output model; the port hinterland generates the economic input variables (i.e. level of import and export of commodities). Hence the two directional flow of import and export commodities are dependent on the aggregate economic and population growth trends of the port hinterland. These economic factors are considered as exogenous to the port.

The physical adequacy of the various logistical port subsystems (i.e. signals, towage berths, Gantry crane, equipment, warehouses and transportation facilities) determines whether a particular port can service a given demand. If the subsystems provide a poor level of service at a given demand level, new combinations of subsystems need to be established. These changes in port configuration over time enable a port system to offer an acceptable quality of service despite demand variations due to economic growth.

The overall objective of the simulation model is to determine the optimal set of port resource requirements which will minimize total ship delay (and optimize freight flow). Hence it is essential

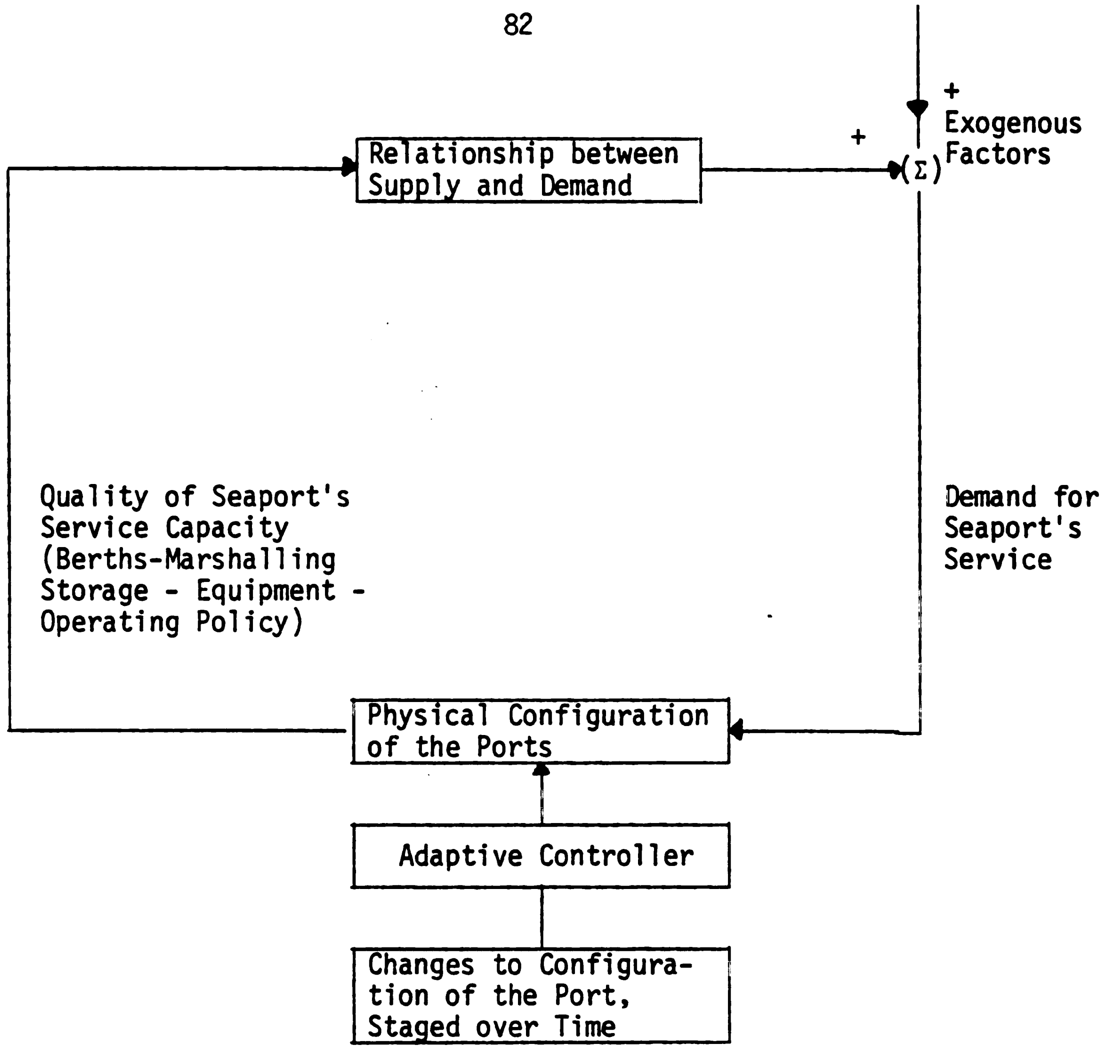

Figure (3-2). PORT CONTROL VOLUME

Source: Wilmes, P. and E. Frankel: Port Analysis and Planning. MIT.

to determine the port level of service and flow rate. Flow rate include not only the flow of ships but cargo movement through the port subsystems.

In simulation of a general cargo port the arrival and service distributions are two main variables. Once the above distributions are defined integral transforms can be utilized in generating random arrivals and random service. The ship at the head of the queue accepts the first vacant gap assuming a first-come first-serve priority. In some models maximum berth service time may be specified. (12) If a vessel is delayed beyond this time, it may depart unloaded. In practice this is only true where there are alternate ports.

Cargo flow rate is also simulated as a function of the loading and unloading equipment and transportation facilities in the port. Import and export flow rates are modelled the same way. However, the logistical directions of the import and export cargo are opposite. Import cargo moves out of the transit sheds into user owned warehouses, port storage warehouses or multimodal terminals. In a simulation model designed to replicate the entire port operations activites are incorporated to describe the ship and cargo flow through the entire port subsystems. (13) Tracking of ship or cargo ceases as it leaves the system. ORNER (14) is an example of such a model which was applied to evaluate future costs of congestion on U.S. Atlantic seacoast ports. In this particular study the principal cost function was time expressed by total ship and cargo delay.

In 1969 the United Nations Conference on Trade Development (15) designed a port simulation model for general cargo ports. This is the most up-to-date and sophisticated model. Numerous variables like towage, signals, pilotage and physical facilities were incorporated into the model. Ship and cargo delay in the port system provided inputs for an investment optimization program. A detailed discussion of the UNCTAD model is in the appendix. The major disadvantage of this model is the high cost associated with each run. Port Simulation Modelling was also applied to the analysis of ship queueing problem in port Kembla, Australia. (16) In this case input data was obtained from vessel turn around cards. The model used in Kembla was derived from the UNCTAD program mentioned above.

3.1 (c) Economic Models. Economic models have traditionally been used to evaluate port investments. The main weakness of this approach lies in the definition of costs and benefits. The cost to the port includes only the outlays necessary to carry out an investment decision. On the other hand, the cost to a nation involves the consideration of all inputs to the GNP resulting from that. In a developing country where there is a downward economic multiplier effect from port congestion, this approach may understate the benefits to be derived from a port improvement project.

As ship and cargo traffic are optimized, the economic activities within the port hinterland increase. This implies that additional employment will be created and extra overland traffic will be induced. The benefits of a port investment can be classified into three broad categories:

- direct benefits to the port
- benefits to users of the port
- indirect benefits to the suppliers of input factors to the investment.

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Table (3-1) lists the nature of these investments.

Since a benefit to one group may be a cost to another group, it is necessary to specify who benefits and at whose expense. In port planning an investment may not be attractive to the port on financial grounds but when the country's economy is considered the investment can be justified. This means that port investments should not be selected only on the basis of limited financial evaluations.

In general, economic models are not accurate for the evaluation of investment alternatives because indirect benefits and costs are difficult to quantify.

In developing countries where the entire economy is import dependent port benefits are even more difficult to quantify. The tendency in such ports is to maximize thorough-put rather than to minimize the pay-back period of the particular investment.

3.2 (a) Identification of Limits in Existing Models and Justification of the Dissertation. Queueing theory is effective in dealing with ship to berth interface, if the arrival and service distribution can be defined by a regular distribution. Total ship delay and cargo delay can be obtained by the application of queueing theory. The major disadvantage of this method is that it is difficult to incorporate the dynamic nature of ship or cargo flow through the system, since the solution of the queueing theory equations is based on steady state conditions.

Simulation models are more effective in analyzing the effect of dynamic patterns. Their major disadvantage is the high cost of data collection and programming. The UNCTAD model which is the most advanced port simulation package consumed $20,000.00 (17) (computer

Table (3-1). POSSIBLE BENEFITS OF PORT INVESTMENT

Direct Benefit to Port	Benefits to Port Users	Indirect Benefits to Suppliers of Input Factors
(i) additional revenue from dues on ships	(i) savings in inland transport cost	(i) increase in income to port-related labor
(ii) increase in net cargo-handling revenue	(ii) savings in cargo-handling cost	(ii) increase in income to port-related industries
(iii) additional rental of land made possible by the project investment	(iii) savings in insurance cost	(iii) increase in benefits through a multiplier effect, if any
	(iv) savings in the interest expense of capital tied up in inventory	
	(v) savings in ships' cost in port	
	(vi) savings in ship's operating cost arising from economy of scale of operating larger ships made possibly by port investment	
	(vii) increase in output of port-user industry made possible by port investment	

Source: United Nations: Appraisal of Port Investments. TD/B/C.4/174 UNCTAD, Geneva, 1977.

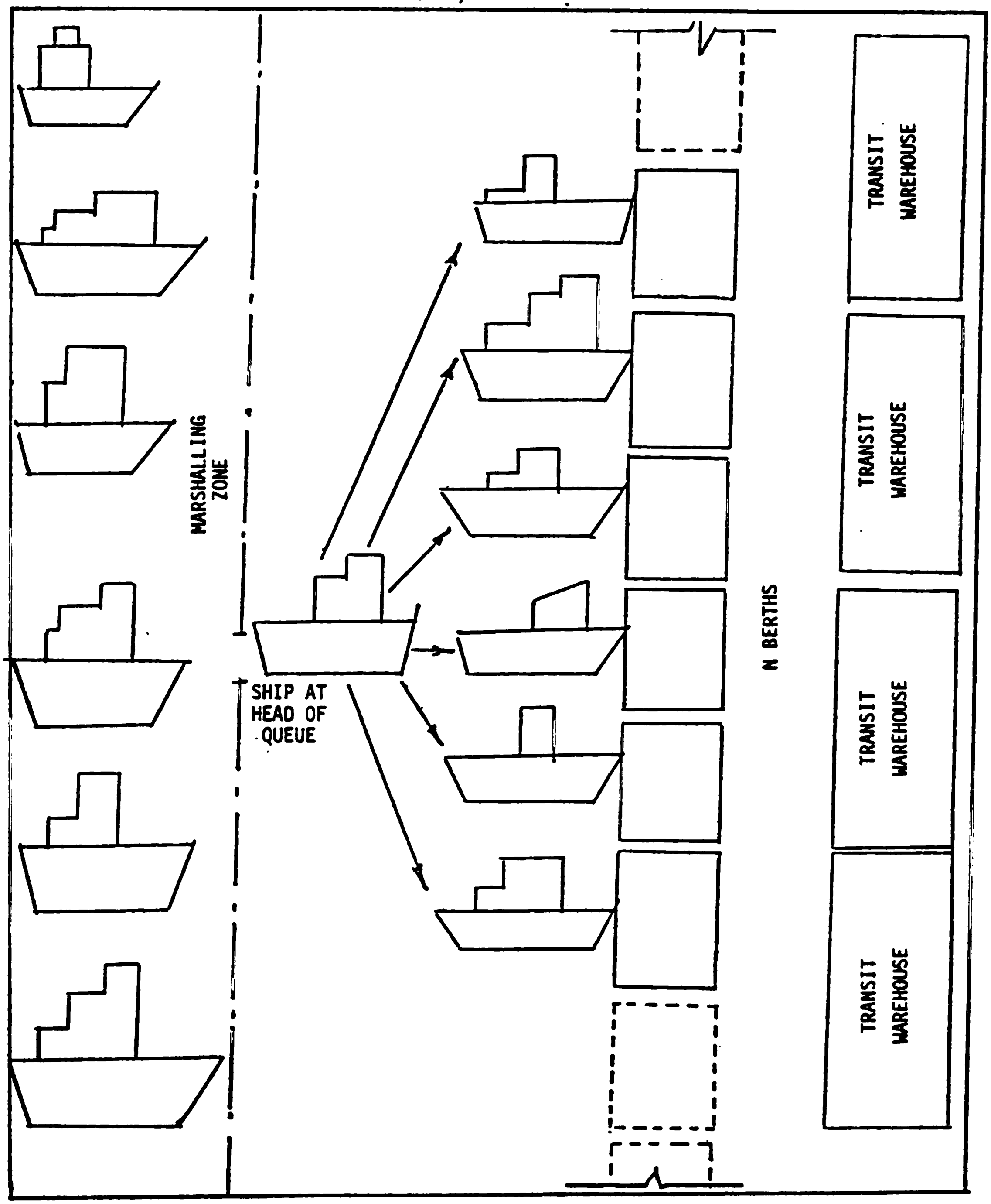
costs) in the study of the port of Casablanca. This is one of the reasons the literature on the simulation of general cargo ports is limited. Most port planners simulated bulk ports which are less complex than general cargo ports.

Economic models can be applied to the evaluation of alternative port investments. Their main weakness lies in the definition of intangible benefits. This area tends to be subjective. In addition in most developing countries ports are state owned and emphasis is on thorough-put rather than investment pay-back considerations. Economic models are in some cases simplistic and ignore the upward multiplier effect on the economy which an efficient port creates in the hinterland.

Analytic, simulation and economic models each have a role to play in port studies. The results of analytic models can provide input into complex port simulation models. Port planners need to employ analytic models to calibrate the simulation models. The results of the simulation models, in turn, become inputs into the economic models employed to consider specific improvements. Hence there is still tremendous work to be carried out in the areas of port analyses and development of investment criteria for general cargo ports. This need is even greater in developing countries where a rapid economic growth rate and higher level of imports are creating congestion in the existing port systems.

3.2 (b) Methodology. Ship traffic through the port system can be analyzed by the application of simulation model of multiple service channel type. Figure (3-3) illustrates the general configuration of such a service system. There are three major assumptions: (18)

Figure (3-3). CONFIGURATION OF SHIP QUEUING SYSTEM ('SINGLE WAITING LINE' DEFINED BY ARRIVAL TIME AND PORT PRIORITY POLICY)



(i) A 'first-come first-serve' queue discipline is assumed.

(ii) All berths have the same service rate (and service capacity).

(iii) Ships do not line up behind one another as they arrive but are held back at the anchorage until a vacancy occurs.

The first assumption is consistent with policies used in major world ports, e.g. Lisbon, Casablanca, Bangkok, and London. (19) However ports do have priority policies for express vessels, military vessels and tankers (in multi-purpose ports). In such a situation a 'first-come first-serve' discipline can be distorted if the volume and frequency of arrival of the priority class is significant. When this occurs preemptive-resume priority statistics is applied to the simulation model. (20) In this technique a class A ship will be served upon arrival unless there is another class A ship already in the berth. Thus in a multiple berth port a class A ship will preempt a class B ship already in one of the berths. The class B ship automatically returns to the head of the queue waiting for the next gap. In practice this situation is not easily carried out because of the difficulties and time cost of unberthing a half off-loaded vessel. The priority ship merely moves to the next vacant berth in some ports. (21)

The second assumption should be discussed in relation to specific ports. In some general cargo ports, with deep natural harbors, berths accommodate all classes of general cargo ships. Cranes and transfer equipment are often drawn from a common pool serving all berths. Thus the second assumption should be considered with conditions in specific ports.

The third assumption is in line with existing Harbor master's policy of marshalling vessels. As a ship arrives at the anchorage it joins the queue and waits until it is at the head of the queue. Figure (3-3) illustrates the multiple channel structure of a general cargo port. It is important to note that even though ships cluster around the anchorage a queue still exists. This queue is based on time of arrival coupled with the port priority policy. The capacity of N ships in the system at any given time is a function of both the physical limitations such as the number of berths available and the level of waiting that is intolerable to arriving ships. With general cargo ships balking rarely occurs because of the high cost of ship operations. This implies that the arriving ship has no choice but to join the queue. This situation is more common where alternate ports are not near the destination ports, e.g. Lagos.

As a result of the above discussion the population of ships are considered infinite. The $(M/M/C):(GD/N/\infty)$ (22) is considered an effective model in dealing with infinite queueing problems. An important assumption is that a single waiting line exists; jockeying and reneging do not apply to ships because of strict harbor control policies. A detailed discussion of the model is given below.

Let $P_n(t)$ denote the probability of n units in the system at time t

Let $\lambda(n)$ and μ_n represent arrival and service rates when n units are in the system: then

$\lambda_n \Delta t$ = probability of one arrival during Δt

$1 - \lambda_n \Delta t$ = probability of no arrival during Δt

$\mu_n \Delta t$ = probability of one service during Δt

$1 - \mu_n \Delta t$ = probability of no service during Δt

In the case where Δt is sufficiently small that both an arrival and a service can not occur during Δt:

$$P_n(t + \Delta t) = P_n(t)(1 - n\lambda t)(1 - \mu_n \Delta t)$$
$$+ P_{n-1}(t)\lambda_{n-1}\ t(\ 1 - \mu_{n-1}\Delta t)$$
$$+ P_{n+1}(t)(\ 1 - \lambda_{n+1}\Delta t)\mu_{n+1}\Delta t \ . \ . \ . \ . \ \text{Equation (A)}$$

From equation A above the probability of n units in the system at any time period is the sum of the probabilities of the following three events:

- n units in the system at t, no arrival or service during Δt
- n-1 units in the system at t, one arrival and no service during Δt
- n+1 units in the system at t, no arrival and one service during Δt

As $\Delta t \to 0$ and dividing equation A by Δt we obtain

$$\frac{dP_n(t)}{dt} = -P_n(t)(\lambda_n + \mu_n) + P_{n-1}(t)\mu_{n-1} + P_{n+1}(t)\mu_{n+1} \ . \ . \ . \ .$$

Equation (B)

At steady state $t \to \infty$ or $dP_n(t)/dt = 0$

In steady state $P_n(t)$ is not a function of t, i.e. t can be excluded and equation B above becomes:

$$0 = -P_n(\lambda_n + \mu_n) + P_{n-1}\lambda_{n-1} + P_{n+1}\mu_{n+1} \text{ for } 0 < R < N \ . \ . \ . \ .$$

Equation (B.1)

$$0 = -P_o\lambda_o + P_1\mu_1\ , \quad 0 = P_N\mu_N + P_{N-1}\lambda_{N-1} \ . \ . \ . \ . \ \text{Equation (B.2)}$$

Equation B.1 and B.2 are the general balance equation of the M/M/C queue. We can solve the general balance equations as shown

$$P_1 = \frac{\lambda_o}{\mu_1} P_o$$

for n = 1, from Equation B.1

$$P_2 = \frac{\lambda_1 + \mu_1 P_1}{\mu_2} - \frac{\lambda_o P_o}{\mu_2}\ , \text{ solving for}$$

$$P_2 = \frac{\lambda_1 \lambda_o P_o}{\mu_2 \mu_1}$$

Generalizing $P_n = \prod_{k=1}^{n} \frac{\lambda_{k-1}}{\mu_k} P_o$ for $1 \leq n \leq N$

but $P_o = \left[1 + \sum_{n=1}^{N} \prod_{k=1}^{n} \frac{\lambda_{k-1}}{\mu_k} \right]^{-1}$, $\therefore$ for $n = 1, 2, \ldots . N$

$$P_n = \frac{\left[\prod_{k=1}^{n} \frac{\lambda_{k-1}}{\mu_k} \right]}{\left[1 + \sum_{n=1}^{N} \prod^{n} \frac{\lambda_{k-1}}{\mu_k} \right]} \quad . \; . \; . \; . \text{ Equation B.3}$$

Table (3-2) shows all the formula deduced from the M/M/C steady state general balance equation. Note that the average time spent in the queue and the average waiting time can be determined provided that the utilization factor $\rho < 1$ (where $\rho = \lambda/k\mu$, λ = arrival rate of ships, k = number of service channels, μ = mean service rate). When $\rho > 1$ the M/M/C steady state model breaks down. This is a major disadvantage of the above model. In addition the M/M/C steady state equations do not consider the dynamic nature of port operations. Hence in this dissertation a simulation model will be developed.

3.2 (c) Optimization. The objective of the optimization program is to specify the 'optimal' set of port resource requirements which will minimize total ship and cargo delay given a defined demand situation. These resource requirements include all subsystems (e.g. berths, cranes, warehouse, storage areas and transfer equipment). Table (3-3) illustrates the UNCTAD definition of the operational subsystems for the port of Casablanca.

In a port system analysis the major objective functions may be

Table (3-2). M/M/C STEADY STATE EQUATIONS

Multiple-station queuing relationships with Poisson arrivals, exponential service-times, and leading vehicle in queue moving to first vacant station for steady-state conditions*

	Queuing model	*Description of model*
1	$p(n) = \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n p(0)$, for $n = 0, 1, \ldots, k-1$	$p(n)$ = probability of having exactly n vehicles *in system* for $0 \leq n < k$
2	$p(n) = \frac{1}{k!k^{n-k}}\left(\frac{\lambda}{\mu}\right)^n p(0)$, for $n \geq k$	$p(n)$ = probability of having exactly n vehicles *in system* for $n \geq k$
3	$p(0) = \frac{1}{\left[\sum_{n=0}^{k-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \frac{k\mu}{k\mu - \lambda}}$	$p(0)$ = probability of having *zero* vehicles *in system*
4	$\bar{n} = \frac{\lambda\mu(\lambda/\mu)^k}{(k-1)!(k\mu-\lambda)^2} p(0) + \frac{\lambda}{\mu}$	$\bar{n}$ = average no. of vehicles *in system*
5	$\bar{q} = \frac{\lambda\mu(\lambda/\mu)^k}{(k-1)!(k\mu-\lambda)^2} p(0)$	$\bar{q}$ = average length of *queue*
6	$\bar{d} = \frac{\mu(\lambda/\mu)^k}{(k-1)!(k\mu-\lambda)^2} p(0) + \frac{1}{\mu}$	$\bar{d}$ = average time spent *in system*
7	$\bar{w} = \frac{\mu(\lambda/\mu)^k}{(k-1)!(k\mu-\lambda)^2} p(0)$	$\bar{w}$ = average time spent waiting *in queue*
8	$P(d \leq t) = 1 - e^{-\mu t}\left\{1 + \frac{P(n \geq k)}{k} \times \frac{1 - e^{-\mu k t[1-(\lambda/\mu k)-(1/k)]}}{1 - (\lambda/\mu k) - (1/k)}\right\}$	$P(d \leq t)$ = probability of having spent time t or less *in system*
9	$P(n \geq k) = \sum_{n=k}^{\infty} p(n) = \left(\frac{\lambda}{\mu}\right)^k \frac{p(0)}{k!\left(1 - \frac{\lambda}{\mu k}\right)}$	$P(n \geq k)$ = probability of having to wait *in queue*

* k = number of service stations or service channels, each having a servicing rate μ.
λ_k = mean arrival rate per station (as used in Example 11.1 and Table 11.8).
$\lambda = k\lambda_k$.

Source: Wohl and Martin: Traffic Systems Analysis for Engineers and Planners. McGraw-Hill, New York.

Table (3-3). UNCTAD DEFINITIONS OF SYSTEM PARTS FOR PORT OF CASABLANCA

System part number	Description	Type of system part	Standard definition
1. . . .	Signal system	Signal system	1. Present system 2. System with new breakwaters
2. . . .	Breakwaters	Breakwaters	1. Present system (two jetties) 2. New jetty (first stage) 3. New jetty (final stage) and extension of the main jetty
3. . . .	Dredging, present harbor	Dredging	1. Present system
4. . . .	Dredging, future dock 1	Dredging	1. No dredging 2. Depth 9 m 3. Depth 11 m 4. Depth 13 m
5. . . .	Dredging, future dock 2	Dredging	1. No dredging 2. Depth 9 m 3. Depth 11 m 4. Depth 13 m
6. . . .	Dredging, future dock 3	Dredging	1. No dredging 2. Depth 9 m 3. Depth 11 m 4. Depth 13 m
7. . . .	Piers, actual habor (general cargo)	Piers	1. Present system (including road and rail networks)
8. . . .	Future pier 1 (general cargo)	Piers	1. No pier 2. Pier (including road and rail networks)
9. . . .	Future pier 2 (general cargo)	Piers	1. No pier 2. Pier (including road and rail networks)

Table (3-3). Continued

System part number	Description	Type of system part	Standard definition
10. . . .	Pilots and crafts (two pilots for a craft)	Pilotage	1. Three pilots on duty during peak periods
			2. Four pilots on duty during peak periods (system at present)
			3. Five pilots on duty during peak periods
			4. Six pilots on duty during peak periods
11. . . .	Tugs and crew	Towage	1. Four tugs on duty during peak periods (system at present)
			2. Five tugs on duty during peak periods
			3. Six tugs on duty during peak periods
			4. Seven tugs on duty during peak periods
12. . . .	Actual general cargo berths	Berths	1. Present system
13. . . .	New berth 1 (970 m)	Berths	1. No berth
			2. Berth, depth 9 m
			3. Berth, depth 11 m
			4. Berth, depth 13 m
14. . . .	New berth 2 (1,010 m)	Berths	1. No berth
			2. Berth, depth 9 m
			3. Berth, depth 11 m
			4. Berth, depth 13 m
15. . . .	New berth 3 (970 m)	Berths	1. No berth
			2. Berth, depth 9 m
			3. Berth, depth 11 m
			4. Berth, depth 13 m
16. . . .	New berth 4 (1,190 m)	Berths	1. No berth
			2. Berth, depth 9 m
			3. Berth, depth 11 m
			4. Berth, depth 13 m

Table (3-3). Continued

System part number	Description	Type of system part	Standard definition
17. . . .	Cranes	Handling equipment	1. No cranes
			2. 100 cranes (67 in use) (present system)
			3. 150 cranes (113 in use)
			4. 200 cranes (150 in use)
18. . . .	Trucks and trailers	Handling equipment	1. 170 units (88 in use) (present system)
			2. 170 units (100 in use)
			3. 200 units (150 in use)
			4. 267 units (200 in use)
19. . . .	Gangs	Handling equipment	1. 88 gangs per shift (at present)
			2. 100 gangs per shift
			3. 150 gangs per shift
			4. 200 gangs per shift
20. . . .	Storage in present harbor	Storage	1. System today
21. . . .	Storage, future pier 1	Storage	1. 0 per cent closed space
			2. 25 per cent closed space
			3. 50 per cent closed space
			4. 75 per cent closed space
22. . . .	Storage, future pier 2	Storage	1. 0 per cent closed space
			2. 25 per cent closed space
			3. 50 per cent closed space
			4. 75 per cent closed space
23. . . .	Refrigerated space	Storage	1. 3,000 m^2 (at present)
			2. 4,500 m^2
			3. 6,000 m^2

Source: Arnold Guy: Modern Nigeria. Lowe & Brydone, Ltd. Norfolk, England, 1977.

cost, delay or thoroughput. Cost and delay are minimized for a specified thoroughput. One example of a measure of port performance might be:

Minimize

$$Z = aX_1 + bX_3 + dX_4 + eX_5$$
$$+ (X_6/T_6 + Cv_6) + (X_7/T_7 + Cv_7) + (X_8/T_8 + Cv_8)$$
$$+ (X_9/T_9 + Cv_9) + (X_{10}/T_{10} + Cv_{10}) + (X_{11}/T_{11} + Cv_{11})$$
$$+ (X_{12}/T_{12} + Cv_{12}) + (X_{13}/T_{13} + Cv_{13}) + (X_{14}/T_{14} + Cv_{14})$$
$$+ (X_{15}/T_{15} + Cv_{15}) + (X_{16}/T_{16} + Cv_{16}) + (X_{17}/T_{17} + Cv_{17})$$
$$+ (X_{18}/T_{18} + Cv_{18}) + CX_{19} + CX_{20}$$

where X_i = capital cost of the i^{th} investment

T_i = economic service life of the i^{th} investment

Cv_i = annual variable cost associated with i^{th} investment

Z = total annual cost of port operation and ownership

where

a = average cost of one ship/unit waiting time

X_1 = estimate of the average ship waiting time in the queue

b = average cost of one ship/unit berthing time

X_3 = estimate of average ship berthing time

d = average cost of one cargo unit waiting time in transit warehouse

X_4 = estimate of average cargo waiting time in the transit warehouse

e = average cost of one cargo unit waiting time within the inner harbor facilities

X_5 = estimate of average cargo waiting time within the inner harbor facilities

X_6 = land allocation investment for anchorage facilities

T_6 = life period of the anchorage investment

X_7 = tug investment

T_7 = life period of tug investment

X_8 = berth investments

T_8 = life period of berth investment

X_9 = Gantry crane investment

T_9 = life period of the crane investment

X_{10} = land allocation investment for open storage paved area

T_{10} = life period of the open storage investment

X_{11} = land transportation investment (unit trains)

T_{11} = life period of train investments

X_{12} = storage warehouse investment

T_{12} = life period of the investment

X_{13} = transit warehouse investment

T_{13} = life period of warehouse investment

X_{14} = dredging investment

T_{14} = life period of dredging investment

X_{15} = signal system investment

T_{15} = life period of signal system investment

X_{16} = handling equipment investment (fork lifts)

T_{16} = life period of lifters

X_{17} = yard transfer equipment

T_{17} = life period of transfer equipment

X_{18} = floating crane investment

T_{18} = life period of floating crane investment

X_{19} = number of labor gangs

X_{20} = number of supervisory staff

X_{21} = average unloading service time for ship

All of the above variables may not be relevant in a specific port situation. Variables which are not relevant may be ignored.

A discussion of linear programming theory is a prerequisite in evaluating the applicability of the above technique to port performance evaluation. Geometrically linear programming relationships are defined by straight lines in two dimensions, planes in three dimensions and by hyperplane in higher dimensions. These relationships are in the form: (23)

$$A_1X_1 + A_2X_2 + A_3X_3 + \ldots\ldots A_jX_j \leq b$$

where A_j's and b are known co-efficients and X_j's are unknown variables.

In general linear programming models consist of simultaneous linear equations which specific conditions of the problem and linear functions which define the objective of the problem. The general setting of a linear programming model is as follows: (24)

Maximize

$$Z = \sum_{j=1}^{n} C_jX_j$$

Subject to:

$$\sum_{j=1}^{n} A_{ij}X_j \leq bi$$

$$X_j \geq 0$$

where $i = 1, 2, \ldots\ldots, M$ and

$j = 1, 2, \ldots\ldots n$

This form of the equation was used to determine optimum investment strategies for Lagos Port.

To minimize Z, multiply C_j's by -1. Note that C_j's, A_{ij}'s and b_i's are inputs. The computer adds slack and artificial variables when a linear programming package is utilized.

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CHAPTER IV

FIELD STUDIES PROCEDURE

4.1 Introduction

In the study of general cargo ports, data collection is usually a costly exercise because of the number of logistical subsystems involved and the disaggregate nature of cargo traffic through the port. The data required for port studies can come from either primary data or historical data. Primary data is ideal but direct measurements and recording require a large number of trained staff, extensive equipment (i.e. boats for harbor and queue reconiassance, automatic recorders, etc.) and substantial budget. In ports with significant seasonal demand variations the duration of primary data collection could be as long as twelve months. Hence labor and other costs involved in primary data collection in a general cargo port can be very high.

In this study historical data will be utilized in combination with extensive surveillance of the entire port complex. The reasons for employing historical data are summarized below:

- The budget for this research is limited and cannot meet the high cost of primary data collection.
- In the shipping industry in West Africa, ship and cargo traffic tend to follow a historical pattern due to the fact that the Conference lines have an established route schedule.
- The port of Lagos has an organized department of port statistics with statistical assistants attached to different port subsystems. Hence historical data published in the daily records are considered reliable.

However there are major disadvantages in utilizing historical or secondary data: the existing recording format may not be as comprehensive as the planner may desire, or the logistical flow sequence of ship and cargo may not be arranged in correct order. The author relied greatly on discussions, tours and boat surveillance for an evaluation of the validity of some of the historical data collected in Lagos port. Physical reconaissance also enabled the researcher to make rational engineering judgments of the problem.

In conclusion, primary data collection is ideal given a large budget and adequate time frame. On the other hand, an accurately recorded and reconciled historical data can be used for analysis of general cargo port with a high confidence level. In the author's opinion the results achieved by using accurate historical data will not be significantly different from a similar analysis using primary data.

4.2 Design of the Data Collection Forms

The development of detailed collection forms is a prerequisite for an in depth analysis. Data collection forms should be tailored to accommodate information concerning the variables discussed in chapter 3. The time ships and cargo spend at different port subsystems and other service variables necessary for logistical coordination need to be recorded. It is important that data forms should be designed to recognize the sequence of events which occur as ship and cargo move through the port system.

Tables (4-1) through (4-7) illustrate the data forms developed and used in this study. Tables (4-1) through (4-6) are aimed at identifying ship and cargo delay at different port subsystems while table (4-7) yields the capital and operating costs of specific port investments.

4.3 Port Morphology

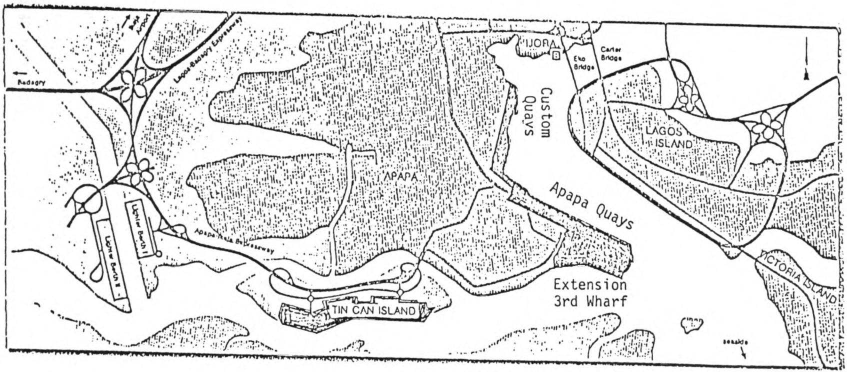
Lagos port complex has a unique geographical advantage. As shown in the location map, it lies on the lake 2.5 nautical miles from the Atlantic shore lines. This means that it is sheltered from high Atlantic waves. Additional protection is achieved by three man-made moles. These moles act as breakwaters (1) and have been effective in the protection of the harbor. The major problem with the moles is rapid settlement. The cost of restoration and maintenance has been a burden to the National port authority. On the average the depth of water in the harbor is 9.14 meters which can safely buoy large ships and ocean tankers.

Figure (4.3-1) illustrates the geographical location of Lagos port. The quays cluster around Apapa which is a mainland suburb of Lagos Island. In administrative terms these quays have been organized as three distinct ports: (2)

· Apapa port		23 berths
· 3rd Wharf Extension port		6 berths
· Tin Can Island port		10 berths
	Total	39

From the point of view of traffic and logistics these 'ports' are indeed one complex port system, because the controller of Harbors directs ship movements in and out of any of the above ports, and

Figure (4.3-1). LOCATION MAP



these ports service ships from the same queue based on arrival time and established cargo and ship priorities. The Lagos port complex is well connected with other modal systems like the railway network, Inland waterways and the highway network (see figure 4.3-1).

Pilotage: The Nigerian Pilotage Regulations Act of 1961 requires all ships exceeding 10.16 tons (gross) to be piloted in and out of Lagos harbor by a pilot licensed in the pilotage district of Lagos. The Nigerian Port Authority has a pool of full time pilots to service foreign ships. These pilotage regulations are in line with international practice in other major world ports. The overall objective is to ensure that collision between incoming, out-going and ships making internal movements are avoided. Historical records indicate that no fatal collisions have been experienced in the port of Lagos over the last five years. (3)

Towage: The authority owns and operates five main tug boats for towage of ships. Note that both the pilotage and towage services are operated for 24 hours a day to minimize ship costs at the port.

Physical Infrastructures

The Apapa quay is the largest quay in Nigeria with an area of 100.36 (4) hectares. The quay has a length of 2,393 m with a capacity of 23 ships at the same time. The average depth of water measured from the apron is 9.14 meters. Berth number 14 is the only container berth at the Apapa port. This berth measures 220 meters and is equipped with a 25.40 ton Gantry crane, mobile cranes and trailers. The addition of berth 14 in 1968 opened the port of Lagos to containerized shipping.

Apapa port handled 400,000 tons in 1977 as against 150,000 tons in 1974. These figures represent a growth of 166.6% (5) over this three year period.

The Third Wharf Extension in Apapa was opened in 1977 to reduce a high berth occupancy rate of 96.5%. This facility has 1,500 meters of open storage space. Three transit sheds and 4 warehouses were constructed to handle the increased cargo flow. A total of six berths were added along Porto Novo Creek (see map). In addition a container stacking terminal covering 103,000 m^2 was established at Lily Pond which has rail and road connections. (6)

On October 14, 1977 the Nigerian Port Authority formally opened the Tin Can Island port. This is an ultra-modern port with 10 berths of 250 m length. These berths are well equipped with 10 Gantry cranes and wide 40 meter aprons to facilitate direct loading and container handling. Covered storage areas include five transit sheds and three warehouses each of 40 m clear span and 175 meters long. (7) The port represents a capital investment of ₦ 200 million and covers and area of 595,000 (8) m^2 along Tin Can Island Creek. The fact that this port has its own electric power station and water supply station makes it unique in Lagos where city utility plants are not very reliable.

The Lagos port complex also includes the custom quay which is located on Lagos Island. This quay has an area of 5.05 hectare with a length of 376 meters along the waterfront. (9) This length is sufficient for mooring three general cargo ships.

4.4 Computation of Annual Investment for Various Logistical Subsystems

Determining the investment cost for general cargo port can be difficult due to the variety of equipment and facilities involved.

Table (4.4-1). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: TRANSIT SHEDS

Location of Facility	Available Storage Space m^2	Capital Cost per m^2	Capital Cost ₦	Service Life	Annual Capital Investment	Annual Variable Cost	Total Annual Cost
Apapa port	81,400	181.00	14,729,300	20 yrs.	736,500	2,945,800	3,682,300
Custom Quays	19,500	181.00	3,531,800	20 yrs.	176,600	706,400	883,000
Tin Can port	35,000	226.00	7,918,800	20 yrs.	395,900	1,583,700	1,979,600
Apapa 3rd Wharf Extension	28,000	226.00	6,335,000	20 yrs.	316,700	1,267,000	1,583,700

Annual Grand Total = ₦ 8,128,600
= $12,355,472

Allowing an Interest of 10%,
Present worth of Investment = $13,591,019

Table (4.4-2). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: WAREHOUSES

Location of facility	Available Storage Space m^2	Capital Cost per m^2	Capital Cost ₦	Service Life	Annual Capital Investment	Annual Variable Cost	Total Annual Cost
Apapa port	44,500	181.00	8,058,000	20 yrs.	402,900	805,800	1,208,700
Custom Quays	18,000	181.00	3,252,400	20 yrs.	162,600	325,200	487,800
Tin Can Island port	21,000	226.00	4,746,000	20 yrs.	237,300	711,900	949,200
3rd Wharf Extension	15,000	226.00	3,390,000	20 yrs.	169,500	339,000	508,500

Annual Grand Total = ₦ 3,154,200.00
= $ 4,794,384.00

Allowing an Interest of 10%
Present Worth of Investment = $5,273,822.00

Table (4.4-3). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: DREDGING

Item Description	Capital Cost ₦	Service life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost
Purchase of Dredger "Sea Lion"	6.7	20	335,000	670,000	1,005,000
2 Pilot cutters	1.5	20	75,000	150,000	225,000
2 Harbor crafts					
Dredging of the Approach Channel and Tin Can port turning basin	20,345,300	20	1,017,700	203,500	1,221,200
$19,700,000m^3$					

Annual Grand Total ₦ = 2,41,200

$ = 3,725,824

Allowing an Interest of 10%
Present Worth of Investment = $4,098,406

Table (4.4-4). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: PAVED OPEN STORAGE SPACE

Location of facility	Available Storage Space m^2	Capital Cost per m^2	Capital Cost ₦	Service Life	Annual Capital Investment	Annual Variable Cost	Total Annual Cost
Apapa port	702,500	41.3	29,014,100	50 yrs.	580,300	145,100	725,400
Customs Quay	50,500	41.3	2,085,700	50 yrs.	41,700	104,300	146,000
Tin Can Island port	595,000	51.7	30,761,500	50 yrs.	615,200	1,538,100	2,153,300
3rd Wharf Extension	330,000	51.7	17,061,000	50 yrs.	341,200	853,100	1,194,300

Annual Grand Total = ₦ 4,219,000.00
= $ 6,412,880.00

Allowing Interest of 10%
Present Worth of Investment = $7,054,168

Table (4.4-5). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: BERTHS

Location of facility	Quay Length	Cost per meter ₦	Capital Cost ₦	Service Life	Annual Capital	Variable Cost ₦	Total Annual Cost ₦
Apapa port	2,393	21,562.7	51,599,600	50 yrs.	1,031,992	516,000	1,548,000
Custom Quays	376	2,156.3	810,800.3	50 yrs.	16,300	81,100	97,300
3rd Wharf Extension Apapa	1,500	27,000	40,430,100	50 yrs.	808,700	202,200	1,010,800
Tin Can Island port	2,500	27,000	67,383,500	50 yrs.	1,347,700		1,684,600

Annual Grand Total = ₦ 4,340,700.00
= $ 6,597,864.00

Allowing an Interest of 10%
Present Worth of Investment = $7,267,650

Table (4.4-7). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: CARGO HANDLING PLANT AND EQUIPMENT

Item No.	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
1	Quay Cranes							
	2½ tonnes	1	68,000		10	6,800	4,500	10,200
	3½ tonnes	33	86,000	4,988,000		498,800	249,400	748,200
	5 tonnes	1	100,000	500,000	10	50,000	25,000	75,000
	6 tonnes	16	124,000	1,984,000	10	198,400	99,200	297,600
	10 tonnes	6	130,000	780,000	10	78,000	39,000	117,000
2	Floating Cranes							
	50 tonnes	1	800,000	800,000	10	80,000	40,000	120,000
	100 tonnes	1	1,500,000	1,600,000	10	160,000	80,000	240,000
3	Mobile Cranes							
	.8 tonnes	22	200,000	4,400,000	10	440,000	220,000	660,000
	.10 tonnes	44	124,000	3,348,000	10	334,800	167,400	502,200
	.18 tonnes	4	156,000	624,000	10	62,400	31,200	93,500
	.25-.30 tonnes	37	270,000	9,990,000	10	999,000	499,500	1,498,500
	50 tonnes	4	593,750	2,255,000	10	225,500	112,000	338,300
							Total	4,700,500

Table (4.4-7) Continued

Brought forward 4,700,500

Item No.	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
4	Forklifts							
	2½-3 tonnes	91	18,000	1,638,000	10	163,800	81,900	245,700
	3 tonnes	142	18,487	2,625,154	10	262,515	131,258	393,773
	4 tonnes	74	22,021	1,629,554	10	162,955	81,496	244,450
	Forklift trucks	100	41,145	4,114,500	10	411,450	205,725	617,175
5	Tractors	93	34,000	3,162,000	10	316,200	158,100	474,300
6	Caterpillar	40	33,890	1,355,600	10	135,560	67,780	203,340
7	Freight lifters							
	13 tonnes	4	33,831	91,324	10	9,132	4,568	13,700
	22 tonnes	4	56,000	224,000	10	22,400	11,200	33,600
	25-35 tonnes	6	137,000	822,000	10	82,200	41,100	123,300
8	Conveyors							
	Mobile	13	63,332	823,316	10	82,312	41,156	123,468
	Fixed	3	90,970	272,910	10	27,291	13,645	40,936
							Total	2,513,772

Table (4.4-7). Continued

Brought forward 7,214,272

Item	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
9	Trailers	188	120,000	225,600,000	10	2,256,000	1,128,000	3,384,000
10	Bag stackers	10	12,060	120,060	10	12,006	6,003	18,003
	Sack Elevators	4	16,050	64,200	10	6,420	3,210	9,630
	Dumping	8	18,250	146,000	10	14,600	7,300	21,900
	Grabs 5 tons							
	Belt loader	5	19,500	97,500	10	9,750	4,875	14,625
							Total =	3,448,158
							Sub Total =	10,662,500

Table (4.4-8).

Brought forward 10,662,500

Item No.	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
	Shunting							
11	Locomotives							
	.265 hp	4	800,000	3,200,000	10	320,000	160,000	480,000
	.300 hp	7	900,000	6,300,000	10	630,000	315,000	945,000
12	Railway							
	Wagons							
	Box Type cars	26	230,000	5,980,000	10	598,000	299,000	897,000
	Flat Type cars	29	200,000	5,800,000	10	580,000	290,000	870,000
13	Weighing Scales	48	5,500	264,000	10	26,400	13,200	39,600
14	Front end loaders	9	64,734.83	582,613	10	58,261	29,131	87,392
15	Freight lifters	13	22,831	296,803	10	29,680	14,840	44,520
16	Industrial tractors	25	6,448	161,200	10	16,120	8,060	24,180
17	Container skeletal	35	6,265	219,275	10	21,928	15,972	37,900

Total = \$ 3,425,592

Sub Total = \$ 14,088,092

Table (4.4-8). Continued

Brought forward = $14,088,092

Item No.	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
18	Highway trailers	29	136,420	3,956,180	10	395,518	147,759	543,277
19	Lorries	19	17,000	323,000	10	32,300	16,150	48,450
20	Cement Conveyors	8	10,000	80,000	10	8,000	4,000	12,000
							Total =	4,029,320
							Sub Total =	14,691,700

Table (4.4-9).

Brought forward 14,691,700

Item No.	Description	Units	Unit Cost ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
21	Buoys and Equipment	16	6,000	96,000	10	9,600	4,300	13,900
22	Shovel loaders	8	90,970	727,760	10	72,776	36,388	764,148
23	Komb Buses	35	4,393	153,781	10	15,378	7,722	23,100

Allowing 10% Interest
Present Worth of Investment = $17,042,080.00

Sub Total = 801,100.00

Sub Total US$ = 15,492,800.00

Table (4.4-10). LAGOS PORT COMPLEX ANNUAL INVESTMENT COST BREAKDOWN: TUGS AND BARGES

Item	Equipment Description	Units	Capital Cost per Unit ₦	Capital Cost ₦	Service Life years	Annual Capital Cost ₦	Annual Variable Cost ₦	Total Annual Cost ₦
1	·Twin Screw ·1,490 hp. 12 Knots Bollard tonnage 22.35	2	1,200,000	2,400,000	10	240,000	120,000	360,000
2	Twin Screw 1,280 hp 11.5 Knots	2	805,000	1,610,000	10	161,000	8,050	24,150
3	·Twin Screw ·1,490 hp 12 Knots Bollard tonnage 15.25	1	950,000	950,000	10	95,000	47,500	142,500
4	Harbor Tugs T6	13	407,933	5,303,129	10	530,313	265,189	795,500
5	Barges	34	115,000	3,910,000	10	391,000	195,500	586,500
6	Pontoons	23	225,000	5,175,000	10	517,500	258,750	6,951,100

Allowing 10% Interest — Total ₦ = 8,859,950

Present Worth of Investment = $14,813,800.00 — Total US$ = 13,467,100

This problem is even more acute in developing countries where investment data and records are not well maintained. In this study the capital cost of storage facilities was based on a 'storage area' criteria (i.e. cost per m^2, see table 4.4-1). The annual capital investment for each piece of equipment or facility was obtained by assuming a straight line depreciation.

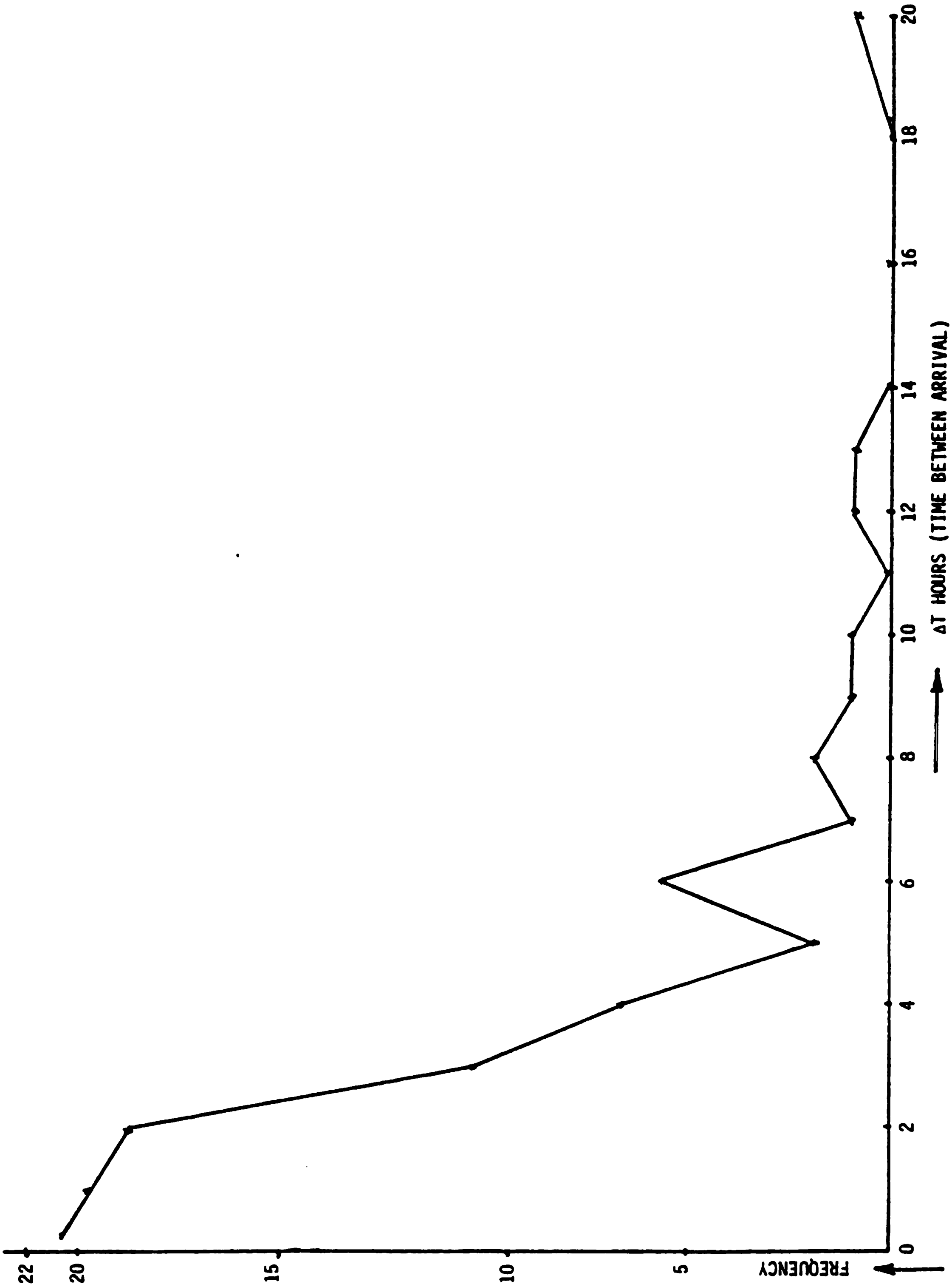
Tables 4.4-1 through table 4.4-10 further illustrate the methodology applied in determining the annual cost of various investments. The overall approach is to amortize the initial capital cost over the service life.

4.5 Ship Arrival and Service Distributions

In the design of ship traffic simulation model the arrival and service distribution should be defined for the following reasons:

- The cumulative arrival and service frequencies provide a statistical basis for prediction of future service patterns.
- Before random arrivals and service times can be generated by the computer the arrival and service distribution must be defined by a known distribution.
- The theoretical distributions which fit the arrival and service data provide a basis for the determination of the probability of the number of such events which occur within a unit time interval.
- In single or multiple server queues the probability of failure can be calculated when arrival and service distributions are known.

Figure (4.5-1). SHIP ARRIVAL DISTRIBUTION



Hence the definition of arrival and service distribution is a prerequisite for the design of a simulation or an analytic model.

The initial step in the fitting of any distribution to traffic data set is to assume a know distribution (i.e. Poisson, Binomial, negative Binomial, negative exponential, Pearson type III, Erlang). For this study a Poisson arrival rate was assumed while service rates was assumed to be negative exponential. The observed distribution is then analyzed to determine whether the postulated distribution is the true population. The Chi-square test is widely accepted as an important index of the goodness of fit of observed and theoretical frequencies of a data set. (10)

Chi-square technique is summarized by the equation:

$$X^2 = \sum (f-F)^2/F$$

where f = observed frequency

F = theoretical frequency

(f-F) = deviation of any cell.

Finally the Chi-square value computed is compared with values obtained in Chi-square tables to determine the probability that such values occur by chance.

Figure (4.5-1) illustrates the ship arrival data frequencies. using a time interval of one hour.

In table (4.5-2) the null hypothesis postulates that arrival distribution is Poisson, i.e. $P(x) = \frac{e^{-m} \mu^x}{x!}$ . . . . (11)

Where x indicate random traffic events.

μ = mean number of occurrences of these events.

Table (4.5-1). ARRIVAL DISTRIBUTION
(Inter Arrival Times)

Serial No	Name of Ship	Date	Time of Arrival	Arrival	Gap (hrs)	Remarks
1	George Armfield	1-7-78	0015	1	0	
2	East Wind	1-7-78	0615	1	6	
3	Joselin	1-7-78	0630	1	.25	
4	YATSENYAVI	1-7-78	1225	1	5.92	
5	PLAYA MAS	1-7-78	1600	1	3.28	
6	NORDRAP	1-7-78	1615	1	.25	
7	PLAYA BLAMCA	1-7-78	1830	1	2.25	
8	MOURA	1-7-78	1835	1	.08	
9	VASTIRAM	1-7-78	1930	1	.92	
10	STOIK SUND	1-7-78	2255	1	3.42	
11	ANNA WESCH	1-7-78	2345	1	.83	
12	FELIPES	2-7-78	0800	1	8.25	
13	MEVENBURG	2-7-78	0910	1	1.17	
14	GREAT MAURICE	2-7-78	1050	1	1.67	
15	AGAPPI (SWLA)	2-7-78	1400	1	3.17	
16	MESSIMIAKI	2-7-78	1730	1	3.5	
17	BABOUNIS COSTAS	2-7-78	2200	1	4.5	
18	FRIO DOLPHIN	3-7-78	0500	1	7.0	
19	TINITO CASTRO	3-7-78	0700	1	2.0	
20	PIRAN	3-7-78	1245	1	5.75	
21	LIDNIGER JADE	3-7-78	1345	1	1.0	
22	BRITISH WILLOW	3-7-78	1615	1	2.30	
23	DANAFRIO	3-7-78	1910	1	2.88	

Table (4.5-1). Continued

Serial No.	Name of Ship	Date	Time of Arrival	Arrival	Gap (hrs)	Remarks
24	Jolly Azurro	4-7-78	0400	1	8.17	
25	SIMONA	4-7-78	1000	1	6.0	
26	DOLLIARI	4-7-78	1400	1	1.0	
27	BRITISH TENT	4-7-78	1405	1	.08	
28	ESPRESS SARDEONA	5-7-78	0810	1	18.08	
29	BLUE AKEISHI	5-7-78	1035	1	2.42	
30	MATADI PALM	5-7-78	1200	1	1.42	
31	PETRELO	5-7-78	1445	1	2.75	
32	ESPRESSO SICILIA	5-7-78	1710	1	2.58	
33	THOMAS WEHR	5-7-78	1800	1	1.83	
34	WEST	5-7-78	1810	1	.17	
35	THUMTANKI	5-7-78	20,00	1	1.83	
36	APAPA PALM	6-7-78	0830	1	12.5	
37	BOREA	6-7-78	1200	1	3.4	
38	ORMOS	6-7-78	1600	1	4	
39	STEFANIA	6-7-78	1830	1	2.5	
40	ENA SIF	7-7-78	0625	1	11.5	
41	FRISIAN TRADER	7-7-78	0800	1	1.75	
42	RHOMBUS	7-7-78	0900	1	1	
43	NELKAR	7-7-78	1000	1	1	
44	DORT SKOU	7-7-78	1100	1	1	
45	STINNES ZEPHIR	7-7-78	1436	1	1.6	

Table (4.5-1). Continued

Serial No.	Name of Ship	Date	Time of Arrival	Arrival	Gap (hrs)	Remarks
46	ATALANTI	7-7-78	1605	1	1.52	
47	PEP SPICA	7-7-78	1848	1	2.95	
48	JANNE FREM	7-7-78	20,00	1	1.8	
49	LEILA BECH	8-7-78	0600	1	10	
50	METTE BRAVO	8-7-78	0715	1	1.25	
51	SOL NEPTUNE	8-7-78	0750	1	.75	
52	TINE BECH	8-7-78	1030	1	2.67	
53	PANDA STAR	8-7-78	1155	1	1.42	
54	PAOLA MONTARI	8-7-78	1220	1	1.27	
55	CLAUDIA MARIA	8-7-78	1336	1	5.67	
56	ALRAZAK	8-7-78	1910	1		
57	ALBERINO	9-7-78	0400	1	7.83	
58	YUE FLOWER	9-7-78	0545	1	1.75	
59	INLAND	9-7-78	0600	1	.25	
60	FREEZER FINN	9-7-78	0730	1	1.5	
61	FLORA 'C'	9-7-78	0845	1	1.25	
62	FRISIAN STAR	9-7-78	1145	1	3.0	
63	BRITISH LOYALTY	9-7-78	1315	1	1.5	
64	BRITISH TRENT	9-7-78	1400	1	0.75	
65	PARTULA	9-7-78	1416	1	.27	
66	ODETTE	9-7-78	1630	1	2.23	
67	SIMOMA	9-7-78	1900	1	2.5	

Table (4.5-1). Continued

Serial No.	Name of Ship	Date	Time of Arrival	Arrival	Gap (hrs)	Remarks
68	ALCARA	10-7-78	0030	1	5.5	
69	AVRA	10-7-78	0230	1	2.0	
70	DORA BALTEA	10-7-78	0345	1	1.25	
71	SASSANDRA	10-7-78	0930	1	5.75	
72	WOERMANN	10-7-78	1530	17	6.0	
73	LIBRA	10-7-78	1530	15	0	
74	EXPRESSO PIEMONTE	10-7-78	1630	1	1.0	NB TWO arrivals
75	LASS	10-7-78	20,00	1	3.5	

m = mean of the Poisson distribution which is also equal to the variance.

As shown in figure (4.5-2) ship service times were also classified into frequencies. In this case the null hypothesis postulates that service times follow a negative exponential distribution curve. In table (4.5-4) the Chi-square statistics was applied to the data set to determine the validity of the initial hypothesis.

The probability density function which corresponds to the negative exponential distribution is given below: (12)

$$f(t) = qe^{-qt}$$

where q is the mean flow rate in ships for unit time.

t = unit time interval.

It is important to note that the average service time (t) varies inversly with the flow rate.

In both tables (4.5-2) and (4.5-4) the basic assumption is that the probability of a headway between t_1 and t_2 is equal to the probability that the first event is between t_1 and t_2. (13)

$$P(t_1 < h < t_2) = e^{-qt_1} - e^{-qt_2}$$

As shown in figure (4.5-2) the mean arrival frequency of 2.89 hours per ship indicate that .35 ship arrives in the port of Lagos every hour. The probability of ship arrival times occurring within an interval of half an hour is .32. The cumulative frequency (f) between an interval of 1-2 hours indicates a good fit with the theoretical frequency (F). In general the results of the Chi-square test indicate that ship arrival distribution follows a Poisson distribution as postulated earlier.

Table (4.5-2). CHI SQUARE TEST APPLIED TO ARRIVAL DATA

Interval (hrs)	Observed frequency (f)	P(x)	Theoretical frequency F	f2/F	Remarks
0.1	21	.32	24	18.4	
1-2	20	.27	20	20.0	
2-3	11	.20	15	8.07	
3-4	7	.12	9	5.44	
4-5	2	.06	4.5	.89	
5-6	6	.02	1.5	24.0	
6-7	1	.00	.00		
7-8	2		.00		
8-9	1		.00		
9-10	1		.00		
10-11	0		.00		
11-12	1		.00		
12-13	1		.00		
13-14	0		.00		
14-15	0		.00		
15-16	0		.00		
16-17	0		.00		
17-18	0		.00		
18-19	1		.00		
	75			76.8	

Mean = 2.89 $\quad X^2 = \sum f^2/F - R$

Variance = 2.89 $\quad \therefore X^2 = 76.8 - 75 = 1.8$

Accept Poisson distribution. $\quad X^2_{0.05} = 9.488 > 1.8$

Hence arrival rate = $\frac{1}{\mu} = \frac{1}{2.89} = .35$ ship per hour

Table (4.5-3). SHIP SERVICE DISTRIBUTION

No	Name of Ship	Date Berthed	Time	Date Departed	Time	Service time hrs.	Tonnage Discharged	Tonnage Loaded
1								
2	YINKA	29-6-78	2000	29-7-78	1300	713	--	8,512
3	MANICA	26-6-78	1500	13-7-78	0845	354	593	3,498
4	EMBASSAGE	26-6-78	0830	5-7-78	815	216	--	612
5	IFEWARA	21-6-78	1015	5-7-78	1430	340	2,497	214
6	ARMADALE	26-6-78	1830	17-7-78	0630	492	1,979	--
7	ALPINA	21-6-78	1400	12-7-78	1815	508	3,716	--
8	BELLO	21-6-78	1730	15-7-78	0930	568	2,363	2,065
9	SKOU	22-6-78	1100	5-7-78	1530	317	1,734	--
10	STAR	28-6-78	1340	3-7-78	1120	118	1,120	116
11	SHERBRO	27-6-78	1930	7-7-78	1730	238	4,373	1,284
12	SANAGA	28-6-78	1100	1-7-78	1000	71	--	4
13	CYPRESS	29-6-78	1000	4-7-78	1100	121	2,915	502
14	NORD	23-6-78	1535	1-7-78	1150	188	100	--
15	ISA	30-6-78	1800	9-7-78	1100	209	1,643	--
16	MONDAY	1-7-78	1630	13-7-78	1500	287	1,444	10,016
17	CANTAL	1-7-78	1800	5-7-78	1430	93	5,399	994
18	ROYAN	4-7-78	1320	8-7-78	1730	100	4,106	164
19	NEGOLU	4-7-78	1000	11-7-78	1700	175	700	--

Table (4.5-3). Continued

No.	Name of Ship	Date Berthed	Time	Date Departed	Time	Service time hrs.	Tonnage Discharged	Tonnage Loaded
20	VERA	5-7-78	1800	24-7-78	1630	455	3,806	--
21	EAST WIND	5-7-78	1100	10-7-78	0930	199	1,943	100
22	GROOT SAND	5-7-78	1330	13-7-78	0800	187	1,130	--
23	IBERIA	5-7-78	1700	9-7-78	1800	90	3,622	714
24	JADE	5-7-78	1115	11-7-78	1700	150	1,401	--
25	RAMSES	3-7-78	1430	4-7-78	1130	20.6	555	--
26	TAMPA	7-7-78	1700	12-7-78	1320	116	902	--
27	Apapa Palm	7-7-78	1900	23-7-78	1630	382	8,053	1,354
28	MARIT	8-7-78	1930	11-7-78	1830	71	2,041	336
29	Armfield	9-7-78	1320	15-7-78	1830	149	1,500	--
30	MARU	10-7-78	1900	15-7-78	1600	117	1,429	--
31	Flora	10-7-78	1245	15-7-78	1125	119	674	--
32	Yue Flower	11-7-78	1930	14-7-78	1900	72	2,000	600
33	Visco Reefer	11-7-78	1800	16-7-78	0730	110	899	--
34	Hercules	11-7-78	1045	14-7-78	1530	77	459	--
35	Blue Akeisiji	12-7-78	1500	14-7-78	1700	50	1,060	--
36	City of Istanbul	13-7-78	1000	28-7-78	1800	368	--	2,195
37	Peisander	14-7-78	1930	28-7-78	0730	324	3,403	--
38	Sassandra	14-7-78	1930	16-7-78	0700	35	3,429	388

Table (4.5-3). Continued

No.	Name of Ship	Date Berthed	Time	Date Departed	Time	Service time hrs.	Tonnage Discharged	Tonnage Loaded
39	Solneptun	14-7-78	2030	18-7-78	1630	101	3,953	--
40	Sea Eagle	15-7-78	1230	16-7-78	1430	26	402	--
41	Glotas	15-7-78	1500	26-7-78	1045	260	3,260	--
42	Maersk	15-7-78	1900	17-7-78	1230	42	1,282	--
43	ENINEER	16-7-78	1750	26-7-78	1640	239	5,333	--
44	Admiral	16-7-68	1100	17-7-78	1145	24.5	2,139	--
45	Delta	17-7-78	1130	24-7-78	0900	165.7	4,312	408
46	STAR	17-7-78	1500	18-7-78	1300	22	1,296	--
47	Thomas	14-7-78	1930	16-7-78	0900	37.5	1,280	264
48	MARIE	18-7-78	1830	23-7-78	1700	118.5	3,540	240
49	SOPHIE	20-7-78	1050	25-7-78	0730	116.7	1,750	150
50	ILRI	23-7-78	2000	26-7-78	1720	69.3	4,347	490
51	Fare well	24-7-78	1130	27-7-78	1000	70.5	3,536	--
52	ANOLIS	29-7-78	1510	30-7-78	1410	23	1,000	--
53	A. Bello	29-7-78	1530	14-8-78	0930	378	--	4,592
54	MAX	30-7-78	1630	10-8-79	1530	263	--	5,306
55	TATALSTAN	26-7-78	1350	2-8-78	0810	162	96	--
56	BOOKA	24-7-78	1410	9-8-78	1450	385	3,887	--
57	SKOY	12-7-78	2000	5-8-78	1815	574	1,342	--

Table (4.5-3). Continued

No.	Name of Ship	Date Berthed	Time	Date Departed	Time	Service Time hrs.	Tonnage Discharged	Tonnage Loaded
58	SLOWMAN	24-7-78	1830	12-8-78	0700	445	4,654	--
59	TEXAS	28-7-78	0900	3-8-78	1230	148	564	570
60	BRITANNIC	27-7-78	1700	7-8-78	0750	231	6,999	--
61	HSIUNG	27-7-78	2000	10-8-78	1545	332	8,145	--
62	SHONGA	23-7-78	1830	2-8-78	0830	230	9	515
63	MARIA	31-7-78	1430	4-8-78	1700	99	4,303	773
64	ANUBIS	29-7-78	1330	6-8-78	1200	191	857	--
65	NAJADE	1-8-78	0930	5-8-78	1100	98	3,805	80
66	NORTHWIND	1-8-78	1630	5-8-78	0830	88	2,203	126
67	POLYXENI	1-8-78	1930	17-8-78	1050	375	10,000	--
68	SKIPPER	2-8-78	1000	13-8-78	0700	261	2,300	--
69	HADEJIA	2-8-78	1030	19-8-78	0800	406	8,583	1,417
70	DANAFRIO	2-8-78	1000	5-8-78	1045	73	454	--
71	MEMBERSHIP	2-8-78	1930	6-8-78	0630	83	3,734	570
72	S. WIND	2-8-78	1450	22-8-78	1450	480	5,340	132
73	BORINGIA	4-8-78	1030	8-8-78	1230	98	4,683	1,080
74	KADUNA	4-8-78	1900	8-8-78	0700	84	3,029	484
75	AJAX	4-8-78	1900	11-8-78	1030	160	1,227	--
76	West Wind	5-8-78	1100	8-8-78	0745	93	1,472	50

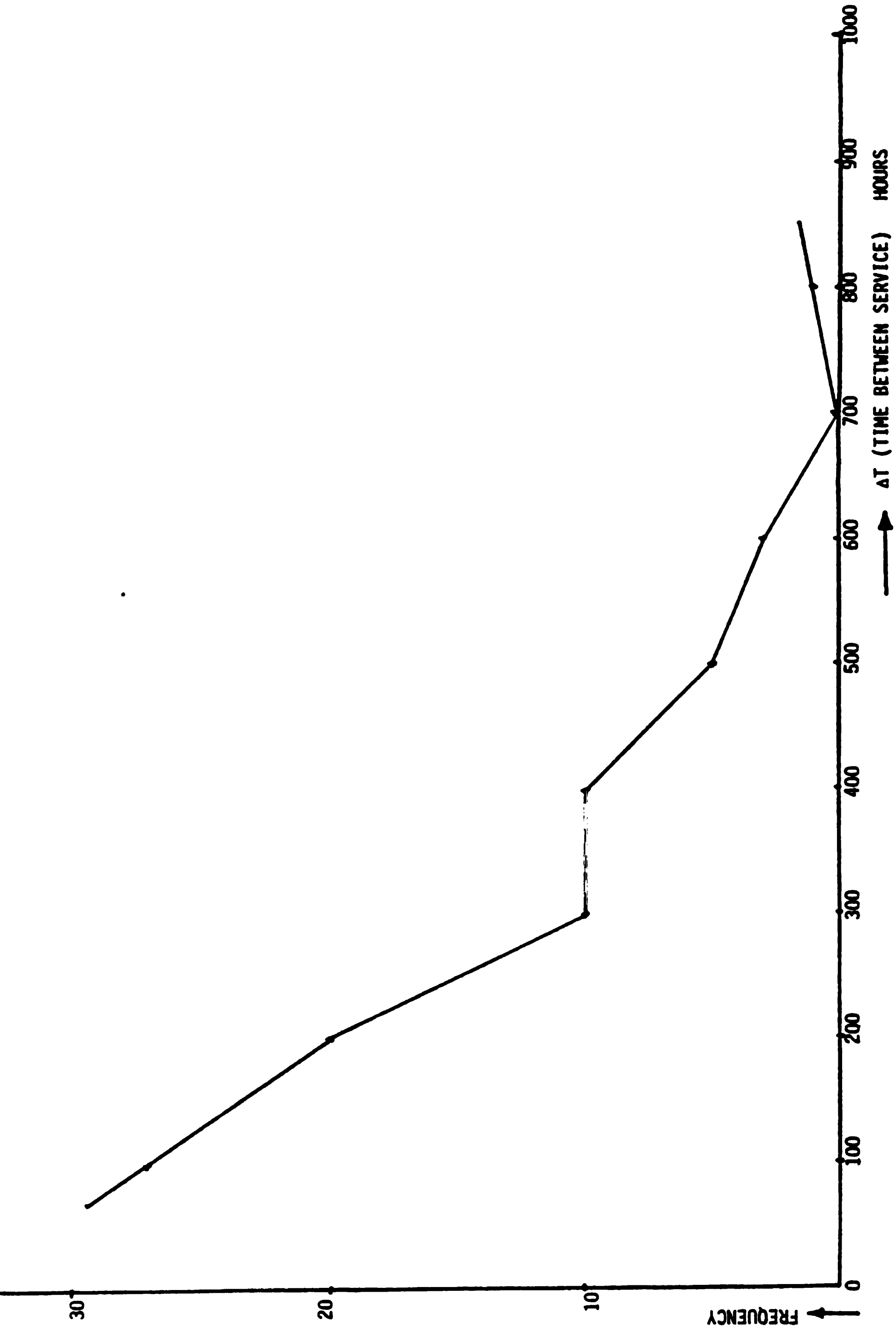


Figure (5-2). SHIP SERVICE DISTRIBUTION

Table (4.5-4). CHI SQUARE TEST APPLIED TO SHIP SERVICE TIME AT BERTHS

Interval (hrs)	Observed frequency (f)	P(x)	Theoretical frequency (F)	f^2/F	Remarks
0-100	26	.39	29	23.3	
100-200	20	.24	18	22.22	
200-300	10	.15	12	8.33	
300-400	10	.08	6	16.67	
400-500	5	.06	4.5	5.56	
500-600	3	.03	2.5	3.6	
600-700	0	.02	1.5	0	
700-800	1	.02	1.5	.67	
	75		75	80.35	

Mean = 199.00 (hrs).

= 8.31 days.

$$\chi^2_{0.05} = \sum f^2/F - R$$

$$\chi^2_{0.05} = 80.35 - 75$$

$$= 5.35$$

From Chi Square table $\chi^2_{0.05} = 12.592 > 5.35$

Hence negative exponential distribution is accepted, i.e. null hypothesis is correct.

Service rate = $\frac{1}{\mu} = \frac{1}{199} = .005$ ship per hour per berth.

$\therefore$ Total Service rate = $\mu K = (.005)(39) = .195$ ship per hour

where K = total number of berths.

Table (4.5-4) shows that mean service time for ships in the port is 199 hours. This means that .005 ship is served every hour per berth. When the entire 39 berths are considered the average service rate is .195 ship per hour. Hence the berthing capacity is far below the arrival rate of .35 ship per hour. This reason explains the infinite nature of the ship queue in the port of Lagos. In addition table (4.5-4) indicates that the probability of ship service times between 0-100 hours is .39 while between 100-200 hours the probability drops to .24. In general the service distribution fits a negative exponential curve as proposed by the null hypothesis.

4.6 Analysis of Cargo Delay

Analysis of cargo delay within the port subsystems is important for the following reasons:

- Cargo delay within transit warehouses provide the basis for determination of warehousing cost in ton hours.
- The rate of cargo flow through warehouses is a logistical criteria for determination of the size and number of warehouses required to accommodate a given daily tonnage.
- The type, volume and class of cargo moved by direct and indirect channels are the basis for determination of the level of improvements required in various port logistical subsystems (i.e. warehouses, rail cars, trucks and handling equipment).
- The distribution of cargo waiting time yields average time for determination of associated costs of handling, insurance and storage.

Cargo loaded or unloaded from general cargo ships moves through two major logistical channels.

· Direct (into trucks, rail cars)

· Indirect (into transit warehouse and open storage areas).

Data obtained from the Lagos port complex indicates that in 1978 cargo moved via direct intermodal transfer made up about 83% (14) of total tonnage handled while indirect cargo tonnage was 17%. These figures are significant as there is a long cargo waiting time (109 hours) for indirect cargo movements. These delays create a tremendous congestion problem in both the transit warehouses and the open storage areas.

<u>Estimation of Direct and Indirect Cargo Tonnage</u>:

		Million tonne
Total Annual Through Put (1978)	=	8.99
Total Liquid Cargo	=	2.43
Total Dry Cargo	=	<u>6.56</u>
Direct Cargo = .83 x 6.56		5.44
Indirect Cargo = .17 x 6.56		1.12

<u>Distribution of Cargo Waiting Time</u>: As illustrated in tables (4.7-2) through table (4.7-5) a sample of 56 units of cargo was examined. Note that only indirect cargos were analyzed because there was no waiting time associated with direct cargo. Both the weight and the total time spent by each unit of cargo was determined. Then the average time spent by one ton of cargo was calculated to determine the annual cumulative time spent by indirect cargo during the clearing and forwarding process:

Total Indirect Cargo tonnage (1978) = 1.12 Million tonnes

Average waiting time per unit = 109 hours

Cumulative Cargo waiting time for 1978 = 109 x 1.12 million ton-hours

= 122,090,000 ton-hours --(a)

Breakdown of Transit Inventory Cost: Inventory related cost can be summarized as follows (8)

Total Costs = Ct + Cs + Cc + Cin + Cob + Cord

where Ct = cost due to tax

Cs = cost due to storage

Cc = cost due to capital

Cin = cost due to insurance

Cob = cost due to obsolescence

Cord = cost due to order processing and handling.

In this study only items which constitute costs to the port will be considered. In addition the port of Lagos is a public port and is exempt from tax. Based on the data obtained from cargo supervisors and traffic officers the cost table below was prepared.

	$	¢
Ct per ton/hr =	--	--
Cs per ton/hr =	--	.25
Cc per ton/hr =	--	.25
Cin per ton/hr =	--	.50
Cob per ton/hr =	--	.25
Cord per ton/hr =	1	--

Total Transit Inventory cost per ton-hour = $2.25 -----(b)

The total cost of the annual cargo waiting time can be obtained by multiplying items (a) and (b).

i.e. $122,080,000 x 2.25

= $274,680,000 per year.

The above cargo delay analysis indicate that there is a great need to reduce the average cargo waiting time. The causes of this delay will be identified by the logistical operations survey.

Table (4.6-1). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth: Cargo Waiting Time Under Gantry Crane (hrs)	Storage Facilities (Warehouse and open spaces)		Time in Storage (hours)	Time in Internal Transfer Facilities (hrs.)	Weight (Tons)	Remarks--Trucks and Rail Departures.
		Date Received	Date Claimed				
1	--	11/1/78 1305	11/4/78 1230	71.4	--	.14	T = Truck
2	--	11/2/78 1450	11/5/78 1700	74.2	--	.6	T
3	--	11/3/78 1630	11/6/78 1240	116.2	--	.7	T
4	--	11/4/78 0930	11/7/78 0840	71.2	--	.8	T
5	--	11/5/78 0730	11/12/78 1350	174.3	--	.7	T
6	--	11/6/78 1030	11/8/78 1420	51.8	--	.5	T
7	--	11/7/78 0820	11/11/78 0730	101.8	--	.9	T
8	--	11/8/78 1200	11/12/78 1405	98	--	.4	T
9	--	11/9/78 1530	11/12/78 10,00	66.5	--	.2	T
10	--	11/10/78 0830	11/14/78 0700	94.5	--	.6	T

Table (4.6-2). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth	Storage Facilities (Warehouse and open spaces)		Time in Storage (hours)	Time in Internal Transfer Facilities (hrs)	Weight (Tons)	Remarks--Trucks and Rail Departures.
	Cargo Waiting Time Under Gantry Crane (hrs)	Date Received	Date Claimed				
11	--	11/11/78 1720	11/13/78 0930	40.2	--	.6	T
12	--	11/12/78 0740	11/14/78 1300	53.33	--	.2	T
13	--	11/13/78 0730	11/16/78 1130	76	--	.1	T
14	--	11/14/78 1500	11/16/78 1040	43.67	--	.5	T
15	--	11/15/78 1300	11/20/78 1105	118.1	--	.9	T
16	--	11/16/78 0950	11/26/78 1145	241.6	--	.65	T
17	--	11/17/78 1315	11/24/78 10,00	140.8	--	.7	T
18	--	11/18/78 0850	11/28/78 1705	248.3	--	.4	T
19	--	11/19/78 1620	11/25/78 0935	137.3	--	.8	T
20	--	11/20/78 0740	11/25/78 1040	123	--	.67	T

Table (4-6.3). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth: Cargo Waiting Time Under Gantry Crane (hrs)	Storage Facilities (Warehouse and open spaces: Date Received	Storage Facilities (Warehouse and open spaces: Date Claimed	Time in Storage (hours)	Time in Internal Transfer Facilities (hrs)	Weight (Tons)	Remarks--Trucks and Rail Departures.
21	--	11/21/78 1105	11/24/78 1230	73.4	--	.61	T
22	--	11/22/78 0830	11/25/78 1400	77.5	--	.83	T
23	--	11/23/78 0950	11/27/78 1120	97.5	--	.01	T
24	--	11/24/78 0800	11/29/78 1430	126.5	--	3.9	T
25	--	11/25/78 1200	11/28/78 10,00	70.	--	9.0	R
26	--	11/26/78 1130	11/29/78 0730	68	--	1.2	T
27	--	11/27/78 0825	11/29/78 0915	48.9	--	6.8	R
28	--	11/28/78 0750	11/30/78 1355	54.07	--	2.6	T
29	--	11/29/78 1405	12/2/78 1028	68.4	--	5.1	T
30	--	11/30/78 1715	12/5/78 0920	64.1	--	6.9	T

Table (4-6.4). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth: Cargo Waiting Time Under Gantry Crane (hrs)	Storage Facilities (Warehouse and open spaces): Date Received	Storage Facilities (Warehouse and open spaces): Date Claimed	Time in Storage (hours)	Time in Internal Transfer Facilities (hrs)	Weight (tons)	Remarks--Trucks and Rail Departures.
31	--	12/1/78 1430	12/5/78 1145	93.3	--	6.5	T
32	--	12/2/78 1200	12/5/78 1155	71.9	--	9.8	R
33	--	12/3/78 1036	12/6/78 0940	71.07	--	2.6	T
34	--	12/4/78 0730	12/6/78 1505	55.6	--	3.5	T
35	--	12/5/78 0830	12/8/78 1205	75.6	--	5.3	T
36	--	12/6/78 1320	12/8/78 1015	68.9	--	7.4	R
37	--	12/7/78 1130	12/10/78 0950	70	--	8.3	R
38	--	12/8/78 1025	12/11/78 1355	75.5	--	4.8	T
39	--	12/9/78 1700	12/11/78 1430	45.5	--	5.7	T
40	--	12/10/78 1130	12/14/78 0830	93	--	8.8	R

Table (4-6.5). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth: Cargo Waiting Time Under Gantry Cranes (hrs.)	Storage Facilities (Warehouse and open spaces): Date Received	Storage Facilities (Warehouse and open spaces): Date Claimed	Time in Storage (hours)	Time in Internal Transfer Facilities (hrs.)	Weight (Tons)	Remarks--Trucks and Rail Departures.
41	--	12/11/78 0900	12/15/78 1340	100.7	--	5.1	T
42	--	12/12/78 1205	12/14/78 1625	49.6	--	7.1	R
43	--	12/13/78 0730	12/17/78 1405	102.6	--	6.5	T
44	--	12/14/78 10,00	12/17/78 1320	75.33	--	8.2	R
45	--	12/15/78 1105	12/19/78 1640	101.6	--	1.1	T
46	--	12/16/78 0800	12/21/78 1020	122.3	--	9.9	R
47	--	12/17/78 1115	12/22/78 0920	118.1	--	1.2	T
48	--	12/18/78 1325	12/22/78 0750	90.4	--	8.7	R
49	--	12/19/78 1400	12/23/78 1240	94.7	--	6.3	T
50	--	12/20/78 1315	12/27/78 0920	164.1	--	2.1	T

Table (4.6-5). Continued

Item No.	Berth	Storage Facilities (Warehouses and open spaces)		Time in Storage (hours)	Time in Internal Transfer Facilities (hrs)	Weight (tons)	Remarks--Trucks and Rail Departures.
	Cargo Waiting Time Under Gantry Crane (hrs.)	Date Received	Date Claimed				
51	--	12/21/78 0715	12/29/78 1355	198.7	--	3.5	T
52	--	12/22/78 1600	1/3/79 1405	262.1	--	2.6	T
53	--	12/23/78 1150	1/3/79 1220	264.5	--	1.2	T
54	--	12/27/78 0915	1/5/79 1140	242.5	--	2.0	T
55	--	12/28/78 0750	1/5/79 1105	195.7	--	4.0	T
56	--	12/29/78 1200	1/10/79 1405	290.0	--	7.6	R

AVERAGE = 108.7   AVERAGE = 3.34

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CHAPTER V

SHIP QUEUING SIMULATION MODEL

5.1 Assumptions

The following assumptions were considered in developing the simulation model:

- A first come first serve queue discipline exists at the study port.
- All berths have the same service time (i.e. there is no significant variation in berth service time).
- There is no reneging or any distortion of the queue discipline.
- Any of the berths can service any class of ship entering the port.
- Ship arrivals into the port have a Poisson distribution
- Ship service time follow a negative exponential distribution.

In the first place, the port of Lagos has an established first come first serve queue discipline. However, when any cargo or ship is considered a priority class, floating cranes are employed in unloading the ship. This means that the established queue discipline is not distorted. The second assumption can be justified because all berths utilize the same number and type of cranes, fork lifts, and warehouses. These equipments are drawn from a common pool. In addition labor gangs assigned to each berth are the same. Thirdly the strict Harbor master's control policy and towage services prevent any reneging. Hence there is no distortion to the established queue discipline. As discussed in section 4.3, the minimum depth along the quayside is 9.14 meters while the maximum draught of ships calling in the port of Lagos is 8 meters. This means that any berth can provide adequate draught required to buoy any ship.

5.2 Logic Diagram and Model Variables

The logic diagram is illustrated by figure 5.2-1. The program is written in a simple fortran language using the University of Minnesota fortran language compiler. The model starts with initialization of the model variables:

RSHIP - Ship arrival time

R Service - Ship service time

TRSHIP - Total ship arrival time

TR Serv - Total ship service time

ATRS - Average ship arrival time

AR Serv - Average ship berthing rate

In the initialization process it is important to specify that arrival rates and service rates have real value. This specification eliminates negative arrivals and service which are absurd in this situation. Secondly, the number of ships are specified as integers for the same reason as above. R Ship and R Serv are time dimensions during which ship arrivals and ship service events occur. Finally the initialization process indicates to the computer the number of observations required.

The next step in model building is to specify ship arrival and service rates. Ship arrival rates is the total arrivals at the study port in one hour. Also ship service rate is the total ship service offered by all the service berths (i.e. number of berths, average berthing time). Definition of ship arrival and service distribution is a major step in the simulation model. Integral transforms are powerful tools for simulating ship arrival and service distribution. With the input above the computer generates and prints ship arrival and service events (i.e. random numbers). Do loop 500 in the logic diagram is responsible for generating these random numbers. The Do loop 300 prints the array of the random numbers generated.

The next major step is to define the variables (TRSHIP, TR Serv, RSHIP, ATRS, AR Serv). These variables are defined with respect to a time axis. At this reference axis time is set at zero and all 39 berth facilites are regarded occupied by ships. Hence the time of arrival of the i^{th} ship = the i^{th} arrival plus the sum of the (i-1) arrival times. Ship service time is also measured in the same manner. The average ship berthing rate is set equal to TR Serv/P where P is the number of ships which have been serviced since time t_o.

The queue is defined by Do loop 465. A queue exists when TR Serv is less than TRSHIP. The logic is that the arriving ship cannot find a vacant berth and is forced to wait in the queue. When a vacancy occurs in the berths, the vehicle at the head of the queue moves to the vacant berth. The model updates the ship arrivals and service using the list of random numbers generated in do loop 500. Additional ships are added in the queue and the simulation continues until the specified ship number is reached.

A list of the computer cards and model format are shown in figure (5.2-2).

Figure (5.2-1). SIMULATION LOGIC DIAGRAM

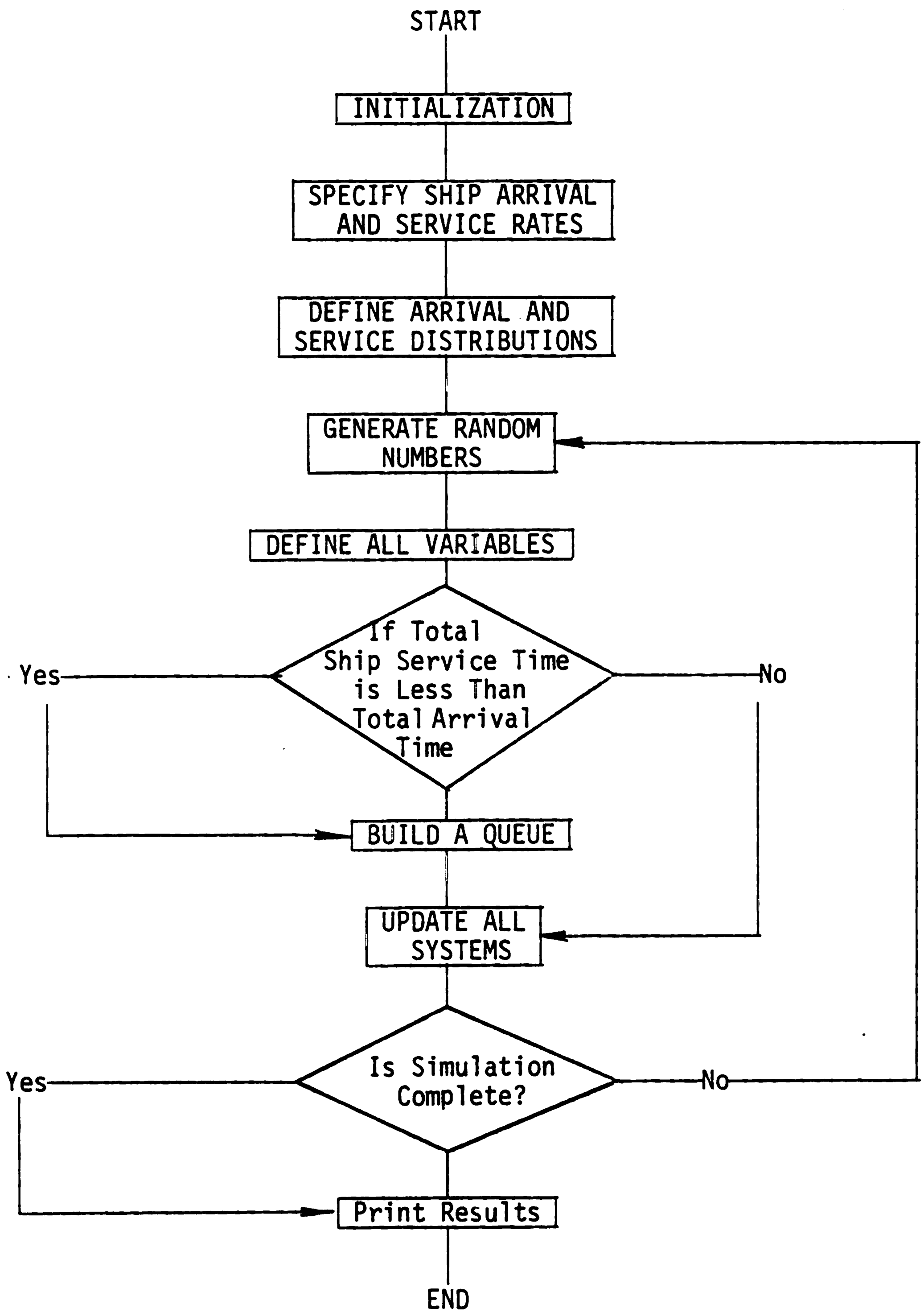

Figure (5.2-2). LAGOS PORT SIMULATION MODEL.

```
UNIVERSITY OF MINNESOTA FORTRAN COMPILER (VERSION 5.2 - 12/02/78) ON THE 6500 UNDER NOS/BE 1.4.0
ON  04/03/79 AT .22.21

                MNF,D,T.

  1.     000000B          PROGRAM SIM (INPUT=65,TAPE10=INPUT,OUTPUT=65,TAPE20=OUTPUT)
  2.     000325B          DIMENSION,RSHIP(500),RSERV(500),
                         *QUE(500),TRSHIP(500),TRSERV(500),
                         *ATRS(500),ATRSER(500)
  3.     000325B          REAL IPRATE
  4.     000325B          INTEGER P
  5.     000325B          BUG=0.0
  6.     007203B          IPRATE=.35
  7.     007204B          SERATE=.320
  8.     007206B          DO 500 I=1,500.1
  9.     007211B          Y=RANF(Y)
 10.     007212B          X=RANF(X)
 11.     007215B          RSHIP(I)=-ALOG(1-Y)/IPRATE
 12.     007232B          RSERV(I)=-ALOG(1-X)/SERATE
 13.     007246B          IF (BUG.EQ.-0.)WRITE(20,50)RSHIP(I),RSERV(I),I
 14.     007272B    50    FORMAT(F15.-7,5X,F1-,7,I8)
 15.     007272B    500   CONTINUE
 16.     007275B          DO 300 J=1,10.1
 17.     007300B          IF (BUG,EQ-0.)WRITE(20,200)RSHIP(J),RSERV(J),J
 18.     007324B    200   FORMAT(F15-7.5X,F10,7,I8)
 19.     007324B    300   CONTINUE
 20.     007327B          TRSHIP(1)=RSHIP(1)
 21.     007330B          TRSERV(1)=RSERV(1)
 22.     007331B          ATRSER(1)=TRSERV(1)
 23.     007332B          DO 400 P=2,500,1
 24.     007335B          TRSHIP(P)=RSHIP(P)+TRSHIP(P-1)
 25.     007345B          TRSERV(P)=RSERV(P)+TRSERV(P-1)
 26.     007356B          ATRSER(P)=TRSERV(P)/P
```

Figure (5.2-2). Continued

```
007362B   400    CONTINUE
007365B          DO 465,P=1,10.1
007370B          IF (BUG.EQ:0.0)WRITE(20,432)TRSHIP(P),TRSERV(P),ATRSER(P),P
007421B   432    FORMAT(3(F15,7),I10)
007421B   465    CONTINUE
007424B          DO 1200 K=1,500,1
007427B          DO 1100,J1=1,500,1
007432B          B=J1
007432B          IF(TRSERV(K).LT.TRSHIP(J1))GO TO 1150
007433B  1100    CONTINUE
007450B  1150    QUE(<)=B-K-1
007461   1120    CONTINUE
007466B          DO 600,L=1,200,1
007471B          IF(QUE(L).LT.0.0)QUE(L)=0.0
007503B          WRITE(20,501)TRSERV(L),TRSHIP(L),L,ATRSER(L),QUE(L)
007536B   501    FORMAT(F15.7,10X,F15.7,I10,10X,F15.7,10X,F15.7)
007536B   600    CONTINUE
007541B          END
```

5.3 Sensitivity of Total Ship Delay to Increase in Number of Berths

The simulation model was utilized to test the sensitivity of additional berths on ship delay. In this test the service time is held constant and equal for all berths. The program creates five new berths each iteration. This means that the port service rate SERATE is increased each time by 5μ (where μ = .005 ships/hr. = average berth service time). With each new service rate the port was simulated and new ship delay and queue lengths determined. The number of berths was constrained such that the utilization factor would be less than unity, i.e. (1)

$$\rho < 1$$

where $\rho = \lambda / X_8 \mu$

λ = ship arrival rate per hour

X_8 = number of berths

μ = average service rate

Table (5.3-1) summarizes the reduction in ship delay due to additional berths. The delay parameters in table (5.3-1) were obtained by considering the 100th ship arrival.

As shown in table (5.3-1) total ship delay is very sensitive to additional berths. The addition of 20 new berths reduced delay be 76% while the addition of 25 berths reduced delay by 87%. A diminishing return is observed with additions of 30, 35, and 40 new berths. It is also important to note that with additional berths the que length decreases. In figure (5.3-1) the queue waiting time associated with a corresponding number of berths was plotted. This curve provides a basis for evaluating whether the reduction in

Figure (5.3-1). SENSITIVITY OF QUE WAITING TIME TO INCREASE IN NUMBER OF BERTHS UNDER EXISTING SERVICE CONDITIONS (i.e. 1978 DEMAND).

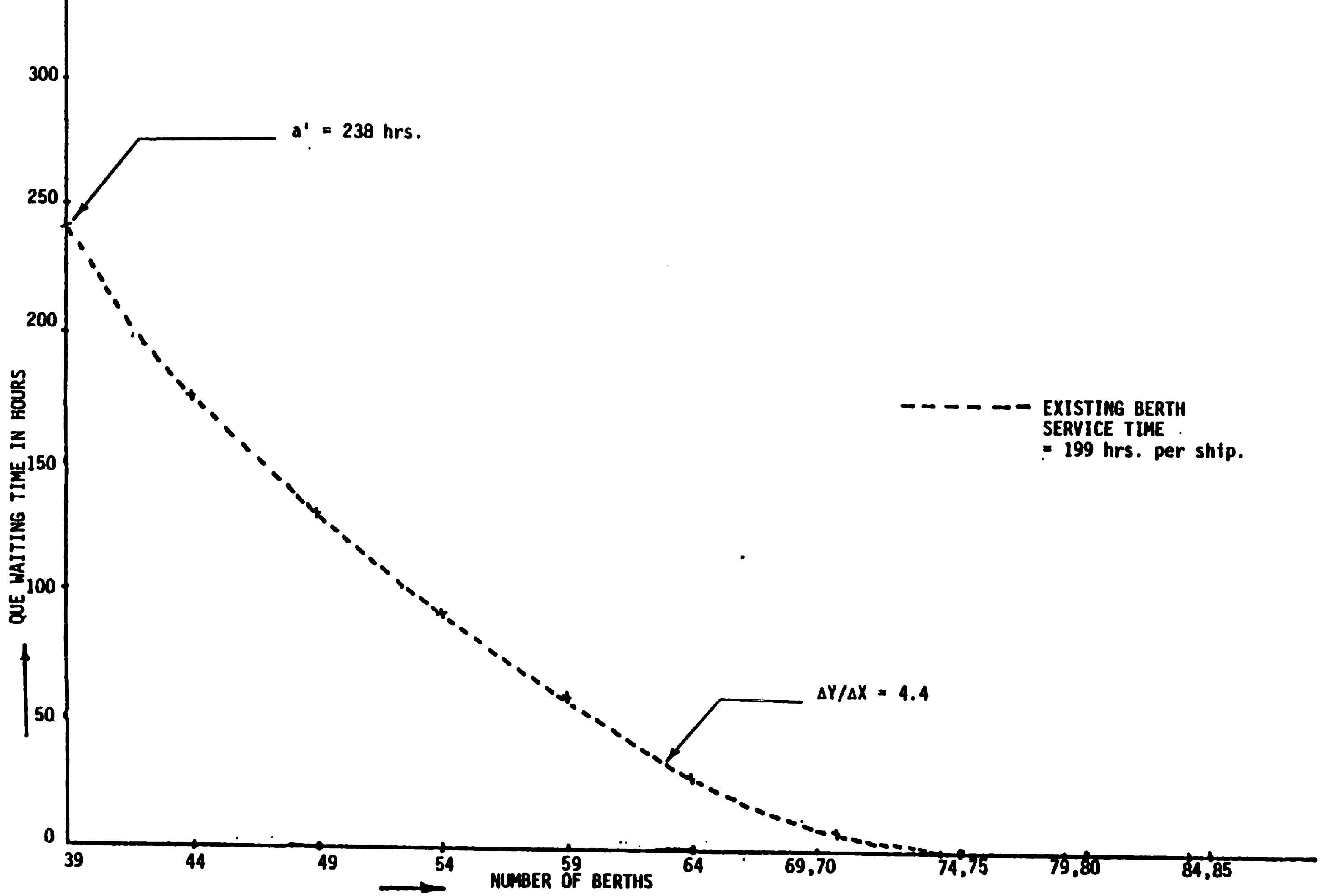

Table (5.3-1). SENSITIVITY OF DELAY TO INCREMENT IN NUMBER OF BERTHS

Number of Berths	Average Berthing Rate One ship every	Que Length (ships)	% Reduction	Waiting Time in Queue (hrs)	% Reduction	Total Delay in Port (hrs)
*39	5.29 hrs.	84	BASE	237	BASE	436
44	4.68 hrs.	72	14.3	171	28	370
49	4.20 hrs.	55	34.5	129	46	328
54	3.81 hrs.	39	53.6	90	62	289
59	3.49 hrs.	28	66.7	57	76	256
64	3.22 hrs.	13	84.5	30	87	229
69	2.98 hrs.	6	93.0	7	97	206
70	2.94 hrs.	3	96.0	3	99	202
80	2.50 hrs.	0	100.0	0	100	199
85	2.42 hrs.	0	100.0	0	100	199
90	2.29 hrs.	0	100.0	0	100	199

*39 is the existing number of berths in the study port.

·Berthing rate is not the service rate at berth but the rate at which service gaps occur. This corresponds to departure rate of ships from the port (when a queue exists).

delay due to an incremental increase in the number of berths is linear. The curve in figure (5.3-1) indicates that the slope of the curves within a given range of berths approximates a straight line. Hence a generalized equation can be developed to relate the queue waiting time (X_1) and number of berths (X_8), i.e.

$$X_1 \geq A_1 - A_2(X_8 - M)$$

where A_1 is the queue waiting time associated with M berths

A_2 is the slope of the curve

X_1 is the queue waiting time

X_8 is the number of berths required for a queue time of less than 3 hours

M = a specific number of berths.

Figure (5.3-1) indicates that when the number of berths is between 64 and 70 the slope of the curve is approximately 4.4. In the range of 49-54 and 54-59 berths the slope of the curve approximates to 7.8 and 6.6 respectively.

It is also observed that between 64 and 70 berths the queue waiting time is tolerable (ranging between 30 hours -- 2.85 hours). Hence the optimization constraint for the linear programming problem should be derived in this range, i.e.

$$X_1 \geq 30 - 4.4(X_8 - 64)$$

The simulation results illustrate the sensitivity of the queue waiting time and queue length to incremental increase in the number of berths. The addition of berths to the port of Lagos is one of several actions which could be taken to reduce delay and associated cost in the port of Lagos. Additional units of equipment, warehouses and labor gangs might reduce ship berthing time and subsequently queue time.

The major question is the cost effectiveness involved in any of the alternatives. The viable approach is to identify what combination of the above actions will reduce total delay to a tolerable level at the least cost. Hence a linear optimization program will be employed in chapter VI.

The sensitivity of queue waiting time to a reduction in berthing time is illustrated by the family of curves shown in figure (6-3). When berth service time is reduced by 20%, que waiting time drops by 38%. A reduction of berth service time by 40% yields 78% reduction in queue waiting time. Hence the family of curves in figure (6-3) provide the basis for setting alternative optimization constraints.

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CHAPTER VI

INVESTMENT OPTIMIZATION

The overall approach is to determine the optimum combination of port resources which will accommodate the specified thoroughput at the minimum annual cost. The following investment options will be considered:

- construction of additional units of berths
- construction of new warehouses
- acquisition of additional units of gantry cranes, fork lifts, yard transfer equipment, and floating cranes
- purchase of additional number of tugs for pilotage and towage services
- purchase of additional train cars and power units for improving cargo delivery
- acquisition of additional land for both anchorage facilities and open storage area
- investment in signal system and traffic control devices
- increase in the number of supervisory and clerical staff assigned to warehouses.

The emphasis is on optimization of the entire port system rather than any of the subsystems mentioned above. A linear programming model can be employed to determine the optimum combination of the above alternatives which will maximize total annual thoroughput at minimum total annual cost. Hence time and tonnage constraints are very important factors.

6.1 The Objective Function

For this program, the total annual cost of port operation and ownership was written as the objective function:

Minimize Z; where

$$Z = aX_1N + bX_3N + dX_4T_t' + eX_5(T_t'')$$
$$+ (X_6/T_6 + Cv_6) + (X_7/T_7 + Cv_7) + X_8/T_8 + Cv_8)$$
$$+ (X_9/T_9 + Cv_9) + (X_{10}/T_{10} + Cv_{10}) + (X_{11}/T_{11} + Cv_{11})$$
$$+ (X_{12}/T_{12} + Cv_{12}) + (X_{13}/T_{13} + Cv_{13}) + (X_{14}/T_{14} + Cv_{14})$$
$$+ (X_{15}/T_{15} + Cv_{15}) + (X_{16}/T_{16} + Cv_{16}) + (X_{17}/T_{17} + Cv_{17})$$
$$+ (X_{18}/T_{18} + Cv_{18}) + CvX_{19} + CvX_{20}$$

where X_i = capital cost of i^{th} investment

T_i = economic service life of the i^{th} investment

Cv_i = variable cost associated with i^{th} investment or labor

T_t' = % of total cargo tonnage which moves through transit warehouse

T_t'' = % of total cargo tonnage which moves through inner harbor facilities

a, b, d and e are cost coefficients defined in table (6.2).

N = total number of ships entering Lagos port in one year. N is not a variable for a specific year

T_t = thoroughput of cargo in one year (tonnes). T_t is not a variable for a specific year

The above equation can be simplified as shown below:

Minimize

$$Z = aX_1N + bX_3\ N + dX_4(T_t^{'}) + eX_5(T_t^{''})$$

$$+ C_{T_6}X_6 + C_{T_7}X_7 + C_{T_8}X_8 + C_{T_9}X_9$$

$$+ C_{T_{10}}X_{10} + C_{T_{11}}X_{11} + C_{T_{12}}X_{12} + C_{T_{13}}X_{13}$$

$$+ C_{T_{14}}X_{14} + C_{T_{15}}X_{15} + C_{T_{16}}X_{16} + C_{T_{17}}X_{17}$$

$$+ C_{T_{18}}X_{18} + C_{T_{19}}X_{19} + C_{T_{20}}X_{20}$$

where $C_{T_i} = (X_i/T_i + Cv_i)$ = Total annual cost per unit of investment or labor

6.2 Determination of Optimization Constraints

The data in table (6.1) was obtained from the work study department of the Lagos port. It provided the basis for estimating additional units of investment as a function of ship service delay. A number of equations were developed to express the reduction in delay as a function of increments in equipment and storage facilities. Using the assumption that these relationships are linear, the following equations are generated:

From Column 1:

$$X_9^{'} + X_{19}^{'} + 2X_{16}^{'} + X_{13}^{'} + X_{10}^{'} + X_{11}^{'} = 12 \text{ days} \qquad \text{--Equation (1)}$$

From Column 2:

$$2X_9^{'} + 2X_{19}^{'} + 4X_{16}^{'} + X_{13}^{'} + X_{10}^{'} + X_{11}^{'} = 10.6 \text{ days} \qquad \text{--Equation (2)}$$

From Column 3:

$$2X_9^{'} + 2X_{19}^{'} + 8X_{16}^{'} + X_{13}^{'} + X_{10}^{'} + X_{11}^{'} = 9.2 \text{ days} \qquad \text{--Equation (3)}$$

Subtracting Equation 2 from Equation 3

$$4X_{16}^{'} = 1.4 \text{ days}$$

$$X_{16}^{'} = .7 \text{ days}$$

From Column 4:

$2X_9' + 2X_{19}' + 8X_{16}' + 2X_{13}' + X_{10}' + X_{11}' = 7.8$ days --Equation (4)

Subtracting Equation 3 from Equation 4

$X_{13}' = 1.4$ days

Detailed discussion of the optimization constraint for each state variable are given in table (6-2).

From Column 5:

$2X_9' + 2X_{19}' + 8X_{16}' + 2X_{13}' + 2X_{10}' + X_{11}' = 7.5$ days --Equation (5)

Subtract Equation 4 from Equation 5

$X_{10}' = .3$

From Column 6:

$2X_9' + 2X_{19}' + 8X_{16}' + 2X_{13}' + 2X_{10}' + 2X_{11}' = 7.0$ days --Equation (6)

Subtract Equation 5 from Equation 6

$X_{11}' = .5$ days

From Column 7:

$3X_9' + 4X_{19}' + 8X_{16}' + 2X_{13}' + 3X_{10}' + 2X_{11}' = 4.8$ days --Equation (7)

Subtract Equation 6 from Equation 7

$X_9' + 2X_{19}' + X_{10}' = 2.2$ days --Equation (8)

From Column 8:

$3X_9' + 6X_{19}' + 8X_{16}' + 2X_{13}' + 3X_{10}' + 2X_{11}' = 3.6$ days --Equation (9)

Subtract Eauation 9 from Equation 7

$2X_{19}' = 1.2$ days $\therefore X_{19}' = .6$ days

Substituting values of X_{10}' and S_{19}' in Equation 8

$X_9' = (2.2 - 1.2 - .3)$

$= 0.7$ days

Hence the ship unloading time (X_{21}) can be expressed as follows:

$$X_{21} = f(\text{Gantry cranes, labor gang, forklift, warehouse, open space storage area, train units})$$

i.e. $$X_{21} = K - .07X_9/X_8 - .3X_{10}/X_8 - .5X_{11}/X_8 - 1.4X_{13}/X_8 - .2X_{16}/X_8 - .9X_{19}/X_8$$

Since these values are based on the assumption that the relationships between each variable are the ship unloading time on independent, and that all relationships are linear, the use of these results should be limited to values near those in table (6.1).

Table (6-1). SENSITIVITY OF AVERAGE SHIP SERVICE TIME TO INCREASE IN NUMBER OF EQUIPMENT AND LABOR GANGS

Port Resources By Berth	Number of Equipment and Combination of Resources							
Gantry Cranes	1	2	2	2	2	2	3	3
Labor Gang	1	2	2	2	2	2	4	6
Fork Lift	2	4	8	8	8	8	8	8
Warehouse	1	1	1	2	2	2	2	2
Open Space Storage area (100 acres)	1	1	1	1	2	2	3	3
Transportation Equipment (Train)	1	1	1	1	1	2	2	2
Average Ship Service (unloading and loading)	12 days	10.6 days	9.2 days	7.8 days	7.5 days	7.00 days	4.8 days	3.6 days

Source: Nigerian Port Authority, Lagos.

Key: Peak Tonnage per ship = 5000 tons
Average Tonnage per ship = 3100 tons

*Study Based on Peak Tonnage

Table (6-2). OPTIMIZATION CONSTRAINTS

STATE VARIABLES	Definitions	Constraints and Remarks
N	Number of ships cleared in the study port in a year.	$N = f(\text{Throughput})$ $= T_t/t_{av}$. where t_{av} = average load carried per ship T_t = total tonnage through the port in one year.
a	Average cost of one ship/unit waiting time in queue.	The 1978 demurage average was \$105.00 per hour.
X_1	Average ship waiting time in the queue	Determined from traffic simulation, i.e. Delay = 30 hrs. if $X_8 = 64$ Delay = 2.85 hrs. if $X_8 = 70$ $\therefore X_1 \geq 30 - 4.4(X_8 - 64) - 1.5X_7$ where $1.5X_7$ is the tug transit time.
X_2	Total time spent by a ship in the system.	$X_2 = X_1 + X_3$ $\therefore X_2 \geq 30 - 4.4(X_8 - 64) - 1.5X_7 + X_3$
X_3	Service time in berth.	$X_3 = X_2 - X_1$
b	Average cost of ship berthing time.	\$200.00 per hour 1978
X_4	Average cargo waiting time in transit warehouse.	Treat as a fixed cost (i.e. constant cost). Shippers are allowed 4 days of grace for storage.
c	Average cost of one cargo unit waiting time/warehouse.	\$2.25 per ton/hr. 1978

Table (6.2). Continued

STATE VARIABLES	Definitions	Constraints and Remarks
X_6	Land allocation investment for anchorage facilities	X_6 = f(Number of berths) $= 2X_8$ $\therefore X_6$ can be replaced in the optimization equation by $2X_8$
X_7	Number of tugs	The constraint specifies a daily Tug/ship ratio of .05, i.e. $X_3 = X_{21} + 1.5\ (\frac{.05N}{356} - X_7)$ where X_3 = service time at berth X_{21} = unloading time 1.5 = transit tug time from queue to berth and back to the queue.
X_8	Number of berths	Determined from the simulation at a specified service rate. However $\lambda / X_8 \mu = \rho < 1$ where λ = ship arrival rate per hour for the entire port μ = ship service rate per unit berth
X_9	Number of Gantry cranes	X_9 = f(Tonnage through the port in a day) $\therefore X_9 = \frac{T_t}{356}\ \frac{1}{24}$ The capacity of Gantry crane under the 8 hour work day = 24 tons. 356 day excludes all public holidays in Nigeria.

Table (6.2). Continued

STATE VARIABLES	Definitions	Constraints and Remarks
X_{10}	Open space storage area in acres.	X_{10} = f(% of indirect cargo tonnage through open storage areas per day, rate at which cargo moves out per day in open storage area). $\therefore X_{10} = \dfrac{\dfrac{.1T_t}{356} - \dfrac{(.60)(.1)T_t}{356}}{20}$ $= \dfrac{.04}{356} T_t \; \dfrac{1}{20}$ acres where, 10% of indirect cargo moves through open storage. 60% of the above tonnage moves out per day. 20 tons is stored in one acre.
X_{11}	Land Transportation Investment (Train units required).	$X_{11} = f\ (T_t)$ $= \left[\dfrac{.83\ T_t}{356}\ 1/1500\right] K$ where 83 = % of the direct delivery cargo moved out of the port by trucks and rail. K = % of the above moved by rail (i.e. 20%) 1500 tons is the capacity of train unit operated in the port

Table (6.2). Continued

STATE VARIABLES	Definitions	Constraints and Remarks
X_{12}	Number of Storage Warehouses.	$X_{12} = f(T_t)$ $= \dfrac{\left[\dfrac{.023\ T_t}{356} - \dfrac{(.60)(.023)\ T_t}{356}\right]}{.001\ m^2}$ $= \dfrac{.011\ T_t}{356} / .001\ \text{meter}^2$ where .023 is the proportion of T_t which moves through storage warehouse. 60% of the above cargo is cleared per day. .001 tons/meter^2 = warehousing storage standard
X_{13}	Number of Transit Warehouses	$X_{13} = f(T_t)$ $= f\ \dfrac{T_t}{356}$ $= \dfrac{\left[.07\ \dfrac{T_t}{356} - \dfrac{(.60)(.07)}{356}\ T_t\right]}{.001}\ m^2$ where .07 is the proportion of indirect cargo moving through transit warehouse. .001 tons/m^2 is the warehousing storage standard.
X_{14}	Dredging Investment	X_{14} = f (length of channel, number of berths) $X_{14} = f(1 + 250X_8)$ $X_{14} = (4633 + 250X_8)$ where 1 = length of channel = 2.5 nautical miles (4633 meters). 250 = length of berth.

Table (6.2). Continued

STATE VARIABLES	Definitions	Constraints and Remarks
X_{15}	Signals Investment	X_{15} = \$30 N where \$30 is the cost of ship signals per entry. N = total number of ships in a year.
X_{16}	Number of Fork Lifts	$X_{16} = f\ (T_t)$ $= \frac{1}{24} \frac{T_t}{356}$ where 24 tons per 8 hour day is the maximum capacity handled by a fork lift. (Union restrictions)
X_{17}	Number of Yard Transfer Equipment	$X_{17} = f\ (T_t)$ $= \frac{1}{40} \frac{T_t}{356}$ where 40 tons is the maximum capacity handled by equipment per 8 hour day
X_{18}	Number of Floating Cranes	$X_{18} = f\ \frac{N}{356}$ $= .2\ \frac{N}{356}$ where .2 is an acceptable floating crane to ship ratio necessary to service a sudden increase in demand. Treat as fixed cost.
X_{19}	Number of Labor Gangs	$X_{19} = f\ (T_t)$ $= \frac{1}{24} \frac{T_t}{356}$ where 24 Tons = daily union productivity limit per gang.

Table (6.2). Continued

STATE VARIABLES	Definitions	Constraints and Remarks
X_{20}	Number of Supervisory Staff	$X_{20} = f\ (T_t)$ $= \frac{1}{1.5}\ \frac{T_t}{356}$ $= .7\ \frac{T_t}{356}$ where maximum daily tonnage processed by on supervisory staff = 1.5 tons per day.
X_{21}	Ship Unloading Time	$X_{21} = f\ (X_9, X_{10}, X_{11}, X_{13}, X_{16}, X_{19})$ $X_{21} = K/2 - 0.7X_9/X_8 - .3X_{10}/X_8$ $- .5X_{11}/X_8 - 1.4X_{13}/\dot{X}_8$ $- .2X_{16}/X_8 - .9X_{19}/X_8$ where K = 15 days (1.1, ...5 are delay minimization achieved by introduction of one additional unit of equipment or labor in a berth.) The coefficients are derived from work-study data.
Safety Constraints	$0 \leq X_9/X_8 \leq 2$	Maximum of two Gantry Cranes per one berth.
	$0 \leq X_{19}/X_8 \leq 3$	Maximum of three labor gangs per one berth. (20 men in each gang)
	$0 < X_{16}/X_8 < 2X_{19}$	

Table (6.3). SUMMARY OF OPTIMIZATION CONSTRAINTS

VARIABLES	CONSTRAINTS
N	$N = \frac{T_t}{t_{av.}}$
X_1	$X_1 \geq 30 - 4.4(X_8 - 64) - 1.5X_7$
X_2	$X_2 = X_1 + X_3$ $X_2 \geq 30 - 4.4(X_8 - 64) - 1.5X_7 + X_3$
X_3	$X_3 = X_2 - X_1$
X_4	Treat as constant cost.
X_6	$X_6 = 2X_8$ $\therefore$ Replace X_6 by^2 X_8 in optimization equation
X_7	$X_3 = X_{21} + 1.5 \frac{.05N}{356} - X_7$
X_8	Determined from simulation
X_9	$X_9 = .04 \frac{T_t}{356}$
X_{10}	$X_{10} = .002 \frac{T_t}{356}$
X_{11}	$X_{11} = .166 \frac{\frac{T_t}{356}}{1500}$
X_{12}	$X_{12} = .03\ T_t$ meter^2

Table (6.3). Continued

VARIABLES	CONSTRAINTS
X_{13}	$X_{12} = .08\ T_t$ meter^2
X_{14}	$X_{14} = (4633 + 250X_8)$
X_{15}	$X_{15} = 30N$
X_{16}	$X_{16} = .04\ T_t/356$
X_{17}	$X_{17} = .03\ \frac{T_t}{356}$
X_{18}	$X_{18} = .2\ \frac{N}{356}$
X_{19}	$X_{19} = .04\ \frac{T_t}{356}$
X_{20}	$X_{20} = .66\ \frac{T_t}{356}$
X_{21}	$X_{21} \geq K/2 - 0.7X_9/X_8 - .3X_{10}/X_8 - .5X_{11}/X_8 - 1.4X_{13}/X_8 - .2X_{16}/X_8 - .9X_{19}/X_8$ where K = 15 days.

where K/2 is the maximum berthing time (15 days for loading and unloading).

Table (6-2) discusses the criteria for establishment of other constraints. The simulation output provided inputs which created berthing and service time constraints.

6.3 The Optimization Process

When the various cost coefficients are introduced the objective function changes to the form:

Minimize Z

$$Z = 105X_1N + 200X_2N + 2.25X_4\ (.17T_t) + 5,128\ X_6 + 179,560X_7 + 169,173X_8 + 21,900X_9 + 46,600X_{10} + 39,829X_{11} + 45X_{12} + 76X_{13} + 240X_{14} + X_{15} + 2,773X_{16} + 15,025X_{17} + 180,000X_{18} + 54,000X_{19} + 3600X_{20}$$

where N = the number of ships entering the port in one year is a constant for the specific year.

T_t = total cargo tonnage through the port in one year is also a constant for the specific year.

The next step is to rewrite the variables in terms of X_8 and T_t as discussed in table (6.2). The objective function changes to the form below:

Minimize Z

$$Z = 105NX_1 + 200NX_3 + 2.25X_4(.17T_t) + 5{,}128X_6$$

$$+ 179{,}560X_7 + 169{,}173X_8 + 21{,}900(.04)\frac{T_t}{356}$$

$$+ 46{,}600(.002)\frac{T_t}{356} + 39{,}829(.166)\frac{T_t}{1500 \times 356}$$

$$+ 45(.03T_t) + 76(.08T_t) + 240(4633 + 250X_8)$$

$$+ 30N + 2773(.04)\frac{T_t}{356} + 15{,}025(.03)\frac{T_t}{356}$$

$$+ 180{,}000(.2)\frac{T_t}{(3000)(356)} + 54{,}000(.04)\frac{T_t}{356}$$

$$+ 3600(.66)\frac{T_t}{356}$$

where T_t = the total tonnage in a specific year

(T_t for 1978 = 1.12×10^6 tonnes)

N = 5000 ships for 1978.

Simplifying the objective function reduces to:

Minimize Z

$$Z = 105X_1N + 200X_3N + .383X_4T_t + 5{,}128X_6 + 179{,}560X_7$$

$$+ 169{,}173X_8 + 2.46T_t + .26T_t + .01T_t + 1.35T_t$$

$$+ 6.1T_t + 240(4633 + 250X_8) + 30N + .3T_t + 1.27T_t$$

$$+ .03T_t + 6.07T_t + 6.7T_t$$

The next step in the reduction process is to write the objective function in terms of X_8 and T_t, i.e.

Minimize

$$Z = 105X_1N + 200X_3N + .383X_4T_t + 10{,}256X_8 + 179{,}560X_7$$

$$+ 169{,}173X_8 + (2.46 + .26 + .01 + 1.35 + 6.1 + .3$$

$$+ 1.27 + .03 + 6.07 + 6.7)\ T_t + 30N + 1{,}111{,}920 + 60{,}000X_8$$

Simplifying the objective function reduces to

Minimize

$$Z = 105X_1N + 200X_3N + .383X_4 + 179{,}560X_7 + 239{,}426X_8 + 24.55T_t + 30N + 1{,}111{,}920.$$

In the above objective function X_4 (average cargo waiting time in transit warehouse) is considered a fixed cost because shippers are allowed 3 days of grace for transit storage. This means that according to the existing contract the minimum value of X_4 is 72 hours. Hence X_4 is set at this value and the associated cost expressed in terms of T_t. When the value of N (N = 5000) is substituted in X_1 and X_3 the objective function reduces to:

Minimize

$$Z = 525{,}000X_1 + 1{,}000{,}000X_3 + 179{,}560X_7 + 239{,}429X_8 + 52T_t + 30N + E$$

where E is the investment level in berthing equipment and labor.

Investment constraints were generated from the work study data in table (6-1). These constraints relate X_3 (berthing time) to the increase in number of equipment and labor gangs. The data obtained from table (6-4) were plotted as shown in figure (6-2). A linear relationship was observed between investment cost of berthing equipment and labor, and berthing time X_3. Hence X_3 can be expressed as a function of the level of investment, i.e.

$$X_3 \geq A_2 - A_3 (E_{max} - E)$$

where E_{max} is the maximum annual investment in berthing equipment and labor.

A_3 is the slope of the curve in figure (6-2).

A_2 is the maximum berthing time associated with an annual investment level E.

Table (6-4). SENSITIVITY OF AVERAGE SHIP SERVICE TIME TO INCREASE IN NUMBER OF EQUIPMENT AND LABOR GANG

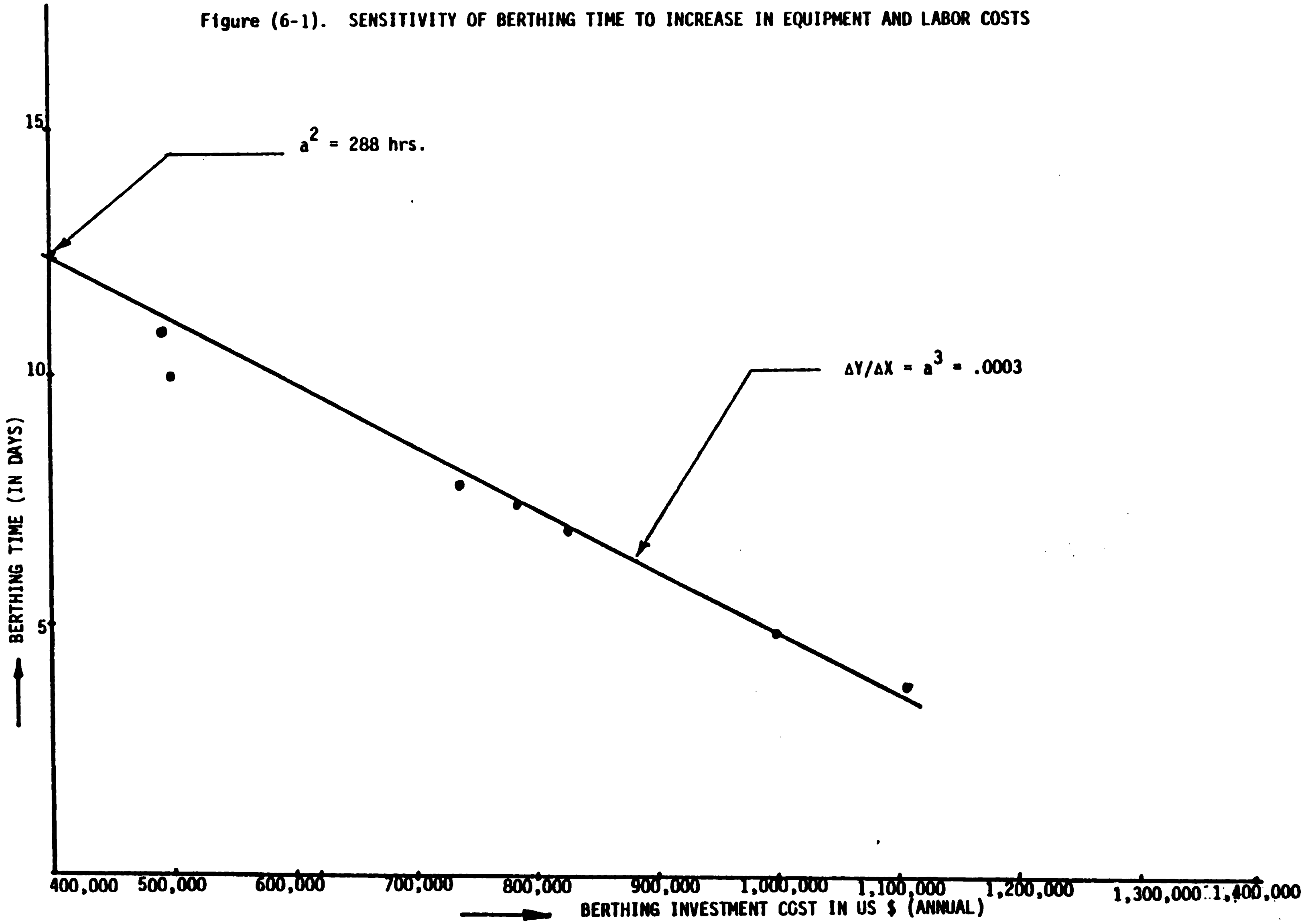
(WORK STUDY DATA)

Port Resources By Berth		Number of Equipment and Combination of Resources							
ALTERNATIVES		(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Gantry Cranes	item no.	1	2	2	2	2	2	3	3
	cost $	21,900	43,800	43,800	43,800	43,800	43,800	65,700	65,700
Labor Gang	item no.	1	2	2	2	2	2	4	6
	cost $	54,000	108,000	108,000	108,000	108,000	108,000	216,000	324,000
Fork Lift	item no.	2	4	8	8	8	8	8	8
	cost $	2,773	11,092	22,184	22,184	22,184	22,184	22,184	22,184
Warehouse	item no.	1	1	1	2	2	2	2	2
	cost $	240,000	240,000	240,000	480,000	480,000	480,000	480,000	480,000
Open Space Storage area (100 acres)	item no.	1	1	1	1	2	2	3	3
	cost $	46,600	46,000	46,600	46,000	93,200	93,200	139,800	139,800
Transportation Equipment (Train)	item no.	1	1	1	1	1	2	2	2
	cost $	39,829	39,829	39,829	39,829	39,829	79,658	79,658	79,658
Average Ship Service (unloading + loading)		12 days	10.6 days	9.2 days	7.8 days	7.5 days	7.00 days	4.8 days	3.6 days
Total Annual Investment Associated with each Combination	$	405,102	489,321	500,413	740,413	787,013	826,842	1,003,342	1,111,342

KEY: Peak Tonnage per ship = 5000 tons; Average tonnage per ship = 3100 tons

* Study based on Peak Tonnage

Figure (6-1). SENSITIVITY OF BERTHING TIME TO INCREASE IN EQUIPMENT AND LABOR COSTS



A knowledge of ship turnaround time is also necessary to describe total ship delay. This time component is based on port investment policy and maximum turnaround time tolerable to the shippers. The turnaround time can be written as follows:

$$X_1 + X_3 - 1.5X_7 \leq Y \text{ hrs.}$$

where X_1 = waiting time in queue

X_3 = total berthing time (unloading + loading)

X_7 = number of tugs and associated transit time to and from head of the queue to berth.

Y = maximum turnaround time tolerable to the shippers.

Linear Programming Model: The package employed is a version of the North Western University Vogelback system. In the Michigan State Computer Center it is identified as APLIB, LTT 5640, P*LP. This package requires a consistent naming of independent variables. Hence the variables with alpha codes were renamed:

$T = X_9$

$N = X_{10}$

$E = X_{11}$

When these identities are substituted, the objective function becomes:

$$Z = 525{,}000X_1 + 1{,}000{,}000X_3 + 179{,}560X_7 + 239{,}429X_8 + 52X_9 + 30X_{10} + X_{11}$$

Care should be taken not to confuse these variables with the initial meaning of X_9, X_{10}, X_{11} in section 6.1.

As shown in the computer printout three alternative port investment combinations were optimized. These alternatives will be identified as cases 1, 2, and 3. Each of these alternatives were run for the 1978 ship and cargo traffic demand.

In case 1 the existing berth service time of 199 hours per ship is kept constant. Fifteen new berths are created in addition to the existing 39 berths. This brings the total number of berths to 54. The solution to the linear program results in a queue waiting time for this alternative of 6.4 hours per ship.

The second alternative proposes a 25% reduction in existing berth service time and the creation of only ten new berths. This reduction in berth service time can be achieved by increasing the investment level in equipment (i.e. the X_{11} variable in the optimization constraints). Table 6.4 illustrates the impact of various investment levels on the ship service time. In case 2, the queue waiting time is 4.4 hours which is 30% lower than case 1. In addition, the annual cost to the port (Z) in case 1 is 23% higher than case 2. Hence alternative 1 is not economically viable to service the short term traffic demand of the port.

The third alternative results in a lower cost than case 2. In this alternative, only five additional berths are created and the berth service rate is reduced to 120 hours (40% reduction). The queue waiting time for this solution is reduced to 1.24 hours. This is due to the associated cost savings resulting from the reduced waiting time. The annual cost 'Z' is 20% lower than the value obtained in case 2, and is the recommended policy for dealing with short term traffic and logistical problems of the port. In section 6.3b specific investments are described to determine the optimum combination of port subsystems to meet 1990 ship and cargo traffic demand.

Figure (6-2). SENSITIVITY OF QUE WAITING TIME TO REDUCTION OF BERTH SERVICE TIME (1978 DEMAND).

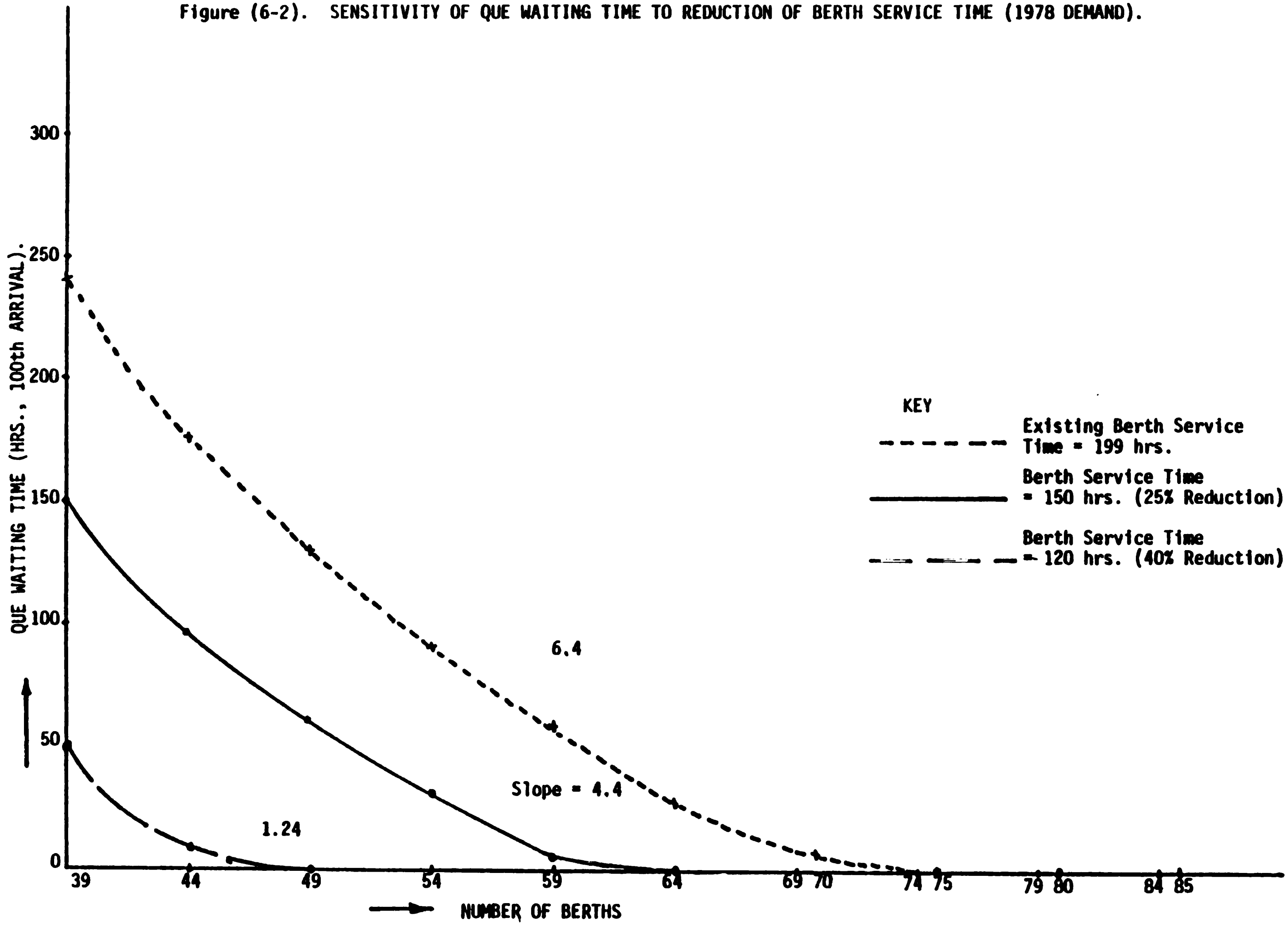


Table (6-5). SUMMARY OF OPTIMIZATION RESULTS (1978 DEMAND) CASE 1

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS
X_1	Waiting time in the Queue	4.4 hours
X_3	Berthing time (unloading + loading)	48 hours
X_4	Cargo Waiting time in transit warehouse	72 hours
X_6	Land allocation investment for anchorage facilities	128 units
X_7	Number of Tugs	21 units
X_8	Number of Berths	64
X_9	Number of Gantry Cranes	71
X_{10}	Open space storage area in acres	7 acres
X_{11}	Train unit Investment	2 unit trains
X_{12}	Number of Storage Warehouses	6
X_{13}	Transit Warehouses	14
X_{14}	Dredging investment	$4,533,250.00
X_{15}	Signals investment	$150,000
X_{16}	Number of fork lifts	132 units

Table (6-5). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS
X_{17}	Number of Yard Transfer Equipment	80 units
X_{18}	Number of Floating Cranes	3 units
X_{19}	Number of Labor Gangs	132 gangs
X_{20}	Number of Supervisory and Clerical Staff	2097

Table (6-6). SUMMARY OF OPTIMIZATION RESULTS (1978 DEMAND) CASE 2.

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 1
X_1	Waiting time in the Queue	4.4 hours	-2.0 hours
X_3	Berthing time (unloading + loading)	150 hours	-49 hours
X_4	Cargo waiting time in transit warehouse	72 hours	--
X_6	Land allocation investment for anchorage facilities	98 units	-10 units
X_7	Number of Tugs	18 units	-11 units
X_8	Number of Berths	49	-5 berths
X_9	Number of Gantry Cranes	90 units	+18
X_{10}	Open space storage area in acres	9 acres	+2
X_{11}	Train unit Investment	2 unit trains	--
X_{12}	Number of Storage Warehouses	8	+2
X_{13}	Transit Warehouses	18	+4
X_{14}	Dredging investment	$4,220,750.00	-$312,500
X_{15}	Signals investment	$150,000.00	--
X_{16}	Number of fork lifts	160 units	+20

Table (6-6). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 1
X_{17}	Number of Yard Transfer Equipment	100 units	+20
X_{18}	Number of Floating Cranes	3 units	--
X_{19}	Number of Labor Gangs	160	+28 gangs = 560 men
X_{20}	Number of Supervisory and Clerical Staff	2600	+503 men

Table (6-7). SUMMARY OF OPTIMIZATION RESULTS (1978 DEMAND)
CASE 3

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 1
X_1	Waiting time in the Queue	1.24	-5.16
X_3	Berthing time (unloading + loading)	120	-79
X_4	Cargo Waiting time in transit warehouse	72	--
X_6	Land allocation investment for anchorage facilities	88 units	-20
X_7	Number of Tugs	13	-16
X_8	Number of Berths	44	-10
X_9	Number of Gantry Cranes	100 units	+28
X_{10}	Open space storage area in acres	12 acres	+5
X_{11}	Train unit Investment	3 unit trains	+1
X_{12}	Number of Storage Warehouses	10	+4
X_{13}	Transit Warehouses	20	+6
X_{14}	Dredging investment	$3,908,250.00	-615,000.00
X_{15}	Signals investment	$150,000.00	--
X_{16}	Number of fork lifts	184	+52

Table (6-7). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 1
X_{17}	Number of Yard Transfer Equipment	112	+32
X_{18}	Number of Floating Cranes	3 units	--
X_{19}	Number of Labor Gangs	180	+48 gangs = 960 men
X_{20}	Number of Supervisory and Clerical Staff	2936	+839 men

Table (6-8). COST EFFECTIVENESS OF 1978 (SHORT TERM) ALTERNATIVES

ALTERNATIVES	MINIMUM VALUE OF Z ($)	SAVINGS ($)	% SAVINGS
Case 1	280,498,739.00	base	--
Case 2	217,044,044.00	63,454,695.00	23%
Case 3*	194,025,418.00	83,473,321.00	31%

NB: Alternative No. 3 is recommended on the basis of minimum cost and reduction in total delay to ships and cargo.

Port Investment Projections: The optimum combination of port investments required to service future ship and cargo demand can be determined by projection. In this projection there are five major steps:

- Forecasting of ship traffic volume for the future year based in historical data. This forecast assumes that there is no radical change in economic growth.
- Forecast of the cargo tonnage for the future year.
- Estimate of ship arrival rate (IPRATE) for the future year.
- Simulation of the future year ship traffic.
- Optimization of port investment requirements for the future.

Ship traffic volume expected to enter the port of Lagos in 1990 can be predicted from figure (2-8) by applying the following equation:

$$N_{1990} = N_{1978} + a(Y_2 - Y_1) \quad \text{(i)}$$

where N_{1990} = predicted number of ships in 1990

N_{1978} = number of ships which entered the port in 1978

a = the slope of the demand curve

Y_2 = projected year

Y_1 = base year.

Figure (2-8) illustrates that there has been a linear growth rate in ship volume between 1974-1978. This growth rate is expected to continue because of the stability in government. Hence the slope of the demand line can be computed as follows:

$$a = \frac{N_{1978} - N_{1975}}{1978 - 1975}$$

$$= \frac{5,800 - 5,200}{3}$$

$$\therefore a = \underline{200}$$

When this value is substituted in equation (i) above the volume of ships expected in 1990 can be determined, i.e.

$$N_{1990} = 5{,}800 + 200\ (1990 - 1978)$$

$$= 5{,}800 + 2{,}400$$

$$= \underline{8{,}200 \text{ ships}}.$$

The next step is to forecast the cargo thoroughput in 1990. This estimate is based on the fact that cargo thoroughput is directly proportional to the number of ships calling at the port.

i.e. When N = 5,800 ships, total tonnage (T_t) = 1.12×10^6 tonnes

$\therefore$ when N = 8,200 ships, $T_t = 1.12 \times 10^6 \times \frac{8{,}200}{5{,}800}$ tonnes

$\therefore T_{t1990} = 1.58 \times 10^6$ tonnes.

Another important variable that should be determined is the expected ship arrival rate for 1990. This estimate is based on a rational assumption that ship arrival rate is directly proportional to the number of ships entering the port. i.e.

When N = 5,800, arrival rate (IPRATE) = .35 ship/hr.

$\therefore$ when N = 8,200, IPRATE = $.35 \times \frac{8{,}200}{5{,}800}$ ship/hr.

arrival rate for 1990 = <u>.49 ship/hr</u>.

This 1990 ship arrival rate was introduced in the simulation model to generate expected ship waiting time and queue length, with the 1990 ship traffic volume and tonnage specified as optimization constraints.

The family of curves shown in figure (6-3) were developed from the results of simulation programs for the projected 1990 ship arrival rates. Ship berthing time was varied from 199 hours to 150 hours and 120 hours (i.e. a reduction of 25% and 40% respectively). Optimization constraints relating queue waiting time X_1 and the number of berths X_8 was derived separately for each curve. These alternative optimization programs are identified as cases 4, 5, and 6. As shown in the problem statements, the cost of the various items in the objective function for 1978 was increased by 10% to reflect the expected increase in unit costs by 1990.

In case 4 the existing berth service time is maintained at the existing rate of 199 hours per ship. The total number of berths is increased to 64. The queue waiting time for this case is 3 hours. In case 5 the berth service time is reduced to 150 hours per ship and total number of berths is reducted to 59, yielding a queue waiting time of 4.8 hours. In case 6, the berth service time is further reduced to 120 hours and only 10 new berths are created. The queue waiting time for this case is 5 hours, which is 20 minutes higher than case 5. However, the annual cost savings of 20% over case 5 offsets this increase in waiting time. Hence this last alternative is recommended as a program for meeting the increased ship traffic and cargo tonnage in 1990.

Figure (6-3). SENSITIVITY OF QUEUE WAITING TIME TO REDUCTION OF BERTH SERVICE TIME (1990 DEMAND PROJECTIONS)

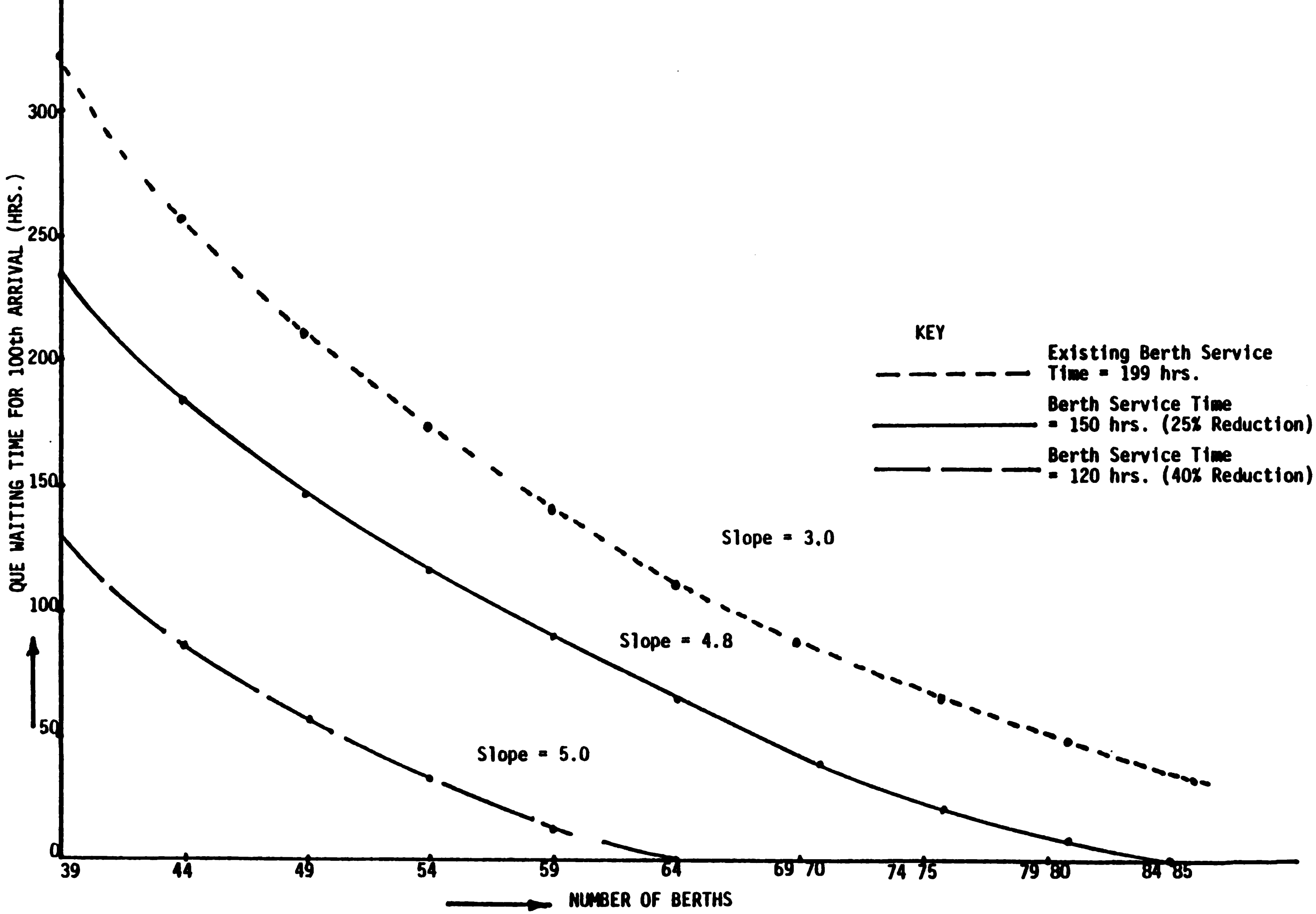


Table (6-9). SUMMARY OF OPTIMIZATION RESULTS (1990 DEMAND) CASE 4

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS
X_1	Waiting time in the Queue	3 hours
X_3	Berthing time (unloading + loading)	199 hours
X_4	Cargo Waiting time in transit warehouse	72 hours
X_6	Land allocation investment for anchorage facilities	128 units
X_7	Number of Tugs	20 units
X_8	Number of Berths	64
X_9	Number of Gantry Cranes	184
X_{10}	Open space storage area in acres	14 acres
X_{11}	Train unit Invest-ment	4 unit trains
X_{12}	Number of Storage Warehouses	12
X_{13}	Transit Warehouses	22
X_{14}	Dredging investment	$5,158,250.00
X_{15}	Signals investment	$270,600.00
X_{16}	Number of fork lifts	190 units

Table (6-9). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS
X_{17}	Number of Yard Transfer Equipment	120 units
X_{18}	Number of Floating Cranes	5 units
X_{19}	Number of Labor Gangs	190
X_{20}	Number of Supervisory and Clerical Staff	3,108

Table (6-10). SUMMARY OF OPTIMIZATION RESULTS (1990 DEMAND)
CASE 5

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 4
X_1	Waiting time in the Queue	4.8 hours	+1.8
X_3	Berthing time (unloading + loading)	150 hours	-49
X_4	Cargo Waiting time in transit warehouse	72 hours	--
X_6	Land allocation investment for anchorage facilities	118 units	+10
X_7	Number of Tugs	24 units	+4
X_8	Number of Berths	59	-5
X_9	Number of Gantry Cranes	230 units	+46
X_{10}	Open space storage area in acres	18 acres	+4
X_{11}	Train unit Investment	4 units	--
X_{12}	Number of Storage Warehouses	15 units	+3
X_{13}	Transit Warehouses	28	+6
X_{14}	Dredging investment	$4,845,750.00	-$312,500.00
X_{15}	Signals investment	$270,600.00	--
X_{16}	Number of fork lifts	238 units	+48

Table (6-10). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 4
X_{17}	Number of Yard Transfer Equipment	150	+30
X_{18}	Number of Floating Cranes	5 units	--
X_{19}	Number of Labor Gangs	240	+50 gangs i.e. 1000 men
X_{20}	Number of Supervisory and Clerical Staff	3800	+692 men

Table (6-11). SUMMARY OF OPTIMIZATION RESULTS (1990 DEMAND) CASE 6

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 4
X_1	Waiting time in the Queue	5 hours	+2
X_3	Berthing time (unloading + loading)	120 hours	-79
X_4	Cargo Waiting time in transit warehouse	72 hours	--
X_6	Land allocation investment for anchorage facilities	98 units	-30
X_7	Number of Tugs	20 units	--
X_8	Number of Berths	49	-15
X_9	Number of Gantry Cranes	250	+66
X_{10}	Open space storage area in acres	22 acres	+8
X_{11}	Train unit Invest-ment	4 unit trains	--
X_{12}	Number of Storage Warehouses	18 units	+6
X_{13}	Transit Warehouses	34	+12
X_{14}	Dredging investment	$4,220,750.00	-$937,500.00
X_{15}	Signals investment	$270,600.00	--
X_{16}	Number of fork lifts	286 units	+96

Table (6-11). Continued

VARIABLES	DEFINITION	OPTIMUM INVESTMENT REQUIREMENTS	CHANGE FROM CASE 4
X_{17}	Number of Yard Transfer Equipment	180	+60
X_{18}	Number of Floating Cranes	5 units	--
X_{19}	Number of Labor Gangs	280	+90 gangs i.e. 1800 men
X_{20}	Number of Supervisory and Clerical Staff	4560	+1,452 men

Table (6-12). COST EFFECTIVENESS OF 1990 (LONG TERM) ALTERNATIVES

ALTERNATIVE	MINIMUM VALUE OF Z ($)	SAVINGS IN ($)	% SAVINGS
Case 4	$321,748,474.00	base	--
Case 5	$267,930,186.00	$53,818,288	17%
Case 6*	$232,411,966.00	$89,336,508	28%

NB Case 6 is recommended for 1990 demand based on minimum annual cost and performance.

6.4 Traffic and Logistical Operations Survey

In addition to the quantitative analysis, a survey was designed and condusted to identify those factors which are considered to be inadequate for present port operations and to obtain information on logistical systems. The survey responses will help the planner to interpret the results of the linear programming models.

The methodology adopted in this survey considered three major groups:

- Port traffic officers
- Port operations officers
- Shippers and freight forwarders.

In order to generate more reliable information, only officers in responsible charge were interviewed. The officers were directly involved in ship and cargo processing. This was done to ensure that experimental subjects have adequate experience in the day-to-day problems in their various areas.

Personal calls were made to each of the selected officers to explain the basic coding format of the survey forms. This is the reason for the high state of response achieved. Table (6.13) on the next page summarizes the responses received from various survey categories. Traffic officers responded 5% more than operational officers or shippers.

TABLE (6.13) RESPONSE TO LOGISTICAL OPERATIONS SURVEY FORMS

CATEGORY	DESCRIPTION	NUMBER OF FORMS	RESPONSE	% RESPONSE
A	Traffic Officers	20	16	80
B	Operations Officers	20	15	75
C	Shippers	20	15	75

As shown in tables (6.14-1), (6.14-2) and (6.14-3), analysis of the survey forms administered to each category are summarized. Traffic officers and operations officers agree that the following facilities are inadequate to service the existing demand.

- Berths
- Gantry cranes and fork lifts
- Yard transfer equipment
- Warehouses
- Signals, tugs and pilotage.

Traffic officers and operations officers remarked that shippers' unwillingness to clear cargo on time is one of the principal causes of cargo delay within the port system.

On the other hand, shippers argue that poor cargo tracing and lack of information about berthing schedules are principal causes of cargo delay. In addition, a majority of shippers see the custom clearing process in Lagos port as complicated and outmoded. Tables (6.14-1) through (6.14-3) illustrate the rating of each subsystem by the different groups.

The highlights of the ranking are shown below:

Group	1st Critical Subsystem	Average Score	2nd Critical Subsystem	Average Score
(a) Traffic officers	Gantry cranes & forklifts	3.4	Yard Transfer equipment	3.7
(b) Port operations officers	Berths	2.9	Cargo clearing process	3.3
(c) Shippers	Berths	1.6	Gantry cranes	2.9

A close examination of the above results indicate that there is a concensus between the two groups (operations officers and shippers) that the number of berths at the port is not adequate for the present demand. Traffic officers and shippers also agree that the number of gantry cranes and forklifts assigned to each berth are not adequate. All the three groups rated signals, pilotage and towage systems as satisfactory.

However group bias was recognized in the question of cargo clearing. Port officials tended to attribute the cause of cargo delay to shippers unwillingness to clear goods in time. On the other hand, shippers blamed port management for the complicated custom requirements involved in cargo clearing. In the writer's opinion both parties share equal blame for the time lag involved in cargo clearing. The solution lies in effective communication between the two parties.

Table (6.14-1). ANALYSIS OF TRAFFIC AND LOGISTICAL OPERATIONS SURVEY FORMS.

Category A: Traffic Officers.

1. Rank the operational adequacy of the following port subsystems. Assessing values (See KEY) to any of the subsystems order.

	1	2	3	4	5	6	7	8	Mean Score
a) Signal System	2˙	1	--	2	--	2	2	3	5.1
b) Pilotage and Tugs	--	1	--	2	--	3	5	2	6.1
c) Berths	--	2	3	2	1	3	3	--	4.6
d) Gantry Cranes and Forklifts	2	2	4	3	--	3	--	--	3.4*
e) Labor Gangs per berth	1	--	2	5	3	3	1	1	4.7
f) Warehouses (Transit sheds)	2	--	--	5	2	5	2	--	4.8
g) Cargo clearing process	--	3	--	5	3	2	1	--	4.3
h) Yard transfer equipment	--	3	2	5	2	1	--	1	3.7

KEY: Excellent = 8 Good = 6 Average = 4 Poor = 2
Very Good = 7 Above Average = 5 Below Average = 3 Bad = 1

2. Rank the major causes of ship delay in the port.

	0	1	2	3	4	5	Mean Score
a) Poor signal, tugs and pilotage	5	6	--	--	--	2	1.2
b) Lack of sufficient number of berths	2	5	--	--	4	4	2.7
c) Lack of sufficient number of Gantry Cranes and Forklifts (loading and unloading)	1	1	1	3	--	9	3.8*
d) Insufficient number of receiving warehouses (Transit sheds)	3	3	1	3	1	3	2.4
e) Labor problems							

NB Rank should run from 1 to 5 (i.e. major cause = 5, minor cause = 1)
KEY: Major cause = 5, Minor cause = 1, Not as a Factor = 0

3. Rank the factors which cause cargo delay in the port of Lagos.

	0	1	2	3	4	5	Mean Score
a) Poor handling equipment (Cranes, forklifts, conveyors)	3	2	1	--	--	7	3.0
b) Lack of contain transfer equipment	1	5	4	1	1	3	2.3
c) Poor record keeping in transit sheds	1	7	1	2	1	3	2.3
d) Complicated custom clearing process	1	3	--	1	1	8	3.6
e) Shipper's unwillingness to clear goods on time	--	--	--	3	3	8	4.4*

NB Ranks should run from 1 to 5 (major factor = 5, minor factor = 1)
KEY: Major factor = 5, Minor factor = 1, No factor = 0

4. Signals, tugs and pilotage services in the port can best be described as:

a) Excellent	2
b) Good	9
c) Average	4
d) Poor	1

*Critical factors/Scores

5. The number of berths in the entire Lagos port System is:

   a) Adequate for present traffic demand ______ ☐ 3

   b) Not adequate for present traffic demand ______ ☐ 11

   c) Adequate for present demand but not adequate for the future ______ ☐ 2

6. The number of Gantry Cranes and Fork lifts assigned to a berth are:

   a) More than adequate at present ______ ☐ --

   b) Adequate at present ______ ☐ 3

   c) Not adequate ______ ☐ 13

7. The capacity of the receiving warehouses (transit sheds) are:

   a) More than adequate for the present cargo traffic ______ ☐ --

   b) Just adequate ______ ☐ 10

   c) Less than adequate ______ ☐ 6

8. Cargo handling and stacking in the warehouses (transit sheds) can best be described as:

   a) Orderly ______ ☐ 5

   b) Average ______ ☐ 8

   c) Disorderly ______ ☐ 4

9. Import cargo clearing process in the port takes an average of:

   a) 1 day ______ ☐ --

   b) 2 days ______ ☐ 1

   c) 3 days ______ ☐ 3

   d) 4 days ______ ☐ 4

   e) 5 days ______ ☐ 3

   f) 6 days ______ ☐ --

   g) 7 days ______ ☐ 1

   h) 8-14 days ______ ☐ 3

   i) More than 14 days ______ ☐ 1

10. The present custom cargo clearing process is:

   a) Simple and does not need a change ______ ☐ 5

   b) Complicated and needs a change ______ ☐ 10

11. The number of supervisory and clerical staff in a warehouse (Transit shed) are:

a) More than adequate ______	☐	--
b) Adequate ______	☐	7
c) Less than adequate ______	☐	8

12. Cargo movement out of the port is delayed due to the fact that insufficient railroad cars are allocated to port operations:

a) True ______	☐	9
b) False ______	☐	3
c) Other ______	☐	2

13. Containerized import goods move through the port faster than general import cargo:

a) Yes ______	☐	14
b) No ______	☐	1

14. Containers are returned to the owners:

a) On time ______	☐	2
b) Late ______	☐	9
c) Abandoned within the port area ______	☐	4

15. Cargo damage in the port is principally caused by one of the following:

a) Pilferage (and theft) ______	☐	12
b) Poor storage ______	☐	1
c) Bad weather ______	☐	1
d) Handling ______	☐	4

16. Longshoremen or dockers should be handled best by:

a) Contractors ______	☐	8
b) Nigerian Port Authority ______	☐	7

17. The Tin Can port extension reduced ship and cargo delay by:

a) 100% ______	☐	--
b) 80% ______	☐	4
c) 60% ______	☐	5
d) 40% ______	☐	3
e) 20% ______	☐	1
f) 10% ______	☐	2

18. What other major problems do you encounter in the day-to-day operations of the port subsystem (i.e. your Department or Section):

a) Lack of adequate operational facilities (4)

b) Poor management policy (2)

c) Frustration resulting from too much work and too poor a salary (2)

d) Shortage of wagons for delivery of heavy cargo (2)

19. What future problems do you anticipate in Lagos port complex:

a) Low staff turnover (5)

b) Trade dispute due to poor compensation (6)

c) Re-occurrence of major port congestion (5)

d) Desertion of experienced staff due to lack of motivation and reward. (4)

20. How do you rate internal communication systems (i.e. radio, telephones, etc.) within the port complex:

a) Very efficient ☐ --

b) Efficient ☐ --

c) Good ☐ 1

d) Fair ☐ 2

e) Poor ☐ 7

Table (6.14-2). ANALYSIS OF TRAFFIC AND LOGISTICAL OPERATIONS SURVEY FORMS.

Category 8: Port Operations Officers.

1. Rank the operational adequacy of the following port subsystems. Assessing values (See KEY) to any of the subsystems order.

	1	2	3	4	5	6	7	8	Mean Score
a) Signal System	--	--	1	--	2	1	7	2	6.5
b) Pilotage and Tugs	--	--	1	1	--	3	4	4	6.5
c) Berths	5	3	3	1	--	2	1	--	2.9*
d) Gantry Cranes and Forklifts	2	3	1	3	1	3	1	--	3.8
e) Labor Gangs per berth	--	--	7	2	3	1	1	1	4.3
f) Warehouses (Transit sheds)	1	2	4	6	1	2	--	--	3.6
g) Cargo clearing process	1	3	--	1	7	--	1	--	3.3
h) Yard transfer equipment	1	1	1	1	4	3	--	2	4.9

KEY: Excellent = 8 Good = 6 Average = 4 Poor = 2
Very Good = 7 Above Average = 5 Below Average = 3 Bad = 1

2. Rank the major causes of ship delay in the port.

	0	1	2	3	4	5	Mean Score
a) Poor signal, tugs and pilotage	4	1	4	2	1	1	1.9
b) Lack of sufficient number of berths	--	2	2	1	2	7	3.8
c) Lack of sufficient number of Gantry Cranes and Forklifts (loading and unloading)	--	1	1	3	5	3	3.6*
d) Insufficient number of receiving warehouses (Transit sheds)	2	2	1	3	4	2	2.8
e) Labor problems	2	5	3	2	1	1	1.7

NB Rank should run from 1 to 5 (i.e. major cause = 5, minor cause = 1)
KEY: Major cause = 5, Minor cause = 1, Not as a Factor = 0

3. Rank the factors which cause cargo delay in the port of Lagos.

	0	1	2	3	4	5	Mean Score
a) Poor handling equipment (Cranes, forklifts, conveyors	--	7	1	1	2	2	2.3
b) Lack of container transfer equipment	--	1	8	3	--	--	2.2
c) Poor record keeping in transit sheds	1	3	1	4	2	3	2.9
d) Complicated custom clearing process	1	3	2	2	5	2	2.9
e) Shipper's unwillingness to clear goods on time	--	1	--	2	4	8	4.2*

NB Ranks should run from 1 to 5 (major factor = 5, minor factor = 1)
KEY: Major factor = 5, minor factors = 1, No factor = 0

4. Signals, tugs and pilotage services in the port can best be described as:

a) Excellent	3
b) Good	7
c) Average	3
d) Poor	--

*Critical factors/scores

5. The number of berths in the entire Lagos port System is:

   a) Adequate for present traffic demand ______ ☐ 2

   b) Not adequate for present traffic demand ______ ☐ 12

   c) Adequate for present demand but not adequate for the future ______ ☐ --

6. The number of Gantry Cranes and Fork lifts assigend to a berth are:

   a) More than adequate at present ______ ☐ 4

   b) Adequate at present ______ ☐ 1

   c) Not adequate ______ ☐ 10

7. The capacity of the receiving warehouses (transit sheds) are:

   a) More than adequate for the present cargo traffic ______ ☐ 3

   b) Just adequate ______ ☐ 1

   c) Less than adequate ______ ☐ 11

8. Cargo handling and stacking in the warehouses (transit sheds) can best be described as:

   a) Orderly ______ ☐ 4

   b) Average ______ ☐ 7

   c) Disorderly ______ ☐ 4

9. Import cargo clearing process in the port takes an average of:

   a) 1 day ______ ☐ --

   b) 2 days ______ ☐ --

   c) 3 days ______ ☐ 4

   d) 4 days ______ ☐ 4

   e) 5 days ______ ☐ 2

   f) 6 days ______ ☐ 1

   g) 7 days ______ ☐ 1

   h) 8-14 days ______ ☐ 2

   i) More than 14 days ______ ☐ --

10. The present custom cargo clearing process is:

   a) Simple and does not need a change ______ ☐ 3

   b) Complicated and needs a change ______ ☐ 11

11. The number of supervisory and clerical staff in a warehouse (Transit shed) are:

a) More than adequate ______ ☐ 4

b) Adequate ______ ☐ 6

c) Less than adequate ______ ☐ 5

12. Cargo movement out of the port is delayed due to the fact that insufficient railroad cars are allocated to port operations:

a) True ______ ☐ 9

b) False ______ ☐ 5

c) Other ______ ☐ 1

13. Containerized import goods move through the port faster than general import cargo:

a) Yes ______ ☐ 12

b) No ______ ☐ 3

14. Containers are returned to the owners:

a) On time ______ ☐ 2

b) Late ______ ☐ 9

c) Abandoned within the port area ______ ☐ 4

15. Cargo damage in the port is principally caused by one of the following:

a) Pilferage (and theft) ______ ☐ 6

b) Poor storage ______ ☐ 2

c) Bad weather ______ ☐ 2

d) Handling ______ ☐ 4

16. Longshoremen or dockers should be handled best by:

a) Contractors ______ ☐ 10

b) Nigerian Port Authority ______ ☐ 5

17. The Tin Can port extension reduced ship and cargo delay by:

a) 100% ______ ☐ --

b) 80% ______ ☐ 3

c) 60% ______ ☐ 2

d) 40% ______ ☐ 6

e) 20% ______ ☐ 2

f) 10% ______ ☐ 1

18. What other major problems do you encounter in the day-to-day operations of the port subsystem (i.e. your Department or Section):

a) Non clearance of cargo by consignees (3)

b) Lack of multi-modal transfer terminals (2)

c) Low and irregular plant availablility in the port (2)

d) Low moral among labor because of poor wages/salaries (2)

e) Delays in processing import/export papers (2)

19. What future problems do you anticipate in Lagos port complex:

a) Labor unrest among dockworkers (4)

b) Poor berth occupancy ratio, i.e. 96% (2)

c) Congestion of transit warehouses (3)

d) The port may not be able to meet 1990 demand (1)

20. How do you rate internal communication systems (i.e. radio, telephones, etc.) within the port complex:

a) Very efficient ______ ☐ 2

b) Efficient ______ ☐ 2

c) Good ______ ☐ 2

d) Fair ______ ☐ 2

e) Poor ______ ☐ 5

Table (6.14-3). ANALYSIS OF TRAFFIC AND LOGISTICAL OPERATIONS SURVEY FORMS.

Category C: Shippers.

1. Rank the operational adequacy of the following port subsystems. Assessing values (See KEY) to any of the subsystems order.

	1	2	3	4	5	6	7	8	Mean Score
a) Signal System	--	--	--	2	2	2	2	5	6.5
b) Pilotage and Tugs	--	--	2	--	2	3	5	1	5.9
c) Berths	7	3	2	--	--	--	--	--	1.6*
d) Gantry Cranes	--	3	2	2	--	--	--	--	2.9
e) Labor Gangs per berth	--	1	1	5	2	2	2	--	4.7
f) Warehouses (Transit sheds)	3	2	7	1	--	1	2	--	3.7
g) Cargo clearing process	3	3	--	2	4	--	--	--	3.0
h) Yard transfer equipment	--	1	2	3	3	1	--	2	4.8

KEY: Excellent = 8, Good = 6, Average = 4, Poor = 2
Very Good = 7, Above Average = 5, Below Average = 3, Bad = 1

2. Rank the major causes of ship delay in the port.

	0	1	2	3	4	5	Mean Score
a) Poor signal, tugs and pilotage	3	3	2	1	2	2	2.2
b) Lack of sufficient number of berths	1	2	1	2	2	5	3.3
c) Lack of sufficient number of Gantry Cranes and Forklifts (loading and unloading)	--	--	3	5	1	4	3.5*
d) Insufficient number of receiving warehouses (Transit sheds)	--	--	3	4	7	1	3.4
e) Labor problems	--	6	2	1	2	1	2.2

NB Rank should run from 1 to 5 (i.e. major cause = 5, minor cause = 1)
KEY: Major cause = 5, minor cause = 1, Not as a factor = 0)

3. Rank the factors which cause cargo delay in the port of Lagos.

	0	1	2	3	4	5	Mean Score
a) Poor handling equipment (Cranes, forklifts, conveyors)	--	3	2	4	3	1	2.8
b) Lack of container transfer equipment	1	1	6	1	2	2	2.6
c) Poor record keeping in transit sheds	2	2	2	3	--	4	2.7
d) Complicated custom clearing process	--	2	1	3	6	2	3.6
e) Shipper's unwillingness to clear goods on time	--	6	1	1	2	1	2.2

NB Ranks should run from 1 to 5 (major factor = 5, minor factor = 1)
KEY: Major factor = 5, Minor factor = 1, No factor = 0)

4. Signals, tugs and pilotage services in the port can best be described as:

a) Excellent	2
b) Good	5
c) Average	3
d) Poor	3

*Critical factors/scores

5. The number of berths in the entire Lagos port Systems is:

a) Adequate for present traffic demand	☐	5
b) Not adequate for present traffic demand	☐	6
c) Adequate for present demand but not adequate for the future	☐	4

6. The number of Gantry Cranes and Fork lifts assigned to a berth are:

a) More than adequate at present	☐	2
b) Adequate at present	☐	3
c) Not adequate	☐	10

7. The capacity of the receiving warehouses (transit sheds) are:

a) More than adequate for the present cargo traffic	☐	3
b) Just adequate	☐	5
c) Less than adequate	☐	7

8. Cargo handling and stacking in the warehouses (transit sheds) can best be described as:

a) Orderly	☐	5
b) Average	☐	4
c) Disorderly	☐	6

9. Import cargo clearing process in the port takes an average of:

a) 1 day	☐	--
b) 2 days	☐	1
c) 3 days	☐	2
d) 4 days	☐	4
e) 5 days	☐	3
f) 6 days	☐	1
g) 7 days	☐	3
h) 8-14 days	☐	--
i) More than 14 days	☐	1

10. The present custom cargo clearing process is:

a) Simple and does not need a change	☐	5
b) Complicated and needs a change	☐	10

11. The number of supervisory and clerical staff in a warehouse (Transit shed) are:

a) More than adequate ______ ☐ 1

b) Adequate ______ ☐ 10

c) Less than adequate ______ ☐ 5

12. Cargo movement out of the port is delayed due to the fact that insufficient railroad cars are allocated to port operations:

a) True ______ ☐ 4

b) False ______ ☐ 9

c) Other ______ ☐ 2

13. Containerized import goods move through the port faster than general import cargo:

a) Yes ______ ☐ 5

b) No ______ ☐ 10

14. Containers are returned to the owners:

a) On time ______ ☐ 7

b) Late ______ ☐ 8

c) Abandoned within the port area ______ ☐ 1

15. Cargo damage in the port is principally caused by one of the following:

a) Pilferage (and theft) ______ ☐ 6

b) Poor storage ______ ☐ 4

c) Bad weather ______ ☐ 2

d) Handling ______ ☐ 3

16. Longshoremen or dockers should be handled best by:

a) Contractors ______ ☐ 7

b) Nigerian Port Authority ______ ☐ 6

17. The Tin Can port extension reduced ship cargo delay by:

a) 100% ______ ☐ --

b) 80% ______ ☐ --

c) 60% ______ ☐ 8

d) 40% ______ ☐ 1

e) 20% ______ ☐ 4

f) 10% ______ ☐ 2

18. What other major problems do you encounter in the day-to-day operations of the port subsystem (i.e. you Department or Section):

a) Poor shipper information (6)

b) Difficulty of cargo tracing (4)

c) High user charges (3)

d) ______

e) ______

19. What future problems do you anticipate in Lagos port complex:

a) Intolerable cargo delay by 1980 (5)

b) Excessive pilferagle and cargo delay (6)

c) High berth occupancy (4)

d) Increase in cargo insurance rates (3)

20. How do you rate internal communication systems (i.e. radio, telephone, etc.) within the port complex.

a) Very efficient ______ ☐ --

b) Efficient ______ ☐ --

c) Good ______ ☐ 5

d) Fair ______ ☐ 4

e) Poor ______ ☐ 4

21. Are you prepared to direct your shipments to the ports of Warri and Koko if these ports offer quicker cargo clearning facilities than Lagos.

Yes ______ ☐ 1

No ______ ☐ 16

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CHAPTER VII

ALTERNATIVES AND RECOMMENDATIONS

Three major alternatives have been identified for detailed evaluation:

(i) Do nothing

(ii) Development of the ports of Warri, Koko, Burutu and Port Harcourt; with the hope that these ports will significantly divert ship and cargo traffic from the port of Lagos.

(iii) Improvement of the quality of service offered by the port of Lagos by implementation of the results of this research.

In selecting these alternatives the author was searching for long term solutions to the problems of the port of Lagos. Heavy investment in floating cranes and utilization of roll-on roll-off ships may provide temporary reduction in ship and cargo delay (1). Alternatives in this category were not considered.

The Do Nothing alternative is not a functional solution to a major national problem (2). Average ship waiting time in the queue during 1978 was 215 hours (i.e. 9 days) while service time at berth was 199 hours (i.e. 8.3 days). This means that the total delay in the port system averages 416 hours (i.e. 17.5 days) including transit time. The demurage and service costs associated with these delays are:

Demurage cost per ship	=$105 x 215	=	$22,575
Berthing cost per ship	=$200 x 199	=	$39,800
Total cost of ship service			$62,375

Cumulative annual cost = \$62, 375 x 5000

= \$311,875,000.

where \$105.00 = the demurage cost per ship hour

\$200.00 = the berthing cost per ship hour

5000 = the number of ships which entered the port of Lagos in 1978.

As a result, a do nothing alternative will not be in the interest of national economy. This annual service cost represents 1% of the GNP (3) of Nigeria. When other costs of port congestion such as the lag in the industrial and construction sectors are considered the social cost of port congestion can be tremendous. Port congestion reduces employment opportunities by creating a downward multiplier on economic activities. In developing countries inflationary pressures can be brought about by the increased cost of imported goods. Hence a 'Do nothing alternative' is not in the interest of balanced economic growth and development.

Alternative (ii) should be considered in light of the spatial distribution of Nigeria's ocean ports. Table (7-1) illustrates the relative distance between Lagos and any other ports. Port Harcourt the country's second largest general cargo port is 315 nautical miles from Lagos. This means 13 hours of sailing time for a ship making a maximum speed of 24 knots. Hence the ports of Port Harcourt and Lagos do not serve the same geographic market. This means that even if Port Harcourt offers a better quality of service, Lagos based shippers will not consign their cargo through that port. The third largest general cargo port is located at Calabar which is even further than Port Harcourt (394 nautical

Table (7-1). TABLE OF DISTANCES PORT TO PORT (NAUTICAL MILES)

	Escravos Lt. Ho*	Forcados*	Burutu*	Warri*	Koko*	Sapele*	Akassa	Bonny	Degema	Port Harcourt	Opobo	Calabar
LAGOS	126	153	158	184	171	192	221	288	330	315	315	394
°Eacravos Lt. Ho.		36	40	46	48	69	119	186	228	213	213	292
*Forcados			5	27	59	80	149	216	258	243	243	322
*Burutu				32	64	85	154	221	263	248	248	327
*Warri					86	107	175	242	284	269	269	348
*Koko						21	167	234	276	261	261	340
*Sapele							188	255	297	282	282	361
Akassa								83	125	109	109	190
Bonny									42	27	57	136
Degema										69	99	178
Port Harcourt											84	163
Opobo												101
Calabar												

*Distances assume a crossing of Escravos Bar when a seaward voyage is undertaken.

Source: Nigerian Port Authority: Handbook 1976. Nigerian Port Authority 26/28 Marina, Lagos.

miles). The same argument as in Port Harcourt applies to the diversion of Lagos traffic to Calabar.

Apart from the ports of Warri and Koko the rest of the ports in figure (7-1) are specialized bulk ports. The ports of Warri and Koko are the nearest general cargo ports lying 184 and 171 nautical miles from Lagos respectively. Even these ports involve an additional 7-8 hours of sailing time from Lagos. This implies increased freight costs for Lagos-based shippers. It is obvious that shippers will be unwilling to absorb this additional cost of cargo diversion. A number of geographical and operational inadequacies also disqualify Warri and Koko ports as alternates for the port of Lagos:

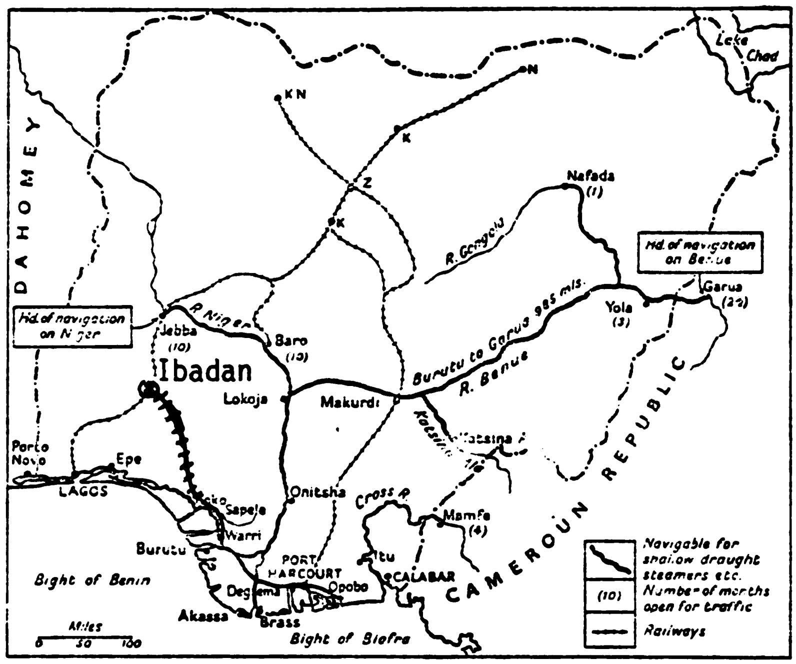
- Warri and Koko ports are inland river ports with an approach channel that is subject to seasonal draught variations. At high water the draught rises to 25', and drops to 15' at low water (4). Hence year round navigation for all classes of general cargo ships is not possible at reasonable cost.
- The channel length of 35 nautical miles (5) from the Atlantic coast to Warri and Koko would require an annual dredging cost of over $16 million.
- Warri port has a berthing capacity for six general cargo ships while Koko port has four berths (7). These facilities are grossly inadequate to receive ships diverted from the port of Lagos.

- The port of Warri and Koko are not integrated into the national rail network system. This means that movement of heavy and bulk cargo will be difficult. As shown in figure (7-1) a total of 150 miles of rail track will be required to connect these ports to Ibadan, which would require a capital outlay of $50,000,000 (8).
- The results of the logistical operations survey indicate that only one out of every sixteen Lagos-based shippers would be willing to consign cargo through the ports of Warri, Koko and Port Harcourt.

In general, the author is of the opinion that the ports of Warri and Koko should not be considered as alternates to the port of Lagos. These ports serve a different geographical market, and deserve development of their own but not as alternates to the port of Lagos.

Alternative (iii) involves the implementation of results of the simulation and the optimization programs. As shown in tables (6.7) and (6.11) case 3 is the most viable combination of port resources for servicing short term demand while case 6 applies to optimum long term port investment requirements.

Figure (7-1). INTEGRATION OF THE PORTS OF WARRI AND KOKO NATIONAL RAIL NETWORK



Source: W. A. Perkins and J. Stembridge: Nigeria: A Descriptive Geography. London University Press, Ibadan, 1962.

As shown in table (7-2) the cost reductions which will be achieved if the results of this research are implemented are compared with the present operational costs of the port of Lagos. The implementation of the optimum combination of investments as determined from case 3 in table (6.8) results in an annual cost savings of $191,224,000.00. This figure represents a 61% reduction when compared with the status quo or do nothing. The above cost savings is the aggregate result of the addition of 5 new berths and extra annual investment in equipment, labor, warehouses, and other logistical subsystem defined in Chapter 3. As shown by the optimization results, the implementation of the above alternative requires an annual investment of $194,025,418. This figure appears high but when compared with the <u>tangible</u> savings of $191,224,000 a benefit to cost ratio of .99 is obtained.

There are also intangible benefits associated with an efficient port operation; particularly in a developing country where the economy is highly import dependent for producer goods. An upward multiplier on the economy is created by increased cargo thoroughput. This situation results in an increase in employment due to higher levels of industrial, agricultural, construction and transportation activities. When these secondary impacts are considered the benefit to cost ratio obtained above will be understating the economic value of total benefits to the nation. Hence the simulation and optimization alternative should be implemented. The details showing the optimum level of improvement required in logistical subsystems are specified in tables (6-8) and (6-11).

Table (7.2). COST EFFECTIVENESS OF ALTERNATIVES.

Alternative	Queue Waiting Time hours	Demurage Cost per hour ($)	Total* Annual Cost of Demurage ($)	Ship Berthing Time (hours)	Ship Berthing Time Cost per hour	Total* Annual Cost of Ship Berthing Time	Total Annual Cost of Alternative	Annual Cost Savings U.S. $
(i) Status Quo	215	105	112,875,000	199	200	199,000,000	311,875,000	BASE
(iii) Simulation and Optimization Case 3	1.24	105	651,000	120	200	120,000,000	120,651,000	191,224,000 i.e. 61% reduction

*Total Annual cost obtained by multiplying the item cost by cumulative number of ships entering the study port in one year.

N = 5000 for 1978.

The results of the logistical operations survey indicate that particular attention should be focused on the following co-ordination efforts:

- Data recording system at the port of Lagos should be revised to generate a more comprehensive set for demand forecasting and delay calculations. The present system of ship and cargo delay recording does not specify idle time at various port subsystems.
- The two independent departments of Port Statistics and Traffic Statistics should be merged to ensure concentration of efforts.
- Further research is required in the area of the cargo clearing process and custom requirements. Computerization can speed up the rate of processing cargo and ships.
- Communication within the port system needs additional investment as indicated by the logistical operations survey. This will facilitate cargo tracing and clearing.
- Regular monitoring of ship and cargo traffic through the port will generate reliable information for the management decision process.

Note that the logistical co-ordination efforts have been stated in broad terms because this research concentrates on traffic analysis, simulation and optimization of physical subsystems. The logistical operations survey was introduced to help in identification of major coordination problems. These problems require in depth study in order to determine specific solutions. The custom cargo clearing process is an example of such a problem. The present process involves a time lag due to the tremendous amount of paper work involved. Shipper information is another area which requires an in depth study. Daily publications should be established to provide information on ship schedules, routes and cargo location. The results of the survey also indicate that the internal communication systems (telephones and radios) within the port are far from adequate. Detailed investigation should be carried out to assess the need and level of improvement required.

The importance of logistical co-ordination efforts cannot be over-emphasized. In the author's opiniom maximum thoroughput and efficiency cannot be achieved unless considerable co-ordination efforts are ensured. The statement above presupposes that an optimum combination of physical subsystems exists. It is also important to update port subsystems in response to changing demand. This process requires accurate data recording and reliable forecasts. When this modification is not carried out the probability of failure is higher and the associated congestion cost can be tremendous. Hence port development should not be considered on an ad hoc basis, but on a long term basis. Continuous traffic and operational survelliance is required in order to identify changing demand and service variables. These changes provide inputs to executive decision process.

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APPENDICES

APPENDIX A

RESEARCH DATA COLLECTION FORMS

Table (4.6-1). PORT INVESTMENT COST BREAKDOWN

Item No.	Name of Logistical Subsystem	Capital Cost	Annual Maintenance Cost	Annual Variable Cost	Service Life (years)	Total Number	Remarks
1	Signal System						
2	Anchorage Facilities						
3	Dredging						
4	Pilotage						
5	Tug						
6	General Cargo Berth (Structures)						
7	Gantry Crane						
8	Handling Equipment (Fork lifts)						
9	Gangs						
10	Transit Warehouse						
11	Land Investment Open Space Storage						

PORT INVESTMENT COST BREAKDOWN (continued)

Item No.	Name of Logistical Subsystem	Capital Cost	Annual Maintenance Cost	Annual Variable Cost	Service Life (years)	Total Number	Remarks
12	Refrigerated Space						
13	Yard Transfer Equipment						
14	Inner Harbour Transportation facilities						
15	Overland Transportation Equipment						

Table (4.6-2). SHIP DELAY (PARAMETERS FOR TIME FUNCTIONS)

Name of Vessel (Ship)	Queing Time (waiting time)-hrs.	PORT SUBSYSTEMS								
		BERTH								
		Pilotage (hrs)	Towage (hrs)	Unloading Time		Loading Time		Total Unloading Time (hrs)	Total Loading Time (hrs)	Internal Ship Movement (if any) mins/hrs.
				Waiting for Labor Crew	Waiting for Gantry Crane	Waiting for Labor Crew	Waiting for Gantry Crane			

Table (4.6-3). PILOTAGE AND TOWAGE VARIABLES

No. Item	Type of Tug	Towing Capacity (Metric tons)	Number of Pilots	Total Number of Tugs	Service Time From anchorage to Berth	Capital Cost of Tug	Variable Cost of Tug (per year)	Priority Service Policy (ship)	REMARKS

Table (4.6-4). SHIP VARIABLES

No.	Name of Ship	Type and Size, i.e. General cargo, Tramp, Bulk, Passenger Express	Draught	Length	Date Berthed	Waiting Time in Queue	Date Departed	Service Time	Import Cargo Type	Export Cargo Type	Remarks

Table (4.6-5). BERTH VARIABLES

Berth No.	Length	Depth	Number of Gantry Cranes	Number of Fork Lifts	Number Longshore-men in a Gang	Container Transfer Facility	Average Ship Loading Service Time	Average Ship un-loading Time	% Berth Occupan-cy	Receiving Warehouse Capacity	Remarks

Table (4.6-6). WAREHOUSING VARIABLES (TRANSIT)

Warehouse No.	Cubic Capacity of Warehouse (cubic ft)	Equipment Inventory (Fork lift)	Total Cargo Tonnage Received (per week)	Total Cargo Tonnage Cleared (per week)	Labor Force in Warehouse	Number of Supervisory Staff	Conveyor Transfer Systems	Remarks

Table (4.4-7). CARGO DELAY (PARAMETERS FOR TIME FUNCTIONS)

Item No.	Berth	Storage Facilities (Warehouse and open spaces)		Time in Storage (Days or hours)	Time in Internal Transfer Facilities (hrs.)	Weight (tons)	Remarks
	Cargo Waiting Time Under Gantry Crane (hrs.)	Date Received	Date Claimed				

MONTHLY SHIP ARRIVAL STATISTICS

Month ______________

Year _______________

DATE	NAMES OF SHIP	TIME OF ARRIVAL	REMARKS
1	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
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	-		
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2	-		
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	-		
	-		
	-		

MONTHLY SHIP ARRIVAL STATISTICS

Month ______________
Year ______________

DATE	NAMES OF SHIP	TIME OF ARRIVAL	REMARKS
3	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
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	-		
	-		
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4	-		
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	-		
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	-		

MONTHLY SHIP ARRIVAL
STATISTICS

Month ______________
Year ______________

DATE	NAMES OF SHIP	TIME OF ARRIVAL	REMARKS
5	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
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	-		
	-		
	-		
	-		

MONTHLY SHIP ARRIVAL
STATISTICS

Month ____________
Year ____________

DATE	NAMES OF SHIP	TIME OF ARRIVAL	REMARKS
7	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
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8	-		
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	-		
	-		
	-		
	-		

MONTHLY SHIP ARRIVAL
STATISTICS

Month ______________
Year ______________

DATE	NAMES OF SHIP	TIMES OF ARRIVAL	REMARKS
9	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
	-		
10	-		
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	-		

LAGOS PORT NIGERIA
TRAFFIC AND LOGISTICAL OPERATIONS SURVEY

1. Rank the operational adequacy of the following port subsystems. Assessing values (See KEY) to any of the subsystems order.

   a) Signal System ________________ ☐
   b) Pilotage and Tugs ________________ ☐
   c) Berths ________________ ☐
   d) Gantry Cranes and Forklifts ________________ ☐
   e) Labor Gangs per berth ________________ ☐
   f) Warehouses (Transit sheds) ________________ ☐
   g) Cargo clearing process ________________ ☐
   h) Yard transfer equipment ________________ ☐

   KEY
   Excellent = 8
   Very Good = 7
   Good = 6
   Above Average = 5
   Average = 4
   Below Average = 3
   Poor = 2
   Bad = 1

2. Rank the major causes of ship delay in the port.

   a) Poor signal, tugs and pilotage ________ ☐
   b) Lack of sufficient number of berths ____ ☐
   c) Lack of sufficient number of Gantry Cranes and Forklifts (loading and unloading ________________ ☐
   d) Insufficient number of receiving warehouses (Transit sheds) ________________ ☐
   e) Labor Problems ________________ ☐

   NB Rank should run from 1 to 5 (i.e. major cause = 5, minor cause = 1)

   KEY
   Major Cause = 5
   Minor Cause = 1
   Not as a Factor = 0

3. Rank the factors which cause cargo delay in the port of Lagos.

   a) Poor handling equipment (Cranes, forklifts, conveyors) ________________ ☐
   b) Lack of container transfer equipment ____ ☐
   c) Poor record keeping in transit sheds ____ ☐
   d) Complicated custom clearing process ____ ☐
   e) Shipper's unwillingness to clear goods on time ________________ ☐

   NB Ranks should run from 1 to 5 (major factor = 5, minor factor = 1)

   KEY
   Major Cause = 5
   Minor Cause = 1
   No Factor = 0

4. Signals, tugs and pilotage services in the port can best be described as:

   a) Excellent ________________ ☐
   b) Good ________________ ☐
   c) Average ________________ ☐
   d) Poor ________________ ☐

5. The number of berths in the entire Lagos port System is:

   a) Adequate for present traffic demand ____________ ☐

   b) Not adequate for present traffic demand ________ ☐

   c) Adequate for present demand but not adequate for the future ______________________________ ☐

6. The number of Gantry Cranes and Forklifts assigned to a berth are:

   a) More than adequate at present ________________ ☐

   b) Adequate at present __________________________ ☐

   c) Not adequate ______________________________ ☐

7. The capacity of the receiving warehouses (transit sheds) are:

   a) More than adequate for the present cargo traffic ☐

   b) Just adequate ______________________________ ☐

   c) Less than adequate __________________________ ☐

8. Cargo handling and stacking in the warehouses (transit sheds) can best be described as:

   a) Orderly __________________________________ ☐

   b) Average __________________________________ ☐

   c) Disorderly ________________________________ ☐

9. Import cargo clearing process in the port takes an average of:

   a) 1 day ___________________________________ ☐

   b) 2 days __________________________________ ☐

   c) 3 days __________________________________ ☐

   d) 4 days __________________________________ ☐

   e) 5 days __________________________________ ☐

   f) 6 days __________________________________ ☐

   g) 7 days __________________________________ ☐

   h) 8-14 days ________________________________ ☐

   i) More than 14 days __________________________ ☐

10. The present custom cargo clearing process is:

   a) Simple and does not need a change _____________ ☐

   b) Complicated and needs a change ______________ ☐

11. The number of supervisory and clerical staff in a warehouse (Transit shed) are:

    a) More than adequate ______ ☐

    b) Adequate ______ ☐

    c) Less than adequate ______ ☐

12. Cargo movement out of the port is delayed due to the fact that insufficient railroad cars are allocated to port operations:

    a) True ______ ☐

    b) False ______ ☐

    c) Other ______ ☐

13. Containerized import goods move through the port faster than general import cargo:

    a) Yes ______ ☐

    b) No ______ ☐

14. Containers are returned to the owners:

    a) On time ______ ☐

    b) Late ______ ☐

    c) Abandoned within the port area ______ ☐

15. Cargo damage in the port is principally caused by one of the following:

    a) Pilferage (and theft) ______ ☐

    b) Poor storage ______ ☐

    c) Bad weather ______ ☐

    d) Handling ______ ☐

16. Longshoremen or dockers should be handled best by:

    a) Contractors ______ ☐

    b) Nigerian Port Authority ______ ☐

17. The Tin Can port extension reduced ship and cargo delay by:

    a) 100% ______ ☐

    b) 80% ______ ☐

    c) 60% ______ ☐

    d) 40% ______ ☐

    e) 20% ______ ☐

    f) 10% ______ ☐

18. What other major problems do you encounter in the day-to-day operations of the port subsystem (i.e. your Department or Section):

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

e) ______________________________

19. What future problems do you anticipate in Lagos port complex:

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

20. How do you rate internal communication systems (i.e. radio, telephones, etc.) within the port complex:

a) Very efficient ______________ ☐

b) Efficient ______________ ☐

c) Good ______________ ☐

d) Fair ______________ ☐

e) Poor ______________ ☐

APPENDIX B

COMPUTER OUTPUT OF THE LAGOS PORT SIMULATION MODEL DEVELOPED IN THIS RESEARCH

Sample of the computer output simulating existing ship service conditions at the port of Lagos. Note that only 150 arrivals and service are shown on the attached printout. Subsequent arrivals and service follow the same format. A total of 500 ship arrivals were simulated.

RANDOM NUMBERS INDICATING SHIP ARRIVALS AND SERVICE TIMES

ARRIVALS	SERVICE	SERIAL NUMBER
2,4793463	15,4155893	1
4,4200469	1,8116979	2
1,7273909	,0322135	3
,9217140	1,8706691	4
3,3379607	2,4735332	5
,4074403	9,1433120	6
2,4089160	,5324835	7
,9249192	4,9679922	8
,2491327	23,8133936	9
11,0854036	6,0707313	10
7,7867265	1,2224367	11
,4000361	10,1786509	12
4,8821635	3,9902176	13
,0542239	1,9335733	14
4,1392427	14,5599591	15
,9757569	4,5101066	16
6,6666002	11,1668628	17
1,9614380	2,5896555	18
5,8695254	13,7188459	19
2,5858966	1,2063168	20
6,2582865	3,1993933	21
2,8255552	3,0353846	22
1,7491765	1,3730780	23
4,1206220	4,5872299	24
1,6762529	3,5040275	25
7,2816231	1,2095630	26
5,0967714	,8495922	27
5,3506052	5,8092281	28
7,4463341	2,3009917	29
,8331192	1,6932403	30
1,3580822	,5033018	31
1,0713823	5,6233371	32
3,0831460	3,6612409	33
,5801828	2,5052962	34
,3526687	9,7889362	35
3,5384055	6,5686757	36
2,9301307	,0817365	37
,2121287	15,7803994	38
1,5709493	2,5137476	39
2,6482046	11,6573193	40
,2269983	4,4010154	41
6,8195965	4,3530962	42
,3706861	7,8669805	43
2,5407207	1,6770104	44
1,7217623	1,3621442	45
2,7938071	8,3664228	46
,4220794	3,7240900	47
2,8687273	6,9136454	48
3,4593209	3,6278663	49
3,9441938	4,2340155	50
1,0823925	3,4073187	51
5,9637819	8,2678236	52
,1245113	11,6804961	53
5,5078196	9,8732560	54
3,3336898	3,5699665	55
,6416521	1,0451929	56
1,0201289	10,0168004	57
,3702678	1,2671157	58
4,7880371	15,7471422	59
2,1925312	4,4125891	60

ARRIVALS	SERVICE	SERIAL NUMBER
3,7427141	2,3067994	61
2,9520994	3,6164006	62
6,2346387	2,4883898	63
4,1292132	10,9126078	64
,3952609	,3986342	65
4,1363914	12,7369681	66
4,1353596	3,6257711	67
2,1069652	15,6367702	68
9,0092977	12,8333524	69
3,9736557	1,9909309	70
4,6520796	12,4291131	71
5,1749947	2,2113852	72
4,6204606	3,1501277	73
2,2366924	10,3717198	74
1,1979948	1,7854813	75
3,4415400	,2516262	76
,5996268	,3533489	77
,2555001	6,9002146	78
2,1555294	3,4724748	79
,3206901	2,3881221	80
,1057565	1,0528843	81
7,2055184	6,0888436	82
2,7878173	14,9390648	83
8,9251432	4,6528345	84
2,1297696	2,1056043	85
,7743369	4,5604406	86
2,8203468	2,7419902	87
1,6832208	5,7009796	88
,6046786	4,7369962	89
2,1233960	4,7639174	90
,8987652	9,7299335	91
,4571685	3,6057152	92
1,0426053	2,4385132	93
,5694725	1,5680865	94
4,8354053	1,8402006	95
11,3701895	,0156565	96
,9890456	,2738379	97
,7030411	3,8114384	98
,3259617	3,9455845	99
2,5485196	7,0567657	100
,1335402	,3521794	101
,2246926	2,7006369	102
1,6661265	8,1363138	103
1,4807598	7,2976421	104
1,5292644	2,9639793	105
,3648248	4,1772004	106
2,7046938	5,4435455	107
3,7226739	1,1503424	108
7,9276403	2,2066182	109
,2703594	25,0156797	110
,9345483	3,0451612	111
3,2535496	1,0618859	112
,4790446	8,1384001	113
8,8485179	,6747065	114
1,5658179	,1228492	115
3,2355203	,1785304	116
,9247001	4,4626421	117
,5227503	4,6725427	118
,6585418	8,4848879	119
1,1032951	2,1940717	120
,2016314	,3196320	121

ARRIVALS	SERVICE	SERIAL NUMBER
,6860568	,7589383	122
4,8861650	1,5207500	123
1,0861954	1,5252515	124
,1571706	,3202450	125
2,8851787	9,0218842	126
1.0514574	6,0557744	127
2,1119007	12,4880021	128
4,3834098	1,9663465	129
1.7106545	4,5471475	130
1.1180498	2,7577317	131
2,3960254	,2191160	132
.2400359	3,8342163	133
3.0291096	5,3926040	134
8,4872574	4,8130044	135
8,1373710	12,1439740	136
2.8115692	6,6938117	137
1,1486991	10,5889792	138
1,4223522	1,2062362	139
2,5843623	2,8100390	140
5,4372869	2,0640746	141
1,0893947	4,2784052	142
1,2824763	2,1011122	143
8,0219547	3,7520017	144
2,8812041	2,4484762	145
2,3890537	1,5318755	146
,9513121	1,1334959	147
1,8398245	21,1145455	148
2,1895806	,1706838	149
1,1310052	2,9857848	150
1,0356840	5,1800177	151
[illegible]	[illegible]	[illegible]

SERVICE TIME (hrs.)	ARRIVAL TIME (hrs.)	SHIP SERIAL NUMBER	AVERAGE BERTHING RATE (hrs./ship)	QUE LENGTH (ships)
15,4155893	2,4793463	1	15,4155893	5,0000000
17,2272872	6,8893931	2	8,0136436	7,0000000
17,2895007	8,6167841	3	5,7531669	6,0000000
19,1301698	9,5384981	4	4,7825425	5,0000000
21,6037030	12,8764588	5	4,3207406	4,0000000
30,7470151	13,2838990	6	5,1245025	4,0000000
31,2794985	15,7828150	7	4,4684998	3,0000000
36,2474907	16,7077342	8	4,5309363	4,0000000
60,0608843	16,9568669	9	6,6734316	9,0000000
66,1316155	28,0422725	10	6,6131616	10,0000000
67,3540522	35,8289990	11	6,1230957	9,0000000
77,5327031	36,2290351	12	6,4610586	11,0000000
81,5229207	41,1111986	13	6,2709939	12,0000000
83,4564940	41,1654225	14	5,9611781	11,0000000
98,0164531	45,3052653	15	6,5344302	13,0000000
102,5265596	46,2810222	16	6,4079100	12,0000000
113,6934225	52,9476224	17	6,0878484	18,0000000
116,2830700	54,9090605	18	6,4601710	18,0000000
130,0015239	60,7785859	19	6,6422065	22,0000000
131,2082406	63,3644825	20	6,5604120	23,0000000
134,4076339	69,6227711	21	6,4003635	23,0000000
137,4430165	72,4483263	22	6,2474099	23,0000000
138,8160965	74,1975028	23	6,0354825	24,0000000
143,4033264	78,3181249	24	5,9751386	24,0000000
146,9073539	79,9943777	25	5,8762942	24,0000000
148,1265169	87,2762008	26	5,6968045	23,0000000
148,9665091	92,3729722	27	5,5172781	23,0000000
154,7757372	97,7235774	28	5,5277049	23,0000000

SERVICE TIME (hrs.)	ARRIVAL TIME (hrs.)	SHIP SERIAL NUMBER	AVERAGE BERTHING RATE (hrs./ship)	QUE LENGTH (ships)
157.0767269	105.1699115	29	5.4164389	24.0000000
158.7695692	106.0030308	30	5.2923323	23.0000000
159.2732710	107.3611130	31	5.1378475	22.0000000
164.5960081	108.4324953	32	5.1530190	23.0000000
168.5576490	111.4356413	33	5.1078136	25.0000000
171.0631452	112.0158249	34	5.0312690	24.0000000
180.6820814	112.3664928	35	5.1672023	27.0000000
187.4237572	115.9068982	36	5.2861321	27.0000000
187.5024586	118.8370289	37	5.0676350	26.0000000
203.2822920	119.0491577	38	5.3495498	30.0000000
205.7956426	120.6201078	39	5.2768369	29.0000000
217.4535569	123.2683116	40	5.4363490	30.0000000
221.8545753	123.4953090	41	5.4110970	30.0000000
226.2080715	130.3149064	42	5.3859065	30.0000000
234.3756540	130.6855928	43	5.4436059	32.0000000
235.7520623	133.2263132	44	5.3580014	32.0000000
237.1142065	134.9480755	45	5.2692046	33.0000000
245.4806293	137.7418846	46	5.3365354	35.0000000
249.2047194	138.1639040	47	5.3022281	36.0000000
256.1283647	141.0326913	48	5.3357993	35.0000000
259.7462311	144.4920122	49	5.3009435	35.0000000
263.9802465	148.4362068	50	5.2796049	37.0000000
267.3875682	149.4885985	51	5.2428934	38.0000000
275.6558849	155.4523804	52	5.3010652	42.0000000
287.3356820	155.5768917	53	5.4214318	43.0000000
297.2191420	161.0847113	54	5.5038730	52.0000000
300.7791074	164.4186011	55	5.4687110	52.0000000
301.8242033	165.0604932	56	5.3897196	51.0000000
311.8411017	166.0705828	57	5.4708965	53.0000000
313.1082165	166.4408498	58	5.3984175	53.0000000
328.8551567	171.2288869	59	5.5738196	56.0000000
333.2679478	173.4214180	60	5.5544658	59.0000000
335.5747472	177.1641327	61	5.5012254	61.0000000
339.1911479	180.1102315	62	5.4708250	61.0000000
341.6795377	186.3508703	63	5.4234847	62.0000000
352.5921455	190.4800835	64	5.5092523	66.0000000
352.9907747	190.8753443	65	5.4306274	65.0000000
365.7277473	195.0117357	66	5.5413295	68.0000000
369.3535109	199.1470954	67	5.5127391	68.0000000
374.9902891	201.2540606	68	5.6616219	72.0000000
387.8736425	210.2633983	69	5.7655600	74.0000000
390.8145724	214.2370148	70	5.7116367	74.0000000
412.2436855	218.8890938	71	5.8062491	80.0000000
414.4550737	224.0640883	72	5.7563204	79.0000000
417.6051944	228.6745489	73	5.7206192	79.0000000
427.9765132	230.9112413	74	5.7834719	84.0000000
429.7623965	232.1092361	75	5.7301653	85.0000000
430.0140277	235.5507761	76	5.6580793	84.0000000
430.3672746	236.1504020	77	5.5891867	83.0000000
437.2675871	236.4059030	78	5.6059947	83.0000000
440.7406639	238.5614324	79	5.5789882	84.0000000
443.1281869	238.8821228	80	5.5391023	83.0000000
444.1810734	238.9878790	81	5.4837169	83.0000000
450.2695139	246.1933974	82	5.4910965	87.0000000
465.2085707	248.9812147	83	5.6049275	89.0000000
469.8616132	257.8963979	84	5.5935930	88.0000000
471.9674176	260.8161275	85	5.5525579	89.0000000
476.5278531	260.7904044	86	5.5410216	88.0000000
479.2696483	263.6108112	87	5.5088488	87.0000000
484.9708279	265.2940320	88	5.5110321	86.0000000
489.7076241	265.8987108	89	5.5023351	85.0000000

SERVICE TIME (hrs.)	ARRIVAL TIME (hrs.)	SHIP SERIAL NUMBER	AVERAGE BERTHING RATE (hrs./ship)	QUE LENGTH (ships)
494.4717415	268.0121066	90	5.4941305	87.0000000
504.2016750	268.9108718	91	5.5406777	86.0000000
507.8073912	269.3680403	92	5.5196455	85.0000000
510.2455024	270.4106456	93	5.4865151	84.0000000
511.8135910	270.9801181	94	5.4448297	83.0000000
513.6541916	275.8155235	95	5.4068862	83.0000000
513.6696470	287.1857130	96	5.3507276	82.0000000
513.9436830	288.1747287	97	5.2983885	81.0000000
517.7551274	288.8777997	98	5.2832155	81.0000000
521.7007079	289.1937014	99	5.2697041	82.0000000
528.7574706	291.7422810	100	5.2875747	84.0000000
529.1096530	291.8758211	101	5.2387094	83.0000000
531.8102899	292.1005137	102	5.2138264	83.0000000
539.9460037	293.7660402	103	5.2422000	83.0000000
547.2442458	295.2474000	104	5.2619639	86.0000000
550.2082221	296.7666044	105	5.2400783	86.0000000
554.3054224	297.1314892	106	5.2300512	87.0000000
559.8225719	299.8361830	107	5.2320465	87.0000000
560.9792113	303.5488560	108	5.1942529	86.0000000
563.1855325	311.4764972	109	5.1668434	85.0000000
588.2016113	311.7460567	110	5.3472874	99.0000000
591.2467744	312.6814050	111	5.3265475	98.0000000
592.3086574	315.9349546	112	5.2884702	97.0000000
600.4471565	316.4139992	113	5.3136908	99.0000000
601.1217670	325.2625172	114	5.2729979	98.0000000
601.2241112	326.8283351	115	5.2282140	97.0000000
601.4731445	330.0638254	116	5.1846823	96.0000000
605.8057805	330.9785255	117	5.1785110	98.0000000
610.5581273	331.4913058	118	5.1742231	99.0000000
619.0432172	332.1502477	119	5.2020438	99.0000000
621.2374809	333.3335428	120	5.1769774	98.0000000
621.3565219	333.5353742	121	5.1368341	97.0000000
622.3155592	334.1914300	122	5.1009497	96.0000000
623.8360091	339.0775959	123	5.0718424	95.0000000
625.3616616	340.1637913	124	5.0432408	94.0000000
625.6721059	340.3204019	125	5.0054568	93.0000000
634.7035818	343.2001406	126	5.0373333	92.0000000
640.7597602	344.2575980	127	5.0453525	93.0000000
653.2477603	346.3694987	128	5.1034982	94.0000000
655.2141116	350.6724085	129	5.0791792	94.0000000
659.7612614	352.3835030	130	5.0750866	95.0000000
662.5126941	353.5016128	131	5.0573969	94.0000000
662.7381001	355.8976382	132	5.0207432	93.0000000
666.5722214	356.1370741	133	5.0118220	92.0000000
671.9645223	359.1667837	134	5.0146636	93.0000000
676.7775347	367.0540411	135	5.0131699	94.0000000
688.9215007	375.7914121	136	5.0656023	94.0000000
695.6157113	378.6029814	137	5.0774870	98.0000000
706.2046975	379.7516805	138	5.1174253	101.0000000
707.4205337	381.1740326	139	5.0892873	101.0000000
710.2705727	383.6783940	140	5.0730069	101.0000000
712.2450473	389.1156818	141	5.0516670	101.0000000
716.5634545	390.1250765	142	5.0462215	100.0000000
718.6645643	391.4075529	143	5.0256263	99.0000000
722.4165605	399.4295075	144	5.0167817	99.0000000
724.8650427	402.2307118	145	4.9990693	99.0000000
726.3465112	404.5397053	146	4.9753214	99.0000000
727.5304141	405.4910773	147	4.9491865	98.0000000
748.6445596	407.3309018	148	5.0584119	104.0000000
748.8256434	409.4404825	149	5.0256083	103.0000000
751.8014221	410.5714877	150	5.0120095	103.0000000

APPENDIX C

SYNOPSIS OF UNCTAD PORT SIMULATION MODEL

SYNOPSIS OF UNCTAD PORT SIMULATION MODEL

FUNCTIONS OF PORT SIMULATION PROGRAMS AND ITS SATELLITE PROGRAMS

CRITERIA: The principal criterion in a port simulation model is time requirements in the entire port system both for ship and cargo. Time is a major cost function in port operations.

PORT SIMULATION PROGRAM COMPONENTS: The UNCTAD port simulation model can be broken up into five phases:

Satellite Programs

(A) (i) Date Accumulation Program

(ii) Forecasting Program

(iii) Traffic Generator Program

(B) (iv) Main Simulation Program

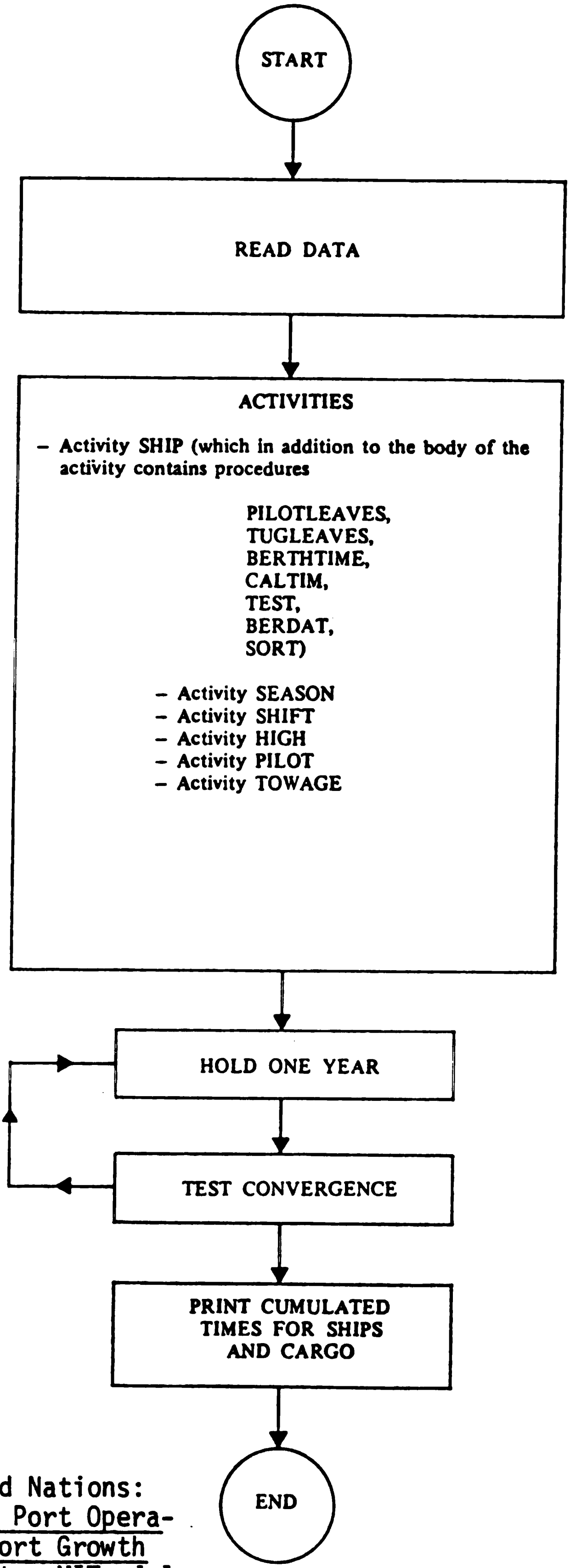
(v) Output Program

The five phases of the simulation program enable greater flexibility to be achieved. The split programs also enable computers with less than 32K words core memory to handle each phase of the simulation rather than one large program.

The attached flow chart illustrates the UNCTAD Port Simulation model. The various programs are briefly discussed below:

(1) DATA ACCUMULATION PROGRAM: This program reads all the punched cards containing data related to ship characteristics (e.g., arrival time, type, amount and nature of cargo). After reading such information the program produces a frequency list. This frequency list is coded as (FRELIS).

Plan of the simulation programme



Source: United Nations: <u>Improvement of Port Operations for Seaport Growth and Development</u>. MIT, July 1969.

FRELIS contains eight different types of information on ships and cargo:

(a) Ship type (e.g., liners, tramp, bulk, etc.)

(b) Ship tonnage (gross registered tons)

(c) Type of import carried by ships (e.g., specialized cargo, refrigerated cargo, not specialized)

(d) Type of export carried by ship (categorized as in c)

(e) Volume of export cargo carried by the ship (in tonnage groups)

(f) Volume of import cargo carried by the ship (in tonnage groups)

(g) Fraction of bulk cargo carried by ship in relation to total cargo (exports)

(h) Fraction of bulk cargo carried by ship in relation to total cargo (imports)

(2) FORECASTING PROGRAM

The Data Accumulation Program prints out a frequency list based on the present port situation. The forecasting program creates a new frequency list for future port situations. This new frequency list or FRELIS is based on the present port conditions and trade forecasts of ship and cargo traffic through the port system. It is important at this stage to note that the forecasting program does not predict future ship and cargo traffic trends. These forecasts are obtained from trade statistics of the economic port environment. The forecasting program above is limited to the reproduction of a future frequency list given future ship and cargo flow forecast. The new FRELIS predicts what new information on ships and cargo are likely to occur in the future [see items (a). . . .(h) in the Data Accumulation Program above].

(3) THE TRAFFIC GENERATOR

The traffic generator translates the data contained in the frequency lists into a traffic pattern (present or future). In situations where ports have seasonal variations a traffic pattern will be required for each major season. This implies that a new frequency list for each season will be obtained from the forecasting program mentioned above. In summary, the traffic generator performs the following functions:

* Determines the arrival times for ships on the basis of time between them.
* It predicts the interarrival time by making use of observed ship arrival distribution and applying average time intervals.
* This program also incorporates ship and cargo priority policies into the frequency list (i.e. FRELIS).
* The program records all the generated parameters for each ship and repeats the entire process for the next arrival.

The traffic generator creates a traffic pattern which provides an input to the main Simulation Program.

(4) SIMULATION PROGRAM

The main simulation program is made up of a master program and several activities. The master program controls the sequence of the activities. Each activity contains several procedures for handling specific problems. The input to the program are as follows:

* traffic pattern obtained from the traffic generator
* list of technical standards assiged to the various port subsystems (e.g., number of pilots, tugs, cargo handling area, stations, queing area, out-of-port transportation)

The program (SIMULA) sets up a time axis. At time '0' the program activities start with each activity marking a new event on the time axis. All events are simulated in sequence of occurrence. In order to highlight the design the various activities and procedures are briefly discussed (see Flow Chart II).

1. Procedure PITUGALL: Allocates pilots and tugs when necessary.
2. Procedure Nounites: Determines number of loading and unloading units available.
3. Activity Ships: Controls ship's movement in the port system.
    3.1 Procedure PILOTLEAVES AND TUGLEAVES: separates the ship from pilot and tugs when necessary.
    3.2 Procedure CALTIM: records cumulative time for different cargo and ships for all seasons.
    3.3 Procedure Berthtime: computes unloading and loading time for each ship.
    3.4 Procedure Test: considers alternative loading and unloading possibilities if the first unit is not acceptable.
    3.5 Procedure BERDAT: indicates the % of berth occupancy and identifies vacant berth.
    3.6 Procedure SORT: queues ships and sorts them according to priority policy of the seaport.
4. ACTIVITY SEASON: makes provision for seasonal traffic and physical variations.
5. ACTIVITY SHIFT: keeps record of the time left of the present shift and determines the number of equipment available for the next shift.
6. ACTIVITY HIGH: Records the water depth and tides in various

sections of the port.

7. ACTIVITY PILOT AND TOWAGE: Keeps account of the number of pilots and tugs in the system and matches these with ship when necessary.

It is important to note that all the activities and procedures mentioned above are for a generalized port situation. In specific ports there may not be need for some of the activities. After the simulation of one-year operations the program performs a test of convergence. The cumulative time consumed by a ship in the simulated n^{th} year is compared to the time consumed by a similar ship in $(n + 1)^{th}$ year. This is only true when successive years have similar traffic flow patterns. When adequate convergence is established the computer prints out the results. The printout contains the time requirements for the entire port and also specific ship and cargo time at various port subsystems.

APPENDIX D

BACKGROUND OF THE AUTHOR

RESUME OF

SAMUEL KINGSLEY NNAMA

HOME ADDRESS

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OFFICE ADDRESS

Department of Civil Engineering
Michigan State University
East Lansing, MI 48824

PERSONAL

Date of Birth: June 14th, 1945
Place of Birth: Awka, Nigeria
Marital Status: Married

Height: 6'¼"
Weight: 175 lbs.
Health: Excellent

CAREER OBJECTIVE

Permanent: Pursue a consulting career in civil engineering and areas related to transportation planning and logistics distribution systems (design and management).

EDUCATION

Ph.D. Michigan State University, East Lansing, Michigan.
Major Civil Engineering, Transportation and Highway Engineering

M.S. Michigan State University, East Lansing, Michigan.
Graduation date: June 1977
Major Transportation Planning and Highway Engineering

B.S. University of Nigeria, Nsukka, Nigeria.
Graduation date: June 1973 (2nd class honours upper division).
Major Civil Engineering

EMPLOYMENT EXPERIENCE

Summer 1977 - June 1979 Division of Engineering Research, Faculty of Engineering, Michigan State University.
Title: Graduate Research Assistant (level 2)
Project: Development and Presentation of Short Courses in Transportation Engineering --
(a) Traffic operations course.
(b) Highway capacity course.
(c) Highway safety course.
Participants include State, County and Local traffic engineers in the State of Michigan. The above course is jointly sponsored by The Federal Highway Administration.

Supervisors: Professors James Brogan and William C. Taylor

Winter 1978 - June 1979 Department of Civil Technology, Lansing Community College, Lansing, Michigan.
Title: Part Time Instructor.
Courses: Civil engineering and related courses.

Winter 1977 - Spring 1977 Civil Engineering Department, Michigan State University, East Lansing, Michigan.
Title: Teaching Assistant
Courses: CE 347 Transportation facilities
CE 499 Highway engineering
Supervisor: Professor James Brogan

PROFESSIONAL EXPERIENCE

January 1975 - September 1976 I worked as an executive engineer with the Federal Ministry of Works, Lagos, Nigeria.

December 1974 - July 1973 I was an executive planning engineer with Kano State Ministry of Works in Nigeria.

June 1966 - January 1968 Served as trainee engineer with NNAMA Shipping Lines (Nigerian Limited).

PROFESSIONAL ASSOCIATIONS

(i) Member of the Nigerian Society of Engineers
(ii) Member of the American Society of Transportation Engineers
(iii) Registered Engineer in Nigeria

HOBBIES

Music, Art, Tennis

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