REPUBLIC OF COSTA RICA
MINISTRY OF PUBLIC WORKS AND TRANSPORT
GENERAL DIRECTORATE OF PORT WORKS

FEDERAL REPUBLIC OF GERMANY
GERMAN AGENCY FOR TECHNICAL COOPERATION (GTZ) LTD

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INTEGRATED ATLANTIC COAST PORT STUDY
MASTERPLAN LIMON/MOIN

VOLUME III
FINAL REPORT

JULY 1980

RRI
RHEIN-RUHR INGENIEUR-GES. MBH

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INTEGRATED ATLANTIC COAST PORT STUDY

MASTERPLAN LIMON/MOIN

CLASSIFICATION

Volume I

Acknowledgement
Abbreviations
Literature
Summary Report

Volume II

A. General

1. Order
2. Scope of Services
3. Assignment of Personnel
4. Organization of the Study
   Annex - Minutes of Meeting (Dec 15, 1979)

B. Present Situation on the Atlantic Coast

1. General Description of the Ports of Limôn and Moîn
2. Description of Structural Facilities in the Harbour of Limôn
3. Infrastructure
4. Port Operation and Handling Systems
5. Existing Port Organization
6. Present Situation of Nautics

C. Traffic Analysis and Forecast

1. Traffic Analysis
2. Traffic Forecast

D. Degree of Containerization and Modal Split Road - Rail

1. Trend of World Shipping and Containerization
2. Change of Modal Split Road - Rail

E. Port Operation

1. Introduction
2. Container Handling
3. Ro-ro Handling
4. Break Bulk Cargo Handling at Limôn
5. General Cargo
6. Banana Handling at Moîn
7. Petrol Liquid Bulk at Moîn
8. Chemical Liquid Bulk at Moîn
9. Fertilizer Hanlding at Moîn
10. Equipment
11. Total Port Operation and Cargo Assignment
    Annex E 1 to E 8

Volume III

F. Recommendations of Extension and Development Forecasts of the Ports of Limón and Moín

1. General
2. Rehabilitation and Extension of Ports of Limón and Moín up to the Year 2000 - Case A
3. Development of the Ports of Limón and Moín up to the Year 2000 - Case B
4. Resumee of Advantages and Disadvantages of Case B Port Development Alternatives
5. Future Traffic Connection to the Hinterland
6. Development of Additional Ports on the Atlantic Coast
7. Masterplan Concept for the Ports of Limón and Moín
8. Cost Estimate

G. Future Port Organization

1. General Port Organization System
2. Port Organization in Costa Rica
3. Recommended Operational Procedures

Annex Chapter G 1 to G 11

H. Nautic

1. Introduciton
2. Future Nautical Requirements
3. Passive Radar Reflectors
4. Manoeuvring Spaces
5. Floating Equipment
6. Repair and Maintenance Facilities
7. Radio Communication
8. Mooring Gangs
9. Harbourmaster
10. Costs for Nautical Improvements

I. Oceanographic, Hydrographic and Hydrological Investigations

1. Introduction
2. Wave Conditions and Consequences for the Design of the Harbour
3. Discussion of Oceanographic Surveys
4. Conclusion
5. Literature

J. Possibilities of Water Supply to the Ports of Limón and Moín

1. Introduction
2. Climate
3. Hydrology
4. Geology
5. Hydrogeology
6. Water Quality
7. Conclusions
8. Recommendations

K. Preliminary Structural Design (Case A)

1. Port of Limón - Case A
2. Port of Moín - Case A

L. Cost-Benefit-Analysis

1. Introduction
2. Estimation of Shadow Prices
3. Identifying of Relevant Costs and Benefits
4. Economic Analysis of the Projects
5. Sensivity Analysis
6. Optimum Length of Northern Breakwater at Moín Harbour

Annex Chapter L 1 to L 4

<u>Volume IV</u>

Drawings
Annexes

Abbreviations:

MOPT	Ministerio Obras Públicas y Transportes
JAPDEVA	Junta de Administración Portuaria y de Desarrollo Economico de la Vertiente Atlantica
RECOPE	Refinadora Costarricense de Petroleo, S.A.
OFIPLAN	Oficina de Planificación Nacional y Politica Economica
CODESA	Corporación Costarricense de Desarrollo
FECOSA	Ferrocarril de Costa Rica

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TABLE OF CONTENTS

(Volume III)

Chapter	Page
F. Recommendations of Extension and Development Forecasts of the Ports of Limón and Moín	
1. General	F - 1
2. Rehabilitation and Extension of Ports of Limón and Moín up to the Year 2000 - Case A	F - 2
2.1 General	F - 2
2.2 Port of Limón	F - 2
2.2.1 Rehabilitation of Railway Facilities	F - 2
2.2.2 Rehabilitation of the Approach Roads to the Port	F - 8
2.2.3 Establishment of a Central Workshop	F - 10
2.2.4 Demolishing of Berth No. 1 of Muelle Metâlico	F - 10
2.2.5 Modification of the Muelle 70	F - 12
2.2.6 Allocation of Areas	F - 12
2.2.7 Gate House at the New Port Entrance	F - 12
2.3 Port of Moín	F - 13
2.3.1 Banana Handling Facilities	F - 13
2.3.2 Ro-ro Facility Moín	F - 21
2.3.3 Ship Yard with Slipway	F - 23
2.3.4 Handling Facilities for Petrol and Chemical Liquid Bulk and Fertilizer Bulk at Moín	F - 23
3. Development of the Ports of Limón and Moín up to the Year 2000 - Case B	F - 26
3.1 General	F - 26
3.2 Alternative B - 1 a	F - 27
3.3 Alternative B - 1 b	F - 28
3.4 Alternative B - 2	F - 30
3.5 Alternative B - 3 a	F - 32
3.6 Alternative B - 3 b	F - 33
4. Resumee of Advantages and Disadvantages of Case B Port Development Alternatives	F - 34
5. Future Traffic Connection to the Hinterland	F - 37
5.1 Reailway	F - 37
5.2 Road Connection	F - 38

		Page
6.	Development of Additional Ports on the Atlantic Coast	F - 40
6.1	Introduction	F - 40
6.2	Description of Coastline from the Panamenian to the Nicaraguan Border	F - 40
6.3	Additional Banana Export Harbours	F - 41
6.4	Tanker Terminal Moîn	F - 41
6.5	Development of Fishing Harbours on the Atlantic Coast	F - 42
7.	Masterplan Concept for the Ports of Limôn and Moîn	F - 44
7.1	General	F - 44
7.2	Masterplan Concept of the Port of Limôn	F - 44
7.3	Masterplan Concept of the Port of Moîn	F - 45
8.	Cost Estimate	F - 47

G. Future Port Organization

1.	General Port Organization System	G - 1
1.1	Highly-Developed Countries	G - 1
1.2	Developing Countries	G - 1
1.3	Analysis of Statements	G - 2
2.	Port Organization in Costa Rica	G - 3
2.1	Organization of NPA	G - 3
2.2	Port Authority Limôn / Moîn	G - 4
2.2.1	Organizational Alternatives	G - 5
2.2.2	Recommended Activities of Port Participants	G - 8
2.2.3	Cargo Handling of Third Parties	G - 9
2.2.4	Recommended Organization Chart for the Port Authority	G - 10
2.2.5	Recommended Administrative Procedures	G - 19
2.2.6	Proposals for a New Tariff Structure	G - 21
2.2.7	Necessary Training Programs	G - 21
3.	Recommended Operational Procedures	G - 24
3.1	General Introduction	G - 24
3.2	Operation Pre-Planning	G - 25
3.2.1	Ship's Dispatch Pre-Planning	G - 25
3.2.2	Data required for Operation Pre-Planning	G - 25
3.2.3	Overall Ship's Planning	G - 26
3.2.4	Full Day Planning	G - 26
3.2.5	Shift Planning	G - 26
3.2.6	Recommendations	G - 26
3.3	Operational Procedures for the Container Traffic	G - 28
3.4	Operational Procedures for the Ro-Ro Traffic	G - 29

Page

3.5 Operational Procedured for the General Cargo / Break Bulk Traffic — G - 29

3.5.1 Loading and Discharging — G - 29
3.5.2 Transfer of Cargo between Shed and Quay — G - 30
3.5.3 Landside Receipt of Cargo — G - 30
3.5.4 Landside Delivery of Cargo — G - 30
3.5.5 Handling of Bananas — G - 30

Annex Chapter G 1 to G 11

H. Nautic

1. Introduction — H - 1

2. Future Nautical Requirements — H - 1

2.1 Buoyage System — H - 1
2.2 Navigational Aids — H - 2

2.2.1 Navigational Layout Limón — H - 2
2.2.2 Navigational Layout Moín — H - 4

3. Passive Radar Reflectors — H - 6

4. Manoeuvring Spaces — H - 7

4.1 Limón — H - 7
4.2 Moín — H - 7

5. Floating Equipment — H - 8

5.1 Tugboat Services — H - 8
5.2 Bunker Boats — H - 8
5.3 Pilot Launches — H - 8

6. Repair and Maintenance Facilities — H - 9

7. Radio Communication — H - 9

8. Mooring Gangs — H - 9

9. Harbourmaster — H - 9

10. Costs for Nautical Improvements — H - 10

I. Oceanographic, Hydrographic and Hydrological Investigations

1. Introduction — I - 1

2. Wave Conditions and Consequences for the Design of the Harbour — I - 3

2.1 General Remarks — I - 3
2.2 Deepwater Waves and Refraction — I - 3
2.3 Investigations for an Extension of the Northern Breakwater — I - 5
2.4 Wave Movement at a Third Berth Planned South of the Banana Pier — I - 7

		Page
3.	Discussion of Oceanographic Surveys	I - 11
	3.1 General	I - 11
	3.2 Performance of Measurements	I - 12
	3.3 Tidal Conditions in the Bay of Moín	I - 14
	3.4 Wind Conditions during the Measuring Period and their Influence on the Water Level	I - 15
	3.5 Current Conditions in the Bay of Moín	I - 17
	3.6 Discharge Conditions of Rio Moín	I - 19
	3.7 Salinity and Suspended Load	I - 21
	3.8 Surface Soil Samples in the Harbour Area and the Bay of Moín	I - 23
	3.9 Resumee of Sedimentation Processes in the Port of Moín	I - 24
4.	Conclusion	I - 27
5.	Literature	I - 28

J. Possibilities of Water Supply to the Ports of Limón and Moín

1.	Introduction	J - 1
2.	Climate	J - 2
3.	Hydrology	J - 3
	3.1 Precipitation	J - 3
	3.2 Runoff	J - 4
	3.3 Evapotranspiration	J - 5
4.	Geology	J - 6
5.	Hydrogeology	J - 8
	5.1 Coral Aquifers	J - 8
	5.1.1 Recharge	J - 8
	5.1.2 Discharge	J - 9
	5.2 Banano River Aquifer	J - 12
	5.3 Chirripó and Zent Rivers Aquifer	J - 13
6.	Water Quality	J - 14
7.	Conclusions	J - 16
	7.1 Ground Water Alternative	J - 16
	7.1.1 Coral Aquifers	J - 16
	7.1.2 Banano River Alluvial Aquifer	J - 16
	7.1.3 Chirripó and Zent Rivers Alluvial Aquifer	J - 16
	7.2 Surface Water Alternative	J - 17
8.	Recommendation	J - 18
	8.1 Coral Aquifer	J - 18
	8.1.1 Production Wells and/or Galleries Investigation	J - 18
	8.1.2 Moín Springs	J - 18

	Page
8.2 Alluvial Aquifers	J - 19
8.2.1 Banano River Alluvial Aquifer	J - 19
8.2.2 Chirripó and Zent Rivers Alluvial Aquifer	J - 19

K. Preliminary Structural Design (Case A)

1. Port of Limón - Case A	K - 1
1.1 Pavement and Fencing	K - 1
1.2 Gate House at Western Entrance	K - 1
1.3 Workshop	K - 1
1.3.1 Large Hall for Straddle Carrier	K - 2
1.3.2 Social Area and Store	K - 2
1.3.3 Hall for Forklifts, Trucks and Trailers	K - 2
1.4 Rehabilitation of Muelle 70	K - 3
1.4.1 Fender System	K - 3
1.4.2 T-Beams	K - 3
1.4.3 Rails on Pier	K - 3
1.4.4 Beam Head	K - 4
1.4.5 Arris Protection	K - 4
2. Port of Moín - Case A	K - 5
2.1 Extension of Banana Pier	K - 5
2.2 Railway Connection	K - 5
2.3 Rain Shed on Banana Pier	K - 5
2.4 Water Supply	K - 6
2.5 Stormwater and Sewage	K - 7
2.6 Power Supply and Telecommunication	K - 7
2.6.1 Power Demand	K - 7
2.6.2 Electrical Supply 220 V - 60 Hz	K - 8
2.6.3 Electrical Supply 440 V - 60 Hz	K - 8
2.6.4 Transformer Station	K - 8
2.6.5 Outdoor Lighting	K - 9
2.6.6 Outdoor Installation	K - 9
2.6.7 Telephone System	K - 10
2.7 Pavement and Fencing	K - 10
2.8 Buildings	K - 11
2.9 Shipyard with Berthing Pier for Harbour-owned Boats	K - 12
2.9.1 Slipway	K - 12
2.9.2 Technical Specifications	K - 13
2.9.3 Winch House	K - 14
2.9.4 Repair Hall	K - 14
2.9.5 Berthing Pier	K - 15

Page

L. Cost-Benefit-Analysis

1. Introduction L - 1

2. Estimation of Shadow Prices L - 2

 2.1 General L - 2
 2.2 Labour L - 3
 2.3 Cost of Capital L - 5
 2.4 Foreign Exchange L - 5

3. Identifying of Relevant Costs and Benefits L - 7

 3.1 Cost of Proposed Investment at Limôn / Moin L - 7

  3.1.1 General L - 7
  3.1.2 Allocation of Costs related to the different Port Development Schemes L - 7
  3.1.3 Equipment Investment (Case A) L - 8
  3.1.4 Construction Costs (Case A) L - 18
  3.1.5 Construction Costs (Case B) L - 19

 3.2 Benefits of Proposed Investments at Limôn / Moin L - 20

  3.2.1 Identifying of Project Benefits L - 20
  3.2.2 Disbribution of Benefits L - 20
  3.2.3 Benefits due to Rehabilitation Measures (Case A) L - 23
  3.2.4 Benefits of the Construction of a New Container Berth in 1995 (Case B) L - 34

4. Economic Analysis of the Projects L - 38

 4.1 General L - 38
 4.2 Economic Rate of Return L - 38

  4.2.1 Cost-Benefit Comparison (Case A) L - 39

 4.3 Net Present Value (Case B) L - 39

  4.3.1 Net Present Value (NPV) Calculation L - 40

5. Sensitivity Analysis L - 41

 5.1 General L - 41
 5.2 Sensitivity of Case B Cost Estimates L - 41

6. Optimum Length of Northern Breakwater at Moin Harbour L - 43

 6.1 Introduction L - 43
 6.2 Method of Calculation L - 43
 6.3 Cost Inputs L - 43

  6.3.1 Construction Costs L - 44
  6.3.2 Ship Berthdays L - 44
  6.3.3 Waiting Time at Anchor L - 45
  6.3.4 Handling Charges L - 46
  6.3.5 Other Costs L - 47

 6.4 Conclusion L - 47

Annex Chapter L 1 to L 4

LIST OF DRAWINGS

(see Volume IV)

DRAWING NO.	TITLE
B. PRESENT SITUATION ON THE ATLANTIC COAST	
B-1.1	MAP OF COSTA RICA
B-1.2	GENERAL VIEW LIMON/MOIN AREA
B-2.1	PORT OF LIMON, PRESENT LAYOUT
B-2.2	MUELLE SETENTA AND MUELLE METALICO PORT OF LIMON, SECTION AND VIEW
B-2.3	CONTAINER TERMINAL UNDER CONSTRUCTION PORT OF LIMON, SECTION AND VIEW
B-2.4	PORT OF MOIN, PRESENT LAYOUT
B-2.5	BANANA PIER UNDER CONSTRUCTION PORT OF MOIN, PLAN - SECTIONS - DETAILS
B-2.6.1	PLANNED BREAKWATER PORT OF MOIN, LAYOUT
B-2.6.2	PLANNED BREAKWATER PORT OF MOIN, SECTION
C. TRAFFIC ANALYSIS AND FORECAST	
C-1	TRAFFIC ANALYSIS AND FORECAST
D. DEGREE OF CONTAINERIZAION	
D-1	DEGREE OF CONTAINERIZATION
E. PORT OPERATION	
E-1	CAPACITY OF CONTAINER TERMINAL
E-2	BERTHDAY REQUIREMENTS
F. PORT DEVELOPMENT ON THE ATLANTIC COAST	
F-2.1	PORT OF LIMON, PRESENT LAYOUT
F-2.2	PORT DEVELOPMENT - PORT OF LIMON CASE A - GENERAL LAYOUT
F-2.3	ROAD CONNECTION TO PORT LIMON INTERCHANGE AVENIDA 1 / CALLE 9
F-2.4	PORT OF MOIN, PRESENT LAYOUT
F-2.5	PORT DEVELOPMENT - PORT OF MOIN CASE A - GENERAL LAYOUT
F-2.6	GENERAL VIEWS OF PORT OF MOIN OIL PIER - BANANA PIER - SHIP YARD
F-3.1	PORT DEVELOPMENT - PORT OF LIMON ALT. 1 a - CASE B, GENERAL LAYOUT
F-3.2	PORT DEVELOPMENT - PORT OF LIMON ALT. 1 b - CASE B, GENERAL LAYOUT
F-3.3	PORT DEVELOPMENT - PORT OF LIMON ALT. 2 - CASE B, GENERAL LAYOUT
F-3.4	PORT DEVELOPMENT - PORT OF MOIN ALT. 3 a - CASE B, GENERAL LAYOUT

DRAWING NO. TITLE

F-3.5 PORT DEVELOPMENT - PORT OF MOIN
ALT. 3 b - CASE B, GENERAL LAYOUT

F-5 FUTURE TRAFFIC CONNECTION TO THE HINTERLAND
AND BETWEEN LIMON AND MOIN

F-6 FUTURE PORT SITUATION ON THE ATLANTIC COAST
OF COSTA RICA

F-7.1 FUTURE PORT DEVELOPMENT
PORT OF LIMON

F-7.2 FUTURE PORT DEVELOPMENT
PORT OF MOIN

H. NAUTIC

H-1 NAVIGATIONAL LAYOUT PORT OF LIMON

H-2 NAVIGATIONAL LAYOUT PORT OF MOIN

I. OCEANOGRAPHIC, HYDROGRAPHIC AND HYDROLOGICAL INVESTIGATIONS

I-1 FREQUENCIES OF SIGNIFICANT
DEEPWATER WAVE HEIGHTS

I-2 REFRACTION OF INCIDENT WAVE SYSTEMS

I-3 REFRACTION OF INCIDENT WAVE SYSTEMS

I-4 REFRACTION OF INCIDENT WAVE SYSTEMS

I-5 REFRACTION OF INCIDENT WAVE SYSTEMS

I-6 SITUATION OF THE HARBOUR AND NOTATIONS

I-7 WAVE HEIGHTS AT BANANA BERTHS

I-8 WAVE HEIGHTS AT BANANA BERTHS

I-9 WAVE HEIGHTS AT BANANA BERTHS

I-10 WAVE HEIGHTS AT BANANA BERTHS

I-11 WAVE HEIGHTS AT BANANA BERTHS

I-12 WAVE HEIGHT EXCEEDANCE FREQUENCIES
BERTHS NOS. 1 AND 2

I-13 WAVE HEIGHT EXCEEDANCE FREQUENCIES
BERTH NO. 3

I-14 GENERAL TIDAL CONDITIONS
ACC. TO DHI, "SEEHANDBUCH"

I-15 TIDE CURVE AT COLON/PANAMA
(FOR ILLUSTRATION

I-16 TIDE CURVES AT MOIN

I-17 TIDE CURVES AT MOIN

I-18 TIDE CURVES AT MOIN

I-19 TIDE CURVES AT MOIN

I-20 TIDE CURVES AT MOIN

I-21 TIDE CURVES AT MOIN

DRAWING NO.	TITLE
I-22	COMPARISON OF CALCULATED (LIMON) AND MEASURED (MOIN) WATER LEVELS
I-23	WIND CONDITIONS MOIN
I-24	WIND CONDITIONS MOIN
I-25	WIND CONDITIONS MOIN
I-26	WIND CONDITIONS MOIN
I-27	WIND CONDITIONS MOIN
I-28	WIND CONDITIONS MOIN
I-29	GENERAL CURRENT SITUATION
I-30	TIDES AND WIND CONDITIONS DURING CURRENT MEASUREMENT
I-31	FLOAT TRACKING MEASUREMENTS
I-32	FLOAT TRACKING MEASUREMENTS
I-33	FLOAT TRACKING MEASUREMENTS
I-34	VELOCITY PROFILES AT RAILWAY BRIDGE
I-35	TIDAL ELEVATIONS AND CORRESPONDING TIDAL AND DISCHARGE VELOCITIES (POINT A) (FOR ILLUSTRATION)
I-36	DETERMINATION OF AVERAGE DISCHARGE VELOCITIES
I-37	RAINFALL AT FINCA MARGARITA AND AVERAGE DISCHARGE VELOCITIES
I-38	RAINFALL AT FINCA MARGARITA AND AVERAGE DISCHARGE VELOCITIES
I-39	SALINITIES RAILWAY BRIDGE
I-40	SALINITIES RAILWAY BRIDGE
I-41	SALINITIES RAILWAY BRIDGE
I-42	SALINITIES RAILWAY BRIDGE
I-43	SUSPENDED LOADS RAILWAY BRIDGE
I-44	SUSPENDED LOADS RAILWAY BRIDGE
I-45	SUSPENDED LOADS RAILWAY BRIDGE
I-46	SUSPENDED LOADS RAILWAY BRIDGE
I-47	LOCATION A TO F OF WATER SAMPLES (SALINITIES AND SUSPENDED LOADS)
I-48	SALINITIES POINTS A TO F
I-49	SUSPENDED LOADS POINTS A TO F
I-50	EVALUATION OF SOIL SAMPLES WITH RESPECT TO CLAY AND SILT CONTENT

J. <u>WATER SUPPLY TO THE PORTS OF LIMON AND MOIN</u>

J-1	UBICATION OF HYDROLOGICAL FEATURES
J-2	DISCHARGE QUANTITIES OF THE BANANA RIVER
J-3	HYDROLOGICAL CHARACTERISTICS OF GREATER LIMON AREA
J-4	GEOLOGICAL MAP OF GREATER LIMON AREA

DRAWING NO.	TITLE
J-5	LOCATION OF EXISTING WELLS IN CENTRAL LIMON AREA
J-6	HYDROGEOLOGICAL CHARACTERISTICS AND GROUNDWATER CONTOURS CENTRAL LIMON AND MOIN AREA
J-7	RESULTS OF PUMPING TESTS IN MOIN

K. PRELIMINARY DESIGN (CASE A)

K-1.1	GENERAL LAYOUT - PORT OF LIMON CASE A - 1982
K-1.2	GATE HOUSE - PORT OF LIMON
K-1.3.1	CENTRAL WORKSHOP - PORT OF LIMON VIEWS
K-1.3.2	CENTRAL WORKSHOP - PORT OF LIMON PLAN AND SECTIONS
K-2.1	GENERAL LAYOUT - PORT OF MOIN CASE A - 1982
K-2.2	TRACK LAYOUT ON THE BANANA PIER STAKING OUT - DETAILS
K-2.3	RAIN SHED WITH ELEVATORS BANANA PIER
K-2.4.1	WATER DISTRIBUTION SYSTEM
K-2.4.2	INFILTRATION GALLERIES
K-2.5	STORMWATER AND SEWAGE
K-2.6	POWER SUPPLY AND TELECOMMUNICATION
K-2.7.1	PAVEMENT AREAS
K-2.7.2	TYPICAL SECTION AND DETAILS OF THE PORT AREA BEHIND THE BANANA PIER
K-2.8.1	SOCIAL BUILDING PORT OF MOIN
K-2.8.2	SOCIAL BUILDING PORT OF MOIN
K-2.8.3	ADMINISTRATION BUILDING PORT OF MOIN
K-2.8.4	GATE HOUSE WITH CHECKING BRIDGE PORT OF MOIN
K-2.9.1	SHIP-YARD WITH SLIPWAY AND TUG BERTH LAYOUT AND DETAILS
K-2.9.2	SLIPWAY - WORKSHOP - WINCHHOUSE SECTIONS
K-2.9.3	SLIPWAY - TUG BERTH SECTIONS

ANNEXES

I-50.1 TO I-50.12	GRAIN-SIZE DISTRIBUTION OF SOIL SAMPLES
J-8.1 TO J-8.7	INVENTORY OF EXISTING WELLS AND SPRINGS IN CENTRAL LIMON AREA.

F. Recommendations of Extension and Development Forecasts of the Ports of Limón and Moín

1. General

The development of the ports of Limón and Moín until the year 2000 will largely depend on the degree of containerization of bananas. Chapter D, which gives a detailed survey of the subject of containerization of bananas, concludes by making two assumptions that are calculated in detail in the masterplan.

Case A : low degree of containerization

Case B : high degree of containerization up to 100 % in the year 2000

After starting operation of Proyecto Alemán and completion of construction, operational and organizational measures as proposed for case A development, both ports Limón and Moín are sufficiently capable to handle the expected traffic volume beyond year 2000. Case B would require that new port facilities be available as early as in 1992 to ensure cargo handling in the ports of Limón and Moín. As nobody can tell at the present stage which development will eventually take place these two assumptions are to be considered an aid for those who are responsible to watch the development carefully and place the investments reasonably according to the actual necessities.

For Case A, the proposed measures must be started right away to ensure optimum cargo handling in the ports of Limón and Moín. The immediate measures are primarily measures of reorganizzation and rehabilitation.

In the event that the high forecast occurs as assumed in Case B,the capacity after reorganization and rehabilitation according to the requirements of Case A of the ports of Limón and Moín,would no longer meet the requirements in 1992, so that new handling facilities would be required. This development may as well occur earlier or later than assumed. Several alternatives will be discussed in length in this Chapter (see drawings D-1, E-1, E-2).

Approximate cost estimations for the reorganization and rehabilitation measures in Case A and for the alternatives of Case B are given at the end of this chapter.

2. Rehabilitation and Extension of Ports of Limōn and Moīn up to the year 2000 - Case A

2.1 General

In the previous chapters, especially Chapter E, the anticipated port needs according to the traffic forecast have been analysed and compared with the supply capacity of the then operating Proyecto Alemān. Required berths, storage facilities and operation-system to achieve the standards for a proper port operation have been determined. From this it was concluded that the port of Limōn will work with an optimim overall utilization during the future period (1981 to the year 2000) of approx. 55 %. In order to reach and maintain this port utilization it is necessary, however, to increase the present inadequate port infrastructure and to supply the technical equipment that this progress will not be hindered.

For the port of Moīn, the most urgent measures are to finish the port structures and provide the necessary infrastructure.

The following sections of this chapter deal with a description of these matters, keeping in mind that for Case A no new port facilities are needed but rehabilitation and extension of existing ones to maintain its optimum productivity during the forecast period.

2.2 Port of Limōn

2.2.1 Rehabilitation of Railway Facilities (Drawing F - 2.2)

The railway facilities in the port of Limōn will have to be planned with a main view to container traffic. They also must be able to handle general cargo and other goods such as paper, iron, silicates and coffee.

Chapter C and D showed what developments in exports and import rail traffic are to be expected. The railway facilities in the port of Limōn, which are already in need of thorough rehabilitation because of their condition, should be modified to meet the requirements of future traffic.

The following tables show the volumes to be handled in the port of Limōn, according to the traffic forecast for the period ending 2000.

Incoming and outgoing rail-carried containers* in Limón

Year	Rail component of total containers	Number of containers 35'	20'	40'
1985	10 %	10,550	460	250
1990	30 %	27,550	1,870	1,010
1995	70 % bananas	Case A) 30,250	3,340	1,800
	40 % others	Case B) 30,250	3,340	23,000
2000	80 % bananas	Case A) 31,150	4,340	2,340
	40 % others	Case B) 31,150	4,340	78,000

* Without containers handled at Muelle 70 or the ro-ro facilities

20-foot containers for rail transportation which are handled at the Muelle 70 or the ro-ro facility with ships' lifting gear, with the same modal split as above:

Year	No. of 20-foot containers
1985	150
1990	740
1995	1,050
2000	1,560

The following table shows the number of freight wagons that will be needed to carry the above-mentioned containers. The given figures are based on the following:

1 freight wagon carries 1 x 35' container or
1 x 40' container or
2 x 20' containers.

360 working days per year are assumed for the container cranes at the port. Traffic peaks (and seasonal fluctuations) are taken into account in the number of wagons per day by using a factor of 1.5.

Year	Number of freight wagons carrying containers (incoming and outgoing)		
	annual	daily average	daily x 1.5
1985	11,105	31	47
1990	28,065	80	120
1995	Case A) 34,245	95	143
	Case B) 55,445	154	231
2000	Case A) 36,440	101	152
	Case B) 112,100	311	467

The next two tables show the numbers of freight wagons for other goods that will be handled in the port of Limón. The approximate utilization rates for the freight wagons were calculated from Fecosa statistics for the year 1978.

<u>Imports</u>

		Iron	Paper	Ferti-lizers	Silicate	General cargo
Rail component		100 %	15 %	100 %	60%*) 80%	15 %
Wagon utili-sation rate		35 t	25 t	28 t	30 t **)	15 t
1985	t/year	63,500	37,000	800	---	11,500
	waggons	1,814	1,480	29	---	767
1990	t/year	79,000	22,000	1,000	39,500	9,000
	waggons	2,257	880	36	1,317	600
1995	t/year	82,000	21,000	1,500	52,500	9,500
	waggons	2,343	840	54	1,750	633
2000	t/year	85,000	19,500	2,000	49,000	9,500
	waggons	2,429	780	71	1,633	633

*) 1990 = 60 %
1995 - 2000 = 80 %

**) estimated

Exports

	General cargo, incl. coffee
Rail component	30 %
Waggon utilization rate	20 t *)
1985 tons/year	29,500
1985 wag./year	1,475
1990 tons/year	27,500
1990 wag./year	1,375
1995 tons/year	31,000
1995 wag./year	1,550
2000 tons/year	32,000
2000 wag./year	1,600

*) estimated (coffee 27 t, general cargo 15 t)

The following summary shows the overall loadings on the station of Limôn on peak-traffic days:

		1985	1990	1995	2000
Incoming waggons from Patio Moín	Containers	24	60	A) 72 B) 116	A) 76 B) 234
	Empty wag. for imports*	20	25	28	28
	Laden wag. for exports*	7	7	8	8
	Total waggons	51	92	A) 108 B) 152	A) 112 B) 152

* Unlike the case for container handling, only 300 days of loading activities were assumed for imports and exports.

The Limôn freight station and its track facilities should be planned for the year 2000. Its capactiy must therefore be such that it can handle an average of

$$\frac{270 \text{ wagons}}{26 \text{ wagons}} = 11 \text{ freight trains}$$

coming from Moín (average of 26 wagons each*)), break up these trains and deliver the wagons to the various auxiliary facilities. At the same time, the same number of wagons coming from the auxiliary facilities will have to be handled, marshalled into trains and dispatched in the direction of Moín.

If one assumes that each incoming freight train will occupy a track of the reception/dispatch group for an average of about 90 minutes and that each departing train will occupy a track for about 120 minutes, the total occupation time for the reception/dispatch group is

(11 trains x 90 min) + (11 trains x 120 mins) = 2,310 mins/day.

In calculating the necessary reception/dispatch tracks, one must also allow for the time required for track maintenance. Experience has shown that only half of the theoretically possible traffic can actually run over a track during a six-hour working shift. The operating time for the reception/dispatch group of 1,440 mins/day must therefore be reduced by 6 x 0.5 h = 180 mins to 1,260 mins/day.

A further fact to be taken into account is that facilities can never be fully used throughout the entire operating time, because there are not only seasonal fluctuations in traffic but also fluctuations over the course of a day. The seasonal fluctuations were allowed for by employing a factor of 1.5 in calculating the daily number of wagons. The fluctuations over the course of a day can be allowed for by calculating with only 80 % of the above-mentioned operating time. One thus arrives at a practical operating time of

1,260 mins x 80 % = 1,008 mins/day.

One can then calculate the necessary number of reception/dispatch tracks:

$$\frac{\text{2,310 mins track occupation}}{\text{1,008 mins eff. operating time/track}} = \text{3 tracks}$$

A fourth track is planned as a reserve for the event of disturbances of operations or excessive traffic loadings at the central marshalling yard in Moín.

These four tracks should have a minimum effective length of 400 m, thus equalling the passing/crossing tracks which the Fecosa plans for the main Moín - Siquirres line. It will then be possible to run freight trains through from San José to Limón without any handling in Patio Moín.

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*) At present, the Fecosa is rehabilitating the Moín - Siquirres section and building 400 m-long passing/crossing tracks. We have therefore also assumed 14 m (wagon length) x 26 plus 20 m (traction vehicle length) plus 2 x 5 m (distance of signals upline and downline of the switches) plus 6 m (for inaccurate stopping of trains) = 400 m.

The tracks of the reception/dispatch group should have a spacing of 4.00 - 4.50 m to allow for possible electrification of the line as far as Limón, as catenary poles would have to be set between them in the station of Limón.
The same applies for the tracks for passenger trains. For the other tracks a spacing of 3.50 m will be sufficient.

As incoming trains are already classified at the central marshalling yard of Moín, only three tracks for turning off wagons for a short time will be needed in Limón. One such track will be necessary for brake wagons, and two with effective lengths of about 330 and 265 m will be needed for container cars.

The reception/dispatch track for passenger trains is that nearest to Avenida 1. The track next to it is planned for turning round traction vehicles, and also as a reserve track for incoming and outgoing passenger trains.

Between these two tracks and the reception/dispatch group for freight trains are the above-mentioned stabling tracks for container cars. These stabling tracks will be for shunting out wagons that must go to the container-handling facilities that arrive in mixed trains, i.e., not in full container trains. The waggons of full container trains can go straight from the reception track to the container-handling facilities. In the opposite direction, waggons coming from the container-handling facilities will always be moved to a track of the reception/dispatch group. Those which have to be loaded once more can then be shunted to one of the two stabling tracks and from there back to the container-handling facilities.

The Bodega de Café is to have a service track of 100 m effective length next to the approx. 130-m long loading track, whilst Bodega No. 7 is to have a loading and service track that also serves as a service track for the Muelle 70, the effective lengths here being 120 m and 200 m. Bodega No. 1 is to have loading and service tracks with lengths of 145 m and 110 m respectively.

The track between the Bodega de Café and the Taller Mecanico is to be used for loading temporarily stored shipments of iron. Next to this is the service track of the Muelle 70 and Bodega 7, followed by a reversing track and then the stabling track for the brake wagons, with effective lengths of 220 m.

A turn-out track extending from the western end of the reception/dispatch group to Bodega No. 5 and thus having a length of 320 m is foreseen for breaking up and marshalling trains.

On principle, the above-mentioned track facilities in the port of Limón are not to be used for stabling waggons for longer periods. This would greatly reduce the capacity of the station. The Fecosa will therefore have to ensure that empty or damaged waggons are moved to the Patio Moín, from where they can be re-allocated or sent to workshops.

It is recommended that reconstruction of the track system at Limón should be carried out in the following steps:

- First it is recommended to reconstruct the western part of the station. The level crossing will have to be moved about 40 m, so that the line from Moîn will pass through the closed Texaco area.

- To give the reception/dispatch tracks an effective length of 400 m, it will be necessary to place the first switch immediately behind the level crossing.

- The next step will be to connect the port station with the "Proyecto Alemân".

- After construction of the central marshalling yard of Moîn and the port facilities in Moîn, the track conncection to the "Muelle Metâlico" can be cut.

- The last stage will be to build a new passenger station.

If the port of Limôn is enlarged later - Construction Phase III, Extension of Container Terminal - there will be no difficulties in connecting its tracks with the track facilities described above.

The above makes clear that the changes in port and railway facilities will be far-reaching.

These changes and developments such as containerization will necessitate very close cooperation between the Fecosa and Japdeva, as operations will have to remain uninterrupted by construction work.

In future, the responsibility of the railway operations should remain in the hands of only one authority - the Fecosa - to ensure a smooth flow of traffic and operations between the port area and the central marshalling yard in Moîn.

2.2.2 Rehabilitation of the Approach Roads to the Port
(Drawing F 2.2, F 2.3)

Whilst there are at present three approaches to the port (cf. Chapter B 3.1), the improvement proposals for the port of Limôn include only the following two entrances:

- on the western side, in prolongation of Calle 9 to Cienegita and the airport, over the land belonging to the old sawmill;

- on the eastern side at the Proyecto Alemân, in extension of Avenida 1.

The entry and exit form Avenida 1 on the level of Calle 1 is to be closed; there is too little space for trucks awaiting customs processing here, and it is also needed as an entrance for pedestrians (port authorities, canteen). This proposal is also in line with the ideas of the Japdeva, which would like to clear this area from truck traffic.

Whilst the eastern approach will serve to handle the traffic from the "Proyecto Alemân" (Berth 10 and 11), the western approach is primarily to serve the western side of the harbour. The port road now passing the Taller Mecânico is to be extended (across the premises of the old sawmill) to the Cahuita road, which runs to Cienegita and the airport.
The origin and destination traffic of the port, practically all of which passes over the western Avenida 1 (to/from Moîn, container and ro-ro parking space on Highway 32, Siquirres, San Josê), will be routed over the port access road, Cahuita Road, and to the western part of Avenida 1. This will necessitate widening Cahuita Road in the Rio Limoncito - Avenida 1 area so that separate lanes for traffic turning off to the left (for south-bound traffic into the port, for north bound traffic into the western part of the Avenida 1) can be provided.

Separate lanes would also appear to be necessary for the strongest streams of traffic turning off to the right. Under these conditions, the above-mentioned part of Calle 9 would have to have a width of 16.25 m, given the recommended lane width of 3.25 m. The necessary space could be provided by taking over a 6.50 m-wide strip over the entire length of the Texaco property, which is now only in limited use. This defines the right-hand side of the roads.

Synchronised traffic lights at the junctions Avenida 1 / Calle 9 and Cahita-Road port access road would be desirable to ensure a smooth flow of traffic, particularly the heavy trucks to and from the harbour. The synchronisation should be such that the streams of traffic turning to the left over the two junctions do not have to stop. The gates should be located far enough into the port area to ensure that trucks waiting for customs processing do not hinder the traffic flow on Cahuita Road.

Avenida 1 will also have to be widened at the eastern entrance to the port area, over the section east of Calle 1, whereby one must however ensure that the Parque Vargas is not affected. A total width of 12.00 m would appear to be enough for two lanes per direction and two waiting lanes, mainly for the heavy trucks. This would avoid excessive jamming of the through-lanes for the traffic of trucks and trailers, particularly as most of the container traffic (Messrs. Sea-Land) will already have gone through customs.

On the section between Calle 8 and Calle 1, Avenida 1 will have to be widened to 7.00 to 7.50 m and improved. This will ensure that all traffic to and from the port of Limôn will use Avenida 1 and not, as is presently the case, Avenida 2 and 3 which run through the heart of the city.

These measures will help relieving the traffic burden on the city centre, particularly as they keep the heavy traffic out. Heavy traffic will bypass the city centre, running along the edge of the port area. As the most northerly of the tracks in Patio Limôn are available, widening of Avenida 1 in the above-mentioned area will not conflict with the interests of the railway yard.

Concerning the design of the junctions Avenida 1 / Calle 9, Cahuita-Road / port access road and Avenida 1, planning for these at-grade intersections will concern a road area of about 5,900 m^2 and a kerb with a length of about 850 m.

A 750-m long section of Avenida 1 between Calle 8 and Calle 1 must be widened to 7.50 m, whilst the 190-m long section between Calle 1 and the eastern gate of the port area alongside the Parque Vargas will have to be widened to 12.00 m.

The new port access road should have a width of 10.50 m, extending 100 m from the toll gate to Cahuita road and then swinging south (alongside the Taller Mècanico) over a distance of 230 m to bring it straight into the present port road. This would mean a straight port road from Muelle 70 to Cahuita Road.

2.2.3 Establishment of a Central Workshop

(Drawings F-2.2, K-1.3.1, K-1.3.2)

The present workshop for the maintenance and repair of equipment in the Port of Limôn is located at the westend of the port area. This workshop is old and not suitable to maintain and repair the new straddle carriers which shall operate on the container terminal. In addition, a rail-mounted hanger crane is necessary in case extensive repairs have to be performed.

Therefore a new workshop is absolutely necessary, as the maintenance and repair activities for the straddle carriers cannot be performed in an open area.

It is recommended to locate the new workshop beside the present entrance of the port (see drawing F - 2.2) due to the following reasons:

- central location as most of the operation activities will be performed on the Proyecto Alemân
- the workshop can be used as parking area for the straddle carriers during the shift changes
- the recommended area is not occupied, so that the port can immediately start with planning/construction.

Especially the last item is very important, as the workshop must be available, when the container terminal starts its operation.

The old existing workshop should also be used in future for the personnel for maintenance and repair of facilities and auxiliary workshop activities.

2.2.4 Demolishing of Berth No. 1 of Muelle Metâlico

(Drawing F-2.2)

The present planning of the Proyecto Alemân provides 115 m space between the berth No. 11 and SE end of the Muelle Metâlico. Actual channel space of 11 m draught only 92 m width where the dredging slope begins. In future vessels have to pass this area if being berthet at No. 10 (ro-ro-facilities). It can be considered that at No. 11 a container vessel of 31 m width will be moored and that general cargo ships of 25 m width or ro-ro-vessels of 22 m width then have to pass the area.

It goes without saying that tug assistance must be provided to ensure a safe manoeuvre, for vessels should be berthed with the bow to the open sea. Under normal conditions, i.e. calm water, it is sufficient that the area where the vessels pass each other will have 3 times the ship's width, if adequate tugboats are used and no turning manoeuvres are required.

In the present planning an actual area for ships to pass 95 m minus the width of a container vessel (at No. 11) of 31 m is provided, i.e. 64 m. Regarding the expected vessels it is not sufficient for general cargo and ro-ro-ships, for which 75 m resp. 66 m are required.

The dominant wind direction is reported to be northeast. But it is obvious that wind and swell may occur from east to south due to local influences.

Furthermore it should be stated that mainly ro-ro-vessels and loaden container ships are affected by wind drifts due to the high superstructures at any time.

The above mentioned conditions require that the tugs must hold the ships in the channel midth and constantly the ships must correct their courses by small turnings. Considering the pessimistic situation when the tugs must hold the ship at position 90^{0} to the hull, the total required width will be

a) ship's width + length of tug lines + tug width = 25 m + 30 m + 8 m = 63 m
=======

if tug wires are used, or in case of American tow method

b) 25 m + 8 m = 33 m
=======

In case a) no reserve space will be the result, in case b) the distance will be 31 m, the required minimum, but then no manoeuvring space for the tugs is available.

To provide a safe passing for vessels in any condition and thus creating no delays, the channel should be widened by demolishing berth No. 1 of Muelle Metàlico.
Then there will be no obstacle which endangers possible collisions and sufficient manoeuvring space for the tugboats.

It is considered to be sufficient to remove approximately 45 m of berth No. 1. Then actual space will be 140 m or 110 m for manoeuvres. It is not necessary to dredge the whole area to 10 m but to a depth that the tugs may pass safely, i.e. 5 to 6 m. The basin depth of 11 resp. 10 m should reach then the today positions of pier end of No. 1.

Thus a space usable for vessels remains of 120 m total or 90 m for passing. This exceeds the required 3 times of ship's width, but it should be reminded that also container ships could be berthed at No. 10 if self-sustained. Then the 90 m are the required minimum. (See drawing F- 2.2).

2.2.5 Modification of the Muelle 70

If case A develops, i.e. low containerization of banana, it seems sufficient to use the Muelle 70 in future for the handling of break bulk and general cargo, if requested. This applies up to the year 2000.

Making the Muelle 70 to a sufficient productive pier the present operation methods must be changed. The width of the pier totals only 17 meters, which is just the necessary width operable for one cargo ship handling gang. Therefore the first improvement will be reached if at that pier only 1 ship will be worked at the same time with a maximum number of gangs. Further improvements to speed up the ship turnaround time is to eliminate direct handling, because it decreases the productivity substantially, for ship gear is not flexible enough to stow cargo directly on railcars or trucks without shunting.

In future the goods should be set on the pier loaded by forklifts on trailers which transport the goods to the storage area or delivery area. In any case the ship operation should have priority and transport and delivery have to be orientated on that. For this purpose also intermediate storage on the pier should be possible if the transport performances do not balance the ship operation.

Presently the Muelle 70 is in a bad condition and rehabilitation is necessary. The railtracks and pavement must allow a safe trailer traffic causing no damage to equipment. The fender system has to be renewed adequately.

As the Muelle 70 will be used up to the year 2000 a continuous regular maintenance must be organized in future. The goods shall flow from/to the pier by trailers. Therefore measurements are necessary to provide proper operation. The vessels should be moored at some distance from the pier end, so that there will be space for the turning circle of trailers, or trailers must be purchased with two couplings at forward and after, thus there is no need to turn the trailers. The whole pier width will be required for the cargo operation.

2.2.6 Allocation of Areas

(Drawing F-2.2)

Due to the limited area at the ro-ro ramp there is no possibility to park the export- and import trailers for a ro-ro vessel. It is estimated that the maximum throughput will come up to 100 trailers. The necessary area can only be provided opposite of the coffee shed near the Muelle 70, so that this area should be reserved for ro-ro trailers. The required storage areas for break bulk can be obtained on the west side of the coffee shop and the east side of the planned ro-ro area.

2.2.7 Gate House at the New Port Entrance

(Drawings F-2.2, K-1.2)

Due to the re-location of the port entrance for trucks to the west-end of the port area, also a new gate house becomes necessary. At present the documentation and storage clearance takes place in an office at the 1st floor of shed No. 1.

This office shall remain as central documentation office for general cargo and break bulk. In order to avoid, however, that trucks enter the port area without permit or pre-clearance of documents, a small house of 20 m^2 is necessary at the new port entrance. The entrance itself must consist of three gates to be controlled by the port guard. A weighing bridge as well as a checking platform are not necessary as containers and ro-ro trailers are allocated to the entrance of the Proyecto Alemân.

2.3 Port of Moîn

2.3.1 Banana Handling Facilities

2.3.1.1 Banana Pier

(Drawings F-2.5, K-2.2, K-2.3)

In future the banana export should be handled exclusively at Moîn, where already 2 banana piers with a total length of 404 m and a water depth of 12 m are under construction, adjacent to the oilpier and the ro-ro ramp.

Due to operational requirements and due to the loading system railtracks must be installed on the pier. Enabling the port to run the two banana piers independently from each other, rail switches are necessary. Thus the length of both piers totals 472 m, allowing two banana vessels up to 180 m length to be loaded by gantry elevators independently from each other.

Figure F-1 shows the operation system. A rain shed protecting railtrack 2 and 3 up to the tray feed of the elevator should be erected enabling banana operation also during rain. The elevators are movable on their tracks and thus flexible enough to serve both berths. The feeding lanes are portable and will be removed after operation.

2.3.1.2 Capacity and Utilization

According to Chapter E-6, two cases (Case A, B) are estimated in future for the trade development. For both projections the terminal was calculated and planned. Thus in case B when the utilization drops enormously after 1990 the berth could be easily converted for other commodities.

In case A the utilization never exceeds 48 % of 360 working days per year even if considered a very low productivity of the gantries (see drawing E-2). Thus there is no need of a thrid banana pier but of a fifth elevator to guarantee an acceptable operation performance to the banana exporting companies. In case B the utilization in 1995 drops to 27 % and will be zero in 2000.

2.3.1.3 Traffic Flow

90 % of the banana volume exported via Moîn will be transported to the port by the railway. Thus the loading system and terminal layout is orientated on that. But also the remaining 10 % coming to the port by truck would be integrated in the operation either if stowed conventionally or in containers, because all bananas will be exported without intermediate storage.

Figure F - 1: Operation System for Banana Loading at Moin; General Scheme of Equipment and Handling Procedure

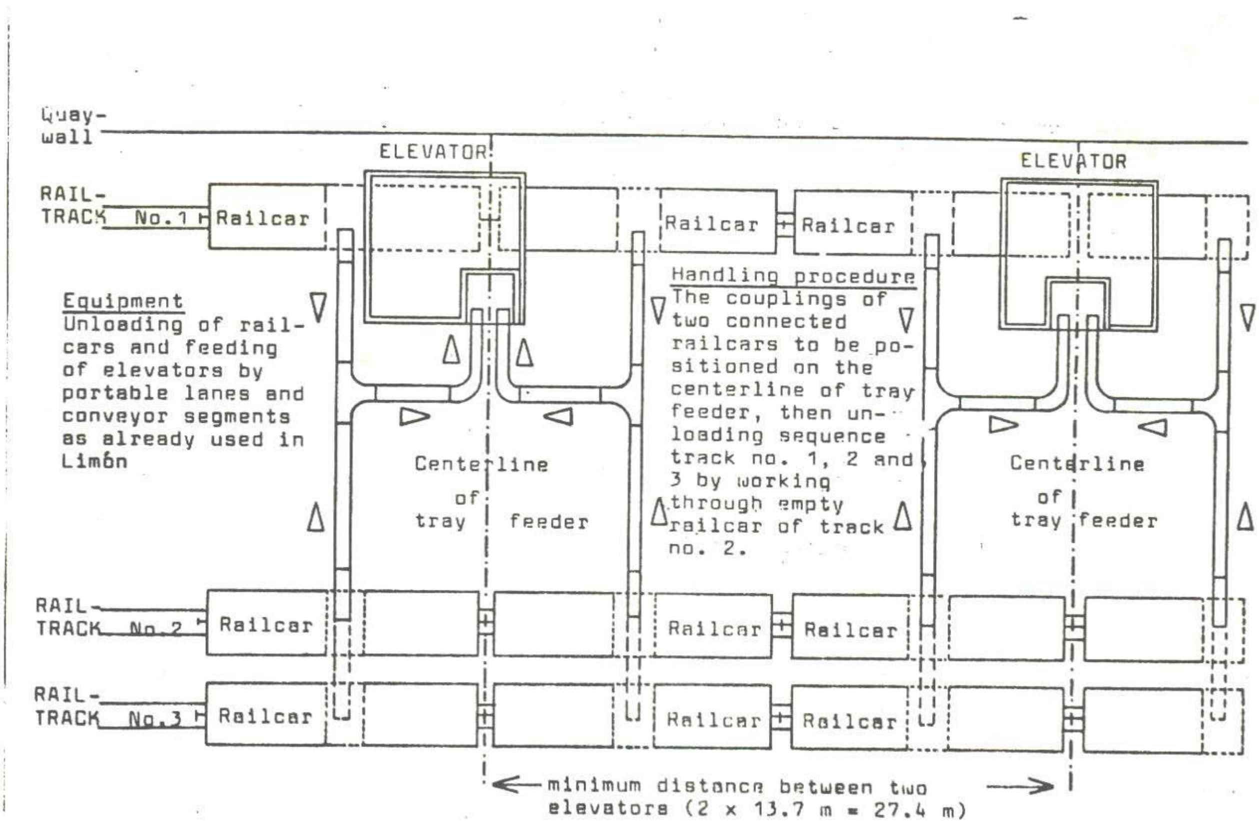
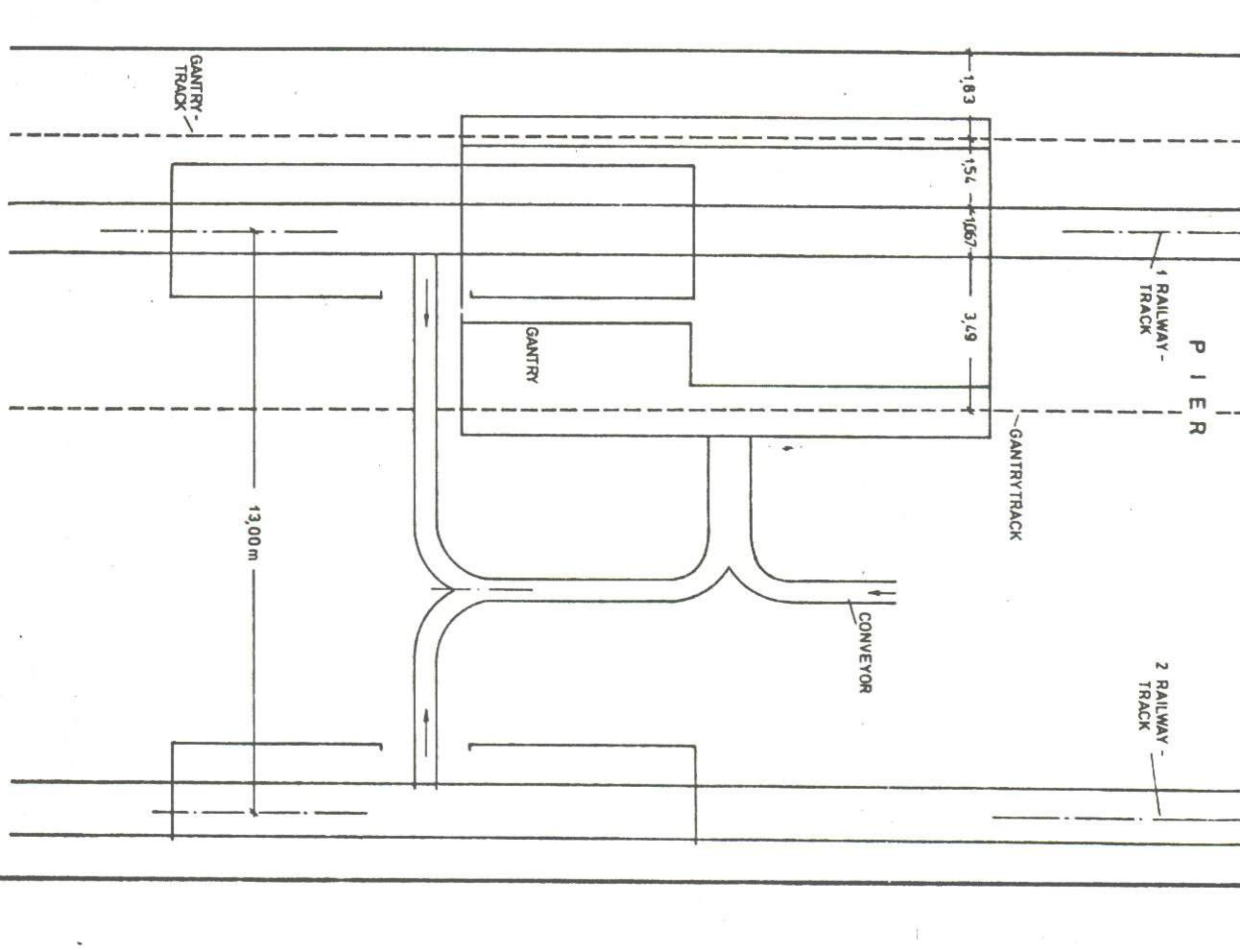


Figure F - 2: Clearance of Banana Loading Tracks



2.3.1.4 Track Facilities for the Banana Pier

(Drawings F-2.2, K-2.2)

Three loading tracks are proposed for each of the two berths. Two tracks would suffice in the normal course of laoding bananas, but a third track would represent a reserve for the event of irregularities, peak traffic, etc.

The positioning of the loading tracks and the distances between will depend on where the gantry crane tracks are to be laid and the type and mode of operation of these cranes.

The client has already specified where the gantry tracks are to be laid: the first rail, looking westwards, is to lie 1.83 m from the edge of the pier. The gantry crane track has a gauge of 6.10 m. The first loading track of the railway runs between the gantry tracks. The loading track centre line should not be in the middle of the gantry track, as the crane superstructures are not symmetrical but lie 3.90 m back above the pier edge.

A clearance of 13.00 m must be observed between the centre lines of the first and second loading tracks because of the loading method (cf. Fig.2). The third loading track should be placed as close as possible to the second loading track, as conveyor belts will have to be laid through the wagons standing on track 2 when working from the outer track and the conveyors must be kept as short as possible. On the other hand, one must ensure sufficient space between the second and third tracks to be able to set up supports for the conveyors and the roofing. A distance of 4.50 m between the centre lines of the second and third loading tracks is proposed for these reasons.

In planning the switches and curve radii on the piers themselves, it was attempted to keep the connections between the loading tracks and the running tracks as short as possible. From the point of view of railway operations, there are several possibilities of connecting the loading tracks of the two berths with the running track.

Alternative 1 (cf. Figure F - 3)

The three loading tracks of the (northerly) berth 1 will be connected at the northern and southern ends, i.e., it will be possible to enter them form both ends. The three loading tracks of the (southerly) berth 2 are also to be connected at both ends, but the northern end will lead into the southern link with the loading tracks of berth 1. This means that this connection with berth 2 cannot be used for operations when the loading tracks of berth 1 are being used or loading is going on from them.

The lengths of the switch sections and track radii will be determined by the necessary length of the banana pier. The drawing "length of the banana pier at Moln, Alternative I" shows the necessary pier length, which is approx. 435 m. In this and the other alternatives, a ship's LOA[1] of 186.2 m (Snow Class Vessels) was assumed in planning the berths.

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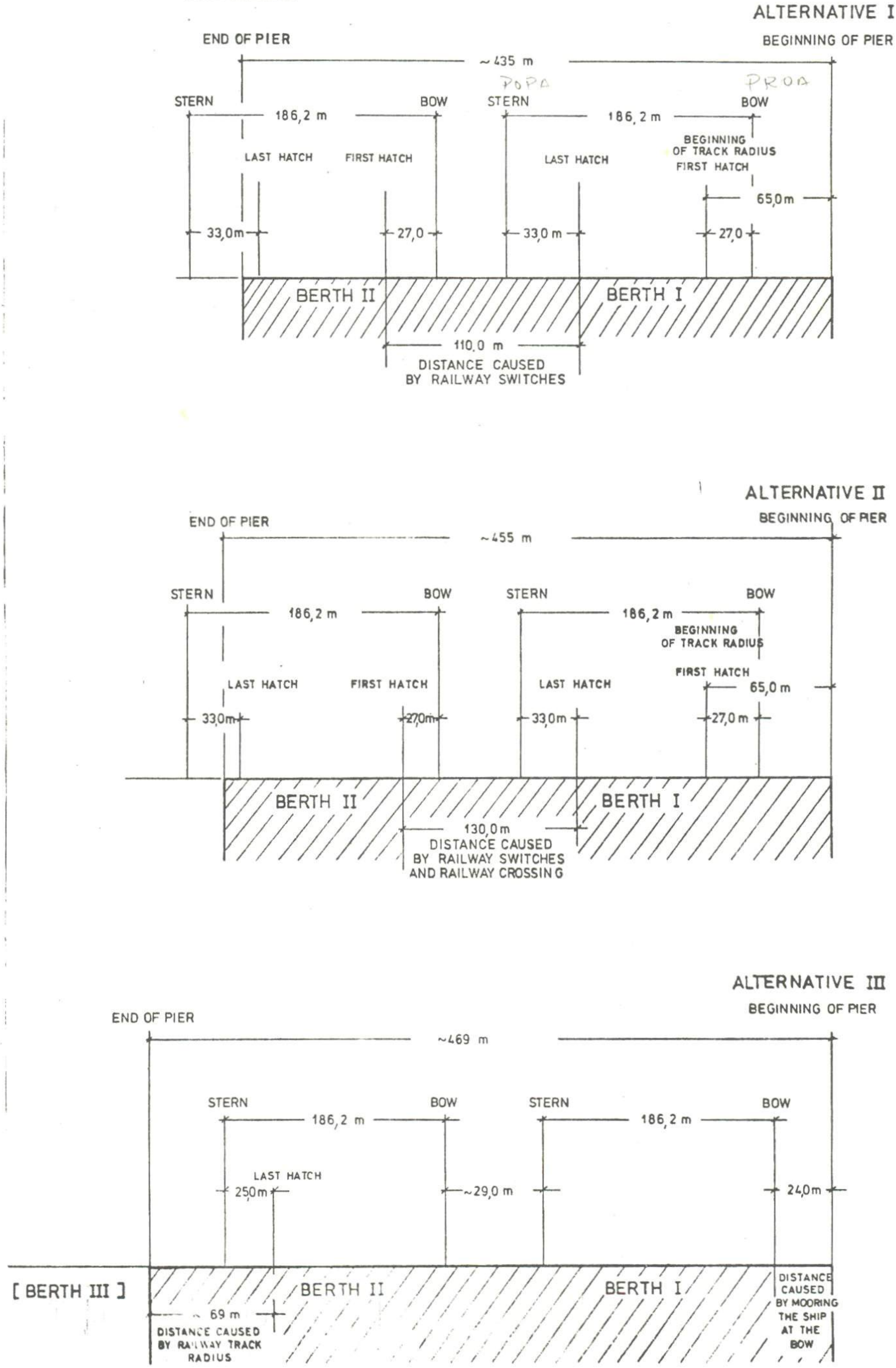
1) LOA = length overall

Figure F - 3: Alternative Configuration of Banana Tracks



Alternative 2 (cf. Figure F-3)

This alternative differs from Alternative 1 only in respect of different connections between the loading tracks of the 2 berths. This alternative has the advantage that the loading tracks of both berths can be used from both ends, even when loading is going on at both. This opens up the possibility of serving both berths, even in the event of operations being disturbed or when reconstruction work is going on at the southern end of the pier.

As this alternative makes more switches necessary, the resultant pier length is approx. 455 m (cf. figure "Length of banana pier at Moín, Alternative 2).

An additional 1.24 m will be required at the northern end of the pier for the bow mooring lines. This is however not a reason for lengthening the banana pier, as was originally assumed and stated in the Interim Report; the first banana wagons have to be brought to a halt about 65 m from the northern end of the pier because the track begins to curve there. For this reason, ships will have to be moored 38 m from the end of the pier.

Alternative 3 (cf. Figure F-3)

In this alternative, the second and third loading tracks at both berths are dead-end tracks. A disadvantage of this alternative is that wagons can only be delivered and collected from one end. In the event of disturbances (derailment, construction work, etc.), this could considerably hinder loading operations. There is however an advantage compared with Alternative 1, in that the system for serving the loading tracks at both berths would be the same: all wagons would have to be pushed into the loading tracks by the shunting locomotive and pulled out. The pier could also be lengthened to provide a third berth. To avoid overloading of the "Patio" at Moín, the approach tracks to the two berths will have to be so designed that most of the shunting work can be carried out on them (cf. Figure "Length of banana pier at Moín, Alternative 3).

Selection criteria

Alternative 2 is doubtlessly the best from the point of view of railway operations. Alternative 2 necessitates a pier length of about 454 m, whilst the pier length for Alternative 1 would be 434 m. A considerably greater (approx. 60 m) length will be necessary if one wishes to keep the option for a third berth immediately behind the second open. In this case, it will not be enough to simply build a retaining wall at the end of the pier.

From this viewpoint - possibility of lengthening the pier to provide a third berth - the pier would have to be lengthened from the present 404 m to about 464 m for the first alternative and to about 510 m if the second alternative is chosen.

As there seems to be no economic justification for the costs of lengthening the pier to this extent, the third alternative described above was developed for the track facilities on the pier. This third alternative partly avoids the disadvantage of the second alternative - lengthening of the pier to approx. 510 m - and would also partly eliminate the disadvantage of the first alternative - different methods of serving the two berths and heavy loadings on the "Patio" at Moín.

The pier length in Alternative 3 is 471.80 m, that is, the present pier would only have to be lengthened by about 68 m. The approaches to each berth would take the form of two tracks, one being used as a buffer zone for full wagons, the other, for empty wagons. These approach tracks should have the greatest possible effective length, to reduce the amount of shunting between the port facilities and the "Patio" of Moín.

At one of the berths, no more than three gantry cranes will be used for the loading of bananas under normal circumstances; this means that each of the loading tracks will be used for unloading six wagons simultaneously. For this reason, the effective length of the approach tracks should be three times the length of six wagons plus the length of a shunting locomotive (= approx. 250 m). As the hourly capacity of the gantry cranes matches the capacity of the banana wagons that can be placed on the three loading tracks, shunting locomotives will only have to run between the "Patio" and the approach tracks once per hour.

The third alternative was therefore given preference, and the MOPT was correspondingly advised of this in early March 1980.

2.3.1.5 Railway operations, Patio Moín - Moín Harbour

The above-mentioned Alternative 3 for the track layout on the banana pier of Moín allows the same operating method for both berths, as already mentioned. Because the loading tracks are only connected to the running tracks at one end, there is however a danger of the loading of bananas being considerably hindered in the event of operational irregularities. This will - among other things - necessitate exact operating instructions being issued to cover railway services to the port sidings. These instructions should cover:

- duty periods, tasks of the shunting personnel and the shunting locomotive
- management, coordination and supervision of the shunting gangs
- coordination of railway and port operations
- use of technical facilities (radio, etc.).

Roughly speaking, railway services to the banana pier tracks for the proposed Alternative 3 will take the following form ;

Banana trains arriving at Patio Moín from the plantation areas will be broken up and the wagons shunted into the sorting tracks. Sorting will be determined by when the wagons are to be taken to which berth and possibly to which hold (different grades of banana, different customers). The sequence for placing wagons on the sorting tracks will have to be agreed between the Fecosa and the port handling office in due time.

The wagons will then be hauled into one of the approach tracks and supplied to the loading tracks in groups of two, four or six wagons, depending on whether one, two or three gantry cranes are in operation at the berth. The wagons will be pushed from the approach track to the loading track, and the empty wagons pulled out into the second approach track. When the second approach track is full of empty wagons, the shunting locomotive will push them to Patio Moin. On the return journey, it will pull the next batch of wagons which are to be unloaded into the approach track. Two shunting gangs will be needed for each berth.

The following table gives an example of the handling of wagons and unloading work at berth 1.

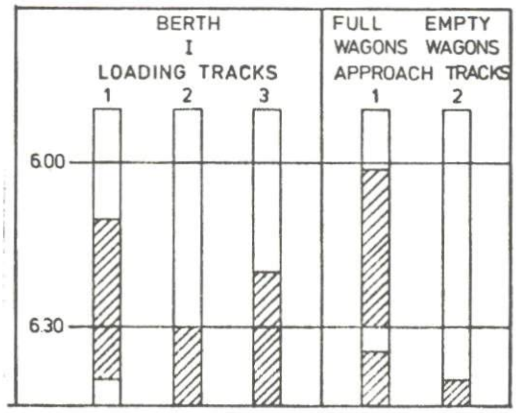
Shunting Locomotive I		Shunting Locomotive II		Gantry Crane	
Time	Work	Time	Work	Time	Work
6:00	Loaded wagons from Patio to approach track, Berth 1				
6:10	Delivery of loaded wagons to T 1				
6.20	Delivery of loaded wagons to T 3			6:20	Unloading of wagons on TI
6:30	Delivery of loaded wagons to T2	6:35	Loaded wagons from Patio to approach track, Berth 1		
6:40	Collection of empty wagons from T1			6:40	Ditto, T3
		6:45	Delivery of loaded wagons to T1		
7:05	Collection of emply wagons from T3			7:05	Ditto, T2
		7:10	Delivery of loaded wagons to T3		
7:25	Collection of empty wagons from T2			7:25	Ditto, T1
		7:30	Delivery of loaded wagons to T2		
7:35	Empty wagons from approach track to Patio				
		7:45	Collection of empty wagons from T1		
7:45	Loaded wagons from Patio to approach track, Berth 1			7:45	Ditto, T3
7:55	Delivery of loaded wagons to T1	8:10	Collection of empty wagons from T3		
				8:10	Ditto, T2

T = track

The following times were taken as a basis in the above table: approx. 7 minutes for moving loaded wagons form the "Patio" to the approach tracks with a shunting locomotive, and the same time for the return journey with empty wagons.

Moving the loaded wagons from the approach track, including positioning them for unloading and returning to the approach track, will take about 8 minutes, whilst the collection of empty wagons will take about 6 minutes. A gantry crane can unload two wagons in about 20 - 25 minutes.

The track occupation diagram below follows the shunting schedule for the two approach tracks and three loading tracks of berth 1.



When the wagons are however fully laden, they must be unloaded in the following sequence:

Track 1 - Track 2 - Track 3

This would mean that the empty wagons on track 2 cannot be collected before and during the unloading of wagons on track 3. It will not be possible to collect the empty wagons from track 2 and 3 until those on track 1 are being unloaded.

If only track 1 and 2 are used for loading, the third track can be used as a reserve track. When changes are made in the sequence of unloading wagons, it can be used for stabling wagons for short periods. The disadvantage of this system of using only two tracks is that even smaller irregularities in the delivery of wagons can hinder the entire loading operation. The port of Golfite, where this system is used, however shows that such irregularities in the handling of wagons by the railway seldom occur.

The above specimen shunting schedule shows that loading at both berths will involve numerous shunting runs between the "Patio" and the approach track and even more between the approach tracks and the loading tracks. A number of these runs will impede each other, thus making it more difficult to maintain a smooth flow of operations.

It will therefore be very important to ensure optimal employment and coordination of all those involved in operations. In the final analysis, this means that the presently used radio system for passing messages and regulating operations will have to be supplemented by shunting signals. The optimal choice would be a modern signalling system with light signals, operated from a control centre.

Communications / Organisation and the interfaces Fecosa - Japdeva in Moin

Apart from an exact description of the various tasks (when and where what work is to be carried out), a smooth flow of operations and loading at the port of Moin will call for definition of the nature and scope of the exchange of data between the Fecosa and Japdeva. To be able to set up plans for the banana-loading operations, the Japdeva will need certain data form the Fecosa, which in turn will need data from the Japdeva to be up to plan with its operations.

The Fecosa should prepare a so-called "guard's journal" at the point of origination of each banana train. This journal should contain the following data:

- station of origin
- date and time of departure of the train
- vessel to be loaded
- wagon numbers and their position within the train
- contents of wagons

The producers should give the Fecosa the names of the vessels to which their shipments are to be delivered and the contents of the wagons (grades of bananas).Immediately after departure of the train, the data from the guard's journal should be transmitted to the Japdeva's operations centre by teleprinter. Any irregularities in train running that will lead to delays can be reported by radio.

After these and data from other sectors have been processed, the Japdeva will cooperate closely with the Fecosa in preparing a so-called "sequence list".

This sequence list tells the Fecosa when, in what order, and at what elevator the banana wagons will be required. It should be transmitted to the Fecosa (operations centre at the marshalling yard) by teleprinter at least an hour before the train arrives.

The operation centre of the marshalling yard in Moin prepares a shunting card on the basis of the sequence list, this being used to distribute the banana wagons to the various sorting tracks at the marshalling yard. All others concerned in shunting operations (delivery of wagons to the sorting tracks and then to the loading tracks) should receive copies of the sequence list and a list of the wagons on the sorting tracks.

2.3.2. Ro-ro Facility Moin

(Drawing F-2.5)

In connection with the berth/day requirements for ro-ro vessels (see Chapter E) it was explained that the ro-ro facility in Moin will only be used in exceptional cases.

The necessary parking area for the trailers can be either located behind the oilpier (if the fertilizer plant will be erected in the south of the banana-berths) or parallel to the banana berth in the back-up area. The latter location would be recommended, if the fertilizer plant will be erected behind the oilpier.

The parking area should be divided into export- and import trailer lots, so that the landside traffic will not hinder the shipside traffic. The traffic flow is easy to describe:

- the landside arrival of export trailers will be performed by the companies one day prior to operation or on the operation day;
- shuttling operation with own trucks of the port between ship and parking area and vice versa;
- landside delivery of import trailers will be performed by the companies at the operation day or after completion of operation.

In case import trailers contain LCL-cargo and have to be shipped, they must be transferred to the shed in Limón.

In order to provide the same documentation services for ro-ro trailers as in Limón, it is necessary to fence the port area and to erect one checking platform between two lanes.

In addition also a small office building should be directly adherent the gates, where the export- and import documents will be presented. Also a parking area in front of the office building has to be made available.

The advantage of the availability of a ro-ro ramp in Moîn is, that the port has the possibility to avoid waiting times if two ro-ro vessels have to be operated in Limón/Moîn at the same time.

Ro-ro Area

An approx. 330 x 55 m ro-ro parking area that will suffice for 90 - 100 ro-ro trailers should be available behind the banana pier. This parking space would lie directly alongside the port service road (cf. Drawing F-2.5).

The routing of traffic to this parking area is to be seen from the draft drawings. One notes that the layout is such that incoming and outgoing ro-ro trailers will not impede each other. Although it will be necessary to cross a railway line and the road to the shipyard to reach the parking area, the disadvantage cannot be regarded as grave because there is very little traffic on this section (dead end). The parking spaces near the road are for import trailers, and those at the bottom of the slope (on the eastern side) are for export trailers. An extension towards the south would be possible in principle, although this would leave very little space for the future building of sheds.

The proposed arrangement of the parking spaces will not lead to a hindrance of the loading of bananas: traffic movements and the loading of bananas will be independent of each other.

2.3.3 Ship Yard with Slipway
(Drawings F-2.5, K-2.9.1, K-2.9.2, K-2.9.3)

Both ports require repair facilities to ensure repair and maintenance of the harbour owned boats, such as tugs, pilot boats etc. The best location for this purpose would be the area between the northern breakwater and the oilpier in Moín. (See drawing F-2.5).

To enable the boats to be moved out of the water for repair, there are basically two possibilities. The one is a slipway, the other an elevator system. In the layout (see drawing K - 2.9.1) it was decided in favour of a slipway system offering easier handling and easier maintenance contrary to an elevator system which is considerably more complicated in maintenance and pays out only when the repair volume is high.

The storage area which is situated at the end of the slipway offers space for about 3 botas of tugboat size. The storage area can be served either by auto crane or by track-bound crane. The advantage of an autocrane would be that it could also serve other purposes, for instance, the tugs at the tug berth for buoy replacement.

A workshop behind the storage area having a ground area of about 1600 sq.m. will accomodate all necessary repair facilities. The workshop will be fitted out with appropriate facilities to do the repair work also on the elevators. The final layout depends, however, on the size of the craft expected to be repaired. That means, it is important to know if also boats from outside are to be repaired and what are the sizes of the tugboats used in Limõn and Moín.

2.3.4 Handling Facilities for Petrol and Chemical Liquid Bulk and Fertilizer Bulk at Moín

Beside the former intention of Recope to handle their petrol imports at Moín via the oil piers, two new projects came up during the Consultant's review phase in Costa Rica. Two companies "Abono Superior" and "Quimicos Holanda" developed plans to handle their goods on the oilpier additionally to Recope's commodities.

After having investigated on the berth utilization for above mentioned commodities there seems no objection to handle all those goods at the oilpier (see also Chapters E-7, E-8 and E-9), considering that Recope's operation will have priority. Also the expertises on the fertilizer samples do not reject the operation although last doubts could not be eliminated that fertilizer handling will influence the banana quality handled in lee of the oil pier.

All three commodities could be handled on the oil pier, the required land areas could be allocated to the private users behind the pier. First extensions as required are possible but further ones limited.

Considering the design vessel as described in Chapter E-9 the water depth has to be determined according to the expected oil tankers.
For oil tankers up to 40,000 dwt fully loaded water depth of 14.50 m will be sufficient and serve all other ships importing chemical liquid bulk and fertilizer.

Presently the oil discharging tower of Recope is under construction already. Near that tower the chemical products need also fixed hose connections which should be installed next to the tower in the direction of the NW-pier end.
Between the oil discharging tower and the ro-ro ramp the fertilizer bulk facilities could be erected either as pier gantry or mobile cranes if the floor loads will be born by the pier (see also Chapter E-9).

Behind the oil pier the landside facilities for chemical liquid bulk and fertilizer could be erected as outlined in the Consultant's drawings (cf. Drawing F-2.5).

The following table indicates the berth utilization based on 360 working days per year.

Berth utilization of oil pier including ro-ro ramp in % of 360 days

Year	Utilization requirements by commodity				Total Utilization
	petrol	chemical	fertilizer	ro-ro	
1985	14	3	10	2	29
1990	17	3	15	2	37
1995	20	3	15	3	41
2000	22	3	15	3	43

Up to the year 2000 the total utilization allows a sufficient availability without severe waiting times for berth space.

The goods from Recope and "Quimicos Holanda" will be pumped through pipes to their storage tanks and thus do not load the port traffic.
In case of fertilizer bulk, which will be bagged in the adjacent plan substantially traffic may occur during peaks.

The main transport will be the railway, thus sufficient rail track length must serve the plant. As also truck delivery is planned a proper road connection must be provided. Ro-ro handling, although estimated at random occasion, need pre-storage space for 100 trailers approximately.

No special aspects have to be considered because of the use of the design vessel for fertilizer.

Particular safety regulations are required only for petrol products and possibly for chemical products. The private users as Recope and the other companies should be obliged to ensure the international safety rules regarding their particular commodity, as there are

- International Safety Guide for Oil Tankers and Terminals,
- IMCO-rules

and other publications. Furthermore the banana handling should not be influenced by fertilizer handling.

Comparison of advantages and disadvantages

advantages

- no further pier construction necessary
- improved utilization of oil pier
- separated port handling by private users located on one pier
- first step of industrialized port zone

disadvantages

- break of port organization because private users work in the port
- priority problems in berth allocation, if more than one ship will be due
- negative influences caused by dust of fertilizer to banana operation
- corrosion problems to the pier construction caused by fertilizer handling
- no further extension of plants behind the oil pier
- bottleneck of road and rail connection between ro-ro ramp and Moín hills
- due to the supply of ro-ro parking space behind the banana piers, restrictions in erecting storage space for other goods.

3. Development of the Ports of Limón and Moín up to the year 2000 - Case B

3.1 General

If, due to the containerization of bananas, Case B should occur as predicted in the forecast, the port facilities in their present concept of the ports of Limón and Moín will not suffice the requirements as far as the container handling is concerned.

This means mainly measures for the extension of container storage area and the construction of new berthing places which subsequently can also result in a modification of the existing handling faciliites for General Cargo and Break Bulk.

Generally, there are two possibilities for a new construction or an extension of the handling facilities for the future container traffic, i.e. the harbours of Limón and Moín.

A construction of a new container terminal in Limón would merely signify an extension of the Proyecto Alemán, whereas a new construction in Moín would have far-reaching consequences for cargo handling in Limón.

When such expensive construction measures are concerned it goes without saying that not only operational and technical requirements have to be fulfilled but it must always be kept in mind inhowfar the harbour could be extended after the forecast period, i.e. beyond year 2000.

In view of the operational and organizational requirements worked out in the previous chapters of this study for this high capacity demand of container handling, the following alternatives were established and analysed. The alternatives explained will offer reasonable solutions for the stated problematics:

Alternative B - 1 a:	Construction of a new container terminal with one berth in Limón.
Alternative B - 1 b:	Construction of a new container terminal with two berths and change of the Proyecto Alemán into a General Cargo and Breakbulk Terminal in Limón.
Alternative B - 2:	Construction of a new container terminal with one container berth and one general cargo berth in Limón.
Alternative B - 3 a:	Construction of a new container terminal with one berth in Moín.
Alternative B - 3 b:	Construction of a new container terminal with two berths in Moín.

The above mentioned alternatives shall be explained in detail in the following chapters giving also particulars on their specific advantages and disadvantages.

3.2 Alternative B - 1 a

- Construction of a new container terminal with one berth in Limôn -
  (Drawing F - 3.1)

As indicated in Chapter E (see also drawing E-1, E-2), the container storage capacity of the Proyecto Alemân with 1044 TEU'S will be reached by the year 1992. Taking into consideration the space requirements for 4,125 TEU'S in total the new container terminal must allow a storage of 3,081 TEU'S in two layers.

The required length of quay is determined by a container vessel of the 2nd generation, which will be expected also in the long run. As already indicated in the requirement calculation in Chapter E, this berth will be equipped with two container cranes up to the year 2000.

When establishing the new container terminal, the integration of a near-by parking area for ro-ro trailers is advisable.

It is therefore recommended to provide the area next to the workshop, so that the ro-ro trailers have only short distances to the vessels, but being separated from the container traffic.

The area needed for the entire terminal will be gained by land reclamation west of the Proyecto Alemân with the pier being designed as deck-on-pile structure.

Between the new terminal and the Proyecto Alemân the width of the harbour basin must be at least 150 m at a depth of 11 m.

The whole terminal must be taken in operation by 1995, the designated ro-ro area, however, as soon as 1992. Until 1994 this area will be used for container stacking.

As far as the entrance for the contianer terminal is concerned, it is advisable to establish centralized entrance gates for both container terminals. Due to the increase in number of straddle carriers the recommended workshop has to be extended by a third box for straddle carriers. This box should be directly adhered to the other two boxes. All other workshop facilities can remain as they are.

Concerning the coordination between both container terminals, long distances for personnel and equipment have to be covered due to the basin between the terminals, if no exact coordination is guaranteed. Therefore, it is recommended to clearly allocate the shipping lines to both terminals, so that a shifting of containers during the operation from one terminal to the other can be avoided. This allocation must be based on the expected container volume per shipping line and the time table of the lines.

Personnel and equipment must be centrally assigned every day according to the operational requirements. When dividing the two container terminals in such a way separate chassis areas, separate rail connections as well as separate inventory control of containers must be available. In exceptional cases if a container vessel will be berthed at one terminal whereas the containers are stacked in the other terminal, the internal transportation must be performed with chassis and trucks.

As general cargo vessels will continue to berth at berth No. 10 interference with the port operations is likely to occur.

In the following, we concentrate the most important advantages and disadvantages:

advantages

- Proyecto Alemân will continue its function, although this alternative means an extension
- although the entire facility is divided into two terminals, due to the basin a central disposition of personnel and equipment is possible
- although the shipping lines must be allocated to both terminals an exchange of both berths is possible in order to avoid waiting times for the vessels, although the operational costs will increase due to the use of trucks and chassis for the internal transportation
- the alternative guarantees an integrated future extension in the direction to the Muelle 70 (see Alternative B - 1 b)
- lowest construction cost.

disadvantages

- no exchange of container cranes possible between the two container berths
- no clear separation of general cargo and container / ro-ro operation.

3.3 Alternative B - 1 b

- Construction of a container terminal with two berths and change of the Proyecto Alemân into a general cargo and breakbulk terminal - (Drawing F - 3.2)

The best solution from the operation point of view would be to construct a new central container terminal with two berths at Limôn due to the high containerization of bananas. major moin

All general cargo and breakbulk operation will be transferred to the Proyecto Alemân. Thus a separation of cargo will be achieved and the trailer operation eliminated.

Like Alternative B - 1 a the new container terminal will be situated west of the ro-ro ramp on reclaimed land and the berths will be designed as deck-on-pile structure. In this case Muelle 70 has to be demolished due to space requirements of this central container terminal.

When the Proyecto Alemân is concerted into a general cargo / breakbulk terminal an additional shed of 6,300 squ.m. becomes necessary. The then available storage space will cover the storage area requirements.
The following table clearly shows the balance:

Storage requirements and provision (in m²) in 2000 (in brackets figures for 1995)	open		covered	
Breakbulk	7,080	(6,840)	5,550	(5,835)
General Cargo	1,480	(1,600)	5,930	(6,400)
LCL-Container	n i l because handled in the CT			
Total	8,560	(8,440)	11,480	(12,235)
provided (see drawing)	9,960		11,700	
balance	+ 1,400		+ 220	

The system of operation does not require anymore the intermediate trailer transport to the storage area. Thus the track driver and the unloading gang at the storage area will be saved, which totals 4 men per gang, if considered that a second forklift driver will support the gang at ship side (see drawings E-4.2, E-5.52).

The elimination of trailer transport will lead to reduced equipment park. Thus all tracks which serve the gangs and the trucks will not be necessary anymore. Then the equipment requirements will look as follows:

	Case A	Case B	savings
Breakbulk (see E-4.6)			
forklifts	18	18	nil
trucks	5	nil	5
trailers	15	nil	15
General Cargo (see E-5.6)			
forklifts	16	16	nil
trucks	5	5*)	nil
trailers	15	nil	15

*) these trucks could not be saved because they are required for ro-ro traffic also.

This system will not create problems of berth allocation near the storage area because all storage space will be adjacent to the piers. Furthermore the landside delivery organization will be facilitated because all consignees will take over their cargo at the Proyecto Alemán. All trucks will use one gate only which is another advantage.

As shown on drawing F - 3.2, the new central container terminal will have two berths. Both berths shall have a length of 250 m, located opposite the Proyecto Alemân while the other berth should be located at the former Muelle 70. Each berth should be equipped with two container cranes until the year 2000.

The necessary container stacking area is located behind the two berths and in the back-up area of the terminal. The stacking area would be divided more or less in the middle by the tracks of the railway in order not to hinder shipside operation. The chassis area will be centralized at the upper boundary of the stacking area. This guarantees a separation from this ship's operation and also acceptable transportation ways for the straddle carriers.

Due to the centralization of general cargo and breakbulk activities on the Proyecto Alemân it is recommended to use the shed near the Muelle 70 as consolidation shed for the stuffing and stripping of containers.

Similar to Alternative B - 1(a) an integration of a near-by parking area for ro-ro tracks is necessary. We recommend to provide this area beside the ro-ro ramp, so that the trucks have only short distances to the vessels, but being separated from the container- and general cargo traffic.

In the following the most important advantages and disadvantages are listed:

advantages:

- one central container terminal without division by a basin
- clear separation of container traffic and other traffics
- the layout guarantees a future integrated extension for the port of Limôn.

disadvantages

- Function of Proyecto Alemân can not be maintained
- no exchange of container cranes possible between the two berths
- construction of a new shed on the Proyecto Alemân
- additional investment for second container berth.

3.4 Alternative B - 2

- Construction of a new container terminal with one container berth and one general cargo berth in Limôn -
  (Drawing F - 3.3)

Alternative 2 implies that the Proyecto Alemân would be changed into a mere container terminal by moving the Bodega of Proyecto Alemân to Muelle 70. This would provide a container storage capacity of 1570 TEU'S if stored in two layers. This capacity would meet the requirements until the year 1994. The general cargo vessels would still be handled at berth No. 10.

In 1994 then the 2nd container berth with its associated storage areas and the new general cargo berth would have to be completed. Like in the other alternatives, the needed space would be gained by land reclamation west of the Proyecto Alemân. The container pier with its length of 250 m and the general cargo pier with 200 m length would have to be designed as deck-on-pile structures.

It is advisable to establish centralized entrance gates for both container terminals. Gates and weigh bridges and related checking platforms have to be provided and the parking area for the ro-ro trailers beside the ro-ro ramp.

The new general cargo terminal will have a width of 35 m and will be a replacement for No. 10. Together with the Muelle 70 general cargo and breakbulk will be handled there. The goods will be transported to the moved shed by trailers or will be stored adjacent to the operation area in case open storage could be performed. The general cargo terminal will be separated by a fence from the container terminal because it belongs to the general cargo/breakbulk section.

Due to the construction of a new basin between the Proyecto Alemán and the new container terminal, long distances for personnel and equipment have to be covered if no exact coordination is guaranteed. As described before, the shipping lines must be clearly allocated to both terminals, so that the moving of containers during the operation from one terminal to the other can be avoided. This allocation must be based on the expected container volume per shipping line and the timetables of the lines.

Personnel and equipment disposition, separate chassis-areas, separate rail connections as well as separate inventory control of containers will have to be similar as described for Alternative B 1(a).

In exceptional cases, internal transportation performed with chassis and trucks is possible.

In the following the most important advantages and disadvantages are concentrated:

advantages

- Function of Proyecto Alemán in its original assignment will be maintained
- although the entire facility is divided into two container terminals, due to the basin, a central disposition of personnel and equipment is possible
- although the shipping lines must be allocated to both terminals, an exchange of both berths is possible in order to avoid waiting times for the vessels, although the operational costs will increase due to the use of trucks and chassis for the internal transportation
- clear separation of breakbulk / general cargo and container / ro-ro operation
- mixed operation of general cargo and breakbulk.

disadvantages

- no exchange of container cranes possible between two container berths
- no possibility of an integrated future extension
- trailer system for general cargo operation
- additional investment for general cargo berth.

3.5 Alternative B - 3 a

- Construction of a new container terminal with one berth in Moîn -
(Drawing F - 3.4)

In case the bananas will be fully containerized up to the year 2000, it is conceivable to build a separate terminal with one berth in Moîn in the year 1992 for exclusive handling of containerized bananas and to operate the facilities in Limôn, i.e. the Proyecto Alemân as they are.

Before giving more details, the major operational problems which would follow such an alternative layout, shall be stated:

- Sealand already calls at Limôn with general cargo containers and will not have vessels merely for containers with bananas.
- Standard Fruit and United Brand are expected in future to decide on a diversification into general cargo to eliminate the unbalanced trade.

Generally speaking, it is not common and very difficult, to assign special shipping lines to both container terminals at Limôn and Moîn, independent of what kind of cargo is transported in containers. Such an assignemnt is usually based on the expected container volume per shipping-line and their timetable for the vessels.

The new terminal will be equipped with a berth of 250 m length, two container cranes up to the year 2000 and 4 entrance gates. This terminal would be larger than in alternative B 2 as the shed on the terminal in Limôn will not be removed to avoid the construction of a new general cargo berth in Limôn.

As the container terminal in Moîn will be separated form the container terminal in Limôn and the other port facilities in Moîn, it is additionally necessary to provide for a new administration building, a new workshop and possibly a consolidation shed, the latter, if a container line would be distributed to Moîn which carries larger amounts of LCL-cargo.

The workshop would cover the same area as in Limôn, i.e. approx. 1,500 sq.m. and should be located at the border of the container terminal. The administration building should provide office space for the Port Authority, Fecosa, customs, and shipping lines, up to approx. 400 - 500 sq.m.

The most important advantages and disadvantages of this alternative in comparison with an extension in Limôn are analyzed:

advantages

- Proyecto Alemân will continue its operation
- There are no traffic peaks due to optimal rail/road connections.

disadvantages

- fixed assignment of personnel and equipment to both terminals (exchange of personnel possible to a certain extent, exchange of straddle carriers impossible);
- no exchange of berths possible as in Limôn (in order to avoid waiting times), as containers cannot be moved from one terminal to the other, i.e. from Limôn to Moîn;

- establishment of a container terminal in Moîn makes an integrated future extension in Limôn impossible;
- necessary creation of a new workshop in Moîn which requires more space than an extension of the workshop in Limôn (due to the degree of utilization);
- possible erection of a consolidation shed (depends on shipping lines assigned to Moîn);
- necessary erection of an additional administration building and de-centralisation of container terminal administration;
- different deviation of the Moîn river;
- early investment caused by starting operation in 1992.
- construction of rival harbours and not of integrated working ports as Limôn and Moîn should be;
- very limited extension possibilities of Moîn for other special types of goods which are to be expected in connection with the industrial and free trade zone;

3.6 Alternative B - 3 b
- Construction of a new container terminal with 2 berths in Moîn -
(Drawing F-3.5)

As explained in Alternative 3 a, a distribution of container traffic between Limôn and Moîn would cause considerable problems. To avoid such difficulties it will be necessary to establish one container terminal with two berths at Moîn with a capacity suitable to cope with the whole container traffic by 1992.

This alternative implies that cargo handling operations at Limôn are restricted to general cargo and break bulk handling.

Alternative 3 b is more or less an extension of Alternative 3a with two berths of 250 m length each and 4 container cranes. Like for Alternative 3 a, this alternative requires also a new administration building, one consolidation shed and one workshop.

In the following the most important advantages and disadvantages are concentrated:

Advantages

- there is only one central container terminal
- there are no traffic peaks due to optimal rail/road connections
- exchange of container cranes possible.

Disadvantages

- conceptually new port system; Proyecto Alemân loses its original function;
- necessary erection of a new workshop
- necessary erection of a consolidation shed
- the future port extension for other goods is very limited
- general cargo and container traffic are divided
- different deviation of the Moîn-River
- early very high investment caused by starting operation in 1992.

- construction of rival harbours and not of integrated working ports as Limôn and Moîn should be;
- very limited extension possiblities of Moîn for other special types of goods which are to be expected in connection with the industrial and free trade zone;
- conceptually new port system; Proyecto Aleman loses its original function;

4. Resumee of Advantages and Disadvantages of Case B Port Development Alternatives

As a result of the statements described in Chapter E, Future Port Operation, the circle of economic trade, technical development, rationalization and modernisation must be closed by adequate port facilities, combined with flexible operation leading to a quick dispatch of the vessels.

As a necessity for all ports in the world, so-called terminals were created characterized by specialization of facilities and equipment for various kinds of cargo. Only due to this specialization, a port can guarantee a high operational productivity.

The present harbours of Limôn and Moîn have to be extended and developed so that they do not work rivally but integrated.

Any investments associated with new construction rehabilitation for such facilities must be valued not only in view of their immediate effects but moreover in view of general benefits beyond the lifetime of single structures. That means, not only operational and technical requirements for a forecast period must be fulfilled but especially possibilities of further extension in later years, i.e. after year 2000.

This applies especially to developing countries, where financial resources are rare and the country's economy may develop different as foreseeable at present. (Development of industrial zones f.i.).

Also, these terminals need according to their quick quay-side operation a well organized land-side delivery of cargo to and from the port.

When evaluating the port development alternatives as discussed in section 3 of this chapter, the most important advantages and disadvantages must be considered under these aspects.

From this, it is obvious that alternative B-1 (a) shows the most important advantages while the disadvantages carry no great weight. This alternative offers the lowest construction cost of the Limôn development possibilities (1 (a) and 1 (b) and 2) and implies future extension capacity as well as a development of Limôn, as started with the Proyecto Alemán, to a container and general cargo port, i.e. a common port. If in the years following 1995 operational difficulties due to the container handling separated by the general cargo operation and its harbour basin will arise and may effect port efficiency, appropriate measures can be undertaken to extend the new 1 berth-terminal by a second berth analog to alternative B-1 (b). Most important, however, is, that the fully operating Proyecto Alemán stays as the basis for effective port operation at least 15 to 20 years.

Alternative 1 (b) shows operational advantages but makes the container terminal concept of Proyecto Alemán doubtful and requires tremendous investments in Limón for container handling.

The third alternative, B-2, is the most unfavourable solution for port development in Limón, slight operational disadvantages which might occur due to the separation of the 2 container berths through the harbour basin are minor as there will be no possibility to an integrated future development. The necessary arrangement of the general cargo berth west of the new 1 berth-container terminal hampers any extension in this direction. Also, this alternative shows higher construction cost compared with alternative B-1 (a).

As stated before, any construction of container handling facilities in Moín would have far-reaching consequences for cargo handling in Limón, i.e. that the main traffic will be transferred to Moín with its limited extension possibilities whereas Limón with its far better development possibilities will decline in its importance. This applies in the same way to alternative B-3 (a) and 3 (b). Whereas alternative 3 (a) would merely be a compromise to introduce handling capacity for excess banana container, the logical way would be to consider alternative 3 (b) as a possible solution. Also it seems theoretically possible to operate 2 by more than 4 km separated container terminals simultaneously for the same customers (since all 3 banana exporting companies might call Limón for balance of trade with respect to empty containers), past experience and new constructed ports in many countries indicate the advantage of unitized terminals. Thus, only alternative B-3 (b) remains as a comparable solution to the propositions made for Limón.

Both alternatives for Moín must be put into operation in 1992, whereas construction measures for the Limón alternatives must be finished earliest 1994/95. In addition, considerable investments must be taken for relocation of the Moín-River outflow, since the dam construction as proposed for now will lay in the future harbour basin of these alternatives. The cost comparison according to Section F.8 tables indicate relatively low construction cost estimates as valued against alternatives B-1 (a) resp. 1 (b), but it should be kept in mind, that, that relocation costs of the river outflow are not included in this cost estimate. In Chapter L it is pointed out, that due to the early investment necessary to finish these alternatives the economic benefits in terms of net present values (NPV - 1980) are lower as compared with the alternatives in Limón (the higher the NPV the more disfavourable the project).

This is illustrated in the following table:

Alternative	Construction Costs in Mio US $ 1979	Construction Costs in Mio US $ 1980[1)]	NPV in Mio US $ 1980	Year of operation
B - 1(a)	50.5	84.6	11.9	1995
B - 1(b)	68.8	115.1	11.8	1995
B - 2	53.8	86.7	12.3	1995
B - 3(a)	35.1	58.8	12.3	1992
B - 3(b)	54.8	91.8	19.5	1992

1) 15 % inflation, 4 % engineering and 40 % foreign exchange cost added.

1979 construction cost include contingency allowances, whereas 1980 prices are adjusted to inflation and foreign exchange components, imputed no local participation. The NPV considers the different years of investment allocation and construction start.

Taking the above mentioned into account, it is recommended to assign the cargo to the ports of Limón and Moín according to alternative B-1 (a). It is obvious, that this division of cargo assignment guarantees the most economical combination of the two ports.

It is secured that there will be extension and development capacity for "general goods" either containerized or conventional resp. in break bulk in Limón and, what is equally important, this scheme offers the possibility to serve in Moín all future needs of prospective port users. Although, as discussed in Chapter C, future customers for the port of Moín could not be identified due to the very early stage of prospecting for industrial developments in this area, it is believed absolutely necessary to provide ingenious extension potential for such developments in Moín as a so-called "special port".

In Section 7 of this chapter, these aspects will be dealt with in a more broader extent.

Based on the recommendations above, the Port Masterplan Concept of the Limón/Moín area rests on an integrated development of the Port of Limón according to alternative B-1 (a) and a future utilization of the Port of Moín specialized commodities.

5. Future Traffic Connection to the Hinterland

(Drawing F-5)

5.1 Railway

Railway traffic plays a major role for the future port operation of the ports of Limón and Moín. Development tendencies and the impact of rail transport are described in Chapter D.2, present rehabilitation measures in Section 3.3.1.

Limón - Moín link

The present track linking Limón and Moín is a single track. It is recommended that this line should not only be electrified but also upgraded to twin tracks, particularly if Case B is to be implemented, i.e. when an important amount of traffic is taken from the port of Moín to the port of Limón. In this case, one can hardly expect the single-track line to be able to handle the increased traffic, particularly as one will also have to expect more passenger trains.Electrification is recommended because trains from Siquirres which are hauled by electric locomotives could then be continued to Limón with the same traction vehicle if necessary. A further consideration is that there are considerable gradients between Moín and Limón which represent less of a problem with electric traction.

It will then be possible to run freight trains through from San José to Limón without any handling in Patio Moín.

Central Railway Yard for the Ports of Limón and Moín

The purpose of the marshalling yard will be to carry out operational tasks as far as possible, partly because of the requirement that railway operations be centralised in the interest of economy and partly to relieve the burden on the ports of Moín and Limón.

The planning and design of the marshalling yard at Moín will be largely influenced by the general concept for the larger area of Limón and Moín. The following therefore describes the operational function of the Moín marshalling yard which results from cooperation between the two ports and the shunting station, and makes a number of recommendations.

The new marhsalling yard should serve as a central shunting station for the area of Limón and Moín. This will avoid the necessity of building two shunting stations within a relatively small area. A second advantage is that centralisation of the shunting operations will allow more efficient employment of both personnel and equipment.

Also to be avoided is the originally planned shunting station for the handling of bananas only. This would be a very specialised station which, in the event of any change in handling systems of the containerisation of bananas, would probably have to be reconstructed. Other functions of the central shunting station will be to handle all freight trains for the Limón/Moín area, to classify bananawagons and prepare those bound for the port of Limón, to collect and forward empty wagons as soon as possible, to clean empty banana wagons and send them on quickly, to detect wagon damage and have it repaired in the main repair shop.

The central marshalling yard should be so dimensioned that it can handle about 10 full banana trains per day and send them to the port of Moín and then collect and distribute the returning empty wagons. It will also have to handle 2 - 5 freight trains from San José, which will continue to the port of Limón. It will also handle trains coming from Limón and going on to San José.

A twin tracked line is to connect the central marshalling yard and the tracks in the harbour. This will allow several shunting movements per hour; a single-tracked line would not be sufficient.

5.2 Road connection

(Drawings F-2.5, F-5)

The following road connections for the port facilities - banana and oil piers and ro-ro ramp in Moín are planned:

A new road is recommended to link the port with Highway 32 (Siquirres - Limón) and to carry the heavy traffic - mainly ro-ro trailers, trucks carrying bananas, and, in future, traffic to and from industrial enterprises in the port area such as the Abonos Superior S.A. This road will simultaneously serve in the future the planned free-trade zone with its industrial firms east of the Recope refinery. The new approach road could be build on level ground parallel to the Limón - Siquirres railway line.

Following the solution proposed by the BEL engineering office in San José, it is recommended that this road should lie between the present railway line and the planned marshalling yard of the Fecosa. The road would link with Highway 32 in the vicinity of the railway bridge over the Rio Moín and would have a length of about 3 km. The extension in the direction of the oil pier would lie parallel to the railway tracks and at about 3 m distance from them; the remaining space between the road and the rising ground on the eastern side would be suitable for ro-ro parking space, sheds and a port authorities building. The alignment between km 0.1 and km 2.9 which was proposed by the BEL Ingeniería can remain unchanged.

It is, however, not believed that the trumpet-shaped crossing at two levels of the port access road and the Highway 32 as proposed by the BEL will be necessary, as the expected volume of traffic could also be handled with at-grade turnoff lanes (in particular, for traffic turning off from Highway 32 to the left). The Limón - Siquirres railway line parallel to Highway 32 should however be crossed on a second level, as already planned by BEL Ingeniería. Approach roads to the planned free-trade zone could be located between the refinery and the marshalling yard and north of the marshalling yard. The exact alignments can not be determined before the planning of the free-trade zone has reached a more concrete stage (refer to Chapter C and F-7, drawing F-7.2).

At km 2.9 (near the railway bridge over the Rio Moín), there should be an approx. 500 m-long link with the road which runs along the coast via Portete to Limón, this representing the second route to Limón. This section of the road would also simultaneously link with the road No. 240 via Empalme Moín to Highway 32.

Road No. 240 is presently used by ro-ro vehicles running to the container and ro-ro terminals of Sea-Land, Pan Atlantic and CGM. Because of the alignment restrictions and because it is unsurfaced, this road does not allow a smooth flow of traffic and can only be regarded as a temporary solution. When the port of Moín is taken into service, the new link road to Highway 32 should also be completed to ensure a smooth flow of port traffic.

The coast road via Portete to Limón should be closed to heavy traffic, to keep this traffic out of the centre of Limón. All origin and destination heavy traffic of the port of Moín should be routed over the above mentioned new link road (cf. drawing F-5).

For Case B, development and for any future industrial and free trade zone development near Moín, we assume that the links with the main road traffic network of the Limón/ Moín region will in general be as described before.

The additional heavy traffic to and from the port of Moín in conjunction with the traffic to and from the free-trade zone could possibly necessitate separate levels for Highway 32 and the port access road at their junction. Whether this is necessary or not has to be proven then by calculations. In any case, one should avoid routing heavy traffic over the coast road to Limón in order to keep it away from the centre of the city.

6. Development of Additional Ports on the Atlantic Coast

(Drawing F - 6)

6.1 Introduction

A further task of the study is to investigate the necessity and suitable locations for other ports at the Atlantic Coastline of Costa Rica. Three main issues arose during the Consultant's review in Costa Rica.

One was the intention to find other possible locations for banana loading besides the present ports. Another reason for this task was the recent idea to construct a pipeline from the Pacific to the Atlantic coast of Costa Rica. The pipeline should serve as a certain substitution for the Panama Canal in crude oil transport of the Alaska oil. This project requires safe and workable transloading facilities navigable for very large crude oil carriers (VLCC'S).
Third, due to the fact that Costa Rica owns a sea-territory of about 500,000 km^2, the possibility of increasing fishery to a small, but efficient self-sustained industry with the main objective to increase income for lower income people and to provide the country with cheap, but valuable protein resources as additional food stuff will have a substantial part in the new development program of the Government.

6.2 Description of Coastline from the Panamenian to the Nicaraguan Border

Introduction and General Aspects

The Atlantic Coast of Costa Rica runs approx. 110 nautical miles northwestwards from the Rio Sixaola mouth up to Punta Castillo near San Juan del Norte / Nicaragua. The coastline shows only few changes, this particularly in the south of Puerto Limón.

The main wind direction is determined by the Trade Winds from north east, although northern and east to south directed wind might happen frequently due to local weather conditions. The current sets south from the Nicaragua border with a speed of approx. 2 to 3 knots up to Limón where it is deviated to south-east with the same speed. The current range seaward up to 30 nautical miles reportedly.
Natural shelters against wind and swell can hardly be found, only in the south of Limón some bays exist.

From the South to the North

The first cape from the Panamenian border is Punta Mona or also called Punta Careta approx. 5 miles NW of the Rio Sixaola delta.

Directly south of Punta Mona there is a small port, Gandoca, where formerly wooden products were exported. The operations were performed on the anchorage at a water depth of 15 m, from there the depth decreases very fast shorewards. Between Punta Careta and the next cape, Punta Cahuita a wide bay runs NW; the ground of sea is coral-shoal up to 1 mile off the coast.

Two small villages, Puerto Viejo and Puerto Vargas, are located there. Puerto Viejo is a small fishing port and Puerto Vargas a small village. The coast from Puerto Vargas to Cahuita is one of the Costa Rican national reservates on the Atlantic Coast. From Punta Cahuita to Puerto Limôn the coast is sandy and of low elevation. The waterdepth between Punta Cahuita and Limôn slightly decreases and the 10-m line lies within a range of 1 mile off the coast.

From Limôn to Punta Castillo near the Nicaraguan border the low elevated coastline runs approx. 65 miles north-westward. There is no shelter against northeast winds and swell. Good anchorage is found approx. 3 miles seawards from the coast. The Bahia de Moîn is the last cape and creates a bay of approx. 1 mile.

The next land cut is found at the mouth of the Rio Parismina, where the low sandy coast opens little to sea. That area also is a national reservate especially for turtles. From there to the mouth of the Rio Colorado no particular place is situated. The Rio Colorado has at its bar a waterdepth of 3 m only which does not allow shipping of bigger seagoing vessels.

6.3 Additional Banana Export Harbours

The necessity of having banana export harbours in addition to the Port of Moîn was brought up due to information gained from the banana producing companies and from meetings with the "Câmera Nacional de Bananeros".

The Consultants have been informed that there are strong intentions to increase productivity of the plantations around Siquirres area of about 20 Mio Cajas and to open new plantations near Pais with an expected output of about 10 Mio. Cajas (land requirements about 2,000 ha). Resulting from this plans, the idea came up to export bananas through near-by new small specialized ports, near Laguna Caldera in the North of Limôn and Laguna Gandoca to the South (refer to Draw. F - 6).

However, as mentioned especially in the foregoing Chapter C and E, the forecasted and expected export volume does not exceed at all the capacity of the new terminal in Moîn. This is also supported by the Consultant's expectation of containerization in banana trade, which makes it necessary to have special handling devices.

In addition, the expected increase of infrastructure supply, especially opening of the new all-weather road to Sixaola - Bri Bri area, National Highway No. 36, and the short distances from the plantations to the Port of Moîn, underline the preference of Moîn as the central banana export harbour.

6.4 Tanker Terminal Moîn

From the nautical view only bays south of Limôn would give a certain natural shelter, the Bahia de Moîn included. The north of Limôn gives no natural harbour, because the only possible location would be the Rio Colorado. But to remove the bar is a very costy enterprise. Furthermore absolutely no shelter against the strong northeastern wind and swell exists at the coast. The waterdepth of at least 20 - 25 m for very large crudeoil carriers is found approx. 1-2 miles off the coast.

Another oecological aspect should be indicated, namely that the national reservates in the north and south would be affected when creating oil transloading points.

For those reasons the Bahia de Moín would be the optimum place because of its already industrialized area, its favourite location to the pipeline track and the already existing infrastructure as port and storage facilities.

The very large crude oil carriers (VLCC'S) should be loaded in the open sea by single buoy mooring systems (SBM'S), because the size and draught of vessels need extremely large pier facilities and dredging.

The required draught for VLCC'S is approx. 25 m,which is found approx. 2,5 miles north of Moín on natural depth.
SBM could operate tankers up to a certain wind speed and swell (approx. 7 BfT) but will be influenced by the wave height when taking over the hoses.

Then another risk should be mentioned. Normally a ship at anchor or at a SBM lies with its bow directly in the direction of swell and wind when having the same direction. If a current is strong enough and setting in another direction a different heading of a vessel results, which means that the waves do not strike the ship at the bow but from different directions and then cause potential damage.

To avoid this risky situation for the environment and vessels one should consider to construct a sea breakwater which eliminates the swell height and produces leeward anchor or SBM spaces.
The wind itself does not affect the tanker in a way that operation must be stopped. This concept still needs further investigations by a model and economic evaluation.

Drawing F - 6 shows the approximate alignment of a Pacific-Atlantic oil pipeline and locations of possible small scale ports.

6.5 Development of Fishing Harbours on the Atlantic Coast

The past has shown that Costa Rica is frequently facing problems in securing basic food. One important aim of the previously mentioned National Economic Plan is to reduce these bottlenecks and search for alternative solutions which would ensure an improved food situation on a long-term basis.

An essential part in this context takes the development of the fishing industry which not only provides the vital proteins but also offers new job places in the coastal regions for the low-income population groups. The development of fishery, that is especially thuna, sardines etc. will above all take place in the Pacific coast regions. For the Atlantic coast the development of lobster fishing along with the erection of processing industries for exportation to the USA and West Europe will be expected.

At present, fishing activities in Portete (Moín), Cahuita and Porto Viejo by local fishermen are concentrated on lobster fishing, mainly for local consumption. The fishing methods applied are simple and not very efficient depending on the natural hindrances of summer and rain periods, and are thus often left to chance.

Considering the great importance fishing and sale could have for the economy of the Atlantic coast area, there are now concrete plans to provide the necessary infrastructure for a systemized development of these activities.

First of all, further detailed studies should be carried out, in order to ascertain the extent of the fish stock and its optimal utilization.

As far as the local construction of fishery harbours is concerned, it can principally be said, that,when considering what has been mentioned above, and that lobster fishery is expected to develop in future, a settlement in the Moïn Bay is not advisable, as the extension of Moïn should be reserved to the special goods from the industrial zone in the area of Moïn, for which, however, from the present state it is not certain, how to realize efficiently this extension in detail.

The area south of Limôn, that is Cahuita and Porto Viejo, are characterized by a brisk lobster fishery, operated, however, by very primitive means. Regarding the promotion of the low-income zones to which this area also belongs, Cahuita should be developed after the necessary technical preconditions, which would guarantee an economic operation have been fulfilled. (Lobster fishery study, exploration of spawning grounds outside the seasonally limited migration to the coast, processing methods).

In the greater Limôn area, there is additionally the Bay of Portete which would be a suitable place to take up the lobster fishing boats to a certain extent. This would mean higher attractiveness also in view of the increasing tendency of tourism on the Atlantic Coast (refer to Drawing F-6). But concerning this matter, as mentioned before, first of all the results of additional studies should be waited for.

7. Masterplan Concept for the Ports of Limón and Moín

7.1 General

Chapter 4 gives a summary of the various alternatives for Case B including judgement and evaluation. The difference between Case A and Case B is that they proceed from different assumptions as regards the development of container handling. Case B, therefore, implies essentially the allocation of the container handling operations to the ports of Limón or Moín and, as a consequence thereof, assignment of the handling of other types of goods, if Case B becomes true. As such development would not occur before the year 1990, the Masterplan study can only outline possible development schemes of the ports of Limón and Moín. This is in conformity with what is generally practised when setting up a Masterplan: setting a rational development framework into which successive construction projects can be fitted as the traffic increases.

For this, the authorities concerned should maintain a permanent ability to recognize changes in demand in order to re-assess the development program. The Masterplan should have a continuous existance as a reference document. It should be modified, for instance, to take a new look at the future situation (in the present rapidly changing stage in shipping and also economic development) or as a result of events in the course of the current period which make a review desirable.

7.2 Masterplan Concept of the Port of Limón
(Drawing F-7.1)

The harbour of Limón as "common port" should be reserved in the future for the transshipment of containers, general cargo and break bulk as homogenous goods, as all necessary installations are existing by the realization of the Proyecto Alemán.

The alternative which would best meet the requirements of an increased container traffic and which at the same time would offer the best possibilities of development is Alternative 1(a),which includes one berth in Limón. For Case B this is a first step towards a further harbour extension. This alternative is so designed that it can be extended to Alternative 1(b)at any desired time, i.e. as traffic volume increases and/or operation requires; that means the construction of a second berth including storage areas.

This would be the 2nd step towards further development of the port of Limón. As discussed before, this step would signify a change of the function of the Proyecto Alemán from a general cargo and container terminal into a general cargo and break bulk terminal, due to the following reasons:

1. If Alternative 1(b) is implemented, Muelle Setenta would have to be demolished and a new place would have to be found for break bulk handling which could only be in Limón because a splitting of break bulk and general cargo handling between two separated harbours would not be reasonable and would be contradictory to common practice of harbour operation.

2. When due to a further increase in container traffic the 2nd step (1b) will be implemented after the year 2000, a separation between two container terminals by a harbour basin and a general cargo pier can no longer be maintained.

From this results that in the long future the total container traffic could be concentrated in one terminal and the present container berth which is then free could be used for break bulk handling. That means, after completion of the 2nd step (1 b) the port of Limón will have one container terminal and one general cargo - break bulk terminal.

This first two steps of the development of the port of Limón can be covered by the forecast and can thus be regarded as realistic if Case B occurs.

From the structural point of view the layout of the two alternatives is such that - except for the construction measures described in the previous chapters - no changes of the harbour protection facilities are involved. That means, first an extension of the breakwater which would forcibly be connected with high investment costs is not required.

In the event that a development is necessary beyond the second alternative, which can not be foreseen at the present stage, the port of Limón offers excellent possibilities of extension provided that the existing breakwater is extended and a new one built from west to northeast providing protection to the harbour by two breakwaters.

This would permit the construction of further berthing places from north to south (Cieneguita). In this case the mouth of the Rio Cieneguita would have to be moved to avoid sedimentation of the harbour and to provide a continuous harbour area. This would also mean that new living space would have to be found for the population that has to give up its present residences due to the construction measures. It results from the planning documents for future projects received from OFIPLAN[1] that the rehabilitation of this part of Limón has long been planned and there are also plans to create new living quarters east of the dead-end branch of the Cieneguita river.

7.3 Masterplan Concept of the Port of Moín

(Drawing F - 7.2)

The future of Moín lies in its potential for spacial development associated with the realization of an industrial zone and other economical activities in the area between the present port and the RECOPE refinery. It would be unreasonable to expect that the industrial planning policies of the government will not be implemented only because such policies are presently not very precise and subsequently growth factors for traffic increase could not be established (Chapter C).

Therefore, this long-termin plan for Moín will place more emphasis on what is desirable than on what the actual data seem to show to be likely. The role of the port includes especially the following tasks:

- to serve the nations need for supply with crude oil and special bulk commodities, which are to be handled at special terminals

- to assist in generating trade and regional development

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[1] Oficina de Planificación Nacional y Politica Economica, San José

This land-use aspect in the neighbourhood of the port is very important since modern developments have made the need for ample land space and nearby port facilities for special uses much more imperative than it was the case in the past.

From the technical point of view, the future port of Moín presents itself as follows:

As there will be no banana handling operations at the banana pier of the port of Moín from the year 2000 if Case B comes true this pier can be used for other goods, such as industrial goods. According to the concept of the diversion of the Rio Moín in Case A, this pier can be extended by about 200 m,i.e. a further berthing place.

The possibility of future further extension are additional berthing places as discussed in connection with the possibilities of a container terminal in Moín. However, it has to be stated, that the extension in Moín would be restricted by the need of discharging the Rio Moín at the root of the southern breakwater as any other place along the coast line would cause a silting up of the river mouth. (refer also to Chapter I).
Summing up, the port of Moín shall in the opinion of the Consultants in future serve as a "specialized port" for industrial and bulk cargo.

8. Cost Estimate

This section includes estimates of the expected investment costs for the different cases of port development. For civil works related to

- Port of Limón
- Port of Moín,

the costs are based on the following criteria:

- unit and base costs which we received from authorities in Costa Rica
- unit and base costs from own experience and from international sources
- direct quotations from manufacturers or from price lists (especially for facilities and equipment)
- comparative costs from harbours presently under construction (Proyecto Alemán, Caldera port).

The quantities are based on the layouts of Case A and Case B alternatives as described before.

The cost for Case A development are based on the preliminary designs for the various structural and civil elements as presented in Chapter K, whereas cost estimates for Case B development are derived on a somewhat rougher scale.

The stage of accuracy of such cost estimates amounts in general to about ± 20 %, bearing in mind, that the degree in confidence in the cost estimates will increase as more design work is carried out. Also it should be remembered, that traffic and shipping forecasts naturally cannot be any more precise.

The unit prices of the single items consider the following factores:

- wages for national foreign personnel
- material costs
- depreciation of equipment, transportation costs
- other site facilities such as offices, workshops
- running costs for operation on site
- venture, profit and business expenses etc.

On the average, wages make up for approx. 10 %, material costs approx. 30 %, depreciation of equipment as well as transportation of equipment also amounts to approx. 30 % while the others also make up for approx. 30 % of the unit prices.

Furthermore, a rough estimate of infrastructure costs (road and railway facilities) outside of the ports of Limón and Moín is given in this section.

The calculated costs are listed in the following tables: (Table F.8-1 to F-8.12):

Construction cost of Case A - Port of Limón [1)]

Item	Unit	Unit Price (US $)	Quantity	Total (US $)
1. Earthworks				
- Slope protection near the ro-ro area	m	500.-	280	140,000.--
2. Demolishing works				
- Demolishing of 45 m of Muelle Metalico	L.S.	---	---	112,000.--
3. Dredging works				
- Dredging until 11 m (NMM) for the widening of the approach channel of Proyecto Alemán	m^3	4.-	15,000	60,000.--
4. Pavement				
a) access roads of concrete slabs	m^2	67.-	6,950	465,700.--
b) parking area of concrete stone	m^2	52.-	9,600	499,000.--
5. Sewerage				
- Sewage of storage areas	ha	60,000.-	1.7	102,000.--
6. Buildings				
a) Gate House	L.S.	---	---	13,000.--
b) Workshop	L.S.	---	---	2,056,000.--
7. Rehabilitation of Muelle 70				
- Rehabilitation including fender, poller etc.	L.S.	---	---	480,000.--
8. Fencing				
- Fence of about 2 m height including rendering and foundation	m	72.--	1,165	83,900.--
	Total			4,011,600.--
	+ 20 % site installation			4,814,000.--
	+ 10 % contingencies			5,295,000.--

1) Price Basis 1979

TABLE F-8.2

Construction cost of Case A - Port of Moin [1)]

Item	Unit	Unit Price (US $)	Quantity	Total (US$)
1. Earthworks				
a) Grading and compacting	m^2	1.5	30,000	45,000.--
b) Cut or filling	m^3	10.-	3,670	36,700.--
2. Dredging				
- dredging of pier extension to -12 m (NMM)	m^3	4.5	73,000	329.000.--
3. Pier Extension				
- extension by 68.4 m including fenders, bollards, pile driving, slope protection and cathodic protection	m	27,600.-	68.4	1,888,000.--
4. Pavement				
a) access roads of concrete slabs	m^2	67.-	18,700	1.253,000.--
b) parking area of concrete stone	m^2	52.-	17,300	900,000.--
5. Water supply and sewerage				
a) water supply	m	100.-	2,340	234,000.--
b) water tank	L.S.	---	---	70,000.--
c) sewerage	m	250.-	3,340	860,000.--
6. Power Supply				
- power supply distribution system incl. lighting transformer etc.	ha	200,000.-	3.6	720,000.--
7. Buildings				
a) gate house with checking bridge	L.S.	---	---	28,500.--
b) social building	L.S.	---	---	303,000.--
c) administration building	L.S.	---	---	196,500.--
8. Rain shed on the Banana Pier				
- rain shed including rendering, eternit sheets etc.	m^2	100.-	4,330	433.000.--
9. Ship Yard				
- ship yard including workshop, tug berth and slipway	L.S.	---	---	7,500.000.--
10. Fencing				
- fence of about 2 m height including rendering and foundation	m	72.-	1,105	80,000.--
			Total	14,876,700.--
		2)	+ 10 % contingencies	16,364,000.--

1) Price Basis 1979

2) no allowance for site installation

Construction cost of Alternative 1 a / Case B

Port of Limôn

Item	Unit	Unit Price (US$)	Quantity	Total (US$)
1. Demolishing works				
- Demolishing of Muelle Metalico and Muelle Nacional down to the water level	L.S.	---	---	425,000.--
2. Dredging				
- Dredging until 11 m or 10 m	m^3	4.-	35,000	140,000.--
3. Land reclamation				
a) hydraulic filling for land reclamation	m^3	9.-	1,300,000	11,700,000.--
b) retaining dike	m	4,700.-	1,270	5.969,000.--
4. Construction of Container Berth				
- 1 Container berth including bollards, fenders etc.	m	26,000.-	250	6,500,000.--
5. Pavement				
a) access roads of concrete slabs	m^2	67.-	57,000	3,819,000.--
b) container stacking area of concrete stone	m^2	52.-	63,000	3,276,000.--
6. Water supply and sewerage				
a) water supply	ha	25,000.-	13	325,000.--
b) sewerage	ha	105,000.-	13	1,365,000.--
7. Power supply				
- Power supply distribution system incl. building, transformer etc.	ha	200,000.-	13	2,600,000.--
8. Buildings				
a) administration building	L.S.	---	---	270,000.--
b) extension of central workshop	L.S.	---	---	257,000.--
c) gate house with weighing bridge and	L.S.	---	---	199,000.--
d) 4 checking bridges	pcs	5,000.-	4	20,000.--
9. Railway				
- railway connection of the terminal including switches etc.	L.S.	---	---	1,390,000.--
10. Fencing				
- fence of about 2 m height including rendering and foundation	m	72.-	140	10,100.--
	Total			38,265,100.--
	+ 20 % site installation			45,918,000.--
	+ 10 % contingencies			50,510,000.--

1) Price basis 1979

Construction cost of Alternative 1 b / Case B [1]

Port of Limón

Item	Unit	Unit Price (US$)	Quantity	Total (US$)
1. Demolishing works				
a) Demolishing of Muelle Metalico and Muelle Nacional down to the water level	L.S.	---	---	425,000.--
b) Demolishing of Muelle 70	L.S.	---	---	770,000.--
2. Dredging				
a) Dredging until 11 m or 10 m (NMM)	m^3	4.-	300,000	1,200,000.--
3. Land reclamation				
a) hydraulic filling for land reclamation	m^3	9.-	1,500,000	13,500,000.--
b) retaining dike	m	4,700.-	1,270	5,969,000.--
4. Construction of Container Berth				
- 2 Container berths including bollards, fenders etc.	m	26,000.-	500	13,000,000.--
5. Pavement				
a) access roads of concrete slabs	m^2	52.-	75,000	3,900,000.--
b) Container stacking area (storage area) of concrete stone	m^2	67.-	65,000	4,355,000.--
6. Water supply and sewerage				
a) water supply	ha	25,000.-	15	375,000.--
b) sewerage	ha	105,000.-	15	1,575,000.--
7. Power supply				
- Power supply distribution system incl. lighting, transformer etx.	ha	200,000.-	15	3,000,000.--
8. Buildings				
a) Construction of new shed	L.S.	---	---	1,880,000.--
b) Administration building	L.S.	---	---	270,000.--
c) Extension of Workshop	L.S.	---	---	257,000.--
d) Gate house with weighing bridges and	L.S.	---	---	199,000.--
e) 4 checking bridges	pcs	5,000.-	4	20,000.--
9. Railway				
- railway connection of the terminal including switches etc.	L.S.	---	---	1,390,000.--
10. Fencing				
- fence of about 2 m height including rendering and foundation	m	72.-	140	10,100.--
	Total			52,095,100.--
	+ 20 % site installation			62,515,000.--
	+ 10 % contingencies			68,766,000.--
				==============

1) Price basis 1979

Construction cost of Alternative 2 / Case B

Port of Limón [1]

Item	Unit	Unit Price (US$)	Quantity	Total (US$)
1. Demolishing works				
a) Demolishing of Muelle Metalico and Muelle Nacional down to the water level	L.S.	---	---	425,000.--
b) Demolishing of ~45 m of Muelle Metalico incl. removal of piles	L.S.	---	---	112,000.--
c) Demolishing of existing sheds	L.S.	---	---	130,000.--
2. Dredging				
- Dredging until 11 m or 10 m (NMM)	m^3	4.-	35,000	140,000.--
3. Land reclamation				
a) Hydraulic filling for land reclamation	m^3	9.-	1,050,000	9,450,000.--
b) Retaining dike	m	4,700.-	1,120	5,264,000.--
4. Construction of a Container and General Cargo Berth				
a) Container berth incl. bollards, fenders	m	26,000.-	250	6,500,000.--
b) General cargo berth incl. bollards, fenders etc.	m	26,000.-	200	5,200,000.--
5. Pavement				
a) Access roads of concrete slabs	m^2	52.-	50,000	2,600,000.--
b) Container stacking area (storage area) of concrete stone	m^2	67.-	53,000	3,551,000.--
6. Water supply and sewerage				
a) Water supply	ha	25,000.-	11,3	282,000.--
b) Sewerage	ha	105,000.-	11,3	1,186,500.--
7. Power Supply				
- Power supply distribution system incl. lighting, transformer, etc.	ha	200,000.-	11.3	2,260,000.--
8. Buildings				
a) Shifting of general cargo shed to the new general cargo berth	L.S.	---	---	928,000.--
b) Administration building	L.S.	---	---	270,000.--
c) Extension of central workshop	L.S.	---	---	257,000.--
d) Gate house with 2 weighing bridges	L.S.	---	---	199,000.--
e) 4 checking bridges	pcs	5,000.-	4	20,000.--
9. Railway				
- Railway connection of the terminal incl. switches	L.S.			1,970,000.--
10. Fencing				
- Fence of about 2 m height incl. rendering and foundation	m	72.-	435	31,320.--
1) Price basis 1979	Total			40,776,320.--
	+ 20 % site installation			48,932,000.--
	+ 10 % contingencies			53,825,000.--

Construction cost of Alternative 3 a / Case B

Port of Moin[1)]

Item	Unit	Unit Price (US$)	Quantity	Total (US$)
1. Demolishing works				
- Demolishing of existing buildings	m^2	45.-	2,200	99,000.--
2. Earthworks				
a) Clearing of site	m^2	1.5	110,000	165,000.--
b) Filling of construction area	m^3	9.-	150,000	1,350,000.--
c) Slope protection	m	4,700.-	330	1,551,000.--
3. Dredging				
- Dredging until 11 m (NMM)	m^3	4.5	500,000	2,250,000.--
4. Construction of a Container Berth				
- 1 Container berth including bollards, fender etc.	m	26,000.-	250	6,600,000.--
5. Pavement				
a) Access roads of concrete slabs	m^2	52.-	48,600	2,527,200.--
b) Container stacking area of concrete stone	m^2	67.-	55,000	3,685,000.--
6. Water supply and sewerage				
a) Water supply	ha	25,000.-	11	275,000.--
b) Sewerage	ha	105,000.-	11	1,155,000.--
7. Power supply				
- Power supply distribution system incl. lighting, transformer etc.	ha	200,000.-	11	2,200,000.--
8. Buildings				
a) Administration building	L.S.	---	---	270,000.--
b) Workshop	L.S.	---	---	2,056,000.--
c) Consolidation Shed	L.S.	---	---	1,600,000.--
d) Gate house with 2 weighing bridges	L.S.	---	---	199,000.--
e) 4 checking bridges	pcs	5,000.-	4	20,000.--
9. Railway				
- Railway connection of the terminal incl. switches etc.	L.S.	---	---	630,000.--
10. Fencing				
- Fence of about 2 m height incl. rendering and foundation	m	72.-	960	69,120.--
	Total			26,601,320.--
	+ 20 % site installation			31,922,000.--
	+ 10 % contingencies			35,114,000.--

1) Price basis 1979

Construction cost of Alternative 3 b / Case B

Port of Moin [1]

Item	Unit	Unit Price (US $)	Quantity	Total (US$)
1. Demolishing works				
a) Demolishing of existing buildings	m^2	45.-	2,600	117,000.--
b) Demolishing of railway bridge	L.S.	---	---	30,000.--
2. Earthwork				
a) Clearing of site	m^2	1.5	138,200	207,300.--
b) Filling of construction area	m^3	9.-	200,000	1,800,000.--
c) Slope protection	m^3	4,700.-	960	4,512,000.--
3. Dredging				
- Dredging until 11 m (NMM)	m^3	4.5	950,000	4,275,000.--
4. Construction of Container Berth				
- 2 Container berths incl. bollards, fender etc.	m	26,000.-	500	13,000,000.--
5. Pavement				
a) Access roads of concrete slabs	m^2	52.-	60,250	3,133,000.--
b) Container stacking area of concrete stone	m^2	67.-	71,500	4,790,500.--
6. Water supply and sewerage				
a) Water supply	ha	25,000.-	13.8	345,000.--
b) Sewerage	ha	105,000.-	13.8	1,449,000.--
7. Power supply				
- Power supply distribution system incl. lighting, transformer etc.	ha	200,000.-	13.8	2,760,000.--
8. Buildings				
a) Administration building	L.S.	---	---	270,000.--
b) Workshop	L.S.	---	---	2,313,000.--
c) Consolidation shed	L.S.	---	---	1,600,000.--
d) Gate house with two weighing bridges etc.	L.S.	---	---	199,000.--
e) 4 checking bridges	pcs	5,000.-	4	20,000.--
9. Railway				
- Railway connection of the terminal incl. switches etc.	L.S.	---	---	630,000.--
10. Fencing				
- Fence of about 2 m height incl. rendering and foundation	m	72.-	1,420	102,240.--
	Total			41,553,040.--
	+ 20 % site installation			49,864,000.--
	+ 10 % contingencies			54,850,000.--
				================

1) Price basis 1979

Construction cost of case A - railway Limón

1. Rehabilitation of harbour tracks in Limón
(see drawing F-2.2)

Item	US $ [1)]
rails (42.5 kg, 6.6 km length)	390,000
sleepers (1,450 pcs/km, 6.6 km length)	209,000
rail fastening	116,000
ballast (0.8 m^3/m)	37,000
drainage	364,000
earth works	32,000
manholes	220,000
single switches (44 pcs)	440,000
earth body	435,000
supervision	99,000
other	193,000
Total	2,535,000

2. Connection track Estrelle line/direction Moín

track incl. earth body (ca. 1 km)	400,000
single switch (1 piece)	10,000
Total	410,000

1) price basis 1979
cost and unit prices are essentially analogous to:
"Estudio de la Situación actual de movimiento de trenes y programación futur de Ferrocarriles de Costa Rica", November 1979.

Construction cost of case A - railway Moín

1. Railway facilities on the Banana Pier [1)]

(acc. to alternative III, chapter F and K, and drawings F-2.5; K-2.2)

Item	US $
tracks (42.5 kg, 3.4 km length)	201,000
sleepers (1,450 pce/km, 2.1 km length)	66,000
rail fastening (2.1 km) (sleeper)	41,000
ballast (0.8 m^3/2.1 km)	12,400
rail fastening (1.3 km) (pier)	19,000
drainage (2.1 km)	118,000
earth works	191,000
drainage (2.1 km)	110,000
manholes (2.1 km)	64,000
single switches (19 pcs)	190,000
crossing (1 piece) (elevator rails)	6,000
Total	1,018,400

1) price basis 1979
the cost items include the tracks from the Ro/Ro ramp until the railway bridge across the Moín River. Further connections behind the oil pier in the direction of the slipway as well as a connecting track to the fertilizer factory are not included.

Construction Cost of Case A

Roads outside of Port Limôn

1. Intersection Avenida 1 / Calle 9

- Areas (see drawing F. 2-3)

Avenida 1	: length 230 m x width 12 m	= 2,760 m^2
Calle 9	: length 17 m x width 11 m	= 187 m^2
Cahuita Road	: length 170 m x width 16 m	= 2,720 m^2
Port access road (connection to gate-house)	: length 200 m x width 10.5 m	= 2,100 m^2
remaining areas	: 6 x 10 x 12 m	= 720 m^2
		8,487 m^2
	rounded off	= 8,500 m^2

- Construction costs[1]	Unit	Unit Price (US $)	Quantity	Total (US$)
precision levelling	m^2	0,75	8,500	6,400.-
subbase 20 cm	m^3	13,20	1,700	22,400.-
base course 15 cm (bituminous)	m^3	25,90	1,295	33,000.-
A C 7 cm	m^2	8,40	8,500	71,200.-
curbs (concrete Bn 600)	m	10,70	1,200	12,800.-
	Total			145,800.-
	10 % contingencies			14,580.-
	7 % supervision			10,220.-
				170,600.-

1) price basis 1979

Construction cost of case A - roads outside the port of Limón

2. Extension Avenida 1

(From intersection Calle 9 to harbour entrance at Proyecto Alemán)

Areas (see drawing F.-2.3)

Avenida 1	: length 720 m x width 7.50 m	=	5,400 m^2
	length 200 m x width 12.00 m	=	2,400 m^2
station squares :			950 m^2
			8,750 m^2
	rounded off		8,800 m^2

- Construction costs [1]	Unit	Unit price (US$)	Quantity	Total (US$)
precision levelling	m^2	0.75	8,800	6,700
subbase 20 cm	m^3	13.20	1,760	23,300
base course 15 cm (bituminous)	m^3	25.90	1,320	34,200
A/C 7 cm	m^2	8.40	8,800	74,000
curbs (concrete Bn 600)	m	10.70	1,840	19,700

Total	157,900
10 % contingencies	15,800
7 % supervision	11,100
	184,800

1) price basis 1979

Construction cost of case A - roads outside of port of Moin

Port access road
(see drawing F-2.5)

- from national highway N.32 (Siquirres - Limón) length ca. 4.0 km
- from Portete - Limón road length ca. 500 m
- unit price/km (estimated) : 110,600 US $ 1)
- total construction : 497,500 US $

1) price basis 1979
Unit prices from: "Programa de inversión pública en transporte realizada por el MOPT, período 1975 - 1985" of 1979.

These costs include the complete new construction with all associated individual costs. Also included is a lumpsum price for structures; however, it is anticipated that the cost of the required bridge across the Fecosa tracks parallel to the N.32 must be calculated separately. The costs of this item are not included in the present breakdown, nor the costs of connections to the planned industrial estate, etc.

G. FUTURE PORT ORGANIZATION

1. General port organization system

If the overall organizational structure of sea-ports in highly developed countries and those in developing countries is compared and evaluated, the following statements can be formulated:

1.1 Highly-developed countries

- The organizational structures in the most important sea-ports in the world are the result of long historic processes reflecting the tradition of the country and the ports, the geographic conditions, the structural conditions of the economy as well as the mentality of the population;

- the port policy and investments in port facilities are of national interest either for the central government or for the federal state/city;

- a characteristic, which has to be considered is that in general a governmental institution (Port Authority, City Council etc.) is the owner of port facilities and also responsible for public port services (e.g. pilotage, waterways), whereas the pure port operation and the investments in cargo handling equipment are in the hands of private companies;

- this system means that the governmental institution invests in port facilities, leasing them for operation to private port contractors;

- in some cases the governmental institution also operates own port facilities besides private engagement (e.g. Antwerp, London, France) or the government / city is financially engaged as shareholder in port operating companies in order to keep sufficient influence in the overall port activities;

- due to the importance of port activities for the cities / countries and the problem of hard competition between ports in special regions, the political institutions of the cities / countries have direct and very close contacts to the export industries and transport institutions which leads to mutual understanding and more or less quick decisions on future port investments;

- the private engagement in port operation leads to the result that the acquisition of additional cargo received large importance for the benefit of the ports in general; this aspect, due to the competitive situation, increases the attraction of the ports and forces the political institutions concerned to support this aspect of attractiveness by necessary investments and unbureaucratic procedures (customs).

1.2 Developing countries

- It is a matter of fact that the developing countries did not undergo so long historic processes regarding port activities compared with the industrialized countries;

- port policy and investments are of high national interest as the developing countries are forced to match the gap which is still obvious with regard to the modern port facilities (e.g. container terminals) and modern port handling equipment;

- due to the high ranking importance of port affairs, most of the developing countries established an organizational structure in having a port authority (or similar institution) which is responsible for the public services in the port(s) and also totally or partly engaged in port operation;

- these port authorities are normally directly adhered to a ministry in order to express the national political interest and because of the reason that developing countries very often receive financial aids from large financing institutes which are only granted to the government itself or to related governmental institutions.

1.3 Analysis of statements

Taking into consideration that the organizational structures of the ports in industrialized countries are based on specific conditions and historic processes, it will be dangerous in transferring these structures to developing countries. The organizational structure in a port in a developing country should take into account at first the local circumstances and necessities and can also adopt several aspects of other organizational structures which are of advantage.

The differences between the organizational structures of ports in industrialized and developing countries cannot be eliminated in the short and middle run. Whether this elimination will be possible in the long rung has to be carefully observed, as it depends on the qualification of personnel, private companies and the political circumstances in the related countries.

As a matter of fact, the political institutions have more influence in general port activities in developing countries than in industrialized countries. This situation cannot be considered as disadvantageous if the governmental institutions are keeping close contacts to private markets and companies and are generally able to guarantee a certain degree of flexibility. As ports in developing countries are forced to invest in modern port facilities, large amounts of money are necessary, normally based on foreign loans. These investments can only be provided by governmental institutions, which will also be involved therefore in the port operation itself. If the governmental institutions would only concentrate on public services, extensive leasing contracts would become necessary between the state and private operating companies. These leasing contracts normally complicate the relationship between both partners and may lead to the result that port facilities lose their standard as private companies are interested in realizing high profits in relatively short times and do not care for the condition of facilities for which a port authority is responsible as owner.

2. Port organization in Costa Rica

Taking into account that a future general port organization shall meet the following requirements:

- realization of an integrated national port policy;
- improved coordination between all partners in port activities;
- avoidance of competition between the national ports which means especially the organizational integration of the ports of Limõn and Moĩn;
- integrated performance of port investments and rehabilitation of facilities;
- follow-up of available port studies with regard to traffic forecast and other developments;
- concentration on port activities by eliminating additional duties which do not relate to port affairs;
- performance of an efficient port administration and operation for the benefit and general reputation of the country;

it is recommended to found a National Port Authority (NPA) which should take over the above duties. This NPA should be founded as autonomous legal entity.

2.1 Organization of NPA

The National Port Authority shall have its domicile in San Josê and shall consist of a main office in the capital and at present two Port Authorities in the respective ports of Costa Rica.

The NPA should be supervised by a board consisting of the following members:

- Minister of Transport
- Undersecretary MOPT
- Minister of Finance
- Director Recope
- Director Fecosa
- two members of private companies (e.g. banana companies, agents or chamber of commerce).

Such combination of various institutions guarantees the observance of different aspects and also consideration of intentions and developments of the private sectors as far as it is relating to the ports.

The general organization chart of NPA is illustrated below and shows the following divisions under the President (Fig. G - 1):

- auditing dept.
- legal dept.
- Port Authority Limõn (responsible for the Ports of Limõn and Moĩn)
- Port Authority Puntarenas (responsible for the Ports of Puntarenas and Caldera)

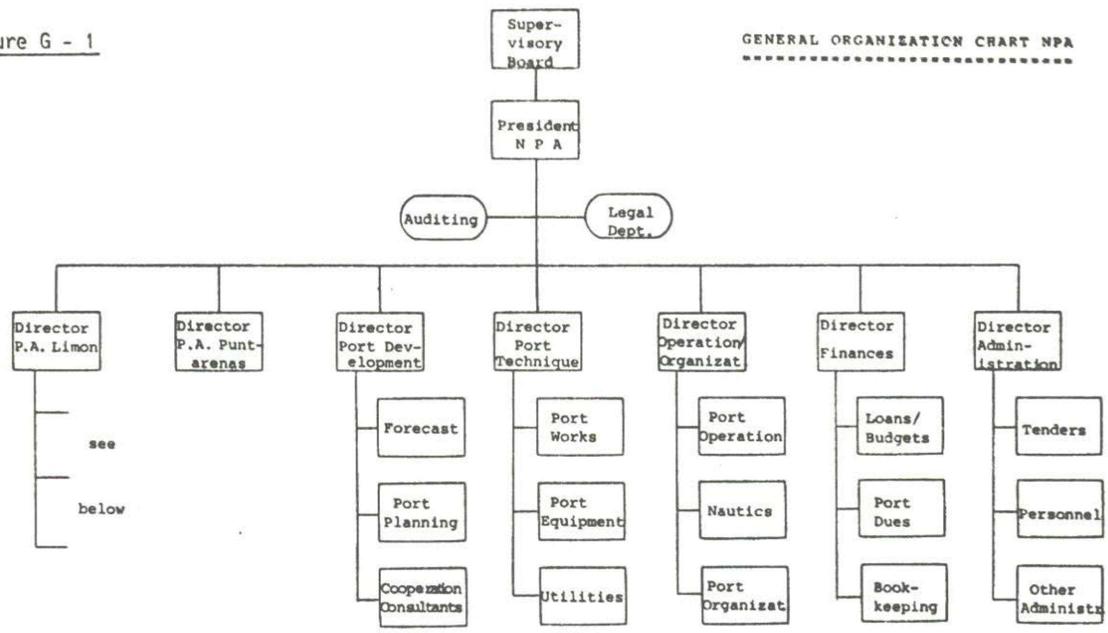
- Director Port Development
- Director Port Technique
- Director Operation / Organization
- Director Finances
- Director Administration.

The Directors of both Port Authorities shall be located in the respective ports and shall directly report to the President of NPA, whereas major activities in the ports shall be coordinated with the various departments of NPA.

In order to guarantee a concentration on port activities and port development, the NPA should be unburdened from the responsibility for the development of the Atlantic Slope.

Figure G - 1

GENERAL ORGANIZATION CHART NPA



2.2. Port Authority Limón / Moín

The new Port Authority Limón / Moín shall act as an integrated administrator of both ports on the Atlantic coast, directly adhered to the NPA, where the general port policy of the whole country is decided. In order to guarantee a concentration on port activities which will receive high importance in future after completion of port projects under construction, the Port Authority shall give up the responsibility for the economic development of the Atlantic Slope (desarrollo department).

Due to the disadvantages of the existing allocation of responsibilities in the Port of Limón, the foundation of a Port Authority must be combined with a new organizational structure in the port in general. Otherwise the new Port Authority would only take over the present activities of Japdeva excluding the responsibility for the development of the Atlantic Slope.

2.2.1 Organizational alternatives

As far as the allocation of responsibilities in the port is concerned, four logical alternatives have been established. All alternatives include the elimination of the activities of the forwarding agents in the port area, but show different fields of activities for the Port Authority and the stevedoring companies.

These four organizational alternatives have been worked out on the basis of the indirect import procedure and are evaluated with their advantages and disadvantages. The alternatives are shown overleaf.

The several phases / activities within the total chain are divided for all alternatives as follows:

a) discharging from vessel to quay;

b) loading from quay to equipment (railcar, trailer, etc.)

c) transportation of cargo to storage area;

d) unloading of cargo from equipment to storage space;

e) storage of cargo

f) preparation of cargo for customs' check;

g) final delivery of cargo from shed to rail-car / truck.

The above evaluation leads to the result that the alternative 4 should be favoured showing a limitation of the stevedoring companies to the ship's side while the Port Authority is responsible for the public services in the port as well as for the shoreside operation.

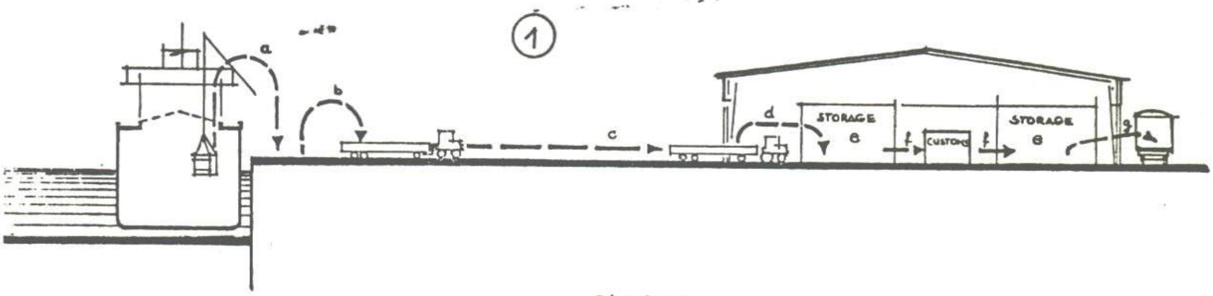
This recommended alternative presents a clear allocation of responsibilities of the entire port, guarantees an uncomplicated integration of the new container terminal and meets also the requirements of the transport chain.

It is absolutely clear, in our opinion, that the problems and disadvantages of the existing organizational structure in the port must be eliminated in future. This means, especially with regard to the operation in the new container terminal that organizational changes will become necessary in any case.

If, however, a new organization system shall be decided upon, this decision will be valid for at least five years as fundamental changes in organizational structures cannot be performed permanently. As therefore such a decision is a decision in the medium run, the chosen structure should be definite which means that existing problems (e.g. limitation of the stevedores) have to be solved now and should not be postponed by compromises or mixing of the above-mentioned alternatives with regard to different sections on the port.

As far as the limitation of the stevedoring companies is concerned, this aspect has to be seen in a special light. Considerations regarding an extension of the stevedore's activities in the general cargo services and an exclusion in the container- and ro/ro-handling could only be of interest for the stevedoring companies in the short and medium run. As the portion of conventional general cargo as well as the banana handling will decrease in foreseeable future to the benefit of containers, the activities of the stevedores would decrease, too.

ALTERNATIVES OF ORGANIZATION



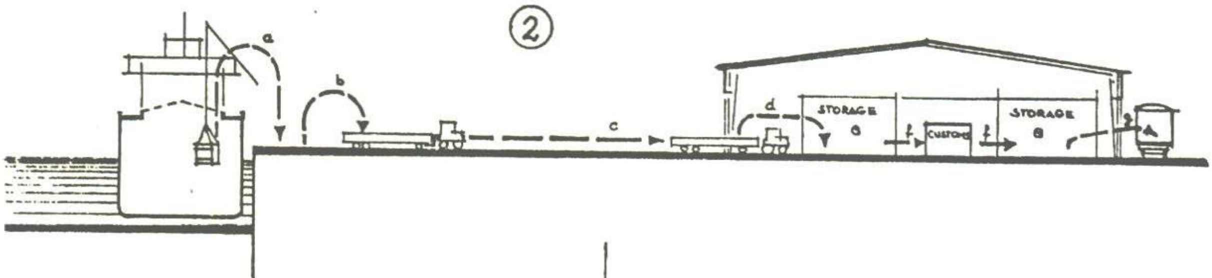
Advantages:

- clearer allocation of responsibilities than today (only one point of transfer);
- elimination of the activities of the forwarders in the sheds

Disadvantages:

- transfer of equipment from PA to stevedores (incl. workshop), i.e. PA and stevedores own equipment;
- System not applicable to the container terminal and ro/ro-operation, as equipment for stacking area cannot be separated from ship's operation;
- difficult definition of responsibilities in case of direct handling;
- no influence of PA on ship's productivities and less influence on ship's preplanning;
- tallying of cargo for the first time at the shed (point of transfer)

ALTERNATIVES OF ORGANIZATION



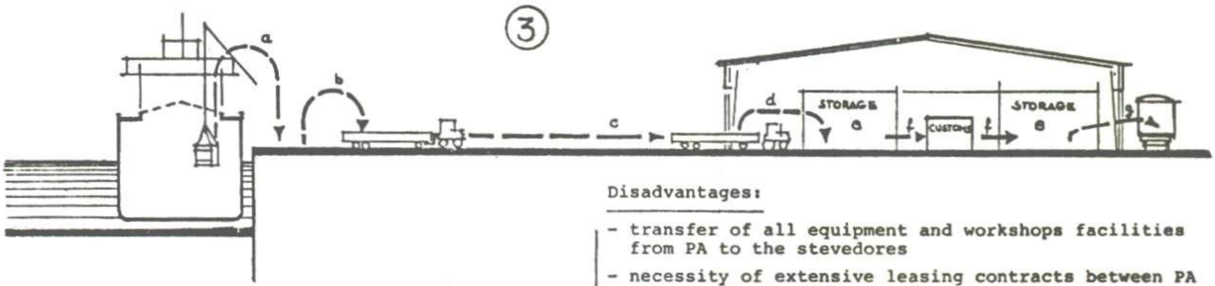
Advantages:

- clear responsiblities, as only one party is responsible for the entire port operation and public services
- elimination of the activities of the forwarders in the sheds

Disadventages:

- all port activities are concentrated in one hand (problematic in general)
- interest of the ship is under-represented
- cancellation of private stevedores (probably a political impossibility)
- no proper tallying of cargo is guaranteed

ALTERNATIVES OF ORGANIZATION



Disadvantages:

- transfer of all equipment and workshops facilities from PA to the stevedores
- necessity of extensive leasing contracts between PA and stevedores (infra- and superstructure)
- very problematic assignment of the small port areas to three stevedores, which will result in a decrease of the general port flexibility
- no influence of PA regarding berth disposition, ship's pre-planning, productivities and storage utilization
- proper supervision of port activities (except public services) by PA nearly impossible
- integrated port planning will become difficult (depends on statements of the stevedores)
- over-capacities of equipment have to be expected due to probably missing coordination between the stevedores

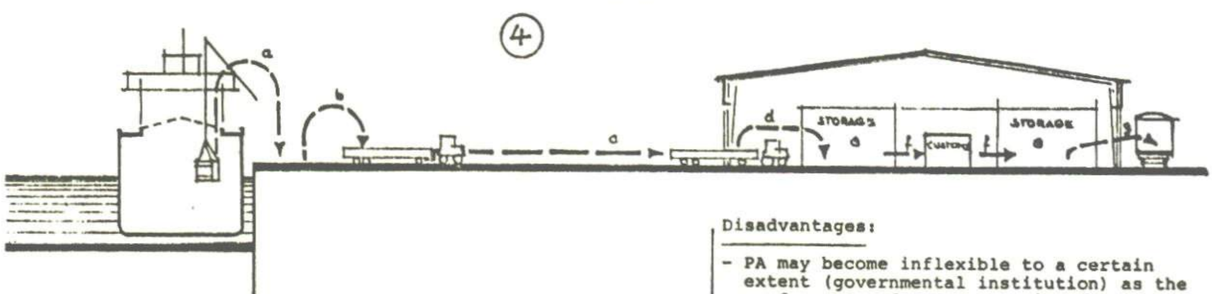
Advantages:

- clear responsibilities, as the stevedores are responsible for the entire operation and the PA for public services;
- elimination of the activities of the forwarders in the sheds;

Disadvantages cont'd

- no interest of stevedores to treat properly the port facilities, as PA is responsible for the maintenance and repair
- fixing of handling charges by the stevedores (except: official port dues)

ALTERNATIVES OF ORGANIZATION



Disadvantages:

- PA may become inflexible to a certain extent (governmental institution) as the performance of port operation requires short-termed decisions

  avoidance of problem:establishment of special rights for PA regarding investments and procedures

Advantages:

- clear allocation of responsibilities between ship and shore
- elimination of the activities of the forwarders in the sheds
- proper tallying of cargo at the quay due to exact separation of responsibilities (this meets the requirements of the transport chain regarding insurances and INCO-terms)
- unproblematic integration of the new container terminal
- port facilities (infra- and superstructure) and equipment remain with PA (no leasing contracts)
- intensive influence of PA regarding ship's pre-planning, productivities, storage utilization and use of equipment

Advantages cont'd:

- reciprocal supervision of PA and stevedores during operation (competition regarding productivities)
- casual labourers of the stevedores could probably be permanently employed with PA

Therefore, it must be the interest of the private stevedores to be also involved in thelong run in the modern services like container and ro/ro. In our opinion, the favoured alternative 4 guarantees the involvement of the stevedores also in the handling of containerized cargo. Therefore the limitation of the stevedores which may have been seen at first, is no limitation in the long run, but a guarantee of working places and activities in future.

2.2.2 Recommended activities of port participants

Based on the recommended allocation of responsibilities in port activities and the principal organizational structure in having a Port Authority, the different activities of the port participants should be as follows:

a) Port Authority Limòn / Moín

1. Public Services

- preparation of port planning (in cooperation with NPA)
- preparation and control of port regulations
- undertaking of port investments
- general administration of the port
- maintenance and repair of port facilities and sea-equipment
- provision of nautical installations
- pilotage and mooring/unmooring
- dredging of port area and entrance channels
- charging of port dues
- establishment of official port statistics
- decision on additional activities in the public port area
- disposition of berths

2. Shoreside Operation

- performance of operational pre-planning
- disposition of personnel and equipment
- execution of shoreside handling of cargo, incl. warehousing and landside delivery
- loading / discharging of containers and ro/ro cargo
- tallying of cargo at the quay
- undertaking of investments for equipment
- maintenance and repair of equipment
- charging of cargo handling rates
- sealing of containers / trailers on behalf of the customs

b) Stevedores

- operational pre-planning on board (in coordination with PA)
- stevedoring on board of vessels
- loading / discharging of cargo aboard (except: containers and ro/ro)
- lashing / unlashing of containers and ro/ro-trailers

c) Ship's agents

- announcement of vessels and delivery of documents
- participation in operational pre-planning
- preparation of stowage plans for containers and ro/ro-trailers

d) Tally - Companies

- tallying of cargo at the quay (on behalf of the ship's agent) and check with PA

e) Forwarders

- preparation of documents for customs clearance
- request of rail-cars and disposition of trucks (in coordination with PA)

f) Fecosa

- advice about rail-cars in the patio (to PA)
- shunting in the patio and port area (in coordination with PA)
- delivery and taking-off of rail-cars (in coordination with PA)
- maintenance and repair of rail-tracks in the port

g) Customs

- customs clearance of cargo
- physical random checks of cargo

h) Recope

- performance of oil discharging operation
- maintenance and repair of pipes and oildischarging tower

These recommended activities include the establishment of private tally-companies which shall be responsible for the tallying of cargo at the quay on behalf of the ship's agents.

This tallying, however, can also be performed by the agents themselves. It is only important that two persons tally the cargo, one representing the interests of the vessel and one those of the port. Both tallies have to be checked against each other and differences have to be eliminated. Then the tally can be the basis for the customs.

2.2.3 Cargo handling of third parties

During the Consultant's site investigations it became obvious that private companies are interested in performing special cargo handling in the port area of Moin. These companies are interested in renting or purchasing an area in the port which also allows future extension and where factories and/or tanks can be erected. These installations and the handling equipment will be borne by the private companies which also intend to perform their operation without any inclusion of the Port Authority and/or stevedoring companies. Nevertheless, both companies intend to settle in the public port area as pier and landside area are already available.

It has to be emphasized in this connection that following statements and recommendations are only based on organizational aspects, neglecting the aspects of port engineering, capacity utilization and costs.

Due to the size of the ports of Limón and Moín and the aspects of necessary flexibilitiy (interchange of vessels between the various berths) only one organization system should be valid for the entire port; a split-up of facilities with different organization systems incurs permanent problems. In order to guarantee this statement, private companies which perform their own operation should not be allowed to settle in the public port area. If such factories would be located in the public port the following organizational problems will arise:

- extension problems for the port as well as for the private companies
- berth priority problems
- if one party is allowed to settle in the public port and to take over investments and operation, other companies will follow; such development would lead to a non integrated split-up of the port area.

In order to guarantee a valid organization system for the ports, two alternatives are possible:

- location of these private companies in the south of the two banana berths in Moín by separation of this area from the public port or
- location of the private companies more or less directly adhered to the oil-pier in Moín and performance of the operation by the Port Authority / stevedores.

From the organizational point of view it is recommended to follow alternative 1 as it implies the clearest organization system and such solution could be the start for an industrial or free trade zone in this area. The second alternative would be possible, but would be subjected by the private companies as it implies a direct interference of the Port Authority/stevedores in the calculations and productivities of those factories.

2.2.4 Recommended organization chart for the Port Authority

The new Port Authority should be headed by a Director General being the superior of six managers for the following departments:

- operation
- technique
- finances and administration
- marketing
- planning
- harbour master

Due to the extension of operation responsibilities and some advantageous combination of departments, the new structure varies to a certain extent from that of the present Japdeva. The recommended organization chart for the Port Authority is shown in Fig. G-2 and shall be commented as follows:

a) Top management

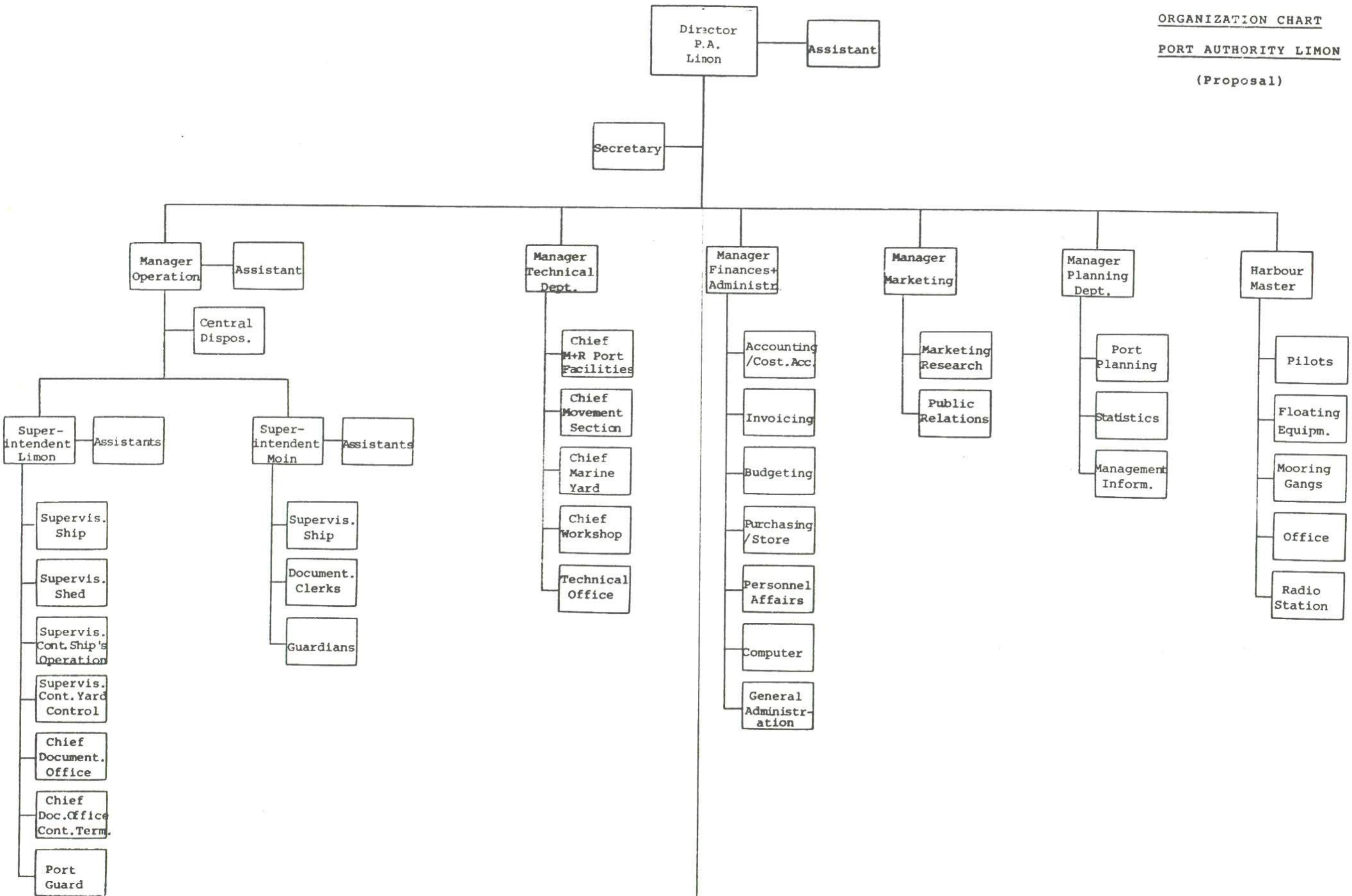
As the Port Authority Limón is directly adhered to the NPA in San José no Board of Directors is anymore necessary. The PA should be headed by a Director General with one assistant, in order to guarantee a clear and direct chain of command and the more or less permanent presence of either the D.G. or the assistant.

Fig. G - 2

ORGANIZATION CHART

PORT AUTHORITY LIMON

(Proposal)



b) <u>Operation department</u> (see detailed chart Fig. G - 3)

The operation department has to be considered as the most important department of the Port Authority. It should be headed by a "Manager Operation" with one assistant, so that a permanent presence of one manager at any time could be guaranteed. The "Manger Operation" should especially be responsible for:

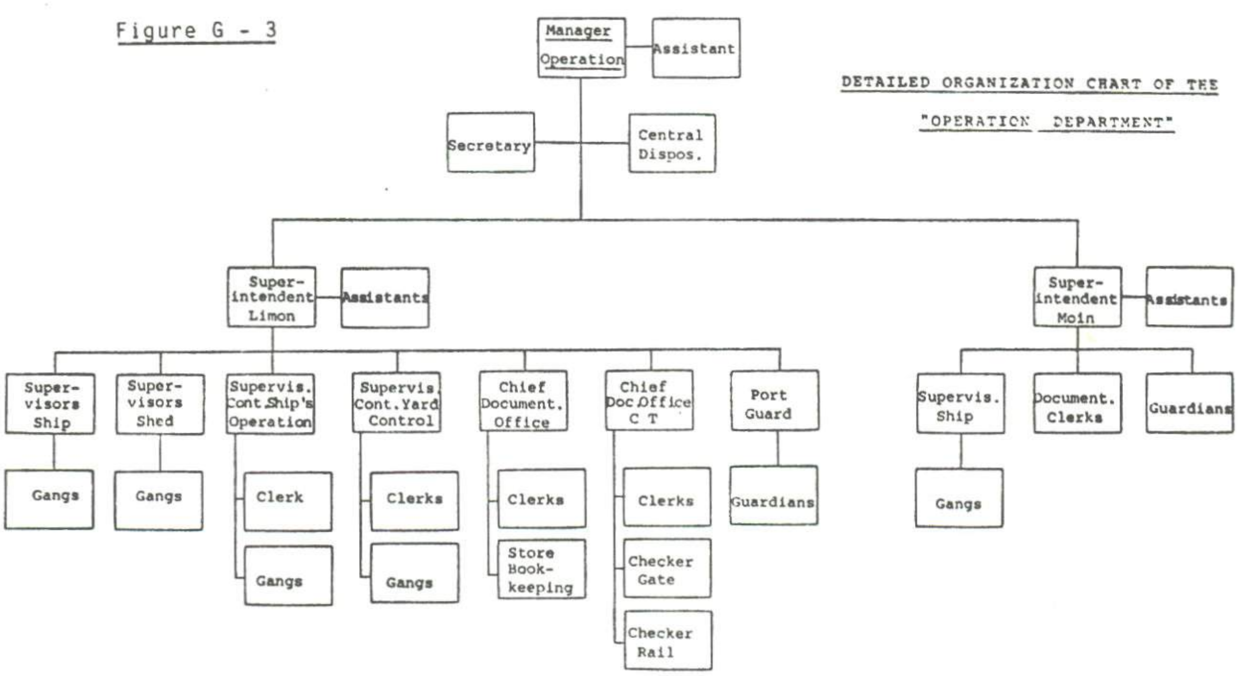
- the coordination of the operational sections,
- the final decision about priorities, dispositions etc. in case of difficulties,
- the observance of the general port security regulations,
- the control of productivities, operational methods etc.,
- the contacts to third parties involved in port operation
- the advice of the Director General in all operational questions,
- the assistance in port planning.

The operation department should be divided into three sections:

- central disposition
- port facilities Limôn
- port facilities Moîn.

Figure G - 3

DETAILED ORGANIZATION CHART OF THE "OPERATION DEPARTMENT"



The most important activities of the superintendents should be:

- detailed disposition of personnel and equipment
- coordination of shipside and shoreside operation
- performance of operational pre-planning
- coordination of landside receipt and delivery of cargo
- definition of productivities to be achieved
- control of operation's performance and information to the central disposition in case of difficulties
- control of the internal operational documentation
- analysis of operation after completion
- coordination with the workshop regarding availability of equipment during the shifts.

The next level under the superintendents consists of supervisors, being responsible for one vessel or one/two shed(s) per shift. The supervisors are conducting and co-ordinating the gangs per vessel / storage area and are especially responsible for:

- control of achievement of productivities
- control of operation's performance
- detailed definition of sequence of work
- filling out the internal operational documentation (work-sheets per shift etc.)
- coordination with the superintendent regarding availability of equipment
- coordination of observance of security regulations at the working places
- detailed disposition of storage areas / container yard

As far as the documentation is concerned it is recommendable to divide within Limôn into two separate offices. One office, as today, should be responsible for the check of cargo documents and central keeping of the store-book for the conventional general cargo. This office should be located near the customs in shed 1 with a small office at the near entrance of the port (at the western end).

As the container traffic requires different and additional documentation, this documentation office should be separated and located in the small gate-house at the weighing-bridge (check of documents, establishment of the interchange receipt) and in the new office-building at the Proyecto Alemân (inventory control and lists). This documentation office should also be responsible for the ro/ro-documentation.

As a last section, the port guard in Limôn and Moîn as well should be directly adhered to the respective superintendent.

Due to the limited size of both ports and the aspect of operational flexibility,it is recommended to create a central disposition for the overall planning of berths, equipment and personnel. This disposition should be performed at exactly defined dates together with the agents, the stevedores, Fecosa and the superintendents of Limôn and Moîn. Such procedure guarantees the most economic utilization of berths and equipment and allocation of personnel to the various port sections.

As far as the division into the operational sections Limôn and Moîn is concerned, it seems to be advantageous to follow this geographical division. The section Limôn implies three berthing places and the section Moîn the same. This means that the field of responsibility of both superintendents is similar as far as the number of vessels is concerned. As Moîn is handling especially the bananas, no storage facilities will be available, whereas Limôn possesses various storage areas. This difference, however, should be equalized by additional supervisors in Limôn compared to the structure in Moîn. Due to the volume of cargo there is no real necessity to divide the section Limôn into the container terminal on the one hand and the remaining facilities on the other hand. Such division for Limôn could probably apply if the container terminal has reached a permanent utilization at the pier.

In order to avoid too many levels within the hierarchy it is recommended to have one superintendent as responsible man per section, assisted by two assistants for each section, working in the second and third shift. This implies that the superintendent works only in the first shift, which is necessary, as the most important facts for the ship's pre-planning and general disposition are decided in the morning. The solution to have one superintendent with two assistants includes also the advantage that one person is responsible for the entire operational section, but nevertheless all shifts are covered by a superintendent.

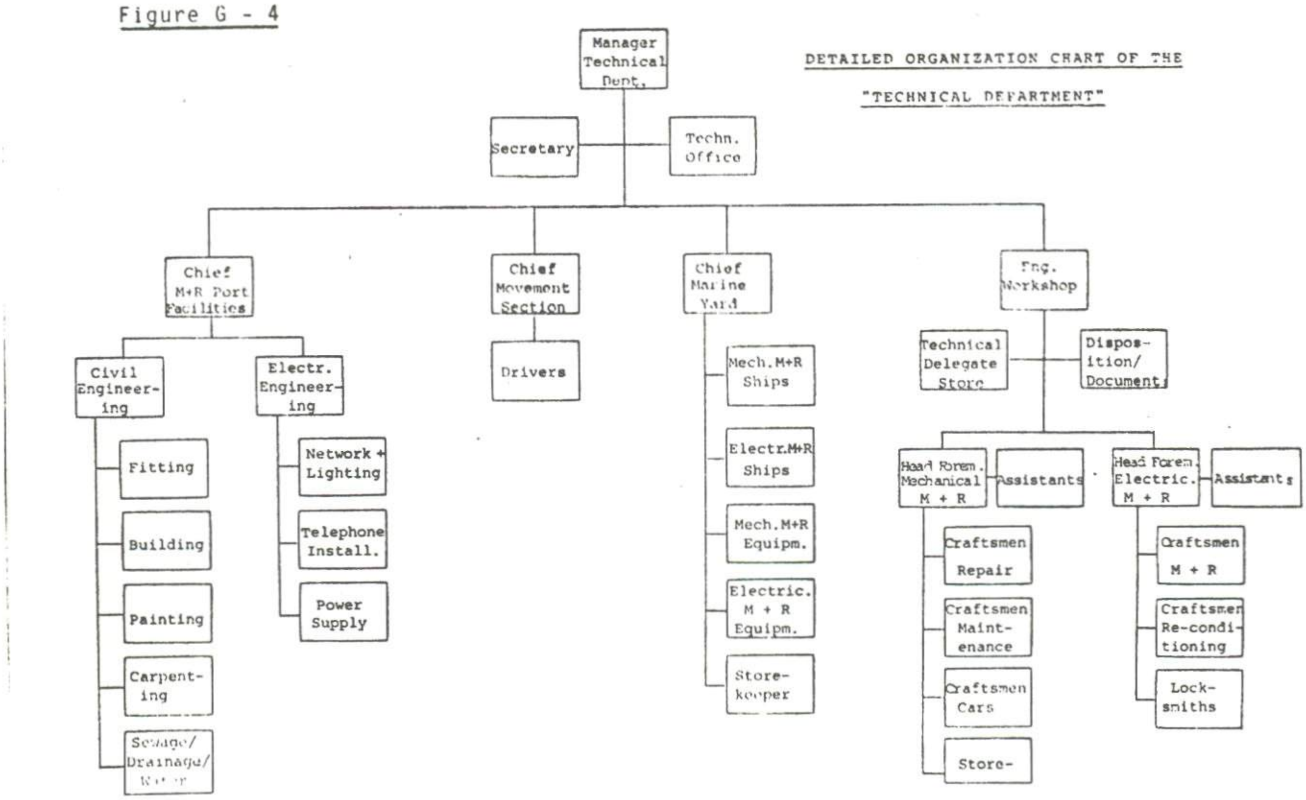
c) Technical department (see detailed chart Fig. G - 4)

It is recommended to form one concentrated technical department being responsible for the maintenance and repair of all facilities and equipment. This department should be headed by a civil or mechanical engineer and should be divided into the following sections:

- workshop for maintenance and repair of port facilities (quays, buildings, surfaces, utilities etc.)
- movement section (disposition of cars and drivers)
- marine yard in Moín as maintenance and repair facility for all floating equipment (including buoys) and the banana gantries and other equipment as well
- workshop for maintenance and repair (in Limón) of all kinds of equipment (cranes, straddle carriers, trucks, forklifts, chassis, trailers etc.)
- technical office (preparation of drawings, technical tenders, supervision of construction, technical planning etc.)

Such centralized organization guarantees a clear allocation of responsibilities and defines exactly the necessary cooperation between the administration, operations, harbour master and the technical sections, which have to be considered as service-sections for the port handling activities.

Figure G - 4



d) Administrative department

As far as the administration is concerned it is recommended to combine the various administration sections and finance-sections under one manager. The advantage is, compared with the existing structure of Japdeva, that one manager covers all activities so that the "span of control" of the Director General improves. This department shall consist of the following sections:

- cost accounting / accounting
- invoicing
- budgeting
- purchasing / store
- personnel affairs
- computer
- general administration

There is no need to describe the various activities of these sections in detail as the duties should remain as they are today with Japdeva. It shall only be mentioned that the section for personnel affairs should consist of personnel administration and the settlement of wages and salaries, which seems to be advantageous in our opinion, as both activities are directly related to each other.

e) Marketing department

As already pointed out in the analysis of the existing organization chart of Japdeva it could be of real advantage having a special marketing department in future. This department should be headed by one manager and shall consist of the following sections:

- marketing research
- public relations

The marketing research section should investigate the traffic flows via the Port of Limȏn to find out which additional trades could be channelled in future through Limȏn. Especially development projects in Costa Rica and neighbouring countries have to be observed regarding the throughput or transit possibilities for construction material etc. via Limȏn. Additionally this section should check and establish the structure of tariffs, dues and charges of the port and compare it with tariffs in competing ports. Changes and/or amendments as well as special rates for attractive trades have to be prepared by this section for the management.

The PR-section should perform the usual activities, amended by the establishment of a port brochure with information about existing port facilities, cargo throughput, special capabilities, future port development programs etc. Such brochure enables the Port Authority to sell the attractiveness of the port.

f) Planning department

This department should be extended regarding its activities compared with the existing situation in Japdeva. It is recommended to divide the planning department into the following sections:

- port planning
- statistics and analyses
- management information

The port planning section should especially be responsible for the adaptation of existing studies / recommendations, planning for additional port facilities and equipment in cooperation with the operational and technical departments, profitability analyses for these investments and analyses about new trends (containerization) and their related consequences. The statistic sections should especially deal with the establishment of necessary statistics, the elaboration of traffic forecasts and analyses of statistics regarding cargo and volume etc. The management information section shall be responsible for the development of a management information system and the execution of organizational activities. This section should prepare, observe and adapt the relevant job-descriptions, organization chart regulation and flow charts. Furthermore, the introduction of additional computerized systems for various activities in the port should be developed. This section should also prepare special reports for the Director General regarding operational analyses (productivities etc.), cargo trends, utilization of facilities etc. in fixed intervals, so that the Director General is able to manage the port on the basis of exact and permanent information.

<u>g) Harbour master department</u>

Due to the increasing importance of nautical affairs it is recommended to establish a harbour master department directly adhered to the Director General. This department should consist of the following sections:

- pilots
- floating equipment
- mooring gangs
- office (port dues)
- radio station

The most important activities of these sections are:

<u>harbour master and office</u>:

- disposition of berths in cooperation with the operation department;
- disposition of pilots, tugs and mooring gangs;
- disposition of ship's supply;
- inspection of ship's- and pier safety facilities, floating equipment and navigational aids;
- ordering of repair at the marine yard;
- port traffic and pollution control;
- establishment of the daily weather report;
- submission of hydrographical information to vessels and international institutions;
- collection of data reg. public services and preparation of invoices for the ship's agents.

pilots:

- performance of ship's manoeuvre with tug-assistance
- information to the harbour master about breakdowns of navigational aids, safety facilities etc.

mooring gangs:

- performance of mooring and unmooring
- supply of water, fuel etc. to vessels
- minor maintenance and repair of mooring and pier devices and navigational aids ashore

floating equipment:

- performance of operation under the order of the harbour master, pilots
- performance of minor M+R work

radio station:

- performance of radio communication

h) External activities

The present external activities in the port, like health control, medical aid and fire fighting should remain, as there is no convincing necessity to include these tasks in the Port Authority. The past has shown that these external activities could be performed without any essential problems.

2.2.5 Recommended administrative procedures

The following recommendations shall concentrate on the purchasing/tendering procedures. All other administrative procedures should remain as they are, because of their missing influence on port operation. Furthermore the experience shows that administrative procedures should only be changed if absolutely necessary in order to avoid too many changes.

a) Purchasing/tendering procedures

In order to speed up the purchase of materials (especially spare-parts for the workshop) it is recommended that the Port Authority Limón receives the right from the NPA to purchase materials within the limit of an approved budget without contacting the NPA.

This means that the purchase- and tender documents will be prepared by the purchase department and can be approved by the Director General of PA. In order to minimize the administrative activities, the following financial limits are proposed:

- Managers of PA = they should be able to order purchases up to a value of ₡ 5,000 without approval of the Director General, provided that they do not exceed their approved budget.

- Director General= he has to approve all purchases of a value between ₡ 5,000 and ₡ 50,000 without tendering

  he has to approve all purchases of a value exceeding ₡ 50,000 with tendering

  in case purchases exceed the approved budget of the PA, the Director General has to receive the approval of NPA for an additional budget.

The tendering procedure could generally remain as it is by cancellation of the approval of the "Consejo Administración", which is no more necessary within the new organization. The Director General has to ensure that his assistant will be vested with the same rights during his own absence, so that no delays in the approval process will occur. These measures could guarantee that the total time for such procedure will not exceed two months.

As far as the spare-parts for the workshop are concerned, special procedures must be applicable, in order to guarantee the availability of equipment for the operation. In order to improve the existing situation, the following measures are recommended:

- the port should concentrate on one or two manufacturers per type of equipment in order to avoid a variety of spare-parts;

- a tendering of spare-parts should be avoided by negotiations with the manufacturers regarding prices and delivery times;

- the manufacturers should be forced to provide special important spare-parts on consignment in the port, which means that the workshop of PA can take out the required spare-parts at any time whereas the invoices of the manufacturers will be settled twice or four time a year only.

These above-mentioned measures have already been realized in some other ports having had similar problems as Limón, and the experience can be considered as very positive.

b) Invoicing procedures

The invoicing procedures must only be changed to a certain extent due to the foundation of a harbour master's office and the take-over of the cargo handling activities of the Port Authority on the shoreside.

As the harbour master is responsible for the performance of the public services in the port it is recommended that his office prepares the invoice for the ship's agents. These invoices should be in accordance with the proposed new tariff (see chapter 2.2.6). Afterwards, the invoice should be sent to the invoicing department where the actual amount should be checked against the advance-bond of the agent.

As far as the "muellaje" and the storage fees are concerned the present procedure should also be valid in future. This implies an arrangement of a bond at the Port Authority and the presentation of documents of the forwarder at the invoicing department of the Port Authority. According to the documents the fees have to be paid prior to customs clearance and the payment will be checked against the advance-bond of the forwarder.

As the new organization concept recommends that the landside operation shall be taken over by the Port Authority, new invoicing procedures for the settlement of the cargo handling charges must be created. As far as the handling of containers and trailers is concerned the handling charges are based on box/unit, independent of the size, weight and kind of cargo. Therefore, it is recommended that the office of the ship's supervisor prepares an invoice for the handling charges according to the stowage plans. This handling charge (for containers) should include already the re-handling of the container from/to chassis and/or rail-car.

This combination simplifies the administrative procedure and does not bear any risk as each container has to be rehandled (except Sea-Land). This prepared invoice should be sent to the invoicing department, where the amount should be checked against an advance-bond of the ship's agent. In case there is a difference the amount missing/overdue has to be settled with the agent.

Regarding general cargo and break bulk the situation is different as the charges will not be based on units but on tons. The invoicing department shall receive the manifests/hatch-lists for loading and discharging as well as the work-sheets of the operational personnel. Then the invoice will be prepared according to the proposed tariff and the amount will be checked against an advance-bond of the forwarder. These documents must indicate whether the cargo was handled direct or indirect in order to calculate properly the charges.

2.2.6 Proposals for a new tariff structure

Based on the analysis of the advantages and disadvantages of the existing tariff structure, a new structure has been worked out. This tariff takes into consideration the organizational recommendations and can be characterized as follows:

- separation of dues for the vessel and for the cargo;
- elimination of minimum items;
- consideration of the different value of the most important kinds of cargo as basis for charging;
- handling charges for the cargo are based on tons, not on hours, in order to leave increases of productivity in the port;
- the handling charges for the cargo have also to take into consideration the difficulty and/or time-consuming handling depending on the kind of cargo (the ton-rates must be higher than for normal general cargo).

The proposed new tariff structure is attached in Annex G-1. This structure and the related charges and dues should be valid, as at present, for all customers of the port. This means that the tariff can be published.

Nevertheless, it should be thought over in future, whether contracts with special charges can be established between special customers and the port. This could especially apply to the container shipping lines.

Such a system would meet the requirements of large customers as it pays attention to the volume of cargo which will be handled per shipping line. This system would be able to increase the attractiveness of the port and may also induce a transfer of additional cargo from other ports to Limón. Such contracts are also a sort of guarantee for the port as their validity normally ranges between 1-2 years. During that period the shipping line would be bound to Limón regarding a certain cargo handling.

2.2.7 Necessary training programs

With regard to the completion of the new container terminal in Limón, the implementation of the new banana handling operation in Moín, the introduction of an integrated operational pre-planning system and the extension of the operational responsibility of the Port Authority, training programs for the management and supervisory staff of the operational department become absolutely necessary in our opinion.

Due to the different fields of operation the training programs should be divided into

- container terminal operation
- general cargo and banana handling operation.

Such training programs should consist of three phases in order to achieve the maximum efficiency. These below-mentioned three phases apply to both fields of operation.

a) Training of management personnel abroad

The supervisory operational staff, as recommended in the organization chart of the Port Authority, should be nominated for the jobs in question. Some of these indigenous experts should be sent to a foreign port, having a similar structure as Limón/Moín. The Costa Rican team to be sent abroad should consist of the following persons:

- container terminal operation
  - .. superintendent Limón
  - .. supervisor container ship's operation
  - .. supervisor container yard control
  - .. chief documentation office container terminal
  - .. manager workshop
- general cargo and banana handling operation
  - .. superintendent Limón (assistant)/Moín
  - .. supervisor ship
  - .. supervisor shed

The numbers of the supervisory staff should be trained abroad for approx. four months. The result of such training must be that the Costa Rican experts become acquainted with the operational procedures for modern traffics (containers, ro/ro), the disposition and operational pre-planning, the necessary coordination with third parties and the related documentation. This training can only be performed successfully, if the Costa Rican personnel will be sent to a modern and high developed port.

b) Preparation-phase Limón

After completion of the training phase abroad, the Costa Rican staff have to prepare many activities for the phase of the management assistance on the spot. During this preparation phase, the Costa Rican staff should be assisted by the future project manager in the management assistance phase.

The preparation-phase, which is estimated to last for three months, should consist of the following main items:

- nomination of personnel of the various levels
- training of different levels regarding operational procedures, documentation etc.
- preparation of necessary documents
- coordination with third parties regarding new procedures etc.
- preparation for the expected team for management assistance

c) Management-assistance-phase Limōn

After completion of the preparation-phase a team of experts should be sent to Limōn for management assistance during the phase of implementation.

The team should consist of the following persons:

- container terminal operation
  - .. project manager / superintendent and supervisor ship
  - .. supervisor yard
  - .. documentation expert
  - .. workshop engineer

- general cargo and banana handling operation
  - .. project manager / superintendent and supervisor ship
  - .. supervisor shed
  - .. two foremen for ship's operation
  - .. two foremen for storage area

This team should work together with their Costa Rican counterparts (being trained abroad) with regard to planning activities, operational performance training of personnel and solution of daily problems.

The period of management assistance should last for approx. six months, which seems to be sufficient for the introduction of new procedures and training of personnel so that the Costa Rican staff will be in the positions to continue the operational activities without any futher general assistance.

3. Recommended operational procedures

3.1 General introduction

The system of operational procedures in a port reflects the degree of coordination with third parties, the clearness of allocation of responsibilities and the complexity of documentation.

As far as Limón and Moín are concerned we are facing the situation that the existing procedures must be improved and new procedures have to be created (container traffic). Before describing these procedures the general statements for the recommended improvements shall be emphasized.
These statements are:

- the central disposition is responsible for the disposition of berths, personnel and equipment; all parties concerned have to participate in the fixed meeting;

- at the time of arrival of cargo in the port, either by rail or by road, the related documents must be available;

  otherwise the cargo cannot enter the port (this applies especially to containers and trailers);

- the existing cargo documents ("formulario de exportación" and "formulario de importación"), should remain as they are and should also be valid for the containers and ro/ro-trailers;

- the receipt and delivery of containers/trailers has to be performed according to the standards of modern ports, i.e. interchange receipts have to be prepared;

- trucks with export cargo or for import cargo which are adviced one day prior to the loading/unloading shall have priority compared to trucks without advice;

- the customs should reduce the cargo checks in order to speed up the operational procedures; the sealing of containers and customs clearance in San José should remain, as it is of real advantage for the implementation of container traffic;

- the customs have to inspect and weigh the respective cargo on the original storage area; it is absolutely nonsense that the whole cargo is at present removed to the customs shed No. 1;

- the preparation of time - and productivity sheets, showing the actual working - time, waiting-time, number of gangs, productivities and kinds of cargo should also be performed in future.

Based on these statements the recommended operational procedures shall be described in the following chapters.

3.2 Operation pre-planning

Operation planning covers long-term planning for installations and equipment and defines the necessary investments for port facilities and short-term planning for ship's dispatch and landside operation.
Both subjects result in the most economic utilisation of the port facilities including man-power allocation. This subchapter will give recommendations applicable for the ports of Limōn and Moīn mainly for the short-term planning, the so-called operation pre-planning.

3.2.1 Ships' dispatch pre-planning

Short-term ships planning can be separated into three categories:

a) overall ships planning,
b) full day planning (24 hours) and
c) shift planning.

The objective of overall ships planning is to achieve the shortes lay-over time possible by optimum performance and minimum allocation of manpower and machinery. Overall ships planning coordinates the allocation of man-power and equipment to the various hatches (slow hatches, easy hatches) in such a way as to avoid significant delays.

Full day planning is one of the aspects of overall ships planning, concerned mainly with allocations of work force and equipment. Full day planning varies according to experience gained from changes in overall ships planning.

Shift planning represents de facto operations and final adaptation to actual situation regarding workforce/equipment planning.

3.2.2 Data required for operation pre-planning

At first the ships' data must be known. Information of technical ship details, sizes and numbers of hatches, decks, gear, draught etc. must be provided by the shipping line. Then the information regarding the cargo should be analyzed, i.e. portion of import and export cargo. Therefore the cargo manifest and booking list must be available, the stowage plan, dangerous cargo list etc.

Furthermore, the time span between arrival and sailing, ETA and ETD* should be indicated by the shipping line. This enables the port to plan a smooth operation without peaks and to coordinate the performance with other ships in port or expected ones.

---

* ETA = estimated time of arrival
ETD = estimated time of departure

3.2.3 Overall ships' planning

After having collected above mentioned data the quay-side operation could be planned as an overall ship's planning. Together with the concerned parties i.e. ship agency, stevedore and Fecosa the central disposition will hold a meeting and discuss the operation, agree on berth space, storage space, which possibly must still be cleared in advance, equipment and manpower allocations, numbers of shifts and achievable productivities.

3.2.4 Full day planning

24 hours before the operation starts the directly involved parties in cargo handling the port and the stevedore discuss and agree on the performance of the following day The shipping agent must report changes in ETA and information given prior for the overall planning.
The manpower, equipment will be allocated for the following day.

3.2.5 Shift planning

Shortly before the shift starts the operational departments prepare the actual operation. Thus superintendent and supervisors guide and supervise the shift operation under the overall planning targets.
Any changes during the shift will influence the whole operation and must be reported immediately.

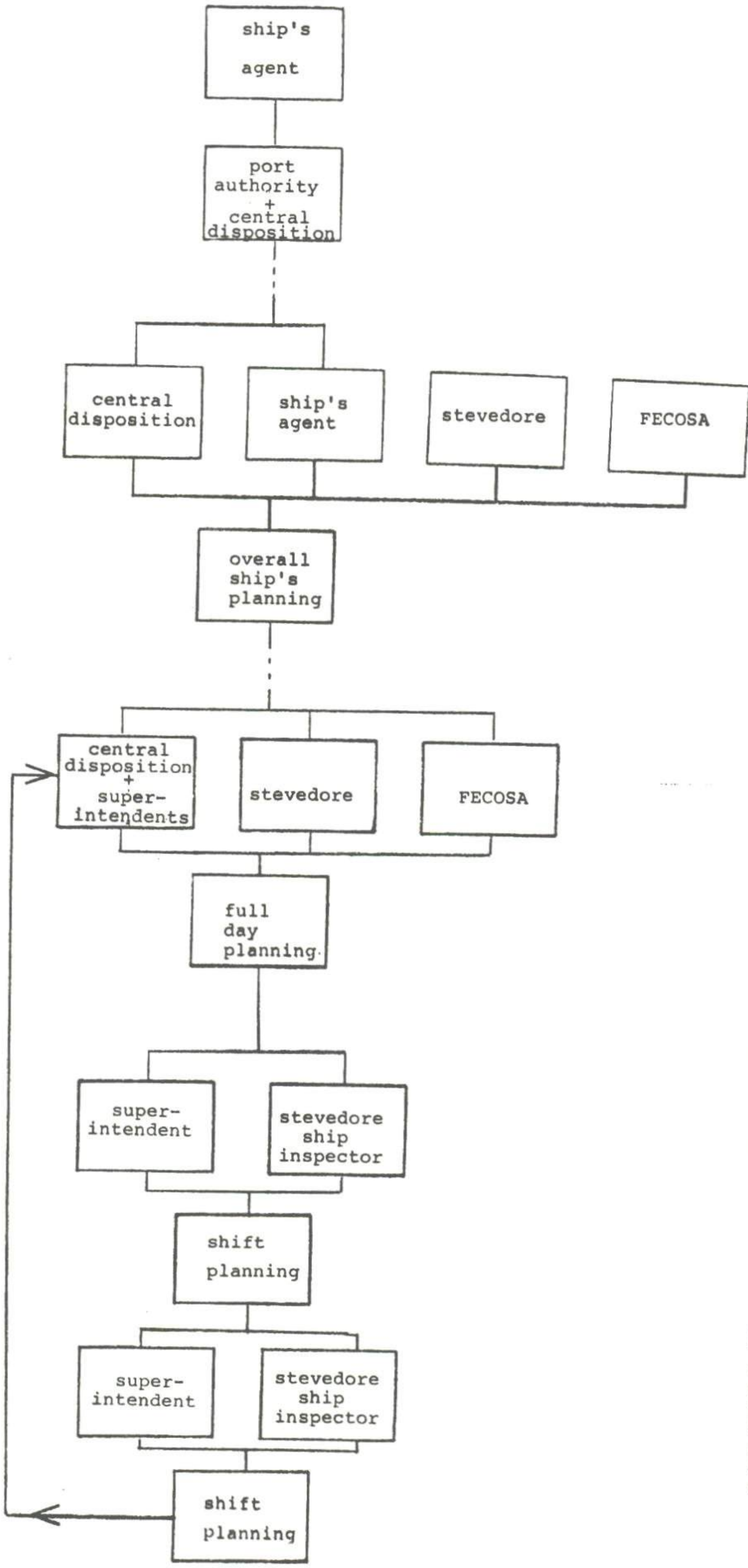
3.2.6 Recommendations

Regarding the situation in the port complex of Limõn and Moīn, the Consultant recommend the following flow of information and interactions between the parties involved in the cargo operation (see also the following figure G - 5).

- one week prior to vessel's arrival
  The shipping agent informs the port i.e. central disposition about the arrival of a vessel, indicated the necessary ship dates, like length, draught at arrival, GRT and NRT, number of hatches, cargo gear. Furthermore, cargo information - if available - should be delivered at least in rough figures like cargo volume to discharge and to load, hatch distributions, kind of cargo, required special gear or performance, the time span available for operation.

- two days prior to vessel's arrival
  The parties involved will hold a pre-planning meeting during which the overall ship's operation will be decided.
  The shipping agent will deliver all required documents like:
  - cargo manifest, stowage plan, dangerous cargo list
  - booking list for export cargo
  - arrival time and expected sailing date

Figure G - 5:



one week prior to vessel's arrival

The ship's agent informs the the central disposition about following data:
Ship's data, cargo volume im- and export, ETA, ETS, technical data et

two days prior to vessel's arrival

Overall ship preplanning meeting:
the ship's agent provides cargo manifest and booking list, stowage plan, dangerous cargo list.
Together with the parties concerne the overall operation will be discussed, the numbers of shifts and gangs decided.

one day prior to operation/arrival

Full day planning meeting:
Having all data available the berth place will be decided, the clearing of storage area, shifts and numbers of gangs, man-power and equipment, railway cars and productivity targets.
Later changes in operation of the last day must be considered and the performance actualized.

two hours prior to shift start

Shift planning:
according the full day planning targets the shift should be planne and performed. Changes must be considered accordingly and reporte to the central disposition and following shift management.

two hours before following shift

the changes of the pregoing shift should be considered for the shift planning regarding the premises of the overall and full day requirements.
Reports to central disposition necessary

The terminal operator together with the stevedore will plan the number of shifts and gangs per shift according to the information above. The railway must decide and be informed what kind of railcars they have to provide and at what time. For the export cargo they have to arrange the allocation of railway transported consignments. (This applies mainly to the banana handling). All partners then lay down the general operation targets.

- <u>one day prior to operation start</u>
  This applies not only to the start of operation but also for each following operation day. Before the day of arrival the berth place will be decided by the port. Together with the stevedore and railway (FECOSA) the manpower, equipment and productivity targets will be agreed for each shift the following day.

  Then the port has to provide the storage area near the berth to guarantee a fast ship operation. For this purpose the area must be cleared and prepared.

- <u>two hours prior to shift start</u>
  The supervisors and stevedore ship inspector control the start of operation and decide possible changes according to actual situation. They have to consider the targets of the overall ship's planning. During that shift they guide and supervise the operation, report productivity and changes, which will influence the following shift and operation. The reports will be delivered to the central disposition and the supervisor of the next shift who must again together with the stevedore ship inspector plan the following shift.

  All changes during the shift operation will influence the following day and therefore must be reported to the central disposition which have to integrate the actual situation in the plans for the next day during the full day planning.

In spite of careful pre-planning it will happen that the program has to be modified at any time because facts have become available which were not known prior to vessel's arrival or shift begin. This may relate to the stowage on board, to the availability of labour or may concern certain cargoes, which, although scheduled for loading, are not made available in time or may even be connected with weather conditions.

In these instances, both the superintendent/supervisors and stevedoring inspector must be flexible enough to adjust the program with certain limits given by the overall planning. The consideration of the new facts will avoid significant delays of the cargo operation. Although it should be possible to make such last minute changes, it must be pointed out, however, that they should be exceptional. Otherwise, all the planning work would prove rather pointless.

3.3 <u>Operational procedures for the container traffic</u>

As the port staff is not familiar with regular handling and stacking of containers, the operational procedures have been prepared in detail. These graphic procedures are attached in the Annex G , together with a recommended form of an E.I.R. (=interchange receipt) and a container damage list, the latter to be filled out at the crane side (see Annexes G-2 to G-9).

The procedures imply that the container trucks are checked at the gates in the Proyecto Alemàn, where also the documents must be cleared before a truck is allowed to enter the port area. This means that the trucks have to park on the Avenida 1. As far as the container operation for Sea-Land is concerned the recommended procedures do not apply. In this case, the supervisor ship only receives the working program from Sea-Land and the ship's foreman has to supervise the sequence of loading and discharging. Only the seal-number has to be checked and reported. In case Sea-Land will also use the railway in future and will stack boxes in the container terminal, the general procedures will be valid.

3.4 Operational procedures for the ro/ro-traffic

The operational procedures for the export and import of ro/ro-trailers should be more or less the same as for containers. The documentation for the trailers must be deposited in the documentation office at the gates of the container terminal or could accompany the truck-driver. Also for these trailers an interchange receipt should be prepared and the seal-No. and damages should be noted during loading and discharging of trailers in order to clearly define the liabilities for each party concerned.

As the trailers are normally delivered to the port a very short time prior to the ship's operation, there is no need to precisely note the exact location of the trailers within the parking area. Only in case of larger quantities, an inventory check prior to the operation (only for export) could be of advantage.

The agent should issue to the Operation Department a list of trailers to be loaded and discharged. This list should be handed over to the central disposition within the operational pre-planning meeting two days prior to vessel's arrival.

3.5 Operational procedures for the general cargo/break bulk traffic

As far as the recommended operational procedures for the handling of general cargo and break bulk are concerned, there is no need to essentially change the existing procedures again.

3.5.1 Loading and discharging

According to the proposed operational pre-planning, the ship's agent delivers the respective ship's documents to the central disposition prior to the start of operation. These documents are analyzed and forwarded to the superintendent/supervisors for detailed preparation of the shift operation. The cargo summary and one of the manifests will be delivered to the Documentation Office for the preparation of the central store-book (in case of import).

Afterwards the ship's operation will be performed by the stevedore (aboard) and the gangs of the Port Authority (ashore). The supervisor of the Port Authority possesses the necessary documents and controls and coordinates the working gangs. He also fills out the work-sheets regarding number of gangs, working time, waiting time, productivities etc. At the point of transfer between stevedore and Port Authority the cargo will be tallied by a checker of the Port Authority and a checker to be ordered by the ship. These tally-sheets have to checked against each other and differences have to be eliminated.

3.5.2 Transfer of cargo between shed and quay

In the case of export, the Documentation Office has to note the storage places for the cargo on the manifests prior to the start of operation. The manifests are forwarded to the respective shed supervisor who coordinates the delivery of cargo to the ship with the respective ship supervisor. The cargo to be loaded must be cancelled in the store-book. In the case of import the shed supervisor receives the cargo summary from the Documentation Office prior to the start of operation, and he decides on the storage area and transfers this information to the ship suvervisor. After completion of operation, the shed supervisor and the ship supervisor together check the quantity of cargo and its location on the storage area. A storage-list has to be prepared and has to be sent to the Documentation Office for completion of the store-book.

3.5.3 Landside receipt of cargo

It is assumed, due to operational advantage, that the export cargo will be handled indirect, i.e. the cargo will be stored in the port before being loaded on board. The detailed procedure regarding the flow of documentation for this activity by truck is graphically described in Annex G-10.Regarding the landside receipt by train the truck-procedure is valid as basis. The trucker will be substituted by Fecosa, which has to inform the central disposition about the railcars, consignees and kinds of cargo. This information will be passed on to the respective shed.

3.5.4 Landside delivery of cargo

As far as the delivery of cargo is concerned, both, direct and indirect handling are possible. The detailed operational procedure for the indirect handling by truck is described in Annex G-11. For the direct handling although not considered as normal the forwarder has to present his documents prior to the start of operation. After settlement of all payments fallen due, the Documentation Office forwards the documents to the superintendent who arranges the direct handling of cargo together with the respective ship supervisors.

Regarding the landside delivery by train the truck-procedure is also valid in general, only the trucker has to be substituted by Fecosa.

3.5.5 Handling of bananas

The operational and documentary procedures for the handling of bananas should remain as they are. However, the Port Authority should tally the number of cartons to have available one official count of cartons of bananas. At the time being, all documents are based on the statements of the banana-companies, as far as the loaded quantities are concerned.

Annex Chapter G

(G - 1 to G - 11)

Recommendations for a future Port organization

Proposed Tariff Structure

	Unit of Tariff
I. Ship's Dues	
1. Basic ship's services (incl. pilots, navigational aids, breakwater dues, mooring/unmooring)	GRT
- general cargo vessels	
- container / ro-ro vessels	
- banana vessels	
- tankers	
2. Tug-boat assistance	h
3. Wharfage dues	quay-m/12 h berthing time
- general cargo vessels	
- container / ro-ro vessels	
- banana vessels	
- tankers	
4. Special ship's services	
- launches	h
- water supply	t
- electricity supply	kw/h
- fuel supply	t
5. Demurrage charges	h
- mooring gangs	
- tug-boat	
II. Cargo Dues	
1. "Muellaje" export	t (weight)
- bananas	
- coffee	
- other agricultural products	
- industrial goods	
2. "Muellaje" import	t (weight)
- forest products	
- iron / steel	
- machinery, spare parts, construction parts	
- vehicles	
- bagged cargo	
- chemicals	
- food	
- miscellaneous general cargo	
- dry bulk cargo	
- liquid bulk cargo	

III. Handling Charges

1. Containers

- loading / discharging 20'/40'	container
- loading / discharging 35'	container
- landside rehandling 20'/40'	container
- landside rehandling 35'	container
- transfer to CFS 20'/40'	container
- transfer to CFS 35'	container
- re-storage direct aboard	container
- re-storage board-quay-board	container
- packing / unpacking of containers	t

2. Ro/Ro-cargo

- loading / discharging of trailers	trailer
- loading / discharging of vehicles	unit
- loading / discharging of rolling stock	unit
- transfer of trailer to CFS	trailer
- packing / unpacking of trailer	t
- loading / unloading of general cargo trailer	t

3. General cargo / break bulk

3.1 Paper rolls	t
- loading / discharging by shore-crane	
- handling from quay to storages area and vice versa	
- direct handling from/to truck and railcar	
- receipt of cargo (indirect)	
- delivery of cargo (indirect)	
3.2 Iron / steel	t
- split-up as under 3.1	
3.3 Bagged cargo (without pallets)	t
- split-up as under 3.1	
3.4 Bagged cargo (pre-slung)	t
- split-up as under 3.1	
3.5 Palletized/unitized cargo	t
- split-up as udner 3.1	
3.6 Machinery/ construction parts	t
- split-up as under 3.1	
3.7 Chemicals	t
- split-up as under 3.1	
3.8 General cargo (non-unitized)	t
- split-up as under 3.1	
3.9 Vehicles	unit
- split-up as under 3.1	
3.10 Heavy lifts (exceeding 3 t)	t
- split-up as under 3.1	
3.11 Cargo measured several times	t
- split-up as under 3.1	

4. Dry bulk cargo	
- loading / discharging with shore crane	t
5. Bananas	
- loading from railcar/truck on board	carton
6. Liguid bulk cargo	
- loading / discharging by pipes	barrel

IV. Storage Fees

1. Containers	cont./day
- 20' container	
- 35' / 40' container	
2. Ro/Ro-trailers	trailer/day
- trailer 20'	
- trailer 40'	
- vehicles	unit/day
- rolling stock	t/day
3. General cargo / break bulk	freight t/day
- man-palletized / unitized cargo	
- unitized / palletiged cargo	

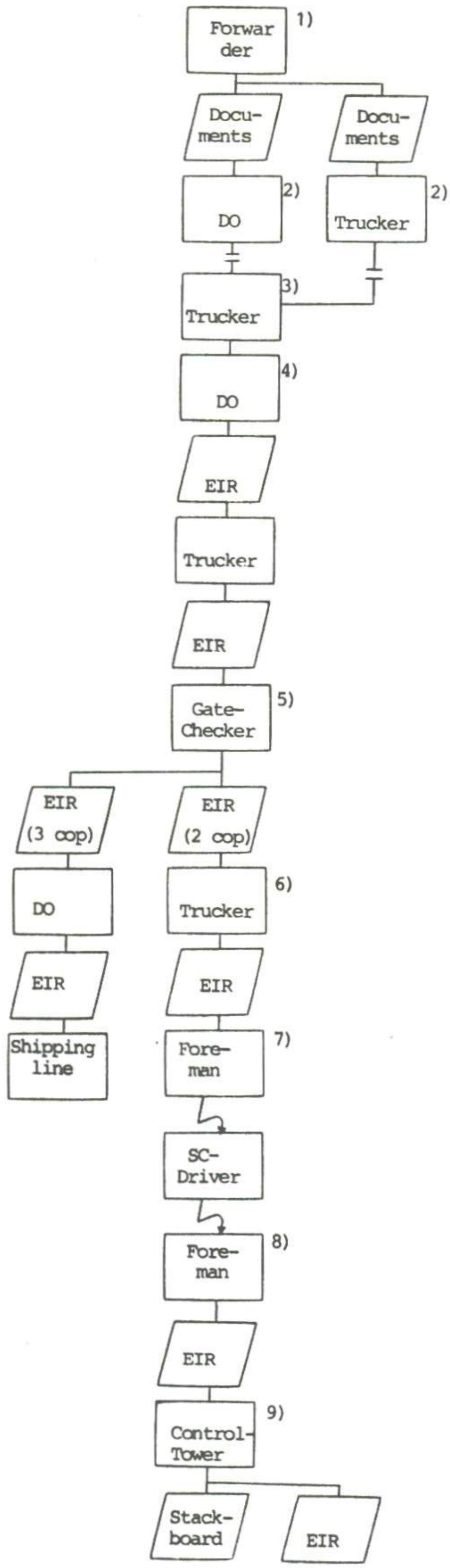
V. Miscellaneous Charges

1. Electricity-consumption for reefer-containers	kw/h
2. Demurrage for gangs	man-hous
3. Weighing of containers, trucks etc.	unit
4. Other services	man-hour plus equipment-hour

Operational Procedures Container Terminal

Annex G- 2

Arrival of Container (Truck)



1) Establishment of documents, performance of customs clearance and pre-clearance with CT. Documentation Office (DCO)

2) Deposition of cleared documents at DOC or issue to trucker

3) Arrival at terminal with export-container and contact to DO

4) Check of presented or deposited documents for container and preparation of Interchange Receipt (EIR)

5) Check an weighing of container; completion of EIR; two copies of EIR to trucker; three copies to DO (one for own file)

6) Trucker drives to foreman of take-over-area and delivers one copie EIR

7) Foreman radios to control-tower and receives location pre-information in the stackboard, Foreman radios to SC-driver the location of container

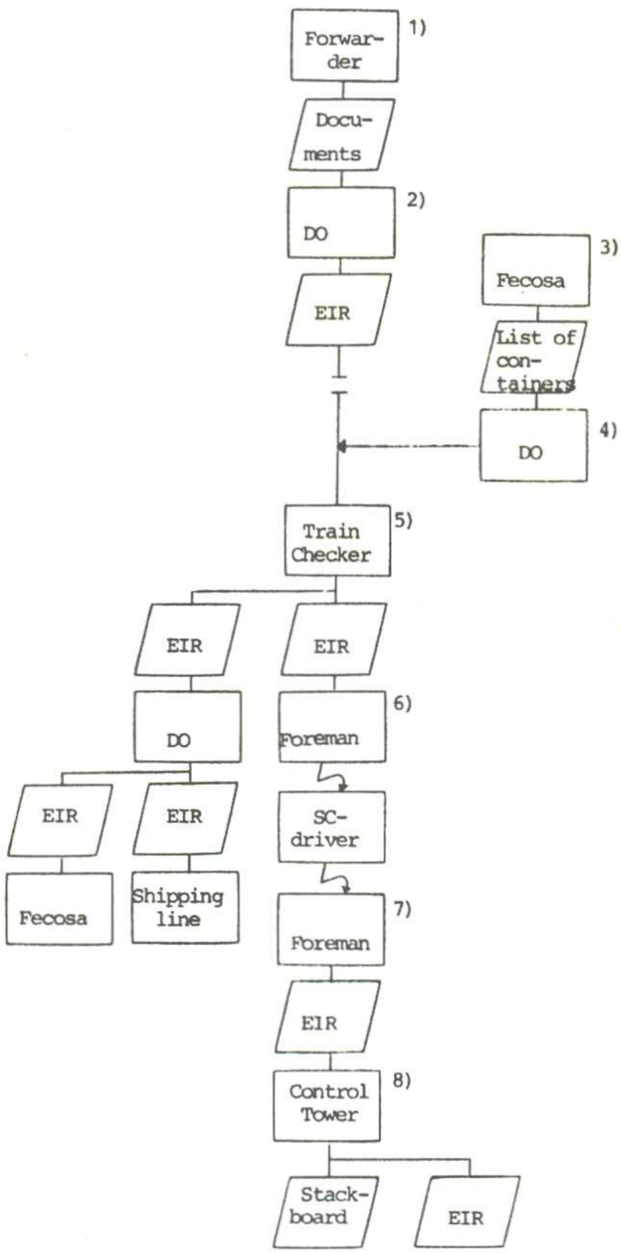
8) SC-driver radios exact location to foreman; completion of EIR and passing to control tower by messenger

9) Completion of stack-board for containerinventory and filing of EIR per vessel/agent

Abbreviations: DO = Documentation Office
EIR = Equipment Interchange Receipt
SC = Straddle Carrier
Control tower = office of the supervisor container yard
SOO = Ship's Operation Office
(= office of the supervisor container ship's operation)

Operational Procedures Container Terminal

Arrival of Container (Rail)



1) Establishment of documents performance of customs clearance and pre-clearance with DO of PA (cont.term.)

2) Deposition of cleared documents at DO and preparation of EIR

3) Fecosa prepares list of containers to be delivered to the terminal

4) Check of list against prepared interchanges and issue of EIR to train-checker

5) Check of containers; completion of EIR; four copies to DO; one copy to foreman

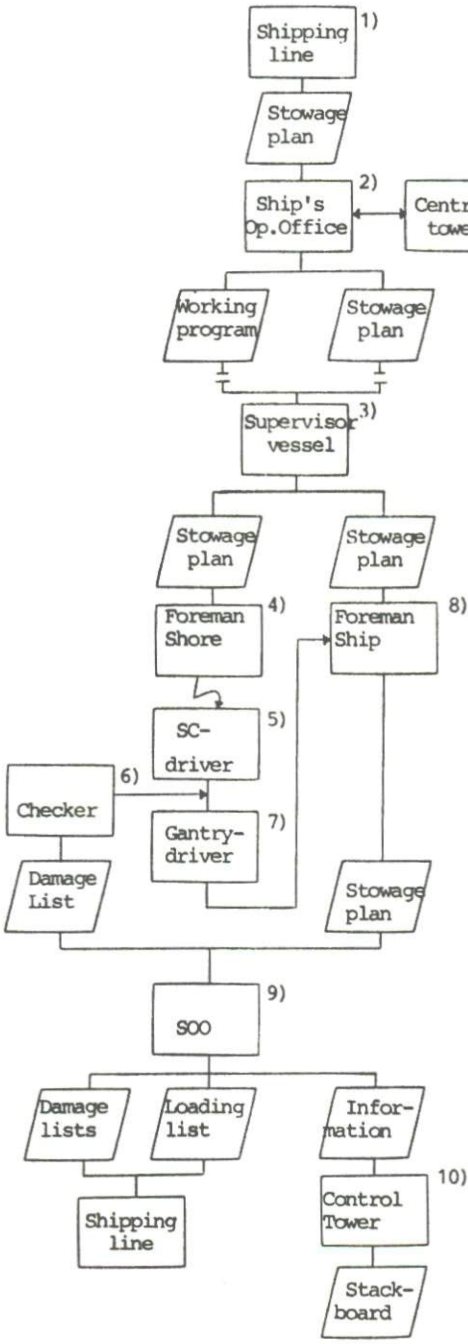
6) Foreman radios to control-tower and receives location pre-information in the stackboard; foreman radios to SC-driver the location of containers

7) SC-driver radios exact location to foreman; completion of EIR and passing to control tower by messenger

8) Completion of stackboard for container inventory and filing of EIR per vessel/agent

Operational Procedures Container Terminal

Loading of Containers



1) Shipping line prepares stowage plan for export containers

2) SOO prepares working program (sequence etc.) and completes stowage plan with location (info from control tower)

3) Control of operation and distribution of stowage plans

4) Foreman shore radios location of containers to SC-driver

5) SC-driver brings container directly to gantry

6) Checker checks container prior to loading and fills out damage list

7) Gantry-driver load container

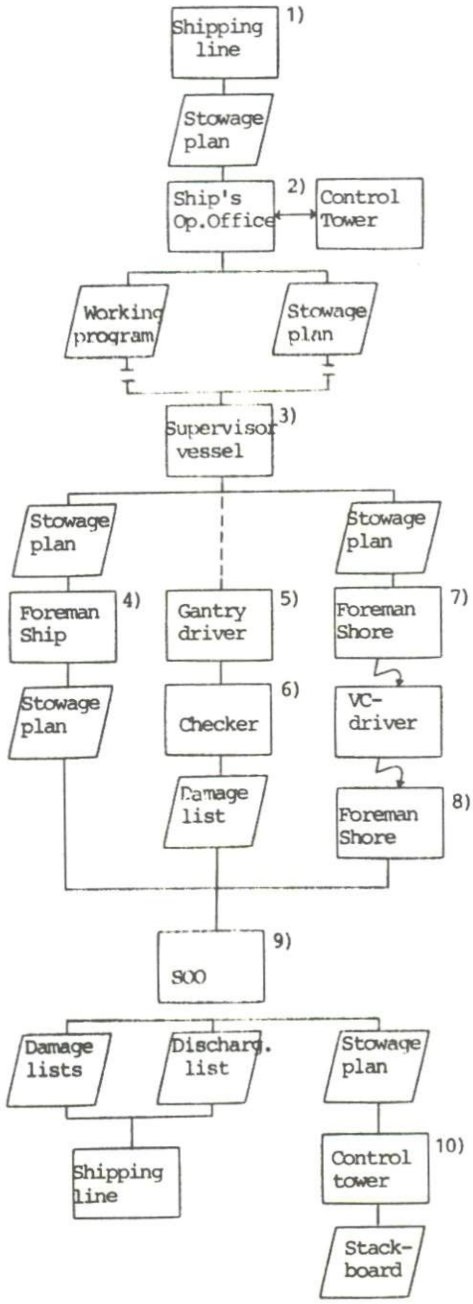
8) Foreman ship checks containers against stowage plan

9) SOO copies damage lists for own file, prepares final loading list and informs the control tower about completion of operation, resp. already between

10) Actualization of stack-board

Operational Procedures Container Terminal

Discharging of Containers



1) Shipping line prepares discharging stowage plan

2) SOO prepares working program and defines stacking area generally (in coordination with control tower)

3) Control of operation and distribution of stowage plans

4) Foreman ship checks containers against stowage plan and indicates containers to gantry driver

5) Gantry-driver discharges container

6) Checker checks containers and fills out damage list

7) Foreman radios general location to SC-driver

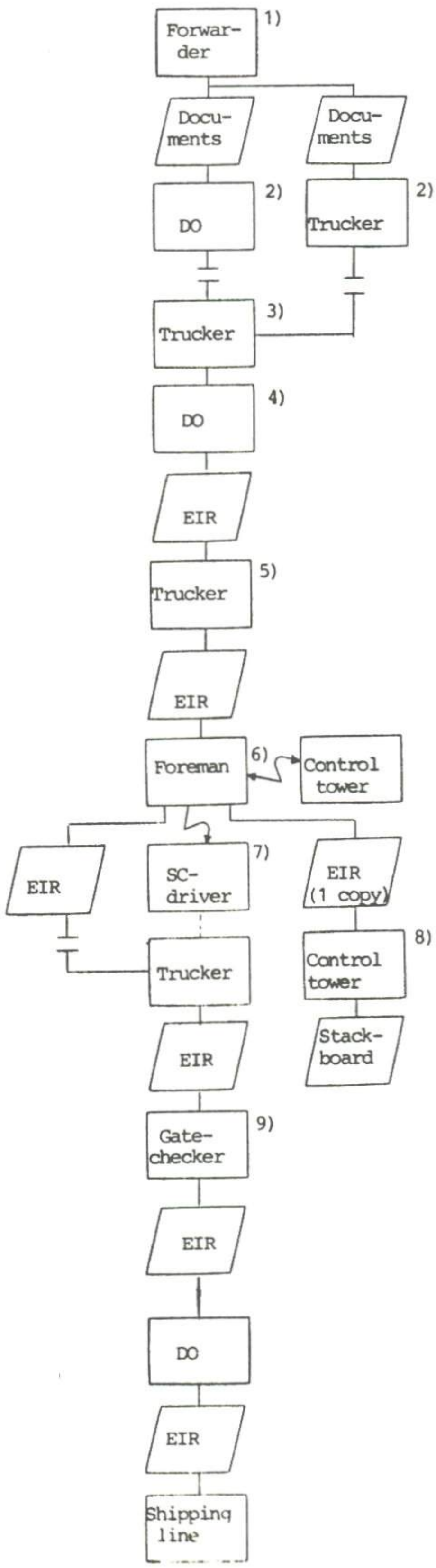
8) SC-driver radios exact location to foreman; filling in of location in stowage plan

9) SOO copies damage lists for own file, prepares final discharging list and informs control tower about location of containers

10) Actualization of Stack-board

Operational Procedures Container Terminal

Delivery of Container (Truck)



1) Establishment of documents; performance of customs clearance and pre-clearance with DO of PA (Cont.Term.)

2) Deposition of cleared documents at DO or issue to trucker

3) Arrival at terminal with empty chassis and contact to DO

4) Check of presented or deposited documents for container and preparation of EIR

5) Trucker proceeds to take-over area and presents EIR to foreman

6) Foreman checks location of container with control-tower by radio and radios to SC-driver exact location

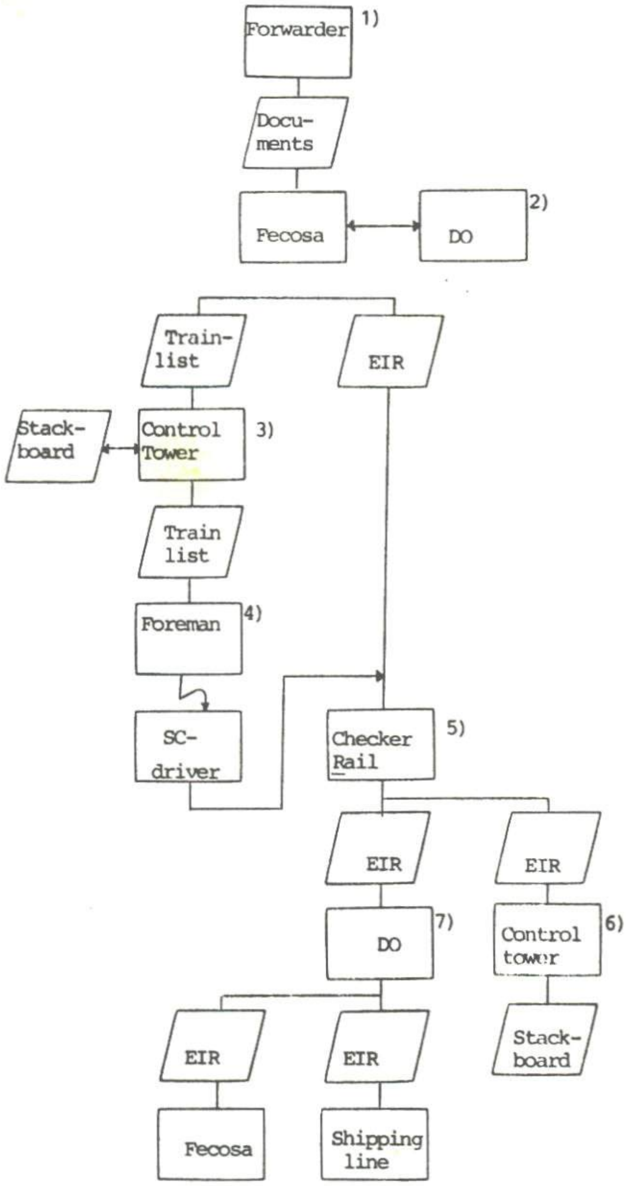
7) VC-driver picks up container and places it on chassis

8) Control-tower cancels container in the stack-board

9) Check of container; completion of EIR; one copy to trucker; rest to DO

Operational Procedures Container Terminal

Delivery of Container (Rail)



1) Establishment of documents; performance of customs clearance and preclearance with DO

2) Deposition of cleared documents at DO and preparation of EIR and train-list in coordination with Fecosa

3) Control-tower checks list against stackboard completion of list by location of containers

4) Foreman radios to SC-driver location of container and railcar to be loaded

5) Check of containers; completion of EIR; one copy to control-tower; rest to DO

6) Actualization of stack-board

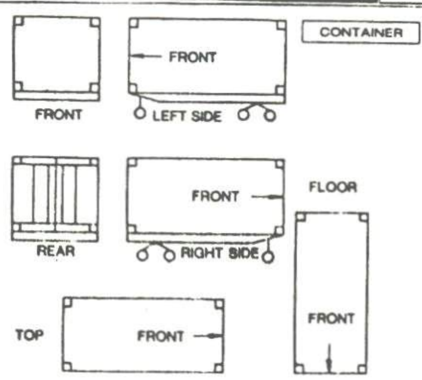
7) Distribution and filing of EIR

Equipment Interchange Receipt/Inspection Report

Steamship Company :

Shipp. Line	Owner	Container-Nr	Con Type	Mode of transp.	cond.	Gross Weight	Vessel	Port of Dest.	Voyage
					☐ load ☐ MTY				

Seal No.	Refrig. Unit No.	Reefer Temperature	Dang. cargo class	Origin	Time	Date



Reefer Thermost-Setting Grad Cels. Grad Fahrenheit

Miscellaneous:

dang cargo class ____________

Use the following codes: D Dent H Hole C Cut B Bruise M Missing BR Broken

The equipment listed above is delivered in good outside order except where noted or the defects specially mentioned in the damage report.

Remarks

Controlled and received by:

____________ Place/date/time ____________ Signature

____________ Signature

Annex

CONTAINER DAMAGE LIST

VESSEL : ____________________ DATE: __________

HATCH : __________ LOADING ☐ DISCHARGING ☐ SHIFT: __________

KINDS OF DAMAGES: [D] DENT [H] HOLE [C] CUT [B] BRUISE [M] MISSING [BR] BROKEN

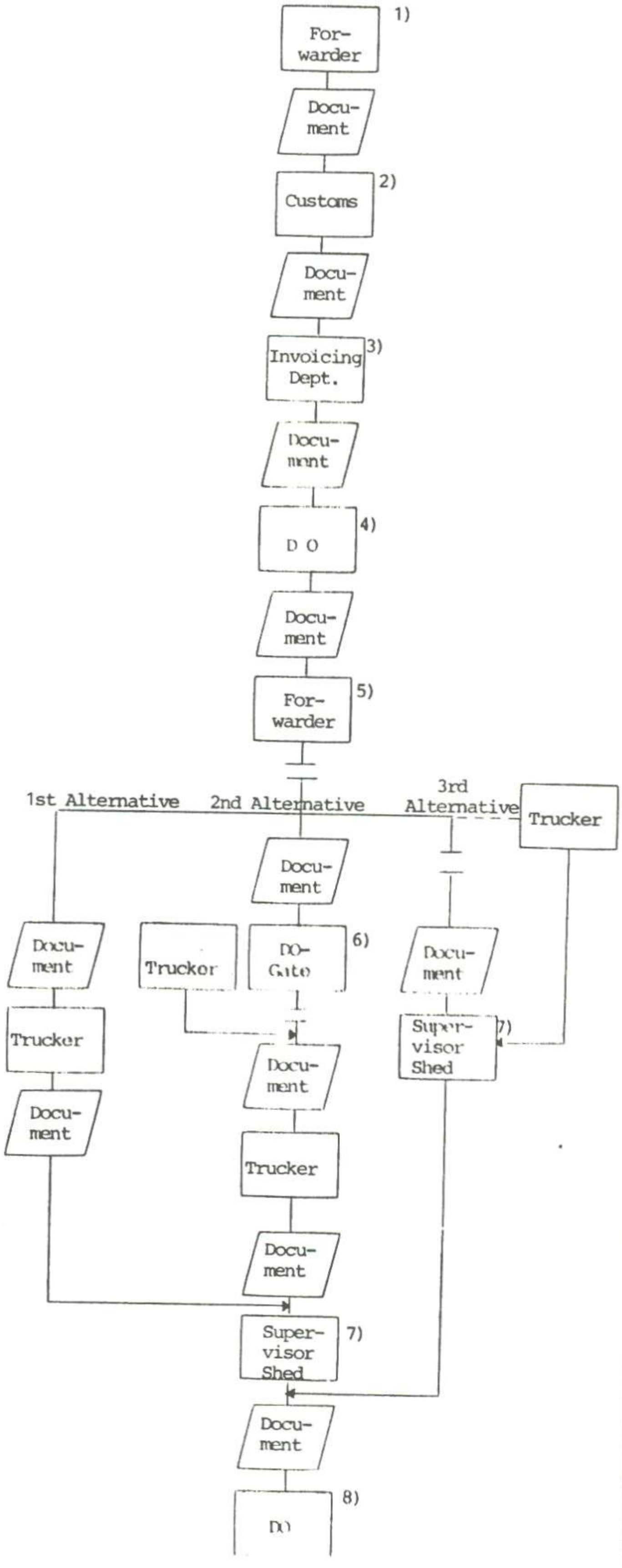
Alpha prefix	Container-no.	Seal-No.	Damages at:					
			right side	left side	front	door	roof	floor

____

Signature

Operational Procedure General Cargo

Landside Receipt of Cargo (Truck)



1) Establishment of documents

2) Check of completeness of documents; payment of customs dues if any

3) Check of completeness of documents, payment of handling charges

4) Check of documents; definition of storage place and notice on document

5) There are 3 alternatives of further procedure
   1. forwarder hands document over to trucking co.
   2. forwarder deposits document at Do-gate
   3. forwarder orders trucker and hands document over to supervision shed and is present during unloading of truck

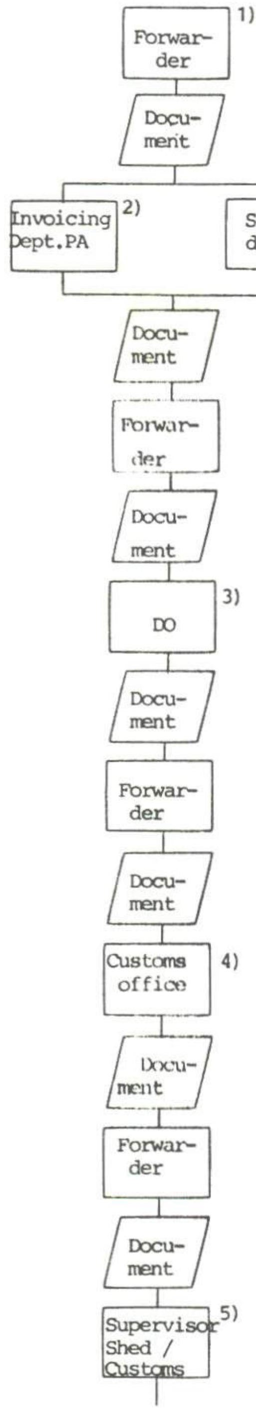
6) DO hands document over to trucker

7) Supervisor shed checks document; orders gang for unloading; notes storage place on document

8) Notice of storage place in store-book

Operational Procedure General Cargo

Landside Delivery of Cargo (Truck)



1) Establishment of documents

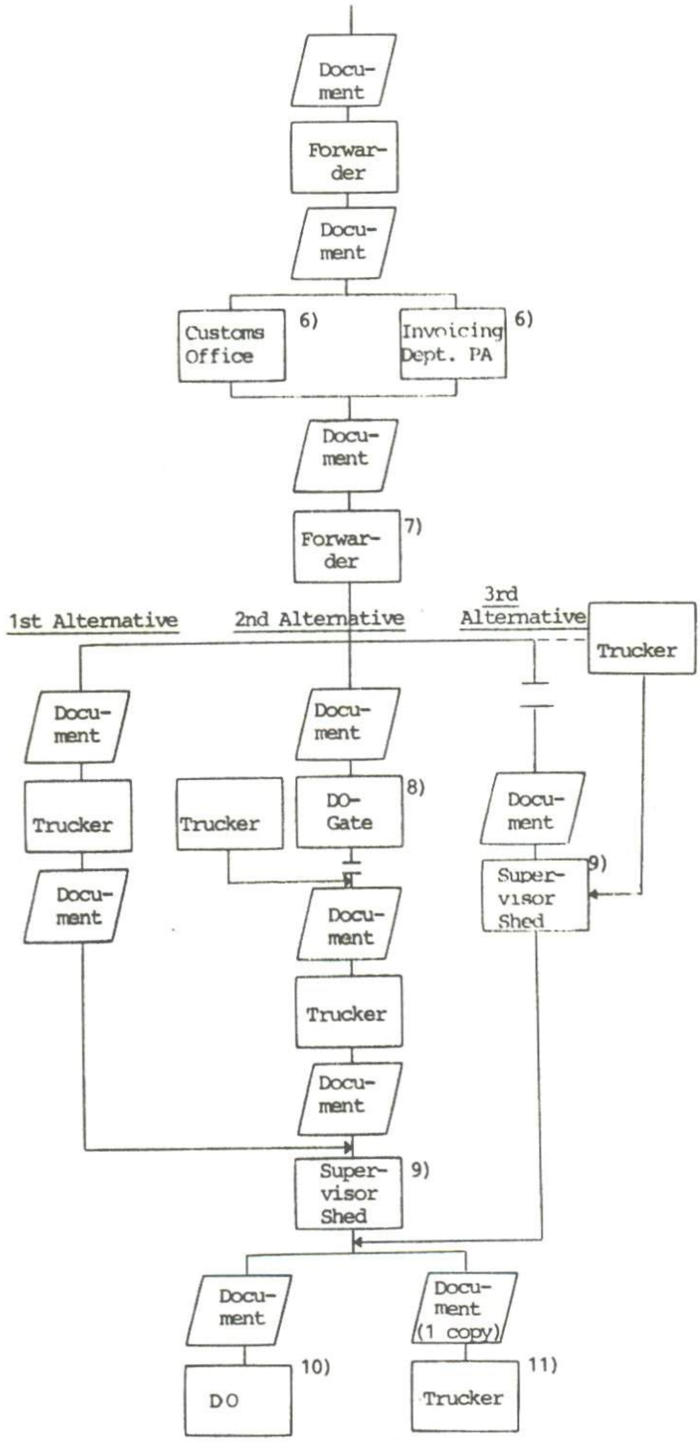
2) Payment of dues

3) Check of completeness and authorization; check of storage place (shed) and notice on document; advise reg. delivery

4) Check of completeness of documents etc.

5) Supervisor Shed checks exact storage place; customs examines cargo and defines customs dues

Landside Delivery of Cargo (Truck) cont'd



6) Payment of customs dues and storage fees

7) There are 3 alternatives of further procedure:

1. forwarder hands document over to trucking co.
2. forwarder deposits document at DO-Gate
3. forwarder orders trucker and hands over doc. to supervisor shed and is present during loading of truck

8) DO hands document over to trucker

9) Supervisor shed checks document; orders gang for loading; cancels cargo in his list and notes personnel, equipment and time needed on document

10) Cancellation of delivered cargo in the store-book/file

11) Trucker leaves port

H. NAUTIC

1. Introduction

In chapter B-6 (nautic-present situation) necessary improvements were listed up and shall be investigated in this chapter. Recommendations are given and technical information as far it is possible. Some requirements need an immediate begin of investments and measures. Some depend on the future development and further economic analyses.

2. Future nautical requirements

2.1 Buoyage system

Special attention was drawn by the consultants to evaluate the system by which the buoys are to be marked with colour and topmarks. Presently two systems exist in the maritime world:

a) to mark out starboard side of navigable water areas with green colour and portside with red colour which refer to the international maritime law of vessels starboard and portside lights, this system is called "System A";

b) to mark out starboard side with red colour and portside with green colour, the so called "System B".

Generally the sides of navigable waters are determined by an incoming vessel which sees the borders at their port- respective starboard side.

The"System A" has been approved by the concerning departments of the United Nations and has been introduced in Africa, India, Australia, Europe and parts of East Asia.

The so-called "System B" is still under study and supported by the United States of America, where the different method of colouring is common. Parts of South America e.g. Brazil use this method. Costa Rica, which owns a negligible number of buoys, has to decide the system applicable to its water areas.

Referring to the neighbour country and the buoyage system of the approach of Almirante/Panama Republic where the "System A" is applicable, Costa Rica should support the "System A". This not only because it is used at Boca de Toro/Almirante but also, because it is the traditional colouring in maritime world and most familiar to seamen from all countries with all levels of education.

This system will create the minimum confusing to approaching vessels and thus cause a minimum risk of errors in navigation. A potential danger normally affects more shore facilities and environmental matters than it cause material damages to vessels because vessels are insured to its value, but the liability to third party damages usually is restricted to certain amounts, which is proved e.g. by tanker collosions in France and Great Britain.

Summarizing all the concerning facts regarding both systems, the consultants recommend the introduction of the "System A" and the approval by the Costa Rican government.

2.2 Navigational aids

2.2.1 Navigational layout Limón

The port area should be divided into two harbour areas, the inner harbour and the outer harbour.

The inner harbour should comprise all dredged basins and vessels are not allowed to enter without a pilot. This area also will be used for turning manoeuvres under assistance of tugboats.

The outer harbour should be the anchorage and clearing area for arriving vessels if they cannot proceed directly to a berth. The pilot has to be boarded in the outer harbour area.

The outer harbour

The outer harbour should be limited by following lines; in the northwest by the connection line of Isla Uvita lighthouse and the breakwater head, in the northeast by the connection line of Isla Uvita lighthouse and the isolated danger mark buoy placed upon the wreck in position 316,2^{0}, 0,91 nautical miles (off lighthouse); in the south by a line directing 232,2^{0} from the isolated danger mark buoy ashore.

The anchorage will provide approx. 8 anchoring circles outside the 11 m line, which could be regarded sufficient. (The circles are calculated for vessels of 200 m length).

The inner harbour

The limits of the inner harbour is defined by the connection line of the breakwater head and the portside entrance buoy in the east; in the south by the dredged basin edges and the basin buoy Nr. 4. Traffic within this area are exclusively under port's control.

Buoys

As already mentioned above the port area needs an identification. This should be erected by an approach buoy or landfall buoy.

As at present there exists a wreck marked out by an insufficient buoy, this buoy should be replaced by a buoy indicating an isolated danger, namely the a/m wreck. The isolated danger mark should be placed just upon the wreck so that vessels could pass at both sides safely. This buoy acts at the same time as the port approach buoy, therefore the buoy must have a sufficient visibility.

The inner port area should be indicated by the entrance buoys. As the breakwater head represents the starboard entrance only the portside requires a buoy. But the buoy should have other functions, it should indicate the dredged basins of 10 and 11 and in conjunction with piermarks the slope of the basins.

This will facilitate the pilot's manoeuvres. The portside entrance buoy has red colour, red light with a quick flash rythm and a cantopmark, the painted number of the buoy must be Nr. 2.

The second buoy indicating the inner harbour should be placed at the basin's edge in front of the sunken wreck near the Muelle setenta. Then it acts as basin guidance and warns of the wreck. Also this buoy should be red, have red light with a flash rythm, can-topmark and the number Nr. 4. This buoy need not to have the same size as Nr. 2.

The following table gives the characteristics and position of buoys at Limón:

Type	shape	colour	topmark	colour of light, rythm	radar reflector	Position x	Position y
Approach Isolated danger mark	pillar	red with black belts below, above	two black sph eres	white two flashes	yes	645 820	218 830
Nr. 2 Portside entrance buoy	pillar	red	can	red quick flash	yes	643 555	218 703
Nr. 4	pillar	red	can	red flash	yes	642 945	219 150

Land marks

The lighthouse of Isla Uvita is in a very bad condition and do not fulfill its function regarding to international standards. The main present failure is the bad maintenance and missing supervision. A survey of the consultants resulted that the steelgirder and the optical equipment could be rehabilitated without greater investments.

The required technical data are the following: range 17 nautical miles, white light, visible over 360^0, rythm flash (2), 5 sec. The power output of the light must be approx. 10.000 cd (candela). Improvement should be made for the power supply. At present a diesel powered generator delivers the electricity. This equipment requires a permanent presence of a lighthouseguard. Reflections should be made to provide the necessary electricity by a seacable from the Proyecto Aleman. Then only in cases of breakdowns or regular maintenance intervals the island have to be visited.

The breakwater head should be equipped with green pile and green light with a flash rythm, the topmark has to be conical.

As a provisional measure, until the pier Nr. 1 will be removed, a pile with a white flash light should be installed at the northern pier end. In conjunction with the buoy Nr. 2 it indicates the western edge of the 11 m basin. This light should be erected not dazzled by other pier illumination.

All pier and port illumination should be dimmed in a way that the navigational light are not dazzled. As a further measurement to facilitate manoeuvring all pier ends such as the Metallico and Setenta should be painted with a reflexion-paint and illuminated by dimmed overhanging lights (Drawing H - 1).

2.2.2 Navigational layout at Moín

The buoyage layout should comprise two steps:

1. The inner port layout which should provide safe and fast access to the piers for vessel entering the harbour. This measure should be realized simultaneously with the completion of the port.

2. The outer port buoyage should indicate the outer port area and should provide at least an approach buoy and limit the anchorage area.
   This step will be necessary when vessels are cleared and dispatched to Moín directly from the sea. Then the pilots have to board also at Moín.

Inner port layout

The entrance channel has to be marked by entrance buoys at both sides, from there the usefullness of the rangelight starts and provides a good sensitivity for vessels not to drift out of the centerline of 331.5^{0}. The breakwater head needs a mark and light indicating the portside of the channel and the end of breakwater.

The northern end of oilpier also has to be marked. The lower leading light (or front light) should be positioned at the Moín Hill (X = 637 569; y = 221 080) with an elevation of the light of 12 m above sea level. The rythm of light should be flash white. The upper leading light or rearlight (X = 637 653; y = 220 987) must have an elevation of 20.8 m above sea level, the rythm of light should be permanent white.

Both lights must be dimmed so that dazzling and disturbing by other illumination of the port do not occur. Furthermore the towers or girders should have effective radar reflectors.

The rangelight's sensitivity is designed from the entrance buoys up to the slope of the 12 to 14 m basin, although they work also further outside of the channel entrance up to 0.75 nautical miles.

Pier marks

The head of breakwater should bear a red pile with a red light of 2-flashes per period (group flash (2)) and with an effective radar reflector. The mark indicates the head of breakwater and portside of channel.

The northern head of the oilpier has to bear also a light (red) and at the other side of the channel unlighted conical buoys should indicate the edge of channel slope. These buoys are to be placed at depth of 10 m of the slope. The buoys gives aid to the manoeuvring pilots and tugs.

Furthermore the coral spot easterly of the present tanker seaberth should be blasted in case that the seaberth will be used also in the future or the area will be used as anchorage in future years. As a present step the outlay of a cardinal danger buoy is recommended, which shows vessels the right passing of the dangerous spot.

The necessary navigational marks at Moín which are recommended to be installed at the completion of the port are listed, the positions given relate to the coordinates of the present by perbolic system used during construction of the facilities.

Range lights

The leading light indicates the centreline of 331.5°, each should have a light-power output of 500 cd (candela), being visible also during misty weather at night time. At daytime both towers should have square shaped plates of at least 1 m side length.

In general all pier illumination used for operation should be design so that they do not shine to the sea and dazzling the navigational lights.

Buoys

The buoyage layout is given in the following table. The entrance, channel buoys and the danger mark refer to immediate measurements, the safewater mark to the future step, when vessels will anchor and take pilots at Moln. (Drawing H - 2).

Buoyage layout Moin

Type	Nr.	shape	colour	Topmark	light colour	light rythm	Additionel equipment	Position x	Position y
Entrance buoys									
Starboard hand	1	pillar	green	conical	green	quick-flash	Radar reflector	636763	222376
Portside hand	2	"	red	con.	red	flash	" "	636975	222490
Channel									
Starboard slope	3	conical	green	nil	nil		nil	637253	221536
"	5	"	"	-	-		-	637360	221345
"	7	"	"	-	-		-	637389	221195
"	9	"	"	-	-		-	637375	221056
Danger Mark									
Cardinal West		pillar	black bands with yellow bands above and below	black double cones points inward	white	flash (9)	Radar reflector	636190	222200
Safe Water Mark									
Approach buoy		pillar	red and white vertical stripes	single red sphere	white	single long flash	Radar reflector	appr. 1 mile NNW of entrance buoys.	

3. Passive radar reflectors

Today the use of radar aboard seagoing vessels is an essential aid to visual navigation. Mainly during bad weather, poor visibility and rain radar provides the necessary informations for a safe navigation and manoeuvres.

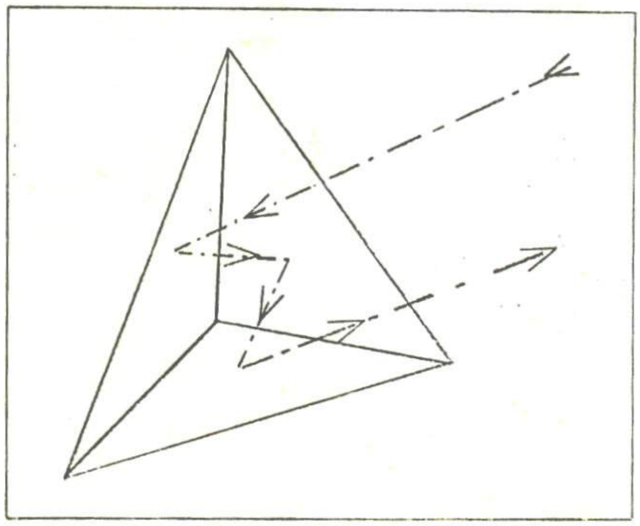
Therefore the navigational aids have to provide additional to their optical equipment the radar reflexion quality. The structures and buoys itself do not secure sufficient reflexion of radar rays due to their circumferential forms. The simplest form of providing radar echo sufficiently is a passive radar reflector.

Radar reflectors may be used on all types of buoys, fixed structure marks, beacon lights and range towers. They are used to reflect an echo back to the transmitting vessel so as to warn shipping of their presence or to mark a particular location.

The common radar reflector consists of four steel plates, which are attached to the buoy superstructure. The four steel plates are welded to a "cross" and horizontal plates are fitted between the wings, which will increase the reflexion quality. The topmarks of navigational aids, which are can or cones could be replaced by the radar reflectors by choosing the right shape. Other developments of radar reflectors of particular shape have risen the reflexion abilities accordingly.

For the whole navigational layout of the port complex Limón/Moín, all marks at sea and ashore should be fitted out with passive radar reflectors to increase the port's and vessel's safety and enabling ships and pilots also to navigate and manoeuvre during bad weather.

Following picture displays the reflexion of radar rays of a part of an octagonal reflector.



4. Manoeuvring spaces

To rise the port's safety it is an international standard to moore vessels with the bow to sea because in a case of emergency those ships could leave the port without tug assistance. This applies mainly for tankers. Only in exceptional cases this system should be altered.
Regarding Limón and Moín special circumstances have to be commented beside other requirements.

4.1 Limón

With the completion of the Proyecto Alemán vessels are to be turned south of the breakwater and then towed by tugboats to the berth. That the tugboats must have sufficient power is selfevident.

Especially for vessels which are to be berthed at the berth Nr. 10 (ro-ro, bodega) apply that they have to pass the container vessels at Nr. 11 (container pier) reverse. That case requires a safe distance from the container vessels and berth Nr. 1 (Muelle Metálico) during the manoeuvre. Therefore it is recommendable to remove berth Nr. 1 when Moín is under operation for banana vessels. Also at the Muelle Setenta the vessels should be berthed with the bow to sea.

The system only should be altered by the harbourmaster in case that operational reasons are evident or the weather situation do not allow the manoeuvre. Turning space is sufficient in Limón.

4.2 Moín

Due to the draught of the banana vessel which random exceeds 9 m the ships could be turned outside the 10 m line in front of the breakwater head. Only if the swell is too high the banana vessels must be towed farer outside.

Arriving fully loaded tankers have to be turned outside the channel i.e. north of the entrance buoys and then towed reverse. Because this manoeuvre has to be performed without any protection against waves, wind and swell this manoeuvre sometimes will be too difficult and dangerous. Thus also tankers must be berthed with the bow inward and after discharging be towed reverse and turned in the channel where the water depth is sufficient for the empty tankers.

For these reasons a turning basin in front of the oilpier would be advantageous and should be evaluated if a further extension of Moín is intended.

5. Floating equipment

5.1 Tugboat services

Keeping in mind the relative narrowness of the manoeuvring spaces at Limôn and Moîn it is highly recommended to supply tugboats which could assist the vessels during berthing manoeuvres.

This need do not only apply for the port's and vessel's safety, this also concerns the reduction of times required for manoeuvres, as the assistance of tugboats will speed up the berthing operation and rise the berth utilization.

For the first step until 1990 two new tugboats will meet the requirements, each having a bollard pull of approx. 20 tons (see also Feasibility Study of Tugboats; Sept. 1979), the present old tugboat should be repaired and assist the others. The tugboats should be equipped with firefighting gear which is demanded by the IMCO for oiltransloading points.

5.2 Bunker boats

The port and Recope should study the demand of fueloil for ships and decide whether a bunkerboat will be economical.

As the refinery at Moîn will produce more fuel oil in future a bunker boat could supply provisions to vessels at Moîn or Limôn. Depending on the prices it could be for interest of shipping companies to bunker at Limôn instead of travelling to certain bunkering ports and thus loosing time.

Especially for container vessels and banana vessels this could apply because they call only for a few ports and the portdays must be minimized.

5.3 Pilot launches

A well equipped and safe manoeuvring pilot launch should be purchased by the port, or the former launch should be repaired, this applies mainly for Moîn in the case that the vessels anchor there and the pilots have to board in the Bahia de Moîn.

6. Repair and maintenance facilities

The economic utilization of floating equipment and navigational aids depend directly on regular maintenance and adequate repair facilities. Therefore it is recommended to create a so called "Marine Yard" with a slipway or liftdock for vessels up to 50 m length, a small pier and a storage area for buoys etc (see drawing F - 2.5).

The task of the marine yard is to maintain, repair and inspect regularly the floating equipment, buoys and navigational aids. It must be fit out with an adequate workshop and crane facility. The location of the marine yard could be best in Moín between the oilpier and breakwater. The workshop facilities could be connected with repair-post of equipment of Moín harbour.

7. Radio communication

The radiostation should be equipped with a 55-channel-VHF-station, enabling the port and vessels to communicate on other channels than Nr. 16, which is the international call and safety channel. This station could be connected to the telefone network and agents or other branches could use the station for public calls with vessels. This would be an additional port service and increase the attractivity.

8. Mooring gangs

The present system of providing mooring gang to berthing vessels is a need born by the wave and swell condition in Limón and the absence of adequate tugboats which particular situation requires experienced men who know to operate the mooring system with shore lines and who know the particular weather conditions.

In future those requirements are negligible because at the Proyecto Alemán and in Moín the wave and swell condition will be quiet enough. Furthermore tugboats will assist berthing vessels and thus the ship crews could perform the mooring and only gangs are necessary ashore. For that reason a mooring gang consisting of a foreman and four workers are to be regarded sufficient, Moín and Limón should have one gang each available per shift. These gangs also could fulfill operation of water supply etc. and perform minor repairs to mooring facilities. This change of system is applicable if following requirements are installed:

- tugboat assistance of adequate power and knowledge
- use of ship lines
- completion of breakwaters.

9. Harbourmaster

A port which provides all internationally required services has to guide so many nautical functions that a particular department should be responsible for all the duties.

For this purpose the position of a qualified harbour-master or port captain should be formed, who will be in charge with his staff to operate and control all maritime services.

The range of responsibilities should comprise following items: (see also organization):

- to prepare and guide the berthing and unberthing activities in conjunction with the operation department
- allocate pilotage and tugboat assistance
- to control and survey all maritime and navigational aids including maintenance and repair
- issue regular weather reports for vessels and operation, keep close contact with international hydrographical institutions and issue changes of navigational matters
- operate the radiostation
- provide water and fuel supply to vessels
- control of harbour traffic and water pollution
- inspect berthing facilities and operate mooring gangs.

10. Costs for Nautical Improvements

Approximate investment cost for nautical improvements as described before are given in the following table. These costs are CIF-Limón costs estimated on the price basis of 1980.

Item	Time of Investment (year)	Investment Costs (US $)	M + R - Costs p.a. (US $)
2 tugboats	1981 / 1982	6,500,000.-	760,000.-
Limón			
buoys	1981 / 1982	80,000.-	4,000.-
rehabilitation lighthouse Isla Uvita	1981 / 1982	30,000.-	10,000.-
improvements of pierlights	1981 / 1982	10,000.-	1,000.-
radiostation	1981 / 1982	15,000.-	1,500.-
Moín			
buoys	1981 / 1982	140,000.-	7,000.-
(approach buoy)	1985	26,000.-	1,300.-
rangelights	1981 / 1982	50,000.-	5,000.-
pierlights	1981 / 1982	10,000.-	1,000.-

I. OCEANOGRAPHIC, HYDROGRAPHIC AND HYDROLOGICAL INVESTIGATIONS

1. Introduction

After problems had occurred during the construction work in 1977, various investigations and analyses regarding the planning and design of the Harbour of Moín in Costa Rica were conducted on behalf of RECOPE and MOPT as follows:

1. Hydrographical conditions in the area of Bahia de Moín, Expert's Opinion on the construction of a New Harbour by Prof. Burkhardt on behalf of RECOPE, February 1978.

2. Hydrological and coastal engineering aspects in the scope of the Integrated Atlantic Coast Port Study, Masterplan Limôn and Moín, Immediate Study, by RRI/ Prof. Burkhardt on behalf of MOPT, October 1978.

3. Expert's Opinion on the determination of the dredged volume in the Port of Moín/Costa Rica, by RRI/Prof. Burkhardt on behalf of BEL INGENIERIA S.A., November 1978.

4. Harbour of Moín, Extension of the Northern Breakwater, Final Design, by RRI on behalf of RECOPE, April 1979.

From these reports like from other studies mentioned in Section 5, it becomes apparent that in the view of maintenance dredging the Rio Moín which flows into the harbour area directly south of the berthing places will play an important role in the future. Not only the possibility of reducing the expected sedimentation, but also ways and means of an effective wave protection at the berths have been discussed on the occasion of various expert meetings on site. Thus, the question of the expected wave movement has to be investigated and to be judged in close relation to an extension of the northern breakwater and a possibly necessary modification of the southern breakwater or even its removal.

The most important questions pending for further investigations are the following:

1. What structural measures will be required to prevent, as far as possible, the transportation of bedload and suspended matter from the Rio Moín into the access channel and the basin of the Harbour of Moín?

2. What would be the expected wave motion at a third berth which may be required additionally south of the two banana berths, already under construction?

3. Will the planned extension of the northern breakwater possibly reduce wave motion at the banana pier expected by the unfavourable effects of the southern breakwater to such an extent that it will no longer be necessary to remove the southern breakwater and would a modification of its head produce sufficiently favourable conditions?

To find an answer to the 1st question, in-situ measurements have been carried out the results of which are being explained in in this report. The measurements comprised in detail:

1. Tidal and current measurements in the area of the estuary of the Rio Moin and in the Bay of Moin;

2. Soil sampling from the sea bottom in the Bay of Moin;

3. Measurements of salinity and suspended load at certain selected locations in the area of the estuary and in the Bay of Moin;

4. Wind and precipitation measurements.

The answers to questions 2 and 3 which shall be treated in the first place are based upon studies already available (for time and cost reasons no wave measurements were carried out). It is anticipated that the studies referred to in this context are known; the most essential results are summarized again. The structural design (design of breakwater and slope structures in the area of the berths to protect against wave action) will not be included in this summary.

2. Wave Conditions and Consequences for the Design of the Harbour

2.1 General Remarks

As no wave measurements of the area of Moin were available, the local wave conditions in the harbour area were estimated according to theoretical procedures.

The deepwater wave parameters which are required as input for determination of the wave action at the berthing places have been determined on the basis of statistical wind data and wave forecasting figures. To find out the local wave heights, next to refraction analyses were carried out for the main wave directions; the locally varying wave heights in the area of the berthing places were then calculated in a computer program for various lengths of the northern breakwater. This computer program took the diffraction and reflection effects caused by the geometry of the harbour also into account.

2.2 Deepwater Waves and Refraction

Drawing I-1 depicts the significant frequencies of wind velocities and the significant deepwater wave heights $H_{1/3}$ ($H_{1/3}$ = mean value of the one-third highest wave heights of the wave spectrum) calculated under consideration of the effective fetch lengths.

The investigated range covered a sector between 0^0 (north) and 90^0 (east), in which about 90 % of all wind observations take place. The highest expected waves come from the direction of 60^0. This direction is at the same time the dominating wave direction as is shown in table 1 which tabulates the relative total frequencies of all wind observations.

Table I-1: Direction of Frequencies of Winds in the Off-Shore Area

Wind direction	Relative total frequency n in %
0	3
30^0	13
60^0	47
90^0	28
other directions and calms	9

The refraction diagrams constructed graphically according to the wavefront method for the directions indicated on table I-1 are shown on drawings I-2 to I-5. It becomes apparent that the Pajaros Island which is situated in fron of the Bay of Moin separates the approaching waves into two different systems. In the immediate shadow area of the island the diffraction effects result in a reduction of the wave heights.

The wave systems approaching from different directions - as also can be seen from aerial photographs - are superimposed in the area of the northern breakwater (formation of crossed wave trains). In the case of waves coming from 0^o (north) wave system 1, and in the case of waves coming from 90^o (east) wave system 2 is dominating.

Based on the wave charts the local wave height can be determined from the distance between the so-called wave orthogonals (dashed lines on drawings I-2 to I-5) by the application of an energy equation. For the original design of the breakwater the significant wave heights in the area of the northern breakwater and near the planned berths were determined in this way in the study of February 1978. At this it became apparent that the waves expected in the harbour will be considerably higher than were assumed for the original design of the structures. This design did not include a northern breakwater; the difficulties encountered during the dredging works actually gave rise to this idea. On the contrary, the southern breakwater was originally assigned to provide shelter for the harbour, based, obviously, on the assumption that waves in the immediate vicinity of the shore are strongly influenced by refraction. As the wave crests are generally bent toward the shore, an observer on the shore will get the impression that the waves in the Bay of Moin approach primarily from a north-west direction. But this is just a local effect and drawings I-2 to I-5 show that the planned alignment of the southern breakwater - irrespective of the direction of the deepwater waves - coincide nearly entirely with the wave orthonogal. Therefore, the effect of the southern breakwater on wave attenuation is small and, in certain circumstances, even unfavourable as in the area of the breakwater head the waves are reflected into the direction of the banana berths, that means wave movement may increase locally due to reflection.

Reference to this unfavourable effect was already made in our Expert's opinion of February 1978. The recommendation therein made to remove the southern breakwater to avoid its unfavourable effects on wave movement was not shared by the expert of SYSTAN INTERNATIONAL INC. commissioned by the Costa Rican Port Authority.

Instead, a site inspection in November 1978 brought SYSTAN to the conclusion that due to the relatively flat, rubble protected slope of the southern breakwater and the high absorption features of the slope structure below the pier platform; the reflection would not have unfavourable effects on the wave movement.

However, as the question of the southern breakwater - as earlier mentioned in this report - has to be judged in close relation to an extension of the northern breakwater and to sedimentation problems resulting from the Rio Moin, this matter shall not be discussed here. Attention is only drawn to the fact that the slope of the southern breakwater at the harbour side is designed very steep and that considerable reflections and re-reflections may occur inspite of the provided slope protection by rocks - especially when flat waves occur. Furthermore, the southern breakwater was actually not completed in the form that had been the basis for the theoretical determination of the local wave heights as applied for the design of the berths of the banana pier. The fact is that the portside slopes of the southern breakwater are presently much more flat than was assumed in the design. According to the latest results from soundings, there are considerable sand deposits at the head of the breakwater which constitute presently yet no obstacle to the generation of waves and wave reflections at the southern breakwater.

2.3 Investigations for an Extension of the Northern Breakwater

The unexpected high waves in the harbour area actually gave rise to the idea of investigating the effects of an extended northern breakwater; the investigations were based on the premise that the significant wave height of 0.3 m at the berths of the banana pier is not permitted to be exceeded on more than 18 days per year on an average.

For the design shown on drawing I-6 to illustrate the situation, reduction factors K' and $\bar{K}'$ at the berths were calculated by an EDP-program, and based on the result of this computation as well as on ocean wave statistics the exceeding frequency of wave heights $H_{1/3} \geqq 0.3$ m at the berths have been determined and transformed into the required breakwater length.

As a first step the relative wave heights and directions of the mentioned part wave systems at the head of the northern breakwater were determined by aid of the refraction diagrams (drawings I-2 to I-5) for randomly chosen breakwater lengths (0 to 450 m).

Table I-2: Relative Wave Heights of Part Wave Systems at the Breakwater Head

Wave direction	Length of northern breakwater(m)	Wave System 1	Wave System 2
0^0	0	0.70	0.63
	150	0.75	0.40
	300	0.78	*
	450	0.83	*
30^0	0	0.55	0.44
	150	0.60	0.45
	300	0.65	0.48
	450	0.71	0.48
60^0	0	0.47	0.60
	150	0.52	0.57
	300	0.56	0.54
	450	0.65	0.52
90^0	0	*	0.61
	150	*	0.60
	300	*	0.60
	450	0.45	0.44

The table shows again the different valences of both wave systems.

The relative wave heights at the breakwater head have been used as input for a diffraction calculation which provided the relative wave heights at the berths.

The relative wave heights at the breakwater head have been used as input for a diffraction calculation which provided the relative wave heights at the berths.

These local wave heights are shown as K'-values on drawings I-7 to I-11. The diffraction calculations take also reflection effects of the northern breakwater and the slope structures into account. The influence of the southern breakwater, however, has been neglected. However, from the geometry of the harbour it must be expected that with increasing length of the northern breakwater this influence decreases. This subject still has to be discussed at an other place. With respect to the probability of occurrence of unacceptably high wave heights at the berths, mean relative wave heights $\overline{K}'$ were assumed for the intermediate berths 1 and 2, as shown in the following table:

Table I-3: Reduction Factors $\overline{K}'$ to Calculate the Wave Heights at the Berths

Wave Direction	Length of northern breakwater(m)	Reduction Factor $\overline{K}'$	
		Berth 1	Berth 1
	0	0.17	0.30
0^0	150	0.11	0.23
	300	0.084	0.19
	450	0.073	0.17
	0	0.15	0.19
30^0	150	0.097	0.14
	300	0.081	0.13
	450	0.069	0.12
	0	0.20	0.28
60^0	150	0.12	0.15
	300	0.084	0.12
	450	0.065	0.10
	0	0.069	0.074
90^0	150	0.035	0.046
	300	0.025	0.037
	450	0.034	0.064

To judge the wave motion at the berths the mean wave height reduction methods were combined with the wave statistics to calculate the probabilities of occurrence of the permissible wave heights as a function of the breakwater length.

The number of days on which the permissible wave heights ($H_{1/3}$ = 0.3 m) at berths 1 and 2 are exceeded is shown on table I-4; the numerical values of table I-4 are represented graphically in drawing I-12.

Table I-4: Number of Days per Year with (mean) Wave Heights $H_{1/3} \geqq 0.3$ m at the Berths

Breakwater length (m)	Number of days per year with $H_{1/3} \geqq 0.3$ m	
	Berth 1	Berth 2
0	70	103
150	25	44
300	8	28
450	3	17

Consequently for berth 1 results a length of the northern breakwater of L = 190 m. The demand to allow mean significant wave heights only on 18 days a year would make it necessary for berth 2 that the northern breakwater is extended to L = 420 m. Not only for economic reasons (see Chapter L-6) but also due to the fact that local wind and ship traffic may produce waves of an order of H = 0.3 m, it has been proposed to limit the extension to L = 190 m, from which results for berth 2 - assuming a wave height of $H_{1/3}$ = 0.3 m - altogether 41 days per year on which this wave height is exceeded. When considering the permissible 18 days a year on which a special wave height can be exceeded - this permissible wave height will be $H_{1/3}$= 0.4 m.

For the breakwater length of 190 m already suggested in the study of March 1979 an economic evaluation was also made within the scope of this study, which gave proof to the feasibility of this length (see Chapter L-6).

2.4 Wave Movement at a Third Berth Planned South of the Banana Pier

The local wave heights in the area of the third berth (see drawing I-6) are shown on drawings I-7 to I-11 as a multiple of the wave heights at the breakwater head ($\overline{K}'$ - values).

The mean wave height reduction methods for the third berth are shown in table I-5 as a function of the length of the northern breakwater.

Table I-5: Reduction Factors $\overline{K}'$ for Berth 3

Wave Direction	Length of northern breakwater(m)	Reduction Factor $\overline{K}'$ at Berth 3
0^{0}	0	0.44
	150	0.37
	300	0.31
	450	0.27
30^{0}	0	0.24
	150	0.20
	300	0.19
	450	0.18
60^{0}	0	0.35
	150	0.20
	300	0.16
	450	0.14
90^{0}	0	0.08
	150	0.06
	300	0.05
	450	0.09

The combination of these reduction factors with the frequencies of the wave height $H_{1/3}$ expected in the off-shore area provides the number of days per year on which certain present wave heights are exceeded.

Table I-6 shows the exceeding frequencies for locally permissible wave heights $H_{1/3} = 0.3$ m and $H_{1/3} = 0.4$ m (according to the explanations of Section 2.3) as well as $H_{1/3} = 0.5$ m are exceeded.

Table I-6: Number of Days per Year with (mean) Wave Heights $H_{1/3} \geqq 0.3$ m $H_{1/3} \geqq 0.4$ m and $H_{1/3} \geqq 0.5$ m at Berth 3

Breakwater length (m)	Number of days per year with		
	$H_{1/3} \geqq 0.3$ m	$H_{1/3} \geqq 0.4$ m	$H_{1/3} \geqq 0.5$ m
0	129	98	70
150	75	45	27
300	55	29	14
450	46	21	10

Like for the calculation of the wave height frequencies at berths 1 and 2, the southern breakwater has been neglected for the present also for berth 3.

The result illustrated on drawing I-13 shows that even at a length of L = 450 m of the northern breakwater which for berths 1 and 2 is not a necessity and would involve considerable cost unpermissibly high waves or rather an unpermissibly high wave height exceeding frequency must be expected for berth 3.

Taking the length of the northern breakwater which was recommended for berths 1 and 2 (L = 190) and assuming the permissible probability of occurrence of 18 days per year a significant mean wave height of $H_{1/3}$ = 0.55 m has to be expected, or assuming a mean wave height of $H_{1/3}$ = 0.4 (0.5) m, an exceeding frequency of about 38 (23) days per year results.

Although essentially no other results relative to the dominating wave directions are to be expected from the geometrical shape of the southern breakwater (the unfavourable influence on the wave movement if the northern breakwater was not built has already been pointed out), the existing computer program to investigate the influence of this southern breakwater has been extended with the breakwater being assumed as a linear, semi-infinite breakwater. The wave height at the breakwater was found by the Sommerfeld diffraction equations and the resulting wave field according to a linear procedure of superposition.

Like in the previously described investigations not only the local refraction effects have been neglected but also the reflection of waves at the southern part of the harbour, as even in the case that the Rio Moin would be diverted - which will be discussed later in this report - it can be assumed that the presently very flat slopes will be largely maintained also at the final extension stage and reflection from the southern harbour boundaries will be of no significant importance.

A comparative calculation for berth 3 for the recommended extension of the northern breakwater of L = 190 m to reduce wave movement at the banana pier died not result in any changes of the system as compared with a solution without a southern breakwater. Due to the superposition with the scattering wave system occurring at the head of the southern breakwater deviations of $\pm$ 10 % may result locally. For berths 1 and 2, the influence of the southern breakwater is also within the arithmetical accuracy.

Considering the limits inherent to any theoretical precedure, it appears justified in view of the expected wave movement in the harbour to neglect the influence of the southern breakwater when a northern breakwater is built (L = 190 m) and to discuss the question of integrating the southern breakwater into the planning concept only under the aspect of sedimentation and silting up. This conclusion would be wrong if the northern breakwater was not built.

When examining the question of sedimentation of the harbour, littoral deposits must be taken into account, as the SYSTAN study also points out.

Modifications at the head of the southern breakwater are not likely to produce any better wave attentuation at berth 3, unless the breakwater would be extended eastward by some 100 m, which, however, would not be reasonable from the operational point of view.

On the other hand, there would be no essential advantages for better wave conditions if the northern breakwater would be further extended, as the calculation has shown.

Considering the high cost expected for harbour protection structures, the first thing to investigate should be whether higher waves with higher probabilities of occurrence could be permitted. Only in the event that difficulties would occur at the final extension stage of the harbour should possibilities of improvement be tested in a hydraulic model, which method is basically more appropriate for investigations of additional wave attentuation measures than any theoretical procedure, which is always simplified in its assumptions, could be.

3. Discussion of Oceanographic Surveys

3.1 General

According to the available information, no major current measurements in the Bay of Moin and the estuary of the Rio Moin have been carried out in the scope of the planning and design of the Harbour of Moin, except some floater measurements plotted in the study "Estudio de las Condiziones Naturales de la Bahia Moin, Costa Rica" (established by CONSULTECNICA LTDA and KENNETH BELL E HIJOS in June 1965)". This study like the study established by the Ministry of Public Works of Costa Rica in 1961, i.e. "Proyecto Preliminar de Canalización, Lagunes del Atlantico", includes some more data that are essential for a judgement of the local hydrographic conditions.

But all in all, the available data and documents do not provide enough information to obtain a satisfactory answer to the difficult question of sedimentation in the harbour.

This complex problem which results from the interaction of tidal and coastal currents, wave action, top water and sedimentation was discussed in length during the expert meetings in Costa Rica in September 1978.

Tidal and coastal currents, wave-generated currents and currents generated by the top water and by different salinities (density currents) are superimposed, and only the resulting currents can be determined by the measurements in-situ, which renders an interpretation considerably more difficult.

Therefore, the current observations that were carried out under different tidal and discharge conditions in connection with the question of diverting the Rio Moin, have been reasonably completed by measurements of salinity and suspended load at certain selected locations. Soil samples were taken from the sea bottom in a wide area to draw conclusions from the grain size distribution on the morphological conditions and sedimentation tendencies. The top water discharges of the Rio Moin were measured under different conditions of precipitation.

It is in the nature of this difficult and scientifically unsolved subject matter that any conclusions drawn from short-term measurements in view of sedimentation can only be of a qualitative nature. These data are, of course, not sufficient to make any definite quantitative statements on the actual influence the Rio Moin has on the sedimentation of the harbour; this would require a far more extensive measuring program over a considerably longer period.

The question of the wave-generated solid load transport in this report is only treated as far as the southern breakwater is concerned and not in connection with sedimentation problems in the harbour entrance and the access channel.

3.2 Performance of Measurements

For reasons of time and cost savings the oceanographical measurements were performed as short term investigations with the aim to corroborate former theoretical assumptions concerning siltation problems by specific in-situ measurements in the course of which also different weather and tidal conditions should be recorded.

The following measurements were carried out:

- recording of tide, rainfall, wind velocity and wind direction
- measurement of the discharge of the Moín river, passing through the harbour basin
- measurement of flow pattern in the bay of Moín
- determination of salinity and suspended load at different locations within the bay of Moín and in the Moín river
- taking of soil samples from the sea bottom within the bay of Moín over an extended area and determination of kind and grain-size of the material.

Some measurements were carried out as sustained recordings (e.g. tide, wind, rain and discharge velocity of the Moín river) and others as representative investigations at fixed periods (e.g. flow pattern, salinity, suspended load).

All measurements were performed during the period between the first half of December 1979 and the second half of May 1980. All measurement, which had to be correiated with reference to position and altitude were connected to the official Costa Rican system of co-ordinates (LAMBERT-system) and to the offical reference level NMM (Nivel Medio del Mar) established by "Instituto Geográfico de Costa Rica".

When starting the site investigations first of all a number of control points was established in the port area in close cooperation with Adriaan Volker Dredging Co., which was also using the DECCA Trisponder position fixing system for the navigation purposes. In order to avoid interferences of both systems when working at same time, electronic time shearing was utilized.

The DECCA Trisponder electronic range-range system was used for all location fixing purposes at sea. A minimum of three stations is required to provide position fixing. These stations are a mobile (master) on board of the survey vessel and two remotes on two fixed control points on land, to which the distances will be measured. For each position ever taken co-ordinates were calculated by a HP 9810 computer and plotted automatically by a connected plotter.

For the recording of tide, rainfall and wind automatically recording equipment was used. An EASTMAN ALPINA tide gauge was installed in the estuary of the Moín river at the "Terminal de Moín" of the JAPDEVA. Tidal data were continuously recorded during the time between December 12, 1979, and May 13, 1980. The gauge was adjusted to Nivel Medio del Mar (NMM) of Costa Rica.

Precipitation data, being representative for the catchment area of the Rio Moîn estuary were recorded from December 12, 1979, to May 16, 1980, by a LAMPRECHT pluviometer installed near the Finca Margarita, that is 8.2 km from the main road Limôn-Siquirres (junction at Liverpool) on the raod in southerly direction (see drawing I-38).

Wind data (wind way and direction) were automatically recorded from December 14, 1979, up to May 18, 1980, (with some interruptions in January and April due to instrument problems) by a LAMPRECHT anemometer installed in the center of the southern breakwater in the harbour of Moîn.

For the measurement of the discharge of the Rio Moîn a current meter from HYDRO PRODUCTS was used. The measurements were performed on the one hand automatically as continuous measurements at one representation point in the flow section below the railway bridge, and on the other hand the whole discharge section was measured at two days and high discharge and different tidal conditions.

Extensive flow pattern measurements were carried out by means of floats in the bay of Moîn at 1.5, 4.5 and 7.5 m depth at different days and tidal conditions. The floats, consisting of round wooden plates (40 cm diameter) the floater, and a cross made of tin plates with 50 cm edge lengths (the drift element), both connected by steel wire, were set out in the sea and drifted away by the currents. The floats were followed by a spead boat and their positions fixed in intervals by the DECCA Trisponder system.

For the taking of water samples a standard water sampler according to RÜTTNER was used. With this apparatus, water samples can be taken from any desired depth. The sampler has a special and well proved closing mechanism.

The water samples were analysed regarding their content of suspended matters by filtration as well as their salinity by applying the hydrometer method.

A grab sampler, system VAN VEEN, was used for taking the soil samples from the sea bottom.

The grab sampler has the dimensions 20/30/60 cm and permits the taking of several kilograms of soil from any desired water depth. It is lowered in open and interlocked condition. When touching the ground the interlocking system is released automatically, the grabs close and grab the soil upon rope pull.

Furthermore, the following survey equipment was used for the necessary basic survey:

Infrared distance measuring instrument "WILD Distomat DI 3 S, theodolite WILD T 2, reduction tachometer ZEISS RT a 4, levelling instrument ZEISS Ni 2.

The checking of water depth was performed by a FAHRENTHOLZ survey echo sounder.

3.3 Tidal Conditions in the Bay of Moín

According to the Deutsches Hydrographisches Institut (DHI), (Westindien- Handbuch, 1. Teil, Die Nordküste Süd- und Mittelamerikas, Hamburg 1958) the tidal phenomena in the West-Indian ocean differ greatly. The diurnal portion is perceptible only in the form of a moderate diurnal inequality between the tide before and after noon. Such diurnal inequalities become apparent generally not only in time but also in level of high and low tide, usually to a different extent.

The spring tide of the diurnal portion - consequently also the maximum of the diurnal inequality - occurs at the time when the declination of the moon south and north from the equator is at its maximum; when the moon crosses the equator the daily differences disappear every 13.7 days on an average. The spring tide of the semi-diurnal portion, however, occurs about 1 day after full moon and new moon, i.e. every 14.8 days on an average. The interplay between semi-diurnal and diurnal portions consequently does not recur in the same way from month to month but changes from place to place.

During perigee of the moon the tidal range not only of the diurnal portion but also that of the semi-diurnal portion is increased, while it is reduced during apogee.

The semi-monthly fluctuation of the tidal range (spring and neap tide) of the semi-diurnal component is best pronounced at the time of equinox and least at the time of summer and winter solstices. The diurnal portion behaves the other way round.

The general tidal conditions according to DHI-Seehandbuch are illustrated on drawing I-14. The tidal movement is essentially influenced by rotation around amphidromic points in the eastern part of the Caribbean and in the Golf of Mexico, which only occur with the semi-diurnal and not with the diurnal tide components. The complex tidal conditions at the east coast of Central America with their comparatively low tidal ranges are shown by the tidal curves for the Panamesan harbour of Colon (drawing I-15). Due to the geographical proximity of Colon and Moín in Costa Rica (distance about 400 km) the tidal conditions at Moín will not essentially differ from those at Colon.

The tides and tidal currents at the east coast of Costa Rica - due to their relatively low tidal ranges and correspondingly small tidal currents - are of insignificant importance for navigators. Only in the vicinity of estuaries can tide-generated currents occur to a larger extent. The harbour engineer must not generally neglect the tide-related water level fluctuations and currents, as the tidal influence on current conditions as well as on sedimentation and discharge situation can be of importance especially in estuaries.

The tidal levels observed constantly during the measurements in the harbour of Moín are shown on drawings I-16 to I-21. Basically, the tide-related water level changes are between -0.20 m NMM and +0.20 m NMM; the lowest water level observed during the measuring period was recorded at -0.29 m NMM, the highest at +0.27 m NMM.

3.4 Wind Conditions during the Measuring Period and their Influence on the Water Levels

The tidal curves registered at the gauge installed in the harbour of Moín confirm the expected conformity in the general tidal events between Colon (drawing I-15) and Moín (drawings I-16 to I-21). Due to the complex tidal occurrence and additional meteorological influences which have a bearing on the tidal event no one equals the other. Any statements on tide-generated influences on current behaviour and on discharge and sedimentation conditions can therefore only be of a more general type and can only be related randomly to individual tidal phases. At this effects from wind must be taken into consideration. The wind velocities and directions have therefore been measured constantly during the investigations.

To judge the meteorological influences on the tidal events, especially as far as the currents measurements described in Section 3.5 are concerned, a special calculation for Puerto Limón has been made by the "Deutsches Hydrographisches Institut (DHI)" in Hamburg, the results of which are directly applicable to Moín because of the proximity of both ports. The DHI computed the times of occurrence and the levels of low and high tides for the month of February 1980 and indicated the reference level for NMM at -15 cm that means the reference level of the DHI is by 15 cm lower than that of the tidal gauge at Moín.

Drawing I-22 illustrates the measured water levels for high and low tides compared with those computed by the DHI. The wind conditions prevailing during the entire period of measurements are depicted on drawings I-23 to I-28. As expected, deviations due to meteorological influences between measured and calculated water levels are clearly recognizable. The shown deviations of ± 15 cm are small compared with the possible fluctuations of wind-raised water levels, however, they reach here already the level of the measured tidal ranges. This fact may be considered an additional proof of the apparent small significance of the tidal events on the hydrological offshore conditions in this sea area.

To judge the meteorological influences on the tidal events during the current measurements, the measured and calculated water levels uniformly related to NMM are illustrated on table I-7. Whereas the water levels on February 10, 1980, show a relatively good conformity of measured and calculated values, the values recorded on the other measuring days show clearly lower high water levels than those calculated. Judged as a whole, the meteorological influences on the water levels recorded on the measuring days were relatively insignificant.

Table I-7: Differences between Water Levels Measured during the Study Period and those calculated by the DHI

		Water level at tidal gauge	Water level calculated by DHI	Water level difference
		NMM	NMM	cm
	Thw	+ 16	+ 16	0
10.2.1980	Tlw	- 10	- 12	+ 2
	Thw	- 8	- 6	- 2
	Tlw	- 13	- 14	+ 1
	Thw	- 5	+ 2	- 7
17.2.1980	Tlw	- 10	- 9	- 1
	Thw	+ 7	+ 13	- 6
	Tlw	- 15	- 19	+ 4
	Thw	+ 7	+ 16	- 9
21.2.1980	Tlw	- 17	- 16	- 1
	Thw	- 6	+ 6	- 12
	Tlw	- 19	- 18	- 1
	Thw	+ 10	+ 18	- 8
22.2.1980	Tlw	- 19	- 18	- 1
	Thw	- 5	+ 3	- 8
	Tlw	- 18	- 17	- 1

3.5 Current Conditions in the Bay of Moín

The currents observed in the Caribbean Sea are primarily characterized by influences from the NE-geostrophic wind on the sea surface and the approaching geostrophic-wind-drift currents originating in the Atlantic Ocean. This current penetrates into the Caribbean Sea through the chain of the Lesser Antilles and passes through this area in a WNW, and later in a NW direction. The coastline and narrow straits influence this relatively strong and permanent Caribbean current in direction and velocity.

An evaluation of the data given in the "Seehandbuch" of the DHI, which are based on an evaluation of vessel's drift, shows that a relatively significant current parallel to the shoreline in a southeast direction must be expected at the east coast of Costa Rica almost all over the year (drawing I-29), due to the fact that a counter current against the northwestern main current in the Carribean is produced in this area. The counter current parallel to the shoreline is fairly constant with mean velocities of between 0.75 and 1.0 nautical mile per hour (≘ 1 knot/hour). Only in the month of May northwest-directed currents with velocities of 0.5 knot/h may occur for a short time in this offshore area.

The "Seehandbuch" of the DHI shows especially for the Costa Rican offshore area from the border to Nicaragua until Punta Blanca a SE directed current whose velocity increases from 1 knot/h to 2 knots/h when approaching the Bahia Moín.

Due to the mentioned small tidal ranges the large-scale current conditions in the Caribbean are hardly influenced by the tidal currents. Only in locally limited areas or at river estuaries can the influence of the tidal currents be higher. Especially at estuaries additional currents caused by differences in the specific density of the water (temperature influence and salinity) which also depend on the surface water of the river must be expected.

The current conditions in the Bay of Moín at the river mouth of the Rio Moín are therefore influenced by all mentioned parameters, i.e. the Caribbean current, tidal currents, density currents and top water discharge of the Rio Moín.

From the dominant influence of the counter current parallel to the shoreline which influences an area of 30 NM off the coast the following general current conditions can be derived as shown on figure 29:
The shoreline projection between Moín and Limón diverts the littoral current in eastern direction. The current passing the Bahia Moín therefore generates a primary roller current in this area in a clockwise direction. Before the harbour construction measures had been started, the Rio Moín flowed at the southeastern tip of the Bay directly into the current of the primary roller diverted at this place towards the west so that the suspended-load-transporting top water of the Rio Moín was moved directly westward into the roller current zone. At the present stage of the harbour the river passes the quay facilities which are presently under construction and flows through the dredged harbour basin at the east side of the Bahia Moín towards the north into the northern part of the bay where the separation line between eastward littoral current and the primary roller generated in the Bahia Moín exists. This line of separation is of course not limited locally, but is influenced largely by local winds, intensity of littoral currents, tidal currents and, after moving the

mouth of the Rio Moin to the north, also by the surface current of the river, so that the Rio Moin presently flows into an area characterized by unstable current conditions.

To investigate the actual conditions of the Bahia Moin extensive current measurements were conducted in this offshore area in February 1980, where current velocities in different water depths have been measured on different days and at different marginal conditions resulting from tide, wind and surface water of the Rio Moin (see section 3.6). The decisive marginal conditions of the measuring days (10./17./ 21./ and 22. February) resulting form tide and wind are shown on drawing I-30.

Drawing I-30 shows also the travel time of the float marked by numbers in a direct relationship to the time axis of the tidal curve and wind data.

Indicating also the measured current velocities and the starting and ultimate time, the measured values of each float are recorded separately according to their measuring depths in drawings I-31 to I-33. A direct comparison is possible by the marginal values from tide and wind which are indicated additionally. Drawing I-31 shows the surface floats with the penetration depth of their cross plates of d = 1.5 m measured on the 10./17./21./ and 22. of February 1980. Drawing I-32 illustrates the float courses over 4.5 m water depth and drawing I-33 over 7.5 m water depth.

Due to the mentioned marginal conditions resulting from the dominating large-scale offshore current and the expected minor significance of the tide-generated currents and due to the winds that change from weak to moderate over the course of one day, and change also in strength and direction, a definite interpretation of the float paths cannot be expected.

Characteristic of the current measurements conducted in the Bahia Moin are in the first place the very slow to slow current velocities of v = 5 cm/s to 15 cm/s, almost irrespective of time and place. In the area surrounded by oil pier and southern breakwater, which is the mouth of the river Moin, the current velocities are almost always below 5 cm/s to 10 cm/s.

Generally, the course of the floats confirms the current conditions shown on drawing I-29 which are characterized essentially by the offshore currents directed to the east and the primary roller current generated in the Bahia Moin.

The surface floats illustrated on drawing I-31 clearly show the unstable current conditions in front of the harbour entrance where the longshore current adjoins the primary roller.

The primary roller current is definitely stronger during high tide (floats 9/10/11) than during low tide (floats 1/2/3). One reason why floats 48/52/53 were deviated is obviously the wind which turned during the measuring period form northeast to east, but mainly responsible for the low current velocities between the Pajaros Island and the continent as compared to the previous days are certainly influences from a larger area.

The courses of the floats over a water depth of 4.5 m illustrated on drawing I-32 show good conformity with the surface floats and confirm also the general statements made on drawing I-29.

At a water depth of 7.5 m, especially in the area between the oil pier and the southern breakwater, the current velocities are extremely slow and are characterized strongly by varying directions. In the outer harbour again the currents equal those measured at 1.5 m and 4.5 m depths. Only the floats installed on February 21, 1980 between the Isle Pajaros and the continent show - similar to the surface floats - an unstable course which cannot be explained by local influences.

Decisive for a general judgement of the hydrological and morphological marginal conditions for a harbour in Moln is that proof has been furnished that a constant westerly current carrying suspended load with the surface water of the river outside the harbour area is expected at the south-east tip of the Bahia Moln in the area of the original mouth of the river Moln. At the present stage, this situation does not occur. Instead, the surface water flows through the harbour at very low velocities and reaches then the unstable separation line between longshore current and primary roller current at the entrance.

The current conditions here described and interpreted must, however, be strictly distinguished from those generated by the breaking waves close to the shore in the littoral zone with their special influence on the harbour access.

3.6 Discharge Conditions of Rio Moln

Due to the unstable nature of the current, discharge measurements in the tidal zone are generally extremely difficult and costly. Though the tidal range in the study area is only very small, no tide equals the other as shown in Section 3.3.

Therefore, the currents in the estuary of the Rio Moln are changeable in both time and place, with the time-related top water discharge of the Rio Moln and the salinity-depended density currents being superimposed on the tidal currents. Despite these difficulties discharge measurements were carried out in the estuary during the study period to receive at least qualitative values on the expected suspended load transport of the Rio Moln.

On two measuring days (December 18, 1979 and February 1, 1980) continuous flow measurements were carried out in the cross section below the railway bridge to get an impression of the velocity distribution over the discharge cross section. The main aim of these discharge measurements, however, was to determine a suitable place in the cross section for permanent measurements. Examples of the discharge measurements are plotted on drawing I - 34.

From these plottings the tidal influence becomes very apparent, yet surface-related negative (upstream during flood tide) velocities exist only in the middle (deep) part of the cross section. On the sides of the cross section up to, say, Profile No. 5, the surface water effects are predominant, i.e. the velocities - apart from the small area near the bottom - are positive, that means directed to the harbour.

From the individual measurements, the discharge quantities q per second (m^2/s) were received by integration of the velocities over the corresponding water depths and, from these, the discharge quantities Q (m^3/s) by integration over the width of the discharge cross section.

For the profile measurements plotted on drawing I - 34 the (resulting) discharge quantities Q per second and mean cross section velocities $\bar{v}$ are as shown in table I - 8:

Table I - 8: Discharge Quantity Q and Mean Velocities in the Cross Section of the Railway Bridge

Measurement	Period of Measurement	Q (m^3/s)	$\bar{v}$ (m/s)
(a)	13.33 / 15.08	57.50	0.30
(b)	15.15 / 17.33	71.00	0.38
(c)	17.39 / 19.35	53.80	0.29

Since cross section 5 is largely unaffected by counter currents and represents more or less mean discharge conditions, constant current measurements have been conducted at this cross section at a depth of 1.75 m. Table I-9 shows a comparison of the mean current velocities $\bar{v}$ calculated from the flow measurements of December 18, 1979 and February 1, 1980 and the velocity v_A at this permanent measuring point.

Table I - 9: Comparison of Velocities $\bar{v}$ and V_A

Mean Velocity in the discharge cross section $\bar{v}$ (m / s)		Corresponding velocity in cross section 5 v_A (m / s)	
0.34		0.33	
0.13		0.08	
0.14	average	- 0.08	average
0.30	$\bar{v}$ = 0.26	0.30	v_A = 0.24
0.38		0.42	
0.29		0.37	

Table I - 9 shows that the chosen permanent measuring point represents the mean discharge conditions in a sufficiently accurate way. Deviations occur above all with low velocities. However, it must be mentioned that the profile measurements could not be carried out simultaneously due to lack of personnel and equipment and that each measurement series took about 2 hours, so that a certain amount of errors is involved which, of course, complicates a direct comparison. Inhowfar the local velocities are subject to temporal fluctuations is shown by the current measurements recorded on drawing I - 35 as examples of different tidal conditions.

Depending on the surface water and the degree of reflection of the tidal wave the current velocities are displaced in phase to the measured water level.

Though the plotted velocities are mean values from individual values measured at 30 minute intervals, it is difficult to recognize apparent dependencies.

Therefore, from the time series of the current measurements the daily average $\bar{v}_A$ was determined as explained on drawing I - 36.

These daily averages $\bar{v}_A$ are shown on drawing I - 37 and I - 38 together with the precipitation rates measured by the pluviometer installed at Finca Margarita. In the period from December 1979 until April 1980 they were between about 0.10 m/s and about 0.65 m/s from which (at a mean discharge cross section of some 190 m^2) a mean discharge between about 20 and 125 m^3/s results.

As expected, the discharges reach the highest volumes after heavy rainfalls. If a mean rainfall quantity of approx. 3300 to 3800 mm per year is assumed corresponding to the annual series for Limón (1960 until 1971) and Moín (1966 until 1972) an average rainfall of approx. 300 mm per month results (from the annual series for Moín 1966 until 1972 the lowest rainfall results in September with about 140 mm, the highest in December with about 550 mm; a comparison of the individual years shown considerable flucutuations).

According to the rainfalls occurred during the measuring time the month of January 1980 can be considered representative for the expected mean discharges of the Rio Moín. Acc. to drawing I - 37, the mean monthly discharge velocity was about $\bar{v}_A$ = 0.25 to 0.30 m/s, resulting in a mean discharge (annual mean value) of Q = about 50 to 60 m^3/s.

3.7 Salinity and Suspended Load

The salinity at the east coast of Costa Rica shows annual mean values of about 36 to 36.5 ‰ acc. to the "Seehandbuch" of the "Deutsches Hydrographisches Institut" (DHI).

The annual fluctuations are low, just like the fluctuations of the water temperatures. The aim of the water sampling was to provide knowledge of the local changes of the salinity by the surface water of the Rio Moín. These samples served also to determine the suspended load. The water samples were taken at the railway bridge profile, where also the discharge measurements were carried out, and at certain selected points in the harbour area.

Drawings I - 39 to I - 42 show the results of the salinity measurements in the estuary of the Rio Moín (measuring days were February 2, 3, 5 and 7, 1980).

The current measurements show that due to the low velocities there is only a gentle mixing of the sea water with the (fresh) surface water; the salty seawater is practically overlain by the specifically lighter surface water (horizontal layers). At the surface the salinities are found to be between 1 and 7 ‰, i.e. on an average at about 3 ‰. In the deeper part of the discharge section the salinities are considerably higher and reach values equal to the mentioned salinity of the seawater. The boundaries of the separating layers between fresh and salt water can, however, not be determined definitely; they are influenced by the tide and by the surface water alike, as the great differences of salinities above all in the lateral areas of the discharge profile show.

The suspended load determined from the filter residue of the water samples taken from the railway bridge profile are shown on drawings I - 43 to I - 46. Generally, the suspended load transport increases with increasing depth. Yet high suspended load concentration does not only occur in the middle (deep) part of the cross section, but also in the lateral parts. The mean suspended load concentration in the discharge cross section results from the measurements and is about 150 to 200 mg/l, which at a mean discharge quantity of 50 to 60 m^3/s corresponds to a rate per second of 7.5 to 12 kg/s. The annual suspended load transport consequently is between about 240,000 and 380,000 tons.

The sampling places (A) to (F) where water samples were taken to determine salinity and suspended load in the area of the harbour are illustrated on drawing I - 47.

As expected, the influence of the surface water on the salinities (drawing I - 48) decreases with increasing distance from the mouth of the Rio Moln. At measuring point (A) in the harbour area the salinities near the water surface are far lower than the natural salinities, but also at measuring points (B) and (D) in the access channel small amounts of fresh water are noticeable near the surface especially when the water runs off.

Yet, when judging the salinities at the water surfaces the local rainfalls must also be taken into consideration.

In deeper and medium water depths the salinities are about 36 ‰ on an average, which corresponds to the values given by the DHI.

The suspended load concentrations determined on the basis of the water samples from measuring points (A) to (F) are summarized on drawing I - 49.

At all measuring points considerable amounts of suspended load was noticeable which with 150 mg/l on an average were of the same order of magnitude as those measured at the railway bridge profile (drawings I - 43 to I - 46). These measured suspended load amounts are likely to reflect the most unfavourable conditions because the surface water discharges observed during the measurements were particularly high (see drawing I - 37). (The velocities measured at the permanent gauge of the railway bridge reached values of v_A = 0.75 m/s (see drawing I - 35) at the time of sampling (February 16, 1980)). But the discharge velocities during the profile measurements (February 1 to 7, 1980) showed definitely lower mean values. The measuring days February 7 and 16, 1980 permit the best comparison. Drawing I - 46 shows that the suspended load in the railway bridge profile can be considerably higher at high discharge velocities (drawing I - 37) than the indicated mean values (150 to 200 mg/l), though the profile measurements could not been taken at the time of maximum discharge velocities, but at about mean discharge velocities.

As due to the phase displacement no definite dependencies can be derived from the individual measurements between water level and (mean) discharge velocities (surface water and tide), no quantitative statements on a change of the suspended matter concentration can be made.

It can, however, be concluded from the measurements that the annual mean values of the suspended load transport in the harbour area are clearly lower than at the river mouth of the Rio Moín, which results already from the comparably larger cross sections and the related low velocities. As shown in Section 3.5 (see also drawings I - 31 to I - 33), the velocities in the harbour are between 5 and 10 cm/s. These velocities are too low to permit transport of the suspended load over longer periods and distances. Therefore a certain amount of the suspended matter carried by the surface water into the harbour will forcibly settle down. This is especially true for the bedload carried by the Rio Moín when the discharge quantities are high; this bedload transport was not measured during our investigation and cannot be measured by direct gauging.

Quantitative statements on the present and expected sedimentation rates can indeed not be derived from the small number of measurements conducted, but the high suspended load concentration measured during the investigations show clearly that the Rio Moín has a quite appreciable influence on the expected sedimentation of the harbour basin.

3.8 Surface Soil Samples in the Harbour Area and the Bay of Moín

Before starting any discussion on the morphological conditions of the harbour area and the Bay of Moín it must be known that the whole area is in a more or less disturbed state as a consequence of the construction work. Especially because of the direct drainage of the depositing pond into the harbour or offshore area almost always practiced during the dredging works, a considerable amount of fine soil particles (clay and silt) was loosened during dredging and was washed back into the harbour and offshore area.

These deposits caused by the dredging works were overlain by sedimentation and sediment transport processes from the River Moín in the breaker and littoral zone.

At the time when the dredging quantities were estimated in 1978, soil samples were already taken along with soundings.

In the inner harbour area surrounded by the head of the southern breakwater and the north end of the oil pier a very soft and fine-grained sedimentation layer of 1.5 m to 2.25 m thickness was found in the dredged zones with a total sedimentation volume of about 200,000 m^3. The soil samples were generally of a grey colour with isolated dark seams, so that the grey soil particles corresponded to the soil found in the harbour area and were regarded as whirled up and washed back dredging material, while the dark particles were judged to result from the direct sedimentation of the River Moín. In the offshore area north of the northern breakwater only coarse material was found near the shore, while at a greater distance to the shore the fine particles in the soil samples increased clearly.

The turbulent currents in the breaker zone carried the fines, originated from to the dredging works near the shores, to greater water depths. At the sea-side flank of the southern breakwater the material found was also coarse, though the breakwater - except a small surface pavement - consists of dredging material. The fines here too must have been carried away by the breaking waves.

To complete the available information soil samples have been taken during the measuring program on a large area in the harbour and offshore zone of the Bay of Moín and grain-size analyses were made. As the amount of fines in the soil samples (clay and silt) at the prevailing conditions permits conclusions on the morphodynamic conditions, drawing I - 50 shows the added percentages of clay and silt as decisive parameters, with the fines from 0 to 25 %, 25 % to 50 %, 50 % to 75 % and 75 % to 100 % being marked differently.

Remarkable are the generally high amounts of fines in the inner harbour area. A high percentage of fines were also recorded in a funnel-shaped area in front of the harbour entrance, while the percentages of fines found near the northern breakwater and in the inner part of the Bay of Moín at the seaside of the southern breakwater were essentially small. The conditions described correspond therefore largely to the results of the investigations conducted for the dredging works. Aside from that, they confirm also the close relationship between morphological and hydrodynamic conditions as the funnel-shape distribution of fines which is caused by the present location of the river mouth corresponds very much to the distribution of fines to be expected according to the registered current conditions.

The grain-size distribution curves of the soil samples mentioned in drawing I - 50 are shown in Annexes I-50.1 to I - 50.12 to illustrate the prevailing soil conditions.

When judging the results it must be kept in mind that the distribution of fines in the area before the present river mouth was not known before the construction work started. The distribution of fines determined on the basis of the soil samples suggest however very strongly that the influence of the new river mouth on the sedimentation process in front of the river mouth is very dominant. It must furthermore be kept in mind that the River Moín formerly flowed into that area of the bay which due to the influence of the littoral currents and the primary roller current did not permit the formation of a sedimentation zone for fine particles. It is expected that the fines transported to the old river mouth are predominantly carried to the west due to the mentioned current influences.

3.9 Résumé of Sedimentation Processes in the Port of Moín

The problems resulting from a discharge of the Rio Moín into the port of Moín have been discussed already during the expert meetings in Costa Rica in September 1978, and solutions of how to cope with the expected problem under economically acceptable conditions have been investigated.

The following alternatives have been discussed among others:

1. Removal of the southern breakwater;
2. Diversion of the Rio Moín, namely moving the river mouth out of the harbour;
3. Construction of an underwater threshold to reduce sedimentation in the harbour.

In section 2 evidence has been furnished that if the northern breakwater was extended by 190 m which originally was not taken into consideration the southern breakwater would no longer exercise an unfavourable effect on the wave motion in the harbour.

It is true that due to the superposition of the approaching waves with the dispersion waves originating at the head of the southern breakwater slightly higher waves will occur locally, generally, however, the influence of the southern breakwater is negligible. If the northern breakwater is extended, the southern breakwater needs not to be removed.

Of course it is recommended - which was already explained against representatives of the client - to remove the NW-SE running end at the breakwater head of the southern breakwater and to shape the breakwater head in a round form, in order to further minimize possible reflections from the breakwater head and especially from the mentioned tip (see drawing F - 2.5).

On the other hand, however, the site measurements have confirmed that the southern breakwater and the course of the river through the whole harbour area caused by it increases the danger of sedimentation and silting up of the harbour and its access.

The percentage of suspended load transport of the Rio Moin is relative high and the current velocities in the port so low that sedimentation is unavoidable. The tendency towards silting up is still increased when the planned dredgings are completed because then the flow cross section will even be larger and the flow velocities even more reduced.

The southern breakwater prevents that the surface water with its suspended load transport flows into the roller current that turns right in the bay (see drawing I - 29). This has changed the morphodynamic marginal conditions substantially, which is proven by the soil samples taken in the bay and in the harbour.

At the present stage the southern breakwater - and this tendency will increase when the northern breakwater is completed - acts like a guide dam. Due to its low current velocities the harbour acts like a settling basin permitting only very fine suspended load material to reach the adjoining offshore area. And the wave-generated current in the littoral zone is opposite to the large-scale coastal current which again increases the danger of sedimentation in the entrance zone.

It is therefore recommended in any case to take structural measures which would prevent surface water with its suspended load transport from penetrating into the harbour area, all the more so as the differences in salinity (brackish water effects) favours the settlement of fine particles.

An underwater threshold as proposed in the SYSTAN study, can and will prevent sedimentation in the harbour only to a limited extent, as due to the low velocities the bedload transport of the Rio Moin at mean discharge conditions will not be particularly high and the suspended load is distributed over the whole discharge cross section.

Any floating trash (plants, branches and the like) will not be retained by an underwater threshold.

The SYSTAN study indicates among others the following reasons which speak in favour of an underwater threshold in connection with a new mouth of the Rio Moin at the root of the southern breakwater:

1. It will provide sufficient velocity to the river discharge to maintain a self-scouring action, and the discharge from the river mouth may help counter the wave-created easterly movement of beach sand immediately west of the root of the South Breakwater.

2. It will permit local fishermen, now operating from the river mouth, to pass safely through the harbour basin. The area to the west of the South Breakwater is now so shallow that waves break in the area and the fishermen cannot use this, their traditional route to the sea, even though the South Breakwater was breacked some months ago to permit them to use this traditional route. The channel through the breach in the breakwater is now completely silted up.

From the site measurements and the experience gained so far it must be doubted that this - in principle correct - solution will have the expected success. The fact that the opening created subsequently at the root of the southern breakwater was silted up already shortly afterwards is, of course, also essentially due to wave action effects. Decisive is, however, that the opening was far too small and the Rio Moin could be discharged unhindered into the harbour. To obtain a sufficiently good scouring capacity of the Rio Moin a discharge of the surface water or even an uncontrollable part discharge into the harbour basin must be prevented.

That is why the dam proposed by SYSTAN INTERNATIONAL INC. should not be an underwater guide dam but a flood free closure dike. This solution would prevent sedimentation problems in the harbour caused by the Rio Moin. Proposals with respect to the present stage of planning and future possibilities of development of the port are depicted on drawings F - 2.5 and K - 2.1.

The southern breakwater is included in the solution proposed for implementation. It actually does have no wave protecion function, as no larger waves from NW occur and also the frequencies of waves from these directions are very low, but it offers good protection of the sea-side harbour slope against drifting sand since these slopes compared with natural slopes of the sea bottom are very steep. This is emphasized clearly by the SYSTAN study. Questions of wave-generated littoral transport have not been treated in the scope of this investigation, but the investigations concerning the problem of the expected wave motion permit conclusions on a material transport directed towards the breakwater root of the southern breakwater.

The fact that the temporary opening in the southern breakwater was plugged almost entirely after a very short period of time confirms that the assumed direction of material transport was correct. It is also assumed here that essential portions of the sand deposits stem from the largely unpaved southern breakwater itself. But in the course of time the sand quantities from the cover layer of the breakwater carried to the newly planned mouth of the Rio Moin by waves will diminish and the concentrated discharge of the Rio Moin with its scouring forces will guarantee a sufficiently large water depth for fishery purposes.

4. Conclusion

The questions asked in the beginning of this report can now be answered as follows:

1. The high suspended load rates of the Rio Moin will lead to a sedimentation of the harbour basin and the access because the current velocities in this area are too low to carry the material over longer distances. As the harbour in its present stage acts like a settling basin it is recommended to create a new river mouth immediately west of the root of the southern breakwater. This measure has the effect that the surface water flows into the area of a natural, right-turning and largely constant roller current generated by the large-scale easterly coastal current. The prevailing current directions in the Bay of Moin prevent a penetration of bedload and suspended matter from the Rio Moin into the harbour. The guide dam of the Rio Moin in the estuary should be of a flood-free design to maintain the high scouring effect of the river. The southern breakwater will avoid that bedload carried locally by sea motion will get into the dredged harbour zones. Its function shall be at the same time to protect the steep - compared with the natural inclination of the sea bottom - sea-side harbour slope from erosion.

2. When the northern breakwater is extended by 190 m, which would be recommended in view of wave motion at berths 1 and 2, wave motion at berth 3 would be as follows:

   At a permissible probability of 18 days per year on which the wave heights are exceeded, the mean significant wave heights are expected to be $H_{1/3}$ = about 0.55 m. A further extension of the northern breakwater would not be reasonably, as the wave heights at the berth would decrease only insignificantly. Therefore it is recommended to permit higher waves than $H_{1/3}$ = 0.3 m or higher probabilities of days on which this height is exceeded, than 18 days. (The economic evaluation of this recommendation is given in Chapter L.6).

3. When the northern breakwater is extended in the proposed manner unfavourable reflection effects of the southern breakwater which without this extension would lead to locally increased wave heights in the area of the planned future berths for banana handling will no longer occur. The southern breakwater has no unfavourable effect on the dominating wave directions, but its influence on the wave motion is also not exactly favourable. The NW-SE running tip at the breakwater head should be removed and the head be shaped in a round form.

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J. POSSIBILITIES OF WATER SUPPLY TO THE PORTS OF LIMON AND MOIN

1. Introduction

Due to the high precipitation the central area of Limón is a humid region. However, this area has always presented shortage of water supply because of the great distance that the major sources of surface water are from the existing towns. Also the water treatment demands high cost and ground water is a scarce resource susceptible to get easily contaminated.

The water supply of Limón City is through ground water by wells and springs with a total yield of about 180 liters per second. However, the actual water demand is of 290 liters per second.

The goal of this study is to present the results of an investigation carried out to determine the possible sources of water supply for Moín and Limón Harbours, which are in process of construction and amplification, respectively.

To accomplish this study, existing ground water and surface water resources, in a convenient distance for development have been considered, as well as other factors that can affect the cost of construction and operation of the systems and finally several reasoned alternatives showing a general overview of the water resources and complementary investigations needed to facilitate the final decision about the most convenient source of water to supply the ports are presented.

The methodology followed in this study comprises the recompilation and analysis of the existing basic information, specially of the hydrometeorological and hydrogeological type, the direct survey in the field of the principal water resources identified, including "in situ" analysis, preliminary tests and evaluations, and water sampling for physical-chemical determinations in laboratory.

In this field investigation, the principal rivers of the area were recognized in important geographical locations to achieve a criterion about their possibilities for utilization. Likewise in hydrogeology direct recognition of the characteristics of the principal lithological units was done and their extension and structural elements were determined by photogeology.

Also the principal existing water developed system, specially for the supply of Limón City were studied in the field.

Most of the basic information was collected from field work, and the following institutions:

Aguas Subterráneas (AQUASUB).
Instituto Costarricense de Electricidad (ICE)
Instituto Meteorológico Nacional (IMN)
Ministerio de Obras Públicas y Transportes (MOPT)
Servicio Nacional de Aguas Subterráneas (SENAS)

2. Climate

Limón area has a tropical and humid climate, with high precipitation during 222 days per year. Moderate rainfall occurs in each month of the year. The highest precipitation occurs during December and diminished in February, March, September and October.

The mean temperature in 1970 was of 25.8^{O}C and the fluctuation of the mean monthly temperature from 24.4 to 26.9^{O}C. The maximum temperature was in May with 30.9^{O}C and the lowest of 21.1^{O}C in February and November. Most of the winds, of north-west direction, had velocities between 84m/s in March and 89m/s in December, with an average of 86 m/s.

The pan evaporation in 1970 was of 1,154 mm, the fluctuation was of 50 mm in December and 282 mm in March.

The average sun hours were of 5.0 hours per day. The highest which occured during 1970-1978 was of 6.4 hours per day. The lowest, at the same period, was of 3.0 hours per day.

3. Hydrology

3.1 Precipitation

The mean precipitation in the area of Limón Port was of 3,360 mm, during the years of 1960-1971. The rainfall distribution in the area is quite uniform. However, it increases in the high parts of Banano River; during the same period the rainfall data in the Asunción gauging station of 3,766 mm per year.

The rainfall distribution during the year from the Asunción gauging station and Limón station is shown in Drawing J - 1.

In Moín station the mean precipitation was of 3,846.3 mm (1966-1972), with a standard deviation of 940.5 mm. The average lowest precipitation during the same period was 141.6 mm in September and the highest average of 546.0 mm in December.

Also in Figure I-1 the rainfall stations of Limón are localized.

Table J-1

Frequencies of the duration-intensities relations in Limón, Costa Rica (1970)

Intensities (mm/h)				
Duration	Frequencies per year			
	1	2	5	10
5'	128.0	121.3	119.3	116.0
10'	98.0	92.0	79.3	75.7
15'	92.0	86.0	76.3	65.0
30'	72.5	70.0	61.7	56.7
1h	60.0	55.0	47.5	42.5
2h	42.5	40.0	36.0	32.0
6h	26.0	24.0	18.0	14.0
12h	20.0	16.0	11.3	8.0

In Table I-1 duration-intensities relation and its return period in Limón during 1970 are tabulated. Data were taken from the report "Ampliación de Puerto Limón, Costa Rica", written by Ministerio de Obras Públicas y Transportes and Rhein-Ruhr Ingenieur-Gesellschaft mbH.

J.2 Runoff

Surface runoff is relatively high and in the area of Limón, due to the high and continuous precipitation. Also, the impermeable soil in the mountain area with almost saturated soil in the valleys helps to increase runoff.

In the area near Limón and Moín Harbours, the Banano River is the only one with continuous hydrometric station (Drawing J-2, Volume IV). One in La Bomba and the other in Asunción (see Drawing J-1). The station with more data is Asunción installed in July 1957. The minimum flow registered was 2.17 m^3 per second which occurred in January 1, 1965 and the maximum, 770 m^3 per second in April 9, 1968. The mean flow was of 17.2 m^3 per second.

In Drawing J-3 (Volume IV) a runoff hydrograph of Banano River in Asunción, 1974-1975, is shown.

Table I-2 shows measurements of base flow of some rivers.

Table J-2

Place	Gauging section	Date	Flow (l/s)
Banano River	300 m. up stream the railroad bridge at La Bomba	4- 9-69	10.000
Banano River	300 m. up stream the bridge at railroad in La Bomba	29- 4-70	19.000
Banano River	300 m. up stream the railroad bridge at La Bomba	17- 5-72	7.879
Banano River	300 m. up stream the railroad bridge at La Bomba	29- 5-72	17.914
Banano River	300 m. up stream the railroad bridge at La Bomba	30- 5-72	15.862
Banano River	300 m. up stream the railroad bridge at La Bomba	1- 6-72	14.955
Banano River	Villa Yunis	4- 9-69	20.000
Banano River	Villa Yunis	17- 5-72	13.166
Banano River	Villa Yunis	30- 5-72	15.273
Banano River	Villa Yunis	1- 6-72	16.916
Banano River	1.000 m. down stream the railroad bridge at La Bomba	29- 5-72	17.262
Banano River	1.000 m. down stream the railroad bridge at La Bomba	30- 5-72	15.735
Banano River	1.000 m. down stream the railroad bridge at La Bomba	1- 6-72	15.916
Limoncito River	Bridge of Santa Rosa	29- 4-70	712
Limoncito River	Bridge of Santa Rosa	16- 6-70	600
Bartolo River	Bridge at Recope	8-12-69	33
Bartolo River	Bridge at Recope	10-10-70	18
Chocolate Creek	S. Hasbun bridge	8-12-69	9
Chocolate Creek	S. Hasbun bridge	10-10-70	14
Piuta Creek	El Fenix	8-12-69	2
Piuta Creek	El Fenix	10-10-70	7

Limoncito River, the second in importance in the area near Limôn Harbour, has a flow usually below 1 m^3 per second. This flow increases or decreases rapidly according to rainfall.

Other important rivers are Moîn, Blanco and Chirripô. Blanco and Toro are tributaries of Moîn River which is a navigable river.

Blanco River has usually flows above 1 m^3 per second and the Chirripô above 25 m^3 per second. The base flow of other rivers in the area is small and it increases rapidly with the rainfall.

3.3 Evapotranspiration

In Drawing J-3 (Volume IV), the rainfall, potential evapotranspiration by Thorntwaite Method, excess of water and use of the field capacity is shown. The data used are the mean values of the period 1964 - 1973 of Limôn Station. It can be noticed that in all the year the deficit of water almost does not exist. The dry season in Limôn is in September with a mean of 100 mm and the wet season in December with 450 mm.

There is an excess of water during the whole year, except in September.

4. Geology

The analysis of the geologic conditions of the study area in this case, has the only purpose of pointing out the principal elements to consider the existing ground water resources in the area.

The explored area is part of the "Limón Basin", an extensive unit that includes the total Caribbean Region of Costa Rica and is formed by a thick sequence of marine sedimentary units from the Terciary Period; these units are folded and intruded. They form the high topographic areas that are limited by alluvial deposits from the Quaternary in their lower parts.

The study area presents the following four main geologic units of formations: Uscari Formation, Gatun Formation, Alluvial Deposits from the Quaternary and the Recent Coral Formations (see Drawing J-4, Volume IV).

The Uscari Formation from the Oligocene Epoche, is formed by dense, gray clays of great thickness and few outcrops; all of this diminishes its possibilities and importance from the ground water standpoint, specially because its low permeability.

The Gatun Formation has been considered as composed by two members: The Lower Gatun and the Upper Gatun. The first has a lithology of gray clays with interstratifications of fine clayish sand layers. This is true specially near the base of the formation. Toward the upper part of this member, sections of coarser sediments (conglomerates), hard silty sandstones and dense brown clays are present.

The total thickness of the Lower Gatun member has been estimated in 700 meters.

The upper parts of this unit present better possibilities of ground water exploitation because its grain size allows a moderate permeability.

However, the physico-chemical quality of the water is low and the aquifer conditions are limited and heterogeneus.

The Upper Gatun member is formed by coral limestones that present interrupted outcrops toward the high sections of the area of Limón and Moín and covered by red coloured limous clays, as products of the decalcification of the limestones.

The corals of this unit are massives, with numerous primary and disolution cavities which make the corals porous and cavernous and have developed certain karstic features with formation of sink holes and a typical young topography from this process. Its thickness is approximately 40 meters. Because of this characteristics it is an important unit from the hydrogeological point of view and has originated aquifer systems with sections of high local yields.

The alluvial deposits of the lower flat zone are formed by heterogeneous fine sediments. They are clays and silts with high content of organic matter, fine sands with clays and occasional fine gravel and sand beds.

These beds can originate minor aquifers of the confining type, but their water quality is bad due to the presence of organic matter and colloidal particles.

The Banano, Chirripó and Zent Rivers have developed in their upper plain zones coarse alluvial deposits in terraces that form important aquifers that can be exploited by wells and infiltration galleries.

The recent coral formations are limited to the coast and immediate areas, showing salients, islets and minor reef forms. Some sections have continuity with the old corals which favours the flow of ground water and their possible interception in the areas near the sea.

From the structural point of view, the principal known elements in the zone are two major faults, the Cangrejos and the Limón Faults, and the Anticline of Limón and the Syncline of La Esperanza.

The two mentioned faults seem to favour the concentration and flow of ground water along them, which could be an important feature for the interception of this water, specially toward the lower sections of the corals of the Upper Gatun formations that are crossed by this structural unit.

La Esperanza Syncline seems to be the principal element in the concentration of the Moín springs that actually are collected by the Instituto Costarricense de Acueductos y Alcantarillados.

These ground water outlets are located in the point where the syncline axis is crossed by a gravity fault.

5. Hydrogeology

This chapter is an analysis of the existing hydrogeological data and some additional limited information attained in a 15 days field work.

Three main aquifers have been identified in the area and are shown in Drawing J -3 and J-5 (Volume IV) and the existing wells and their characteristics are presented also in the resp. tables (Annex 8.1 to 8.7, Volume IV).

These aquifers are: Coral aquifers south-west of Limõn and Moîn
Banano River alluvial aquifer
Chirripõ and Zent Rivers alluvial aquifer.

5.1 Coral aquifers

These coral formations crop out in the mountainous zone toward the south-west of Limõn and Moîn, limited by the Blanco and Rene Rivers at the west and the Limoncito River at the south.

The area of this mountainous zone is about 35 km^2, but the extension of the aquifer over the entire zone is not well known yet, neither its hydraulic continuity.

The thickness of the coral beds is very variable due to erosion and valves from 3 to 50 meters have been reported from perforations.

The saturated thickness of the aquifer has not been measured, but is supposed to be small, because no springs are known in high places and all the existing springs are below a datum of 20 meters above sea level.

Underlain the coral beds exist very thick sedimentary formations from the Tertiary Period and formed mainly by dense clays with some small silty sandy lenses. These Tertiary formations although saturated with water, yield very little by wells and are regarded as an aquiclude.

The aquifer material is formed by dark yellow organic corals with a micro-vesicular texture and secondary features as disolution caves and sink holes.

5.1.1 Recharge

The recharge to this coral aquifer occurs by direct precipitation and infiltration. The infiltration percentage of precipitation for this material can be estimated on about 20 %.

The average amount of recharge per unit area per year calculated on the basos of the 20 % of the annual average precipitation of 3,360 mm, for a period of 10 years (1960-1971) for Limõn Station is 672 mm. Due to the small knowledge of the lateral extent of the aquifer and doubts about is continuity, no calculations regarding the total recharge or the monthly distribution recharge can be made.

Most of the water infiltrates through sink holes and small streams which are numerous in the area and flows rapidly to discharging interconnected points (springs). Ground water velocities of 8 m per hour have been reported from tracer experiments by Aquasub.

Due to the proximity of the recharging sink holes to the discharging springs, the high flow velocity of the water and the fissure and cave flow type aquifer that shows little filtration to the water, high potential of contamination risk exists in this aquifer.

Some water also infiltrates to the corals through a layer of soil derived from the meteorization of corals. This soil is of darkredish colour and its texture is silty.

5.1.2 Discharge

The natural discharge of this coral aquifer is mainly through springs at the foot hills of the coral beds.

The discharge at the springs varies greatly upon the season and rain distribution and intensity.

a) Moín springs

The main discharge of the aquifer is through the Moín Springs (Drawing J -6, Volume IV). They consist of a group of about 7 points of discharge from disolution caves located in a 160 m line at the base of the corals and about 600 m south of Moín Harbour.

This group of springs have been collected by the Instituto Costarricense de Acueductos y Alcantarillados (AyA) a national institution in charge of the water distribution in Costa Rica, and are part of the water distribution system for Limón City and surrounding areas.

Before the collecting of these springs by AyA in 1972, some discharge measurements were made by Aquasub and are shown on Table J-3.

Table J-3

Discharge measurements of Moín Springs

Date	Discharge (l/s)
14-11-69	81
25-11-69	101
18-12-69	91
12- 3-70	87
16- 4-70	100
29- 5-70	98
19- 6-70	86
15- 7-70	83
12- 8-70	81

Recently, in November 1979, AyA staff reported a pumping discharge of only 40 liters per second at the end of the past dry season, but the rest of the year its yield was over 100 liters per second.

b) Springs between Limôn and Portete

Some minor discharge of the coral aquifer occurs at some small springs along the road between Limôn and Portete.

Their outlet is also from small disolution caves at the foot hills of the coral and the response of flow to rain is very fast. Some houses exist behind some of these springs in the immediate recharge area and the zone is likely to be developed with urban and industrial schemes and their contamination from domestic and industrial wastes is evident in a short term if not immediate protective and corrective action is taken.
Some discharge measurements were made last November at the end of the past dry season and are shown on Table J-4.

Table J-4

Discharge during dry season in springs between
Limôn and Portete

spring number	distance from Moîn harbour (km)	distance from Limôn harbour	discharge l/s
1	6	3	5
2	3	6	2.4
3	3	6	5.4

The collection and capture of these springs will need some land movement and cleaning of the place from existing debris.

The location of the springs is shown in Drawing J -6, Volume IV.

c) Direct seepage to the sea and infiltration galleries

At the end of the coral reefs, below land surface, exist some seepage of ground water to the sea through debris and fill material.

The total flow from the coral aquifer to the sea cannot be computed at the moment because the data on hydraulic characteristics, like hydraulic gradient, transmissivity and the boundaries between the coral reef and the lose material are not well known. But some data have been taken from short pumping tests done in four small trenches situated at the foot hills of the coral beds at Moîn Harbour at an elevation of about 4 m above sea level.

The drawndown data obtained during the tests was corrected for the trench storage and aquifer dewatering effects and the results are presented on Table J-5. In Volume IV, Drawing J-7, the graph and analysis of the pumping tests are presented.

Table J-5

Pumping tests in four small trenches at the foot hill of the coral beds in the Site of Moín Harbour

Trench reference	Areal dimensions (m)	Depth of trench (m)	Depth of water level (m)	Water level datum above sea water (m)	Constant discharge l/s	Transmissivity (T) M^2/day
A	3.06x3.02	2	0.955	4.82	1.60	T_1 = 101.20
						T_2 = 9.43
B	2.50x2.00	1.30	0.57	3.70	4.034	T = 66.43
C	2.80x1.30	1.78	0.50	3.66	2.633	T = 11.89
D	6.80x1.00	1.56	0.230	4.23	3.785	T_1 = 32.30
						T_2 = 7.14

From Table J-5 can be noted that the transmissivity varies greatly from one trench to another (from 7.1 to 101 m^2/d) possibly because of karstic features heterogeneous development and in two sites, negative barriers or drying of saturated caves existed.

Using the levelling of the trenches some equipotential lines were drawn in Figure I-6, Volume IV and a hydraulic gradient of about 2.5 % was determined. Using this gradient and an average transmissivity (T) of 50 m^2/d a ground water flow across a frontage (W) of 100 m was calculated by the Darcy's Law (Q = TiW) in 2.9 liters per second which is very low.

However, we know from the pumping test that additional flow can be induced by lowering the water table although it is not possible at the moment to determine the long term safeyield of this additional flow.

It is possible that beneath some of the recharging small streams higher transmissivities could have developed because of coral dissolution, and infiltration galleries, or wells situated along the lower parts of these small streams could intercept a ground water flow enough to meet the demands of the harbours, but some other pumping tests at these sites should be carried out for this evaluation.

The total natural flow to the sea in a frontage of 4 km, between Limón and Moín calculated on the above basis is about 116 l/s, in the dry season.

If an infiltration gallery or well is to be constructed at the foot hills of the corals, the depth of excavation or drilling must not exceed the sea level datum because there is a potential danger of saline water intrusion if lowering of the water table by pumping, to a point at which the hydraulic gradient is inverted, and causing the sea water to flow to the gallery or well.

5.2 Banano River aquifer

The Banano River flows from west to east some 9 km, south of Limôn City. This river has deposited alluvion from material eroded from the higher parts of its 205 km^2 basin.

At the base of the alluvion exists the thick sedimentary formation from the Terciary Period known as Gatun Formation which is formed by thick clay strata with occasionally thin mixed gravel and clay strata and is regarded as an aquiclude.

The Banano River alluvion changes greatly in grain size. In the lower part of the river the alluvion is composed by very fine sediments of fine sand, silt and clay which confound itself with the fine marine sediments of the coastal plain which extend from Limôn Harbour to the south-east along most of the Atlantic Coast in a trip of land with a width that varies from 2 to 5 km. The wells in these fine sediments yield very poor quantities of ground water of doubtful quality and is regarded as a poor aquifer on an aquiclude. In the middle and upper part of the river, west of the village called La Bomba, and in a strip of about 6 km long, with an average width of about 300 m the alluvion consists in sandy gravel from coarse to medium in size. The material has been deposited in terraces and alluvial fans.

The hydraulic conductivity of the alluvion in this area is estimated in a range from 250 to 1,000 meters per day and the specific yield from 20 to 10 %. The saturated thickness of the permeable alluvion in this area range from 3 to 7 m. Aquasub has reported transmissivities from 1,500 to 8,500 m^2/d.

Preliminary calculations using the above data show that 75 to 90 % of the ground water extraction by wells comes as induced recharge water from the river when the wells are sited 100 m away from the river bed.

The main water supply to Limôn City comes from 3 wells owned by AyA at the site of La Bomba Village which induce water from the Banano River and that is filtered through the alluvion formation.

The total ground water pumped from these wells is about 100 liters per second. Each of the wells yield from 25 to 35 liters per second. The depth of them varies from 13 to 17 meters approximately.

The AyA well field at La Bomba has decreased substantially and although the causes of this failure have not been properly established yet, it is possible that a combination of some of the following facts has affected their performance: 1 removal of large quantities of gravel from the adjacent river bed for civil constructions in the area have affected the hydraulic communication of the river whith the aquifer and the aquifer permeability itself. 2 Clogging of the well screens by bacterial grout . 3 other types of incrustation and/or corrosion of the well screens.

5.3 Chirripó and Zent Rivers Aquifer

At the junction of the Rivers Chirripó and Zent, some 3 km south-west of Zent Village and about 30 km west of Limón City, alluvial formation has been developed.

In this area an extensive aquifer exists in the alluvial formation. Although some of the recharge occurs by direct precipitation,it is possible that most of the recharge is originated from the river flow.

The limited number of existing wells shows that the alluvial formation in some areas is over 70 m thick and productions from 5 to 14 liters per second have been reported. No hydraulic parameters are known in this aquifer because no pumping tests have been carried out but they seem to be very favourable for high extraction of good quality ground water and calcualions based on estimated parameters for this type of aquifer conditions show that the through flow of ground water across a frontage of 1 km width is at least 50 liters per second without taking into account any induced recharge from the river which could provide as much as 90 % of the water extracted from any well conveniently located.

6. Water quality

The preliminary study of the water quality which could be used from the study area, was done first, according to existing data; second, for physical-chemical water analysis of samples collected in the field and third, electrical conductivity measured on the field.

The existing data refers only to ground water. This data is taken from a study done in 1967-1970 by the project of ground water investigations in selected areas (UN). These studies show that during the season of high precipitation, the water yield by the coral beds, is of the potassium and sodium bicarbonates types, during the season of low rainfall, of the calcium bicarbonate type.

The total iron of these waters also present variations according to changes of climate, increasing the iron content during the high precipitation season, some times above the recommended limit.

The main springs show that they become bacteriologically contaminated, specially during the rainy season.

That means, that they need to be treated by chlorination for human use.

For the ground water of the alluvion aquifer of Banano River, the existing data shows that they are calcium-bicarbonated and of good chemical and bacteriological quality for human use.

The physical-chemical quality of the water samples taken from the field, during the actual investigation (November 1979) shows that the water yield by the coral aquifer are in general hard water with high content in iron and sometimes out of the recommended quantity (Table J-6 on the following page).

The laboratory analysis of a water sample from Moin River at 100 m upstream the confluence with Toro River, shows an acceptable physical-chemical water quality with exception of the iron content.

To determine the sea water intrusion into the Moin River, several measurements of electrical conductivity were done along the stream of Moin River from its mouth to the confluence of Matina River. From these measurements the stratification of salty water due to the sea water was determined up to the confluence with Toro River. Downstream the Toro River confluence the interface fresh water/salty water were approx. 2 m deep. The water of Moin River near its mouth was contamined and muddy.

Table J-6

Physical-chemical water analysis of coral springs and Moín river

Sample	No. 1	No. 2	No. 3	No. 4
Date	18.11.79	18.11.79	18.11.79	24.11.79
Colour	2.50	5.00	18.50	60.00
Turbidity	16.00	55.00	77.00	21.00
Odour	neg.	neg.	neg.	neg.
pH	7.52	7.11	7.76	7.09
Suspended solids (ppm)	--	--	--	--
Silica (ppm)	4.00	8.00	16.00	20.00
Carbodioxide (ppm)	12.90	30.30	4.10	7.10
Phenolphtalein alkalinity (ppm)	--	--	--	--
Alkalinity to methylorange	212.00	197.00	134.00	46.00
Total hardness (ppm)	265.00	235.00	176.00	55.00
Carbonate hardness (ppm)	212.00	192.00	134.00	46.00
Calcium hardness (ppm)	218.00	204.00	141.00	41.00
Magnesium hardness (ppm)	47.00	31.00	35.00	14.00
Chloride (ppm)	10.90	15.30	20.80	17.80
Fluoride (ppm)	0.36	0.14	0.16	0.14
Sulfate (ppm)	28.80	28.80	28.80	1.90
Calcium (ppm)	87.20	81.60	56.40	16.40
Total iron (ppm)	0.59	4.30	6.75	1.98
Magnesium (ppm)	11.30	7.40	8.40	3.40

Sample No. 1: Trench No. B
Sample No. 2: Spring No. 1
Sample No. 3: Spring No. 3
Sample No. 4: Moín River (100 m upstream, confluence with Toro River)

7. Conclusions

Alternatives of water supply for Moîn and Limôn Harbours are presented in this section.

7.1 Ground water alternative

Three main aquifers have been determined in the study area: the coral aquifers, the Banano River alluvial aquifer and the Chirripô and Zent Rivers alluvial aquifer.

7.1.1 Coral aquifers

This is the nearest source of water to the harbours. The ground water of the coral aquifers can be exploited by the capture of springs, wells or infiltration galleries. The total yield from this aquifer cannot be determined with the limited existing data. However, by indirect methods, the potential yield of the entire aquifer can be expected in at least 150 liters per second in the dry season. From this quantity, 40 to 50 liters per second are already captured by AyA in Moîn springs. The remaining flow (about 100 l/s) could be intercepted by galleries or wells conveniently located if the hydrogeological conditions are favourable.

The chemical quality is good for drinking purposes, but hard. Bacteriological contamination may exist in some areas. However, it could be treated by chlorination for drinking purposes.

7.1.2 Banano River alluvial aquifer

By existing wells and geological survey it is shown that a good alluvial aquifer exists upstream from La Bomba Village, along the Banano River. The main recharge of the aquifer comes from the river and high quantities of good qualitiy water can be withdrawn by reduced recharge wells or infiltration galleries.

7.1.3 Chirripô and Zent Rivers alluvial aquifer

In the area of the confluence of Chirripô and Zent Rivers, around the Village of Zent, an extensive alluvial valley has been developed. High quantities of good quality water can be expected from this aquifer by means of wells or infiltration galleries.

7. 2 Surface water alternative

In addition to the Banano, Chirripó and Zent Rivers mentioned above, the Rivers Limoncito, Blanco, Toro and Moín have enough quantity of water for the harbours's supply, but its quality needs intensive treatment for sediments and biological contamination.

The survey of electrical conductivity in Moín River indicates sea water intrusion for about 12 km upstream from its mouth.

If any of these surface water sources are to be considered for the supply of the ports, studies of sediments and water quality should be done.

8. Recommendation

The following recommendation refers to the investigations that should be done before the final decision is taken.

8.1 Coral aquifer

Although the water potential of this aquifer is the lowest of the remaining sources mentioned in this study, higher attention should be given to this alternative due to the proximity to the harbours which means the more economic solution; however, it has the disadvantage that is a vulnerable aquifer from the biological contamination point of view.

8.1.1 Production wells and/or galleries investigation

For this reason the following investigation should be done: five wells for pumping tests and two of them with one observation well. The purpose of these wells is to determine the hydrogeological characteristics of the aquifer for designing of production wells and/or galleries. The drilling diameter should be of 20 cm, and their depth from 30 to 10 m depending on the site.

Other five exploration wells in the higher areas of the corals, should be done in order to determine the hydraulic continuity of the coral aquifer, the saturated thickness and hydraulic gradient. In order to determine the infiltration rate, a limnigraph should be installed in some of these wells during at least three months. The recommended diameter should be also 20 cm with a depth from 40 to 100 m.

The approximate location of the wells is shown in Drawing J-6 (Volume IV).

8.1.2 Moín springs

These springs belong to AyA. The springs, at 600 m, south from Moín Harbour, are at the foot hills of the coral beds. The flow at the end of the dry season is 40 liters per second. During the year it can yield up to 250 liters per second.

By recent informal talks with the Director of AyA, he agreed with the possibility of giving the springs to the Moín Harbour once the treatment plant of surface water from Banano River in La Bomba is constructed. This treatment plant, of 250 liters per second, will be ready at the end of 1980. However, to use the springs for Moín harbour it is necessary to negotiate this alternative with the AyA Board of Directors.

8.2 Alluvial aquifers

The two alluvial aquifers mentioned in this study have enough water and probably of good quality to supply the demands of the ports but have the disadvantage of a high cost of transportation of the water by pipe lines: about 13 km from La Bomba near the Banano River and about 30 km from Zent near the Chirripó and Zent Rivers.

8.2.1 Banano River alluvial aquifer

Future schemes to develop ground water by induced recharge wells or infiltration galleries in this water course aquifers should have the following on site investigations for proper design of a well field or the gallery:

a) a field recognition of the water course formation to determine the best location to develop the scheme taken into account hydrogeological and economical factors.

b) one or two investigation/production wells with five or six small observation wells conveniently located in relation to the pumping wells.

c) one or two pumping tests to determine the hydraulic characteristics of the site to make final design.

8.2.2 Chirripó and Zent Rivers alluvial aquifer

The same previous investigations mentioned for the Banano River aquifer should apply to this aquifer before any developing scheme is put into practice.

K. PRELIMINARY STRUCTURAL DESIGN (CASE A)

1. Port of Limôn - case A

1.1 Pavement and fencing
(Drawing K-1.1)

For the surfacing of roads, Ro/Ro areas and break bulk areas a cover of concrete slabs and -stones has been chosen. Whereas the roads will be provided with concrete slabs, the storage areas (incl. Ro/Ro stevedore areas) will be paved with concrete blocks. The structure of surfacing will by as follows:

1. Concrete slabs

This surfacing consists of approx. 20 cm thick, double-reinforced slabs with the necessary joints and shall be laid upon a foil. The subbase consists of an approx. 30 cm thick crushed-stone course with stone chippings and screenings filled into the caveties by vibration.

2. Concrete stone pavement

The crushed-stone substructure shall be approx. 36 cm thick. The about 10 cm thick concrete blocks shall be placed upon a 4 cm thick mortar bed. For the purpose of marking the carriageways and storage areas, coloured concrete blocks shall be used on concrete block pavement. The total harbour area will be surrounded by a 2 m high fence after extension of Avenida 1.

1.2 Gate house at western entrance
(Drawing K-1.2)

The function of the gate house is to check all incoming and outgoing traffic at the west gate. The building is a single-storey building with an area of approx. 24 m^2. The bearing structure consists of a reinforced steel skeleton filled with brickwork. The roof can be made either of timber or concrete alternatively. A rafter structure is chosen as roof structure which will be covered with corrugated asbestos cement. The brickwork will be plastered inside and rendered outside. The floor cover shall consist of stoneware.

1.3 Workshop
(Drawings K-1.3.1, K-1.3.2)

The repair hall shall be a steel structure which system shall be statically determined both in longitudinal and transverse direction. The distances between the outer axis in longitudinal and in transverse direction amount to 68.50 m and 22.00 m resp. The stiffening of the hall in transverse direction shall be carried out by columns fixed in individual foundations and in longitudinal direction by a bracing of the column rows. The roof slope in the direction of the longitudinal walls is at least 6^0.

The roofing consists of corrugated asbestos cement sheets which are fastened to steel purlins. The roff will be constructed without draining units. Corrugated asbestos cement sheets form the outer facing above the window rows. Below the window rows the outer wall is made of brickwork. The reinforced floor slab shall be embedded in a compacted gravel layer. All steel parts shall be protected against corrosion by adequate measures. Due to its future use the hall shall be divided into 3 areas:

- large hall for straddle carrier
- 2-storey social building and storage
- hall for forklifts, trucks and trailers.

1.3.1 Large hall for straddle carrier

This western part of the hall has a clearance of 18.60 m and a length of 20.00 m. The girder-to-girder distance is 5.00 m. The roof trusses of the single-span hall are hinged to the external columns. The travelling crane with a lifting capacity of 5.00 t shall be operated in longitudinal direction of the hall. In the southern longitudinal wall 2 rolling gates are located with a clearance of 8.00 m of width and 12.5 m of height.

Two window rows one above the other in the northern longitudinal wall and 1 window row above the rolling gates will be lighting the interior of the hall.

1.3.2 Social area and store

This 2-storey part of the hall is 10.00 m wide and set back about 2.00 m from the northern longitudinal wall. Here the roofed entrance is located adjacent to which are the stair case and the toilet rooms. The warehouse is situated in the southern hall area with a clearance of 6.00 m. The floor and the three-flight stair structure will be carried out in reinforced concrete. The upper floor shall accommodate office rooms and the necessary sanitary facilities. The clearance up to the suspended ceiling amounts to 2.50 m. The rooms located in the middle will be illuminated by 6 dome lights which shall be installed on the roof and shall extend up to the suspended ceiling.

The brickwork stiffened by steel columns is loaded in the ground floor by the supports of the reinforced steel ceiling and has only a space limiting function in the upper floor.

1.3.3 Hall for forklifts, trucks and trailers

The eastern 2-span part of the hall has a clearance of 8.75 m and a length of 68.50m. The distance between trusses is 5.50 m. The central column row is 8.50 m away from the northern and 13.50 m from the southern row of columns. The southern columns are fixed in individual foundations. Two travelling cranes with a lifting capacity of 3.0 t each are operated in longitudinal hall direction up to the stiffended transverse wall. This brickwall limits the repair area for trailers at the eastern gable.

In the southern longitudinal wall 4 rolling gates are situated with clearances of 5.00 m of width and 5.00 m of height each and 1 rolling gate with a width of 4.00m and a height of 5.00 m. The repair pits, one in each working area for trucks and trailers, are 1.70 m high and 1.80 m deep. The pit bottoms will be provided with a slope in the direction of the pump sump. Grids on steel angles which are concreted into the pit walls will serve as working platforms. The working pits will be covered with grids permitting vehicles to drive on.

1.4 Rehabilitation of Muelle 70

In order to keep Muelle 70 operable as pier also in the future and to prevent damage to berthing ships rehabilitation measures shall be taken immediately. These measures are described in the following.

1.4.1 Fender system

The fender system including the fender supports are in an extremely desolate condition. For Limón as a swell harbour a soft fender type with low initial force and long way of compression should be applied. The southern front edges should be equipped with rubber or sisal corner fenders.

1.4.2 T-beams

The covering concrete on the bottom of the T-beams below the pier slab is scaling on about 25 % of the beams. By this surface scaling, the main reinforcement steel bars are exposed to the salt water and are corroding. The bearing capacity of the pier slab can be maintained in that the beams with damaged reinforcement are replaced by new prefabricated members. Longitudinal beams with reinforcement which is not damaged can be rehabilitated by sand blasting and applying air-placed concrete provided with chemical aggregates as protection against corrosion.

1.4.3 Rails on pier

The rails are placed on the prefabricated T-beams and are fastened with anchored clamping plates. Partially the rails have loosened and move up and down when driven with heavy loads.

Rehabilitation can be achieved by

- uncovering the rails and clamping plates
- unscrewing of anchoring bolts
- adjusting of rails according to height and track gauge
- boxing up with non-shrinking mortar.

On the left and right side of the rails corner protection angles will be anchored in sealing concrete in such distance as to allow later unscrewing of the anchor bolts and thus enable adjustment of rails. The rail bedding will be filled with an elastic sealing compound up to the bottom of the rail head.

1.4.4 Beam head

At the western pier side a beam head is broken from the outer edge of the vertical double pile row in transverse direction up to the bottom of the edge beam support. Re-establishment of the former construction state can be achieved by concreting a new beam head.

Because the uncovered reinforcement is not sufficient as connection reinforcement an backside anchoring in the beam web is proposed. In order to keep the weight of the beam head low it shall be constructed as a vertical reinforced concrete plate with a thickness of approx. 0.20 m.

Prior to concreting, all loose, weathered and damaged concrete parts shall be removed. The contact surface shall be cleaned properly, e.g. by sand blasting, and shall be roughened as well as freed from dust by water jetting. The anchoring reinforcement has to be enclosed with sufficient concrete covering.

1.4.5 Arris protection

Along the total pier edges the concrete arris is seriously damaged. Where mooring ropes are led and chafe along the pier edge the reinforcement is uncovered up to the top of the pier slab.

An effective protection against further damage is by demolishing the concrete arris up to approx. 0.15 m below top of pier slab. After adjusting the existing reinforcement a steel profile provided with claws shall be concreted as arris protection. The seaside boundary shall be a railway track on cement mortar supports anchored in the in-situ concrete slab.

2. Port of Moin - case A

2.1 Extension of banana pier
(Drawing K - 2.1)

In chapter F-3, several possibilities of a railway link to the banana pier and the alignment of the tracking system on the pier have been developed. The one which constitutes an optimum in both operational and economic aspect was finally selected. The alternative chosen implies an extension of the banana pier by 68.40 m. The structural design of the pier extension could be carried out in correspondance with the report and the planning documents of the "Final Design of the Banana Pier" which have been drawn up and submitted by Rhein-Ruhr Ingenieur-Gesellschaft mbH at an earlier date.

2.2 Railway connection
(Drawings K-2.2, K-2.7.2)

For the alignment and fastening of the tracking system on the banana pier, Rhein-Ruhr has also worked out already accurate planning documents in the scope of the "Final Design of the Banana Pier". Attention has to be paid when placing the tracks on the quay slab that the rail joints match accurately with the joints of the concrete construction, that means that they are located directly beside them. The tracks outside the pier slab shall rest upon a ballast bed of a thickness of approx. 40 cm. On traffic areas, the tracks and switches shall be embedded in the pavement. To keep the rails open, a flange way rail should be installed as pavement boundary line.

2.3 Rain shed on banana pier
(Drawings K-2.3, K-2.7.2)

In order to facilitate banana handling also during rain, the construction of a roof as rain protection on the banana pier has been proposed in chapter F-3. Furthermore, each of the 4 elevators shall be equipped with a cantilevered roof which shall be welded onto the elevators to protect the transition area between elevator and rain roof.

Each berthing place shall receive one rain roof with the design characteristics as laid down in the following:

The main loadbearing part of the building shall be a double-hinged frame with different heights of columns making the horizontal member sloping to one side. The columns shall consist of double T-profiles , with variable web heights, while the horizontal members consist of parallelly flanged I-profiles.

The wind load acting on the longitudinal side of the building shall be transmitted by wind bracing into the foundation below. All assembly joints shall be bolted connections. The girder-to-girder distance shall be 7.20 m. The flat single-pitch roof, consisting of steel purlins and asbestos cement corrugated sheets, shall be sloped at an angle of 18 %. The purlin-to-purlin distance shall be 1.15 m.

The roof is to be covered in a way that overlapping lengths of 0.20 cm occur. No drainage elements will be provided on the roof.

The roof dimensions shall be as follows:

head clearance	:	4.30 m	= 14 ft
width	:	15.24 m	= 50 ft
length	:	144.00 m	= 473 ft.

2.4 Water supply

(Drawings K-2.4.1, K-2.4.2, K-2.7.2)

The possibilities of an external water supply of the harbour of Moín are described in chapter J. Concerning the cost factor a connection to the AyA sources seems to be most favourable. Since even in the dry season 40 l/s can be gained the volume of the reservoir can be kept relatively small if supply is provided from there. A second possibility would be to install an infiltration gallery at the slope in the harbour of Moín. From this gallery the water will be led to a pumping station and then to the water tank. To allow an exact structural design of this possibility preliminary investigations are necessary which are specified in chapter J. For this reason, at present a preliminary design can only be made in general.

The water of the sources will be led through perforated stoneware pipes into the discharge basin from where the water is led via tight pipes to the collecting manhole. In front of the collecting manhole a grit catcher is placed from which the water reaches the collecting room via an overflow. The collecting tank is provided with discharge pipe, overflow and drain pipe.

The pumping room equipped with 2 pumps in order to have 1 stand-by pump in case one pump failed is located above this tank. These pumps will pump the water into the elevated tank.

For the water supply in the harbour of Moín the following system was chosen:

- water feeding from the AyA sources or the infiltration galleries to an elevated tank.
- Water distribution in the harbour by gravity via ring lines and dead end lines.

The system shall be designed for the following peak demand:

1. Fire extinguishing water with
   Q_p = 26.6 l/s for 2 hours
2. Bunker water for ships with
   Q_p = 100 m^3/h = 27.8 l/s
2. Drinking water for buildings etc. with
   Q_p = 1.2 l/s

Since it can be assumed that either fire extinguishing water or supply water will be used the network in this pre-design is designed for Q = 30 l/s. Since the peak value for supply water is above that of fire extinguishing water, a separate system for fire extinguishing water can be neglected.

Thus a minimum tank volume of V = 300 m^3 results. This tank would have to be installed at a minimum height of 35 m according to the pre-design in order to guarantee a minimum pressure at the hydrant of 15 m water column. The pipe diameters indicated in the plans also result therefrom.Asbestos cement was chosen as building material. The ring network is so designed that also during repair works of one circular train of pipes the required water quantities and pressures at the oil pier are guaranteed.

2.5 Stormwater and sewage

(Drawings K-2.5, K-2.7.2)

The drainage network is based on design rainfall of Q = 250 l/sha. The water quantity which runs from the eastern slope to the harbour will be collected in a gutter to be constructed in trapezoid shape, led to corresponding collection pipelines and discharged into the sea. This gutter shall not be covered. The remaining feeding gutters shall be of rectangular shape and rounded off at the bottom. If necessary, these gutters have to be covered with I-profiles or railway tracks to allow crossing. The width of the concrete gutters to be covered shall not exceed 50 cm. The depth of the top of the slope shall amount at least to 50 cm. The slope shall be at least 0.005. The diameter of the collector pipes shall be at least 50 cm. The pipe outlets will be secured by special flap valves. The space between the gutters shall be constructed in a roof-like manner. Since the level at which the oil pipelines are conducted is not known sluice pipes in the inlet gutters may become necessary.

The waste water from the administration and the social building will be led to 3 septic tanks and after clearance drained into the ground. The waste water from the gate house will be led to one septic tank and after clearance drained into the ground.

2.6 Power supply and telecommunication

(Drawings K-2.6, K-2.7.2)

Connection shall be provided at the 34.5 KV, 60 Hz overhead line which shall be laid at the main street in the vicinity of the harbour building.

2.6.1 Power demand

of the harbour estimated power demand:

- pier and outdoor lighting
- street lighting
- shed lighting
- cranes
- social building
- office building and gate control
- shipyard building etc.

2.6.2 Electrical supply 220 V - 60 Hz

Amounts to approx. 420 KVA at cos phi 0.85 and utility factor 0.83.

2.6.3 Electrical supply 440 V - 60 Hz

For engine drive as well as supply of extension buildings as shipyard - fertilizer plant etc. about 440 KVA.

2.6.4 Transformer station

Open-air station at the harbour boundary.

34.5 KV - 60 Hz with transformer 34.5/4.16 KV - 1,600 KVA
4.16 KV compartment for supply in the harbour, with
4.16 KV switchgear incoming and outgoing cables.

Transformer station SS 1

Shall be of prefabricated, sheet-steel clad compact-type for outdoor installation and shall consist of:

4.16 KV compartment
transformer compartment with three-phase transformer,
cast resin-type 630 KVA - 230/130 V/ 60 Hz
three phase-four wire system.

Protective measure:

multiple protective earthing and potential equalization.

Transformer station SS 2

As described before
with three-phase transformer 630 KVA - 460 V, 60 Hz
vector group : DY 15
LV-compartment with 0.46 KV distribution board for
connection : machinery and power consumers
service voltage : 3 x 440 V, 60 Hz
three phase-four wire system

MV - 4.16 KV cables

From transformer station to substations SS 1 and SS 2, by means of MV-three-phase cables, directly embedded in the ground.

2.6.5 Outdoor lighting

Pier and area lighting

The lighting shall be provided by high pressure sodium vapor lamps 400 W installed in floodlight devices mounted on concrete poles with platform and access ladder,
height of poles : approx. 25 m
distance : approx. 80 m

Average illumination approx.:

pier : E_{ave} = 20 lux.
on-shore : E_{ave} = 15 lux.

A distribution board shall be mounted at each pole to carry electrical switchgears.

Street lighting

E_{ave} = 15 lux.
plastic lightpoles,
height 12 m
distance approx. 30 m.

Shed lighting

E_{ave} = 60 lux.
ceiling luminaires with fluorescent lamps 65 W.

Navigation lighting

According to international guidelines (acc. to chapter H).

Installations/cables

Power cables 0.6/1 KV from SS 1 to the individual consumers shall be laid in cable ducts.

2.6.6 Outdoor installation

Pier

connections for ships 3 x 220 / 127 V
connections for ships - telephone
laying of cables in cable ducts

Cranes

Connection 3 x 220 / 127 V by means of socket outlets.

Buildings

Each building shall be provided with one main distribution, corresponding to requirements with : 3 x 440 V or 3 x 220 / 127 V.

2.6.7 Telephone system

Designed for 5 direct exchange lines and 30 extensions with exchange installed in the office building to supply:

- office building
- gate house
- pier connections
- workshops.

2.7 Pavement and fencing
(Drawings K-2.7.2, K-2.7.2)

The pavement chosen for the service areas and the Ro/Ro handling areas are concrete slabs and concrete stone pavement. No pavement has been provided in this study for the area behind the oil pier, since there are plans to use this area for a ship-yard and possibly industrial facilities. The same applies for the extension area north of the entrance gate. The two different types of pavement shall be as follows:

Concrete slabs

The concrete slabs shall be double-reinforced slabs of a thickness of 20 cm with the required joints. These slabs shall be laid upon a ballast course of a thickness of about 22 cm where the voids have been filled and compacted by vibration with chippings or screenings. The ballast layer shall be overlain by a bituminous bearing course of about 8 cm thickness.

Concrete stone pavement

The ballast course shall have a thickness of approx. 18 cm .The overlying bearing course of about 18 cm thickness shall be placed in 2 or 3 layers. The concrete blocks of a thickness of about 10 cm shall be laid upon a bedding that shall consist of silica sand of screening with a thickness of 4 cm. The sand bedding shall be stabilized with cement. Attention shall be paid that the concrete stone pavement is separated from the rails by adequate joints to prevent the pavement from breaking up due to rail movements. To make a continuous vertical joint it will be required to fill up the sides of the rails with concrete blocks, in-situ concrete or a bituminous material, before the pavement is laid. For the pavement between the tracking systems square-shaped or rectangular blocks shall be used if the dimension of the blocks used for the normal pavement is not suitable.

The markings on the roads and storage areas shall be effected by concrete blocks of different colours in the case of concrete stone pavement, and roadstuds of aluminium with round heads in the case of the concreted areas, because coloured markings have a low abrasion resistance. The whole port area will be surrounded by a 2.00 m high fence.

2.8 Buildings

(Drawings K-2.8.1, K-2.8.2, K-2.8.3)

The premises in the harbour of Moîn consist of

- social building
- administration building
- gate house.

The repair workshop for the elevators will be integrated into the shipyard complex. The social building with canteen, toilets etc. was designed for approx. 170 men/shift.

The kitchen in the canteen is a mere food warming kitchen with storage boards, sink units and heating facilities. The building is designed as a single-storey building and has an area of about 290 m^2. The office building can satisfy the room requirements for the below mentioned parties:

- shift manager
- rooms for 3 banana companies
- FECOSA
- customs
- JAPDEVA
- sanitary facilities

The office building is a single-storey building with an area of approx. 404 m^2. The gate house at the harbour entrance has to fulfill two functions:

- checking of incoming and outgoing traffic
- management of shunting operations.

Therefore, the gate house is a two-storey building equipped with a checking bridge. In the ground floor there shall be the check point for incoming and outgoing traffic, whereas the shunting management shall be accommodated in the first floor. The total area amounts to approx. 48 m^2.

All three buildings have mainly the same design criteria which will be explained below. The bearing structure consists of a reinforced concrete skeleton which shall be lined with masonry. The ceiling can consist of timber or concrete alternatively. A rafter construction has been chosen as the roof system which will be covered with corrugated asbestos cement. The masonry will be rendered and plastered. The floor cover in the total social building shall consist of stone. The same applies to all toilets, floors and staircases. The rooms themselves shall be laid out with PVC. Windows and doors are made of timber. The checking bridge is laid on reinforced concrete beams. The service gallery is provided with a steel railing and covered with corrugated asbestos cement.

2.9 Ship-yard with berthing pier for harbour-owned boats
(Drawings K-2.9.1, K-2.9.2, K-2.9.3)

Chapter F-3 gives the reason why the decision in this preliminary design has been taken in favour of a solution with a slipway. The crane proposed in this preliminary design is a rail-bounded crane, but an auto-crane can also be used alternatively. The following chapter includes a brief description of the design of the shipyard facilities:

2.9.1 Slipway

The slipway plant is designed in a way that slipped up ships can be:

- repaired on the slip trolley if minor repairs have to be done and
- shifted transverse and lowered again in case of bigger repairs.

The slop trolleys are constructed in a way that longitudinal and transverse shifting can be arranged without turning the ships or lowering them in intervals.

The slop trolleys are constructed that ships with lateral rise of floor can be supported sidewise by means of spindle blocks. Depending on the slope of the rise of the floor, the spindle blocks can be moved and fixed in a pair of girders at any desired position. In case a ship with flat bottoms has to be slipped up, the spindle blocks can be removed completely.

According to the length, weight, and longitudinal centre of gravity of the ship to be slipped up, the slip trolleys are coupled by a distance holder according to the distance of the transverse rail system and are fixed at the initial position. The longitudinal centre of gravity of the ships to be slipped up shall be in the middle of both trolleys. The spindle blocks shall be brought in the probably correct position already before. Both trolleys to be moved exactly to the middle of the rail cross and to be lifted up uniformly by hydraulic lifting cylinders. The bogie wagons to be turned by 90^{o} and the trolleys to be lowered again.

The transverse shifting of the slip trolley will be done by means of warping capstan; steel cables run through a moving single block each, the exact position of which results in the transverse distance. The moving single blocks shall be shackled on the anchorings situated in cavities of the foundation of the shipyard platform. In order to keep the trolley under constant control, the slip cable will be shackled over a moving single block arranged between the rails on a bridle rope which connects both trolleys thus braking the speed.

Arrived on the stocks both slip trolleys will be lifted up simultaneously by means of the hydraulic cylinders; under the ship hard wooden blocks will be arranged in front, in the middle, and at the rear side.

In addition the ship will be supported laterally by means of props. The slip trolleys will be lowered again, the ship rests on the wooden blocks and the slip trolleys can be removed.

After completion of repair, the reverse process will take place for lifting the ship on the slip trolleys.

The transverse back shifting will take place in the reverse way, too, with the exception that the slip trolleys will be pulled by means of a slip cable on the longitudinal rail system. The slip trolleys will be kept under control by means of an auxiliary cable running over the warping capstan.

The launching will be done by the warping capstan by means of an auxiliary cable running over a system of guide pulleys.

In order to control constantly the passing from the horizontal to the gradient the slip trolleys are fastened with the slip cable. The ship can then float off in the initial position.

2.9.2 Technical Specifications

Slipway

The slipway shall have an inclination from top to bottom of 1:15 overcoming a difference in altitude of about 10.00 meters.
The works shall be carried out in an open construction pit. The rails for the four-rail trolley shall be fastened on reinforced in-situ concrete slabs. The slabs under water shall be 12.10 m wide and 15.00 m long. Their thickness has to be 0.60 m. Above the water surface, their length is about 4.00 m and their thickness 0.40 m.

The reinforced concrete slabs shall be laid upon a compacted gravel layer. Dolphins shall be driven on the right and left side of the foot of the slipway. Slope protection under water shall be provided by a gravel layer. Above water slope protection shall consist of rip-rap. The rails in the transition area to the repair place shall be arranged parabolically.

Repair Areas

The repair area shall have a width of 80.00 m and shall be about 40.00 m long in the towing direction. This area is covered by reinforced in-situ concrete slabs of about 50 sq.m. each, founded in a compacted gravel layer.

The thickness of the slabs from bottom of rails to improved subgrade amounts to 0.40 m. To enable cross movement, 12 rails shall be fastened on the concrete slabs acc. to the gauge of trolley.

The top of the rails shall be flush with the slab surface. All return pulleys and bollards for the rope guidance of the slipway and cross-moving system shall be firmly anchored in the reinforced concrete slabs. The water-side slab edges shall be protected by a ground beam or a driven pile sheeting wall of reinforced concrete piles. This pile sheeting wall will not be exposed to vertical forces but only to earth pressure.

2.9.3 Winch House

The ground area of the winch house shall be approx. 6.00 m x 3.00 m. The anchors for the rope winch shall be embedded in the reinforced concrete slab which shall have a thickness of about 0.50 m. The rising brickwork will support the wooden roof construction. The roof cover consists of asbestos cement corrugated sheet.

2.9.4 Repair Hall

The repair hall shall be a light steel construction with isostatic systems in both the longitudinal and the transverse direction. The ground area of the two-span hall is about 20.00 x 70.00 m; the girder-to-girder distance is 6.50 m while the head clearance in the hall is about 5.00 m. Both aisles of the hall shall be equipped with an overhead travelling crane with crab of an 8 Mp lifting capacity. The crane rails shall extend beyond the southern end of the building by 8.20 m. Both cranes are so designed that they can take up loads outside and can carry them inside the hall building.

Single foundation bases shall be provided under all columns and strip foundation under all external walls. The stiffening of the building in transverse direction shall be effected by the intermediate columns which are fixed in the single foundation bases. In each row of columns there will be braces to provide stiffening of the building in the longitudinal direction. The reinforced concrete floor slabs, d = 15 cm, shall be poured in sections of about 50.00 sq.m. and shall be separated from one another by 1 cm joints. The soil slabs shall rest upon a compacted layer of gravel.

The roof shall be sloped toward the longitudinal sides of the building at an angle of about 10^{0}. The roof cover shall consist of asbestos cement corrugated sheets. No provision will be made for roof drainage. Ventilation of the hall will be effected by providing special roof sheets with openings. The external walls, up to the level of the first steel girt, i.e. about 2.00 m above floor, shall be built of 20 cm thick brickwork. This brickwork shall be left without rendering, only the joints shall be properly pointed to become a smooth area.

Above that, the wall consists of asbestos cement corrugated sheets. Illumination of the hall will be provided by high-level window rows on both longitudinal sides of the hall. Both window rows will be separated by gates with a man-door on one side.

The gates at the southern gable wall (crane rail extension) shall be steel-sheet sliding gates or folding gates.

All steel parts of the hall construction shall be protected suitably against corrosion (sand blasting, two protective prime coatings, two finish coatings).

2.9.5 Berthing Pier

The pier edge of the berthing pier shall be protected by a steel sheet piling with a single-type anchorage. Shore-side directed forces and earth pressures will be taken up by steel cable anchors which shall be fastened to anchor plates in the ground. The sheet piling head shall consist of a reinforced concrete beam manufactured on site.

The protection of the shore-side upper pier edge shall be provided by a quarter-circle edge protection with claws. This reinforced concrete beam will also hold the anchorages of bollards and fastening devices for the fendering system.

Anti-corrosion measures of the steel sheet piling wall shall be chosen according to local requirements.

The backfilling of the sheeting wall up to the required height of the ground surface will be followed by a gravel layer which shall be adequately filled and compacted. Upon this layer, the concrete paving will be embedded in sand.

L. COST-BENEFIT ANALYSIS

1. Introduction

Investments allocated to the Ports of Limôn and Moîn as the major ports of Costa Rica for external trade are of fundamental influence for the development of the country. Foreign exchange earnings derived from trade are important to the Costa Rican economy.They form the basis for purchase of capital goods and other necessary imports. Production for export provides substantial employment.

As stated in the National Development Plan 1979-1982[1], the public sector is expected to be first of all economic development efforts. Thus, beyond the commercial horizon of the JAPDEVA, which is the responsible agency for the administration and operation of the Port of Limôn, port investments have to be analyzed on the extent to which they serve best the development aims of Costa Rica.

The major national objectives include maximization of real income, stimulating growth of economy, increasing the employment level and generating more trade.

The improvement of transport facilities is an essential precondition for the fulfillment of these objectives. Thus, as contribution to the national objectives port investments serve the needs and requirements of Costa Rican international trade. The port development schemes, outlined in Chapter F are planned to provide sufficient and adequate port facilities and an efficient performance of port operation for continuous flow of good in and out of the country.

To state economic attractiveness of the proposed improvements at Limôn/Moîn, the benefit-cost analysis is applied.

The method applied, the respective costs and benefits of the individual measures as described in Chapter E and F are outlined in the following as to their major assumptions and finally compiled in the benefit-cost analysis.

The project period covered by the benefit-cost analysis starts with the full utilization of the "Proyecto Aleman" which is probably not before the end of 1981 and at which time although all the construction works at Moîn, at present underway and additional not yet commenced, will be finished. Thus, the analysis period was taken as the span between 1982, when the Ports of Limôn and Moîn are fully operating, and the year 2000.

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1) Plan Nacional de Desarrollo 1979 - 1982, "Gregorio Josê Ramirez" OFIPLAN, San Josê, Costa Rica 1979

2. Estimation of shadow prices

2.1 General

The basic economic problem facing all countries is that allocating inherently limited resources (such as labour, capital, land, as well as foreign exchange etc.) to a variety of different uses in such a way that the net benefit to society is as large as possible. Given the limitation of resources, choices must be made among the competing uses.

At a general level, nearby all countries may be assumed to have two primary and simultaneous objectives: to increase the national income, the growth objective, and to improve the distribution of national income, the equity objective.

Project analysis assesses the benefits and costs of a project and reduces them to a common denominator. For this, economic costs and benefits are measured by "shadow prices", which may well differ from the market prices appropriate for financial costs and benefits.

The "shadow" price of a commodity is defined as the market price at which the supply of the commodity is just sufficient to satisfy the demand. In the context of a free market economy in equilibrium the actual prevailing market price for a commodity is the price at which the supply-demand relationships is in equilibrium.In such a context, the "shadow" price and the actual prevailing market price are identical.

Where there are significant constraints or imperfections in the natural operation of a free market economy, a discrepancy is introduced between the actual prevailing market price and the "shadow" price of a commodity. The greater the deviation from a free market economy, the greater the discrepancy between actual prevailing market prices and "shadow" prices. In other words, the result of substantial market imperfections is that actual prevailing market prices fail to represent accurately economic costs. The concept of "shadow" prices is thus introduced to provide a monetary correction to an imperfect market measure of resources consumed in the production of a commodity. The resources to which "shadow" prices are mostly commonly and effectively applied are cost of capital, wages, and foreign exchange.

If one assumes, that at the margin all units of income were equally valuable from the growth point of view and ignored the equity objective; such shadow prices are here referred to as "efficiency prices".

Recently, planners and theorists came to the realization that the separation of the growth and equity objectives may not be justified: that is,
that the resp. Government's ability to redistribute income in general may be limited. On this basis it was concluded that project analysis should investigate the impact of projects not only on the distribution of income between consumption and investment but also on the distribution of income between the rich and the poor. Shadow prices that include both these distributional aspects are described as "social prices".

2.2 Labour

Where there are regulations on wages (such as minimum wage laws) or inflexibilities in the employment practices, the result is that in some case the actual, prevailing wage rates may not properly reflect the real (i.e. economic) cost of labour. In situations of high unemployment or underemployment, the real cost of unskilled labour is less than actual wages.

Where there appears to be significant discrepancy between actual, prevailing wages and the real economic cost of labour, a "shadow" price for wages is utilized. The "shadow" price is the economic cost of labour. The "shadow" price for wage rates is difficult to estimate and cannot reasonably be undertaken within the context of a Port Masterplan study. It should be noted, however, as the case for Costa Rica, Governmental regulations for conducting economic studies could be used and time consuming other research work avoided.[1] The opportunity costs of labour referred in this report are defined as social prices.

It should be pointed out that if a shadow price for unskilled labour were introduced the result would be to reduce the economic cost of construction. There would be no basic change in economic operating costs because the direct labour in these costs is for the most part skilled (mechanics, drivers, transport enterprise, administrative) staff.

At first step in finding methods for calculating the social price of labour (shadow prices or opportunity costs) is to make an analysis of the labour market with the aim of investigating its characteristics and effects independent of the attitude one adopts finally towards the most reasonable shadow price. Related to these characteristics. the market price can either be correctly calculated or can deviate from the social opportunity costs of the factor 'labour'.

The before mentioned study of OFIPLAN has considered the following aspects in the analysis of the labour market of Costa Rica:

A Population
B Manpower
C Employment
D Wages and salaries
E Unemployment
F Migration
G Social charges

The sources used to get information were demographic surveys and, in particular, national surveys of households, employment and unemployment rates that have been conducted in 3-months intervals since July 1976. In addition to the available published data, further information has been obtained from the wage and salary lists of this survey from the Ministry of Labour and Social Affairs. For the first two points above, the growth rates were analysed according to town/country and male/female population. For the employment analysis, not only the related growth rate divided up according to town, country and female/male population was analysed, but also the development of industries as a source of creating job places, the various categories (employee, employer, self-employed businessmen as well as family members without any earthings) and different professions (independent profession,s employees, workers, etc.) with

[1] OFIPLAN, Seminario sobre los precios sociales en la evaluaciōn de proyectos, Julio 1979

particular consideration to the classification of workers and craftsmen. The reason that special consideration was given to these professions is that it is intended to estimate the social price of the unskilled workers, since this group plays an important role in every investment project because of its participation in the opportunity costs.

Investigated under the item wages and salaries were the real wages in the different industries, the effects of the minimum wages determined by the central government on the wage level of the market and, in particular, the difference between the wages of unskilled workers in agriculture and unskilled workers in the cities. The study about unemployment was carried out separately according to zone, region, sex, age and education. Not only the evident unemployment but also apparent under-employment has been analysed.

From an analysis of the 8 items above the conclusion can be drawn that the characteristics of the labour market in Costa Rica are as follows:

- Large mobility of manpower (at least geographically).
- Lack of effective minimum wages determined by the government. Even if there is a minimum wage determined annually by the government, the market wage is always higher.
- Wage levels are influenced mainly be supply and demand. There are no major "protected" markets.
- Based on the available information it can be concluded that the unskilled workers employed in the country and in the town receive wages which correspond to the amount of their limit contribution to the gross national product.
- This results form the high percentage of employees in the working population the high percentage of employees working 40 hours a week or more and from the low unemployment rate.
- The difference between the wages of unskilled workers in agriculture and those in other fields in the city can be explained above all by the difference in the local cost of living, that is most of the time a compensating difference.
- The only sector where the government intervenes is the social charges imposed on employees and employers. For the employer these social expenses mean more or less taxes on the utilization of manpower, and for the unskilled workers it is assumed that both contributions reflect the value these workers contribute to the social insurance for their performance.
- The average real wages increased in the last 10 years by 3.6 % annually, and during the past 5 years by 2.6 %, despite a very unequal growth of the average wages in every industrial branch within the mentioned periods of time.
- Low unemployment figures in the town and in the country.

From these characteristics results that the market wages for unskilled workers and craftsmen in rural regions and in cities generally determine the opportunity costs of manpower.

2.3 Cost of capital

The economic or "shadow" cost of capital is referred to as the opportunity cost of capital. The opportunity cost is the value or return to capital that could be achieved by the best alternative investment of the capital. The actual interest paid on a capital loan is the financial cost of capital. This often has little relationship to the opportunity cost of capital. This is because government regulation of the capital market and government tax and subside policies can and do dramatically effect the financial cost of capital.

The World Bank and United Nations have carried out a number of studies in selected countries to determine the opportunity cost of capital in those specific countries. Opportunity costs of capital for developing countries can be as high as from 15 % to 20 %. Since OFIPLAN has established a manual for project evaluation, their figures should be applied within the Masterplan study. OFIPLAN prefers the use of a "social rate of capital return" rather than the use of the more common "internal rate of capital return". OFIPLAN and most contacted experts agree that the economic cost should be at least 12 % but more realistic 16%.

The opportunity cost of capital recommended for this study are within a range of 10 to 16 % as for section 6, - Uncertainty, Sensitivity and Risk - and for the general calculation of respective net present values and economic rates of return in section 4, a rate of 16 % is applied.

2.4 Foreign exchange

Where a currency is freely convertible in an open market with other currencies, the prevailing foreign exchange rate typically approximates the economic cost of foreign exchange. In the case of a controlled currency, however, the official regulated exchange rate does not typically correspond to the economic cost of foreign exchange. When there appears to be significant difference between the two exchange rates, a "shadow" price (i.e. economic price) for foreign exchange is introduced for foreign exchange calculations.

The relative difference between the two exchange rates can often be indirectly assessed. For example, where a premium (i.e. discount) is offered for purchase made in freely convertible foreign currencies,the magnitude of the premium can be used as an indicator. Likewise, the prevailing exchange rates on the so-called "black-market" can also serve as an indicator.

In the opinion of financial experts contacted in Costa Rica the present fixed exchange rate does not represent the true value of exchange. It is estimated, that 1 US $ is affected by not less than 10 ₡ but a probably higher figure in comparison to the official exchange rate of 8.54 ₡. The exchange rate used within the study is assumed to be 13 ₡. Therefore, the foreign exchange element in costs has been shadow priced 40 % above the market rate to reflect its true value.

Taking into account such indicators, foreign exchange costs have an economic cost which is 40 % greater that the official exchange rate. Likewise foreign exchange benefits would have economic benefit which is 40 % greater than the official exchange rate. Pending further research into this subject area, it is recommended that this preliminary figure be used for feasibility studies in the immediate future.

3. Identifying of relevant costs and benefits

3.1 Cost of proposed investment at Limôn / Moîn

3.1 General

The costs of the port development program which have been specified in Chapter E and F (operational and engineering section) are compiled and structured for the economic evaluation by the following criteria:

- allocation of costs related to the different port development schemes

- kind of costs: investment and operating cost

- allocation of cost in time

The costs which are estimated for each year of the project period cover only the Masterplan development program and do not refer to existing facilities and such under construction, which are expected to be in operation by the end of 1981. They also do not refer to existing facilities and performance of Japdeva and Recope.

Principally, all cost inputs of this chapter are given net of taxes and at the price level of 1980. In order to reach this, to all construction costs given in chapter F, tables F.2-1/2, which are in 1979 prices, an inflation rate of 15 % is added according to an increase in construction material prices as experienced for the period January 1979 to September 1979.

3.1.2 Allocation of costs related to the different port development schemes

In chapter F the different port development schemes according to normal increase of traffic volume (case A) and in relation to a 100 per cent containerization of Banana export commodity (case B) have been elaborated and discussed.
Cost estimates as presented in the following follow this procedure: all investments - in equipment and for structural works and infrastructure - are split up in such a way that for each berth/commodity the relevant investments are calculated separately.

3.1.3 Equipment investment (Case A)

3.1.3.1 Investment and operating cost

All investment costs for new equipment according to Chapter E are given in US $, whereby the cost estimate is based on European experience (if costs are employed in DM, an exchange rate of 1 $ equal 1,80 DM is used). All costs of investment refer to CIF-Limón, the cost level is 1980.

The investment costs stated in the tables L-1 to 5 do not include spare parts and training of operating labor. The figures set out in these tables are based on approximate annual maintenance costs as a percentage of the equipment purchase price. Half of these costs in Europe represent the cost of trained labour.Ports in developing countries usually need to alter the labour cost element, but for the purpose of this study a total figure is entered in the tables.

Depreciation is calculated on a straight linear basis and an assumed economic life. Equipment replacement may be needed on two accounts: gradual deterioration or obsolence and sudden failure. Since reliable data on maintenance cost trends could not be obtained,guideline figures as stated in the UNCTAD publication "Port development" have been employed. These figures are basically derived from European experience and the Consultants own knowledge of German Ports, but they are broadly applicable to developing countries since the longer life justified by the lower labour cost is offset by the generally more intensice use under more arduous climate conditions.

If the economic life time of an investment object expires within the project period and the rest value, indicating the difference between investment and the accumulated depreciation costs become zero, a reinvestment takes place automatically in the following year. The rest value as compiled for the end of the project period in the year 2000 is entered lateron into the cost-benefit-analysis on the benefit side.

In addition to the a.m. breakdown of the investment costs the foreign exchange component visualizes the effect of the economic evaluation.

3.1.3.2 Equipment costs for Muelle 70

Proper operation of the assigned cargo to be loaded and unloaded at Muelle 70 require the following equipment: In 1982 13 forklifts, 9 with 3 t load capacity, 4 with 7.5 t capacity, 5 trucks and 15 trailer. Equipment replacement and maintenance costs in relation to the investment are given in the table on the following page.

In 1990, resp. 1998 this equipment has to be replaced, and an additional forklift of 3 tons capacity must be purchased. No consideration was made for calculating the need for slinging gear, pallets etc. as these items are included in the economic evaluation of the "Proyecto Aleman".

Maintenance Repair per anum

	Lifetime years	investment (i) (US $)	M+R costs p.a. (in % of i)
Forklifts	8	---	---
3 t		35,000	14
7.5 t		80,000	14
Trucks	8	85,000	10
Trailer	8	12,000	3

The total investment and operation (maintenance)costs are listed in Table L-1, resulting from the allocation of costs to the individual years of the project period from 1982 to 2000. After the allocation of the investment costs according to the year of full operation and the construction (purchase) period given in semi-annual terms, the operating costs start in the first year following the construction period. The operation costs are held constant throughout the project period on a level of full capacity utilization.

3.1.3.3 Additional equipment cost - Berth 10

The equipment referred to in the following base on the assumption, that the future cargo volume assigned to berth 10 cannot be handled if no additional equipment in access to the existing facilities and that equipment purchased for "Proyecto Alemån" will be available.

Therefore, in this analysis Ro-Ro trucks and 9 trailers as they belong to stage H-0 (Proyecto Alemån) investments, have not been considered.

According to the foregoing chapters E and F as well as the traffic forecast the following new equipment is necessary for operation in 1982:

13 forklifts of 3 tons capacity
1 forklift of 7.5 tons capacity

Replacement shall take place after 8 years, i.i. in 1990 and 1998 respectively.

Investment costs, lifetime and maintenance requirements are similar to those stated in section 3.1.3.2 of this chapter. Table L-2 gives the total investment and maintenance costs and the allocation of costs in time for the project period.

Table L-1 : Additional Equipment for Muelle 70

Investment Cost :	US $ 1,240,000
Foreign exchange :	40 % 496.000
Total investment cost :	US $ 1,736,000
Annual maintenance and repair cost :	US $ 191,520

Starting year of investment : 1981 Year

Construction period : 1981 Year

Depreciation : US $ 217,000 Per Year Lifetime : 8 Years

ALLOCATION OF COST IN TIME
(IN US $)

Year	Investment/ Reinvestment	Annual Cost	Depreciation	Rest Value
1980				
1981	1,736,000			
1982		191,520	217,000	
1983		191,520	217,000	
1984		191,520	217,000	
1985		191,520	217,000	
1986		191,520	217,000	
1987		191,520	217,000	
1988		191,520	217,000	
1989		191,520	217,000	
1990	1,785,000 (6,860)	198,380	223,125	
1991	plus one new forklift (3 t)	198,380	223,125	
1992		198,380	223,125	
1993		198,380	223,125	
1994		198,380	223,125	
1995		198,380	223,125	
1996		198,380	223,125	
1997		198,380	223,125	
1998	1,785,000	198,380	223,125	
1999		198,380	223,125	
2000		198,380	223,125	1,115,625

Table L-2 : Equipment for Berth 10 (General Cargo)

(General Cargo)

Investment Cost : US $ 640,000

Foreign exchange : 40 %

Total investment cost : US $ 896,000

Annual maintenance and repair cost : US $ 125,440
(14 % of investment cost)

Starting year of investment : 1981 Year

Construction period : 1981 Year

Depreciation : US $ 112,000 Per Year Lifetime : 8 Years

ALLOCATION OF COST IN TIME
(IN US $)

Year	Investment/ Reinvestment	Annual Cost	Depreciation	Rest Value
1980				
1981	896,000			
1982		125,440	112,000	
1983		125,440	112,000	
1984		125,440	112,000	
1985		125,440	122,000	
1986		125,440	112,000	
1987		125,440	112,000	
1988		125,440	112,000	
1989		125,440	112,000	
1990	896,000	125,440	112,000	
1991		125,440	112,000	
1992		125,440	112,000	
1993		125,440	112,000	
1994		125,440	112,000	
1995		125,440	112,000	
1996		125,440	112,000	
1997		125,440	112,000	
1998	896,000	125,440	112,000	
1999		125,440	112,000	
2000		125,440	112,000	560,000

3.1.3.4 Additional equipment costs - Berth 11

The costs of equipment investment dealt with in this section refer to additional equipment to the facilities assigned for operation of the Proyecto Alemân. Study case H-0, which is understood as full operating Proyecto Alemân, includes the following equipment:

1 Container crane
3 Van carriers
Chassis trailer and lifting gear

According to the cargo forecast it is necessary to improve the equipment in order to satisfy the future cargo handling requirements (study case A/1). Therefore comparison was made for additional equipment fulfilling these needs as shown below:

Year	Equipment H-0		New Equipment A/1		Total A/1 Equipment		Replacement H - 0		Replacement A/1	
	crane	VC	crane	VC	crane	VC	crane	VC	crane	VC
1980	1	3	-	-	1	3	-	-	-	-
1981	1	3	-	-	1	3	-	-	-	-
1982	1	3	-	-	1	3	-	-	-	-
1983	1	3	-	-	1	3	-	-	-	-
1984	1	3	-	-	1	3	-	-	-	-
1985	1	3	-	2	1	5	-	-	-	-
1986	1	3	-	-	1	5	-	-	-	-
1987	1	3	1	1	2	6	-	-	-	-
1988	1	3	-	-	2	6	-	3	-	-
1989	1	3	-	1	2	7	-	-	-	-
1990	1	3	-	-	2	7	-	-	-	-
1991	1	3	-	-	2	7	-	-	-	2
1992	1	3	-	-	2	7	-	-	-	-
1993	1	3	-	1	2	2	-	-	-	1
1994	1	3	-	-	2	8	-	3	-	-
1995	1	3	-	-	2	8	-	-	-	1
1996	1	3	-	-	2	2	-	-	-	-
1997	1	3	-	1	2	9	1	-	-	2
1998	1	3	-	-	2	9	-	-	-	-
1999	1	3	-	-	2	9	-	-	-	2
2000	1	3	-	-	2	9	-	3	-	-

The costs of this additional equipment, as well as replacement and maintenance base on the following assumptions:

Table L- 3 : Additional equipment cost for Berth 11

Investment Cost : US $ 3.0 Million (container crane); US $ 472,000 (1 VC)

Foreign exchange : 40 %

Total investment cost : US $ 4.2 Million (container crane); US $ 660,800 (1 VC)

Annual maintenance and repair cost : 12 % for crane
5 % for VC

Starting year of investment : 1984 Year

Construction period : 1984 Year

Depreciation : crane 280,000 Per Year Lifetime : crane 15 Years
VC 110,000 VC 6

ALLOCATION OF COST IN TIME
(IN US $)

Year	Investment/ Reinvestment	Annual Cost	Depreciation	Rest Value
1980				
1981				
1982	660,800 · 2			
1983	1321.600			
1984	1,321,600			
1985		159,600	220,220	
1986	4,2 + 0,66	159,600	220,220	
1987	4,860,800	449,400	610,330	
1988		449,400	610,330	
1989	660,800	529,200	720,440	
1990		529,200	720,440	
1991	1,321,600	529,200	720,440	
1992		529,200	720,440	
1993	1,321,600	609,000	830,550	
1994		609,000	830,550	
1995	660,800	609,000	830,550	
1996		609,000	830,550	
1997	1,982,400	688,800	940,660	
1998		688,800	940,660	
1999	1,321,600	688,800	940,660	
2000		688,800	940,660	1,822,940

3,000.000
40% 1,200.000
4,200.000
660.800
4800.800

Table L-4 : Additional equipment for banana pier Moin

Investment Cost : US $ 500,000 (used elevator) — 4 grúas

Foreign exchange : 40 %

Total investment cost : US $ 700,000

Annual maintenance and repair cost : 5 % of new crane cost (1.3 Million)

Starting year of investment : 1981

Construction period : 1981

Depreciation : US $ 58,333 Per Year Lifetime : 12 Years

ALLOCATION OF COST IN TIME (IN US $)				
Year	Investment/ Reinvestment	Annual Cost	Depreciation	Rest Value
1980	500.000 + 40% 200 700.000			
1981	700,000			
1982		91,000	58,333	
1983		91,000	58,333	
1984		91,000	58,333	
1985		91,000	58,333	
1986		91,000	58,333	
1987		91,000	58,333	
1988		91,000	58,333	
1989	700,000	182,000	116,666	
1990		182,000	116,666	
1991		182,000	116,666	
1992		182,000	116,666	
1993		182,000	116,666	
1994		182,000	116,666	
1995		182,000	116,666	
1996		182,000	116,666	
1997	700,000	182,000	116,666	
1998		182,000	116,666	
1999		182,000	116,666	
2000		182,000	116,666	291,667

Equipment	Lifetime years	Investment (in US $)	M/R costs p.a. (% of i)
Container crane	15	3,000,000	5
Van Carrier	6	472,000	12

The related costs and allocation of these costs in time are summed up in table L-3.

3.1.3.5 Equipment costs for Banana piers at Moín

At present there are 4 gantry elevators available at Moín for loading of the Bananas after completion of the port works. The findings of chapter E-6, Port operation-Banana handling, showed that in order to serve the forecasted amount of banana boxes in the future years for case A, these 4 elevators work under tight operational performance. It is pointed out, that supply of a fifth elevator would reduce overall berthtime substantially below 24 hours and reduces the utilization ratio. It is suggested therefore to purchase a fifth elevator crane in 1982.

No van a usar fajas para los otros atracaderos

Since no other data are available, the following assumptions upon investment cost, lifetime maintenance and repair costs have been made: the purchase price of a new elevator crane would be in the range of US $ 1.3 Mio., but it could although be possible to receive a used crane similar to the four existing cranes. For the following calculations a price of US $ 500,000 has been entered as a cost input, but maintenance costs are based on new equipment purchase price (5 % per annum). Economic lifetime is assumed as 15 years.

Table L - 4 shows the total investment costs and the annual schedule of the investment, operating and depreciation cost for the study period, proposing purchase of a used elevator crane. In the table it is indicated that in 1989 a sixth' crane would although be necessary to handle efficiently and economically the forecasted export volume. Rest value at the end of the period are entrered into the C/B analysis as benefit input.

3.1.3.6 Summary of equipment cost

A summary of total equipment cost including annual maintenance and repair is given in tables L - 5/6.

Explanation to Table L-5 on the following page:

1) Rehabilitation of Muelle 70, construction of entrance gate house
2) Interchange Avenida 1/Calle 9, 60 % of rehabilitation costs of railyard Limón
3) Refer to table L-1
4) Costs include rehabilitation of traffic ways inside part, Ro/Ro storage area, dredging costs, demolition of berth 1 at Muelle Metalico (but no maintenance dredging)
5) Include widening and paving of Avenida 1, and 40 % of rehabilitation cost of railyard.
6) Refer to table L-2
7) Workshop, fences etc.
8) Refer to table L-3

Table L-5 : Summary of investment cost for construction and equipment measures, case A, Limón *)

LIMON	MUELLE 70			BERTH 10			BERTH 11		
YEAR	STRUCTURES 1)	INFRA-STRUCTURE (RAILROAD) 2)	EQUIPMENT 3)	STRUCTURES 4)	INFRA-STRUCTURE 5)	EQUIPMENT 6)	STRUCTURES 7)	EQUIPMENT 8)	TOTAL INVESTMENT COST (000 US $)
1980	-	-	-	-	-	-	-	-	-
1981	1,073	2,603	1,736	2,996	1,657	869	4,657	-	15,618
1982	16	30	192	30	23	125	35	-	451
1983	16	30	192	30	23	125	35	-	451
1984	16	30	192	30	23	125	35	1,322	1,773
1985	16	30	192	30	23	125	35	160	611
1986	16	30	192	30	23	125	35	160	611
1987	16	30	192	30	23	125	35	5,310	5,762
1988	16	30	192	30	23	125	35	449	901
1989	16	56	192	30	51	125	35	1,190	1,695
1990	16	30	1,903	30	23	1,021	35	529	3,669
1991	16	30	198	30	23	125	35	1,850	2,309
1992	16	30	198	30	23	125	35	529	987
1993	16	30	198	30	23	125	35	1,931	2,389
1994	16	30	198	30	23	125	35	609	1,067
1995	16	30	198	30	23	125	35	1,270	1,728
1996	16	30	198	30	23	125	35	609	1,067
1997	16	56	198	30	51	125	35	2,671	3,184
1998	16	30	1,983	30	23	1,021	35	689	3,829
1999	16	30	198	30	23	125	35	2,010	2,469
2000	16	30	198	30	23	125	35	689	1,147
RV **)	258	886	1,116	150	534	560	1,152	1,823	6,479

*) Rounded to full 1,000; Basis 1980

**) Rest value

Table L-6 : Summary of investment cost for construction and equipment measures, case A, Moin

	MOIN		
YEAR	EXTENSION BANANA PIER [1)]	ADD. EQUIPMENT (ELEVATORS) [2)]	TOTAL INVESTMENT COST (000 US $)
1980	-	-	-
1981	2,519	700	3,219
1982	13	91	104
1983	13	91	104
1984	13	91	104
1985	13	91	104
1986	13	91	104
1987	13	91	104
1988	13	91	104
1989	13	882	859
1990	13	182	195
1991	13	182	195
1992	13	182	195
1993	13	182	195
1994	13	182	195
1995	13	182	195
1996	13	182	195
1997	13	882	895
1998	13	182	195
1999	13	182	195
2000	13	182	195
RV [3)]	1,162	292	1,904

1) extension of 2. banana pier (68.40 m)

2) supply of additional elevators (5. elevator in 1981 etc. refer to Table L-4)

3) RV - rest value at year 2000

104+63?= 47?

3.1.4 Construction costs (case A)

Preliminary construction design was drawn up in which the quantities for the main construction parts were stated and unit prices worked out (see chapter F). The following illustrates which prices were used to determine the individual costs of the main construction parts of case A development, as they were used as input in the benefit-cost analysis.

While breakdowns in mechanical or electrical equipment and the deterioration of roads and buildings is evident, the need for maintenance of the basic breakwater, wharf and jetty structures is less noticeable but not less important.

Since the engineer could not realize reliable cost data on port structure maintenance while being in Costa Rica, estimates of maintenance costs similar to those which have been suggested by UNCTAD were used in the following table (see table L-5).

In particular, for each of the investment items as compiled in chapter F-8 the following additional cost factors have been included:

- Design and engineering 4 % added to the construction cost
- Maintenance and repair as percentage of investment cost

  1 % annual for railway works,
  1 % plus 2 % administration costs
  for road and pavement works,
  1.5 % structural works
  1.5 % general works.

IMP.

Furthermore, for most of the works, the import portion of the design and construction costs has been estimated. In the respective tables in the annex of this chapter, the method of cost calculation is shown on the example of Muelle 70.

A summary of all investment costs referring to construction measures and equipment supply as applied in the cost-benefit analysis is given in table L-5 for Limón and table L-6 for Moín.

3.1.5 Construction costs (case B)

In Chapter F construction cost estimates have been established for the different port development alternatives. These costs are based on present-day costs (1979) and it should be mentioned that inflation rates in construction costs have not been assessed. The costs base on rough engineering estimates for the major structural items, including contingency allowances of about 10 % and engineering and design costs of about 4 %. A pretence of a greater accuracy in this stage of masterplanning should be avoided (usually ± 20 %), bearing in mind, that the degree of confidence in the cost estimates will increase as more design work is carried out, i.e. preliminary design similar to case A development.

For the economic evaluation, it should be remenbered, that traffic and shipping forecasts cannot be any more precise.

The cost estimates have been divided into portions of local and foreign currency, under the assumption that a foreign Contractor will be chosen with a larger foreign exchange component.

Annual average maintenance costs for structural elements are assumed for estimating purposes to amount to 1.5 %.

The following gives a summary of the total construction costs of the alternatives worked out in Chapter F:

Alternative Case B	Total construction costs[1] (000 US$) local (20 %)	foreign	forex.	Total	M/R
Limón:					
(1) 1 container terminal (1 berth)	12,082	48,328	19,331	79,741	1,200
(1b) 1 container terminal (2 berths)	16,449	65,795	26,318	108,562	1,628
(2) 1 container-gen.cargo terminal (1cont.berth 1gen.cargo berth)	12,380	49,519	19,808	81,707	1,225
Moín:[2]					
(3) 1 container terminal (1 berth)	8,399	33,597	13,439	55,435	831
(3b) 1 container terminal (2 berths)	13,110	52,482	10,993	86,585	1,299

1) including 10 % contingencies and 20 % mobilization (incl. site installation); using 15 % price inceasing for 1980 prices.
(values from tables F 8-3 to F 8-7, chapter F.6)

2) Relocation cost of River Moín outflow as well as maintenance dredging in the port basin and entrance channel excluded.

3.2 Benefits of proposed investments at Limón / Moín

3.2.1 Identifying of project benefits

The difficulties of benefit-cost analysis in the field of port evaluation do not lie in measuring the costs involved as in quantifying the benefits. It could be thought that all what is needed are the differences in the market prices of sea transport services between the situation which will exist with the development program initiated and that which might be expected to exist without the project. But the quantification of these differences is rather sophisticated and can be made to a large extent only intuitively and not on the basis of rational mathematical calculations.

The Masterplan Development Program results in two major kinds of benefits:

- Benefits due to rehabilitation measures on port operation and equipment after construction of Projecto Aleman and the port facilties at Moín (mainly case A)
- Benefits of the new construction of an additional container berth (case B)

When evaluating the development program, a breakdown into three cargo groups was necessary:

- General cargo and break bulk
- Containerized cargo
- Bananas

The quantification of the general cargo and break bulk benefits induced by modern equipment and operation methods includes savings in:

- Congestion surcharge
- Ship and cargo waiting time
- Dwell time savings

whereas the benefits of investment in banana handling methods will consist mainly of:

- Reduction in ship waiting time for berth and reduction in ship time at berth

3.2.2 Distribution of benefits

The benefits accruing from the port development program according to Chapter F are transport cost savings identified when comparing the port related costs "without" and "with" the project. Due to the increasing importance attached to the container technology for the general cargo system and banana export during the Masterplan period the savings refer basically to the specialization and unitization of cargo.

General cargo transport costs are essential components of the domestic price of goods. Principally, the effect of the Masterplan program is to lower the port related transport costs. It is assumed, that the cost savings accruing from the national port users are fully accounted as national benefits. This assumption, however, is not as optimistic as it looks since additional benefits from induced traffic will eventually compensate the variation between export and import incidence ratios.

Quantifyable benefits from the project include the below listed savings which have been identified as being attributable to the Costa Rican economy; not quantifyable benefits are listed as indirect benefits for reasons of introducing the involved problematic.

I. Surcharge savings

Surcharges levied by conference lines are usually the result of excessive waiting times. Any port rehabilitation and expansion program that reduces the waiting time to normal will yield benefits in form of foreign exchange savings and other monetary effects associated with reduced ship waiting times. The savings are expressed in US $ per freight ton and should accrue directly to the Costa Rican economy-

II. Reduction in ship time waiting for berth and at berth

Savings are expressed in operating costs, in US $ per ship per day. These benefits should accrue to Costa Rica through avoidance of demurrage until the port begins to be fully utilized.

The improved cargo handling rates resulting from the projects will reduce the time alongside berth for ships to load (discharge) cargo. These savings for instance are expected to amount to 2,000 ship days in 1980 for Muelle 70, increasing thereafter with traffic growth.

A major part of savings related to general cargo liner and charter ships could accrue to Costa Rica in the form of lower charter rates or higher port charges for a better level of service.

In calculating the economic return, only half of these benefits are assumed to accrue directly and immediately to the Costa Rican economy due to uncertainty over whether the entire savings will be passed on to Costa Rica immediately by the shipping lines.

These benefits could be expressed to a high amount as "foreign exchange" benefits, since the majority of shipowners calling at Limón are foreign companies.

III. Cargo turnround savings

These benefits would accrue mainly to the port users and finally to consumers. Faster turnround of ships means also faster delivery of the cargo and the benefits in form of savings in capital represented in the cargo can be quantified and attributed to the assessed operational equipment and new port facilities. Reduction in transit times for goods include also savings of insurance costs, reduced risks of market fluctuations and smaller stocks. Under the different kinds of benefits only the reduction in working capital is quantified.

IV. Reduction in damage to cargo

At present excessive damage to cargo, especially imported general cargo due to present handling methods. Any increase in mechanizations and unitization is usually accompanied by a reduction in damage if compared with traditional cargo handling methods.

Usually, estimates of damage savings are rated of 1 % of the value of imported general cargo, but inspite of no precise data presentation of figures which save only of theoretical worth, these saving will not be included into the study.

V. Avoidance of delays to cargo

The reduced period goods spend in port and on ships will free capital tied up in goods and thus give indirect economic benefits to the country as a whole. Rehabilitation of existing transport infrastructure of the port hinterland, i.e. railway to banana fincas, road connection, transport means to Central Valley will in addition produce transport cost savings.

Savings due to avoidance to delay to cargo are not listed in the following calculation.

VI. Freight savings (transport cost savings)

Use of larger and more modern ships made possible by the project will reduce the freight costs (per ton of cargo).

Importing liquid bulk can be done more efficiently through the new oil-terminal at Moín. Benefits will be a considerable reduction in freight costs.

For general cargo this benefit accrues only to the shipowners; only if assumed that a growing number of Ro/Ro and container vessels will sail under Costa Rican flag, Costa Rica would benefit. Under this assumptions, freight saving benefits are considered for this study as not quantifyable indirect benefits.

VII. Linkages

In the case of bulk fertilizer reduced sailing time (through seperate berthing and unloading facilities)will directly result in lower freight rates, and thus lower costs of fertilizer products to the Costa Rican customer. In spite of exact data on import amount and purchase value, however, these benefits can not be quantified, also they are not significant in total value.

VIII. Other benefits

There will be a number of other benefits such as avoidance of delays to export cargo etc., which are not significant in total value and have, therefore, been ingored.

3.2.3 Benefits due to rehabilitation measures (case A)

3.2.3.1 Muelle 70 (conventional general cargo and break bulk)

Surcharge Savings

The freight rates in the liner traffic are presently burdened with a congestion surcharge for the east/west bound, which is the Europa trade. For 1980, the surcharge is estimated at US $ 5.30 per freight ton.

The traffic forecast for using Muelle 70 shows a cargo proportion of about 70 % import cargo, which is supposed constant during the project period since no fundamental change in the international trade pattern of Costa Rica is expected. 90% of this cargo consists of European trade.

For compilation of the surcharge the weight-tons of the traffic forecast (metric tons) is converted into freight tons and adjusted according to the share of European cargo (Table L-7).

The benefits start in the year 1982 after the end of the construction period for the Proyecto Aleman and purchase of the modern equipment.

Reduction in ship time waiting for berth and at berth

Additional berth capacity means cost savings for ship owners since their ships have reduced waiting times for berth and at the berth. For the compilation of the total annual ship waiting time during the project period estimations about the number of ships arriving annually and the serivce time per ship have been made. The application of queuing theory could be used to give a good approximation of the waiting time for various system capacities. UNCTAD [1] research work formed the basis for our calculations.

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[1] UNCTAD: Port development, New York 1978

Table L-7 : Congestion surcharge savings and ship waiting time savings for Muelle 70 (in 1,000 US $)

YEAR	CARGO VOLUME IN METRIC TONS (1000') 1)	CARGO VOLUME IN FREIGHT TONS (1000')	SHARE OF IMPORT (%) 2)	SURCHARGE IN US $ (1000') 3)	LOSS OF SHIPDAYS AT BERTH (DAYS) 4)	LOSS OF SHIPDAYS AT ANCHOR (DAYS)	TOTAL LOSS OF SHIPDAYS (DAYS)	PORT COST SAVINGS IN US $ (1000') 5)
1979								
1980								
1981								
1982	240	332		1108.6	227	7,850	8,077	30,288
1983	254	352	average	1175.3	252	8,450	8,702	32,632
1984	270	374	for	1248.8	272	8,600	8,872	33,270
1985	281	389	period	1298.9	276	9,000	9,276	34,785
1986	294	390		1302.2	277	9,000	9,277	34,789
1987	301	389	70 %	1298.9	278	8,850	9,128	34,230
1988	308	389		1298.9	279	8,750	9,029	33,859
1989	312	390	years 80 - 2000	1302.2	280	8,700	8,980	33,675
1990	314	391		1305.6	280	8,720	9,000	33,750
1991	320	402		1342.3	288	9,100	9,388	35,205
1992	324	412		1375.7	304	9,550	9,854	36,952
1993	327	424		1415.7	326	9,900	10,226	38,347
1994	329	438		1462.5	342	10,250	10,592	39,720
1995	331	451		1505.9	356	10,500	10,856	40,710
1996	332	458		1529.3	364	10,700	11,064	41,490
1997	332	464		1549.3	372	10,850	11,222	42,082
1998	332	468		1562.7	375	10,950	11,325	42,469
1999	331	468		1562.7	378	10,960	11,338	42,517
2000	330	463		1546.0	380	10,970	11,350	42,562
							187,556	703,332

1) Cargo Volume assigned to Muelle 70
2) 90 per cent of Import cargo consist of European trade cargo as an average for Muelle 70
3) Congestion surcharge 1980 US $ 5.30 per freight tons - Europa trade East/West bound
4) Figures based on queuing theory using UNCTAD research tables $T_b/T_w = 19$
5) Port-Costs of general cargo vessel per day 7500 $ (1980) (10,000 DWT 8 years old, liner trade)

The waiting time/service time ratio is used as a measure of the level of service provided by the pier (Tw/Tb).

Due to the lack of calculabel waiting times for berth in case that the berth utilisation exceeds 100 % (i.e. congestion) we assume that at 95 % the berth will be fully congested. At 100 % and above the waiting times will be indefinite.

At utilisation of 95 % for a single berth the ratio Tw/Tb will be 19, i.e. the waiting time for a berth will be 19 times the expected berth service time. We know that the actual time will be much higher but it is considered not being calculable. As a replacement value the ratio of Tw/Tb at 95 % will be used.

The calculation will be performed according following equation:

$$Tw/Tb = U \ / \ (1-U)^2 \left(1 + \frac{U}{1-U}\right)$$

whereas Tw/Tb = ratio of waiting times as portion of berth service time
U = utilisation factor
in our case U = 0.95 %, then

$$Tw/Tb = 0.95 \ / \ (0.5)^2 \ (1 + \frac{0.95}{0.05}) = 19.0$$

The total loss of ship days at berth and at anchor is given in Table L-7 supposing no modern equipment under appropriate personal employment will be used. From 1982 to the year 2000 a total loss of 187,556 ship days would arrive, giving a total saving amount of US $ 703,332 Million or if discounted at 16 % annually a 1982 present worth of US $ 65,438 Million. The computed savings in ship time have been valued in terms of anticipated daily ship operating costs (assuming that the costs per ship day of a 10,000 dwt, 8 year old trade liner are about US $ 7,500 for the period 1980 to 2000 and that these benefits accrue, under the assumptions stated before only to a half to the Costa Rican economy.

Cargo turnround savings (dwell time savings)

The basis for compilation of the cargo turnround savings is the traffic forecast for the general cargo/break bulk commodities excluding transshipment goods. These savings apply only for the indirectly handled cargo. It is assumed that the average stay in port after completion of improvements will decrease from 15 days to 10 days.

In order to find the average value per ton for general cargo the foreign trade statistics have been analysed. If only import cargo is considered, the value of goods handled in Limôn amounts to US $ 672.8 Million in 1978. The import cargo handled in Limôn amounts to 1,179,000 tons. If allowance is made for an inflation rate of 19 % as between 1978 and 1980 the average value of imported general cargo arrives at ca. US $ 680 per ton.

The total cargo turnround savings can be calculated by conversion of the 16 % interest represented in the capital value of cargo (Table L-8) into a daily basis.

Table L-8 : Cargo turn-round savings at Muelle 70

YEAR	CARGO (TONS) WITH REDUCED STORAGE TIME ('000') [1]	IMPORT CARGO (%)	VALUE OF IMPORT CARGO (1000 US $) [2]	CARGO - TURNROUND SAVINGS (1000 US $) [3]
1979				
1980				
1981				
1982	202		96,152	210,74
1983	214	average	101,864	223,26
1984	223	for	106,148	232,65
1985	233	period	110,908	243,09
1986	239		113,764	249,35
1987	245		116,620	255,61
1988	249	70 %	118,524	259,78
1989	253		120,428	263,95
1990	257	years	122,332	268,12
1991	259	80 - 2000	123,204	270,21
1992	262		124,712	273,34
1993	264		125,664	275,43
1994	265		126,140	276,47
1995	266		126,616	277,51
1996	267		127,092	278,56
1997	268		127,568	279,50
1998	268		127,568	279,60
1999	269		128,044	280,64
2000	269		128,044	280,64

1) Tonnage stored in port 10 days savings of storage days: 5 days

2) Average value of import cargo discharged at Limón assumed at 680 US$/ton

3) Savings calculated: Value of cargo x approx. cost of capital x saving days/days per year 4)

4) Opportunity cost of capital assumed at 16 per cent

3.2.3.2 General cargo berth No. 10 (Proyecto Aleman)

Surcharge savings

The cargo volume assigned to berth 10 applies after completion of the Proyecto Aleman and is estimated for general cargo only. It is assumed that the freight rates in the liner traffic will although be burdened with a surcharge if the future cargo volume cannot be handled by the existing port facilities, if no additional equipment and modern operational methods are provided for.

Since the majority of traffic is Europe trade import cargo (east-west bound) only this volume is applied for in the saving calculation.

Table L-9 shows the benefits to be expected for the study period 1982 to 2000.

Reduction in ship waiting time for berth and at berth

The improved cargo handling rates resulting from the project will reduce the time alongside berth for ships to load/discharge cargo and thus, minimize ship waiting time at berth. Assuming, the assigned future cargo will be handled with the present not sufficient productivity per gang-hour as experienced at Muelle 70, there will be in any case congestion, that means, a berth utilization of close to 100 %. It should be kept in mind, that this exert cargo cannot be handled over any other pier, since the remaining berth's are already congested.

Then, a total loss of shipdays in port as shown in Table L-9 will lead to a calculable saving in port costs of about US $ 619,634 Million, accumulated for the study period (1982 present worth of US $ 42,844 Million).

Cargo turn round savings

Cargo turnround savings, using the same assumptions made in Chapter 3.231,will amount to US $ 154,410 in 1982, decreasing slightly with the berth traffic development (see Table L-10).

3.2.3.3 Containerized cargo, berth 11 (Proyecto Aleman)

It it is assumed that the number of Van carriers for the pierside container movements and installation of a second container crane will not be increased resp. take place (and the port facilities remain essentially as after completion of Proyecto Aleman) the cargo forecast for the period from 1985 through 2000 falls into two principal categories, as follows:

- Container cargo that can be moved over using existing pier installations
- Cargo that cannot be moved over the existing facilities but may be handled in an alternative manner, such as by diversion through the other piers (berth No. 6/7 or 10 - conventional cargo) or even fail to be realized.

Table L-9 : Congestion surcharge and ship waiting time savings at berth No. 10

TABLA L-13

YEAR	CARGO VOLUME IN METRIC TONS ('1000') 1)	CARGO VOLUME IN FREIGHT TONS ('1000')	SHARE OF IMPORT (%) 2)	SURCHARGE IN US $ ('1000') 3)	LOSS OF SHIPDAYS AT BERTH (DAYS) 4)	LOSS OF SHIPDAYS AT ANCHOR (DAYS)	TOTAL LOSS OF SHIPDAYS (DAYS)	PORT COST SAVINGS IN US $ ('1000') 5)
1979								
1980								
1981								
1982	148	459	average for whole period 70 %	1532.6	456	11,900	12,356	46,335
1983	124	384		1282.2	393	10,600	10,993	41,224
1984	106	328		1095.2	351	9,600	9,951	37,316
1985	95	294		981.7	320	9,100	9,420	35,325
1986	90	279		931.6	316	8,700	9,016	33,810
1987	90	279		931.6	310	8,600	8,910	33,412
1988	90	279		931.6	309	8,600	8,909	33,409
1989	91	282		941.6	309	8,600	8,909	33,409
1990	92	285		951.6	309	8,600	8,909	33,409
1991	93	288		961.6	306	8,500	8,806	33,022
1992	92	285		951.5	300	8,400	8,700	32,625
1993	90	279		931.6	291	8,300	8,591	32,216
1994	85	264		881.5	280	8,000	8,280	31,050
1995	83	257		858.1	268	7,600	7,868	29,505
1996	78	242		808.0	256	7,200	7,456	27,960
1997	74	229		764.6	248	7,000	7,248	27,180
1998	72	223		744.6	242	6,800	7,042	26,407
1999	72	223		744.6	237	6,700	6,937	26,014
2000	72	223		744.6	225	6,700	6,935	26,006
							165,236	619,634

1) Cargo volume (General cargo only) after completion of berth for 1982
2) 90 per cent of total import cargo consists of European trade cargo
3) Congestion surcharge 1980, US $ 5.30 per frT-European trade East/West bound
4) Figures based on queuing theory, using UNCTAD research tables $T_b/T_w = 19$
5) Costs of general cargo vessel in port 7,500 US $ (1980) (10,000 DWT, 8 years liner trade)

Table L-10 : Cargo turn-round savings at berth No. 10

YEAR	CARGO VOLUME IN METRIC TONS (1000')	CARGO VOLUME IN FREIGHT TONS (1000')	IMPORT CARGO 1) (%)	VALUE OF 2) IMPORT CARGO (1000 US $)	CARGO TURNROUND SAVINGS (1000 US $)
1979					
1980					
1981					
1982	148	459		70,448	154,41
1983	124	384		59,024	129,37
1984	106	328		50,456	110,59
1985	95	294	average	45,220	99,11
1986	90	279	for	42,840	93,90
1987	90	279	period	42,840	93,90
1988	90	279		42,840	93,90
1989	91	282		43,316	94,94
1990	92	285	70 %	43,792	95,98
1991	93	288		44,268	97,03
1992	92	285	years	43,792	95,98
1993	90	279	80 - 2000	42,840	93,90
1994	85	264		40,460	88,68
1995	83	257		39,508	86,59
1996	78	242		37,128	81,38
1997	74	229		35,224	77,20
1998	72	223		34,272	75,12
1999	72	223		34,272	75,12
2000	72	223		34,272	75,12

1) Tonnage stored in port 10 days leads to savings of 5 storage days
2) Average value of import cargo US $ 680/ton

Table L-11 : Congestion surcharge savings and ship waiting time savings for excess volume due to lack of van carriers at berth No. 11

TABLA L-14

YEAR	CARGO VOLUME IN WEIGHT TONS (1000')	TEU's (1000')	MOVES NOT HANDLED (EXCESS) (1000 MOVES) 1)	CARGO VOLUME NOT HANDLED 2) WEIGHT TONS (1000')	FREIGHT TONS (1000')	VAN CARRIERS TO BE PROVIDED	SURCHARGE 3) IN US $ (1000')	LOSS OF SHIPDAYS AT BERTH (DAYS)	LOSS OF SHIPDAYS AT ANCHOR (DAYS)	TOTAL 4) LOSS OF SHIPDAYS (DAYS)	PORT COST 5) SAVINGS IN US $ (1000')
1979											
1980	95	15									
1981	200	30									
1982	285	46									
1983	355	58									
1984	425	69									
1985	487	77									
1986	535	86	4	13	40	5	212	65	1,235	1,300	4,875
1987	585	93	17	47	150	6	795	240	4,560	4,800	8,000
1988	625	99	28	78	250	6	1,325	395	7,505	7,900	29,625
1989	665	104	37	108	340	7	1,802	540	10,260	10,800	40,500
1990	691	110	44	138	429	7	2,274	673	12,787	13,460	50,475
1991	725	114	51	158	490	7	2,597	785	14,915	15,700	58,875
1992	750	118	57	176	560	7	2,968	880	16,720	17,600	66,000
1993	775	122	62	194	610	8	3,233	970	18,430	19,400	72,750
1994	805	125	67	212	660	8	3,498	1,045	19,855	20,900	78,375
1995	814	127	71	228	705	8	3,736	1,112	21,128	22,240	83,400
1996	840	130	74	242	750	8	3,975	1,180	22,420	23,600	88,500
1997	870	132	78	256	800	9	4,240	1,240	23,560	24,800	93,000
1998	885	134	82	268	840	9	4,452	1,300	24,700	26,000	97,500
1999	895	135	85	280	870	9	4,611	1,360	25,840	27,200	102,000
2000	906	136	88	289	897	9	4,754	1,410	26,790	28,200	105,750
										263,900	989,625 6)

1) Excess moves in storage area due to non-availability of Van-Carriers (vc)
- Comparison Ho (3 vc) against A/1 - P.A.
2) 100 per cent Import cargo
3) Congestion surcharge for all cargo 5.30 $ per Frt (1980)
4) Comparison Ho (1982 = 3 vc's) and A/1 - PROJECTO ALEMAN
5) Port costs of a general cargo vessel (1980) 7,500 $ / day
6) Discounted to base year 1986 US $ 106,807,000

IMP

Table L-12 : Surcharge savings and ship waiting time savings if only one crane operates at berth No. 11

YEAR	CARGO VOLUME IN WEIGHT TONS (1000')	TEU's (1000')	BOXES EXCEEDING CRANES CAPACITY (PCS) 1)	CARGO VOLUME IN BOXES (1000 t WEIGHT) 2)	CARGO VOLUME FREIGHT TONS (1000')	CRANES TO PROVIDE	SURCHARGE IN US $ (1000') 3)	LOSS OF SHIPDAYS AT BERTH (DAYS)	LOSS OF SHIPDAYS AT ANCHOR (DAYS)	TOTAL LOSS OF SHIPDAYS (DAYS) 4)	PORT COST SAVINGS IN US $ (1000') 5)
1979											
1980	95	15									
1981	200	30									
1982	285	46									
1983	355	58									
1984	425	69									
1985	487	77									
1986	535	86						41	15	56	560
1987	585	93	3,500	35	110	2	583	65	42	107	1,070
1988	625	99	7,000	70	240	2	1,272	84	87	171	1,710
1989	665	104	10,500	115	360	2	1,908	100	150	250	2,500
1990	691	110	13,600	149	460	2	2,438	114	218	332	3,320
1991	725	114	16,000	170	550	2	2,915	120	268	388	3,880
1992	750	118	18,000	195	630	2	3,339	125	306	431	4,310
1993	775	122	19,500	215	700	2	3,710	129	348	477	4,770
1994	805	125	21,500	240	760	2	4,028	131	405	536	5,360
1995	814	127	23,900	262	814	2	4,34	133	463	596	5,960
1996	840	130	25,000	280	880	2	4,664	135	538	673	6,730
1997	870	132	26,000	295	925	2	4,902	137	621	758	7,580
1998	885	134	27,500	310	960	2	5,088	139	711	850	8,500
1999	895	135	28,500	325	990	2	5,247	141	809	950	9,500
2000	906	136	29,600	338	1,047	2	5,549	143	908	1,051	10,510
										7,626	76,260

1) Comparison of H-o against A/1 for capacity of container crane (H-o 1982 = 1 crane av.)
2) Surcharge assumed applicable for all cargo volume
3) Congestion surcharge $ 5.30/frT
4) Comparison H-O against A-1
5) Port costs of a containervessel- 2nd generation (1980) 20,000 $/day
6) Discounted to base year 1986 US $ 8,230,000

These categories of traffic provide the principal components of benefit analysis for this additional improvement cost.

It was assumed first, that any cargo, which can be discharged according to one crane's capacity but not be further handled along the pier and storage area due to lack of van carriers, will be diverted and shipped by conventional methods. Thus, it is possible to calculate "hypothetical" values of excess cargo volume, for which congestion surcharge and ship waiting time costs could be calculated.

It was further assumed, that a major portion of the forecasted cargo volume cannot be handled by conventional methods, thus remain as containerized cargo(rereference to Part E, Part C, Trend of World Shipping and Containerization). It is imputed (for the sake of assigning benefits only) that if the Port of Limón or Moín is unable to handle all of its traffic, no diversion may involve for containerized cargo utilizing a port in a neighbouring country. The container ships will queue at anchor, causing considerable delay time.

Under these assumptions, the methodology as employed before can be unsed to assess benefits due to computed saving in ship time (valued in terms of anticipated daily ship operating costs resp. charter costs) and savings due to expected surcharge costs.

Table L-11 shows the annual schedule of congestion surcharge savings and port cost savings for diverted general cargo, assuming a handling capacity similar to the 1979 experienced.

The annual schedule of incremental benefits, i.e. congestion surcharge savings for excess volume if only one crane operates and port cost savings arising due to lack of crane capacity are indicated in Table L-12.

3.2.3.4 Banana export in Moín

The length of time that banana vessels must spend in Moín depends on the availability of berths and the time required to load. As stated in Chapter E-6, the most economic number of gantry elevators working on the two banana berths would be 5, serving a 150,000 boxes exporting vessel and one with 100.000 boxes at the same operation time of 15.6 hours as against 19.7 hours per ship with 4 gantries, applying pessimistic elevator producticity.

The utilization of 5 gantries will be lower that that of 4, because the amount of exported banana boxes will be kept constant, but would relief the tight operational performance substantially, i.e. giving time for profound preplanning, maintenance, control of operation etc.

Using a productivity of 3,200 boxes per gang-hour, additional waiting days at anchor and lost service days at berth arrive as shown in Table L-13 accumulated annually for the study period 1982 to 2000. The savings in total shiptime due to purchase and employment of additional banana gantry cranes (first in 1982, second in 1990) amount to US $ 32 Million and accrue to full extent to the Costa Rican economy, calculated by using a charter cost rate of US $ 8,500 per day in 1980 prices (see Table L-13).

Table L-13 : Port cost savings (loss of ship days) for additional elevators

TABLA L-15

YEAR	LOSS OF SHIPDAYS AT BERTH (DAYS)	LOSS OF SHIPDAYS AT ANCHOR (DAYS)	TOTAL LOSS OF SHIPDAYS (DAYS) 1)	PORT COST SAVINGS IN US $ (1000') 2)
1979				
1980				
1981				
1982	74	36	110	935.0
1983	74	35	109	926.5
1984	75	34	109	926.5
1985	77	33	110	935.0
1986	81	33	114	969.0
1987	85	34	119	1,011.5
1988	90	35	125	1,062.5
1989	95	37	132	1,122.0
1990	100	39	139	1,181.5
1991	104	45	149	1,266.5
1992	108	52	160	1,360.0
1993	112	61	173	1,470.5
1994	115	70	185	1,572.5
1995	117	79	196	1,666.0
1996	120	87	207	1,759.5
1997	122	94	216	1,836.0
1998	124	101	225	1,912.5
1999	126	108	234	1,989.0
2000	128	115	243	2,065.5
			3,055	25,967.5 3)

1) Comparison Ho (4 elevators) and A/1 (5 elev. 1982, 6 elev. 1990)
2) Port Costs of a bananavessel (built 1970) 8,500US $/day (1980)
3) Discounted to 1982 present value US $ 1,547,850

3.2.3.5 Summary of benefits

A synopsis of all benefits accruing to the case A cargo development system for investment of additional operations equipment is given in Table L-14. Table L-15 gives this portion of benefits which are considered applyable to the C/B analysis. It can be seen, that all port cost savings, accumulated for Limón, are excluded , i.e. the Consultants feel that it is very problematic to consider any immediate return to Costa Rica. Only in the case of banana shipping it is resumed, that according to the 40-40-20 rule of international shipping, which are enforced by a growing number of developing countries, 40 % of the calculable benefits will accrue to the Costa Rican economy.

3.2.4 Benefits of the construction of a new container berth in 1995 (case B)

In case that the trend in containerization of bananas increases as proposed for case B, such that by the end of year 2000 almost no conventional handling of bananas in boxes will take place, the existing port facilities, especially able to handle container, are not sufficient to serve this new demand. It is therefore necessary to supply additional container handling capacity in order to export this for the Costa Rican economy outmost valuable commodity.

As it is almost impossible to outline all future effects to the banana export and thus to the economy in general if this demand cannot be satisfied, the Consultants used a simplified method of allocating benefits of the necessary investments.

It is imputed that if the port facilities at Limón and Moín remain essentially unimproved, no traffic diversion may involve utilizing a port in a neighbouring country. For the purpose of this study it is expected that exports of banana that cannot be handled at the 1995 existing facilities would be unrealized. With the proposed new facilities the length of time that banana vessels must spend in port would be reduced to normal operation time for anchorage, discharge and load of container (empty and full) and thus permit savings in shiptime in port.

It is imputed further that all measures, i.e. structural alternatives to fulfill the demand differ only in such matters as location- Limón or Moín - and constructional details but will create identical benefits.

In Table L-16 the total loss of shipdays due to unsufficient supply of port facilities is calculated using an amount of US $ 20,000 of port costs per shipday for a second generation container vessel. A total loss of 22,535 shipdays from 1990 to the year 2000 would give a total saving of about 225 Million US $, assuming that as before only max. half of the benefits accrue to the Costa Rican economy.

Table L-14 : Case A benefits due to additional equipment investments in 1,000 US $ (1982 - 2000)

TABLA L-16

	Muelle 70			Berth 10 CARGA ALEMAN			Berth 11 CONTENEDORES ALEMAN				Moin
YEAR	SURCHARGE IN US $ (1000')	PORT COST SAVINGS IN US $ (1000')	CARGO TOURNROUND SAVINGS (1000' US $)	SURCHARGE IN US $ (1000')	PORT COST SAVINGS IN US $ (1000')	CARGO TURNROUND SAVINGS (1000' US $)	SURCHARGE (CONV. CARGO) IN US $ (1000')	PORT COST SAVINGS (CONV. CARGO) IN US$ (1000')	SURCHARGE (CONT. SHIPS) IN US $ (1000')	PORT COST SAVINGS (CONV. CARGO) IN US$ (1000')	PORT COST SAVINGS (BANANAS) IN US $ (1000')
1979											
1980											
1981											
1982	1108.6	30,288	210,74	1532.6	46,335	154,41					935.0
1983	1175.3	32,622	223,26	1282.2	41,224	129,37					926.5
1984	1248.8	33,270	232,65	1095.2	37,316	110,59					926.5
1985	1298.9	34,785	243,09	981.7	35,325	99,11					935.0
1986	1302.2	34,789	249,35	931.6	33,810	93,90	212	4,875		560	969.0
1987	1298.9	34,230	255,61	931.6	33,412	93,90	795	8,000	583	1,070	1,011.5
1988	1298.9	33,859	259,78	931.6	33,409	93,90	1,325	29,625	1,272	1,710	1,062.5
1989	1302.2	33,675	263,95	941.6	33,409	94,94	1,802	40,500	1,908	2,500	1,122.0
1990	1305.6	33,750	268,12	951.6	33,409	95,98	2,274	50,475	2,438	3,320	1,181.5
1991	1342.3	35,205	270,21	961.6	33,022	97,03	2,597	58,875	2,915	3,880	1,266.5
1992	1375.7	36,952	273,34	951.6	32,625	95,98	2,968	66,000	3,339	4,310	1,360.0
1993	1415.7	38,347	275,43	931.6	32,216	93,90	3,233	72,750	3,710	4,770	1,470.5
1994	1462.5	39,720	276,47	881.5	31,050	88,68	3,498	78,375	4,028	5,360	1,572.5
1995	1505.9	40,710	277,51	858.1	29,505	86,59	3,736	83,400	4,34	5,960	1,666.0
1996	1529.3	41,490	278,56	808.0	27,960	81,38	3,975	88,500	4,664	6,730	1,759.5
1997	1549.3	42,082	279,60	764.6	27,180	77,20	4,240	93,000	4,902	7,580	1,836.0
1998	1562.7	42,469	279,60	744.6	26,407	75,12	4,452	97,500	5,088	8,500	1,912.5
1999	1562.7	42,517	280,64	744.6	26,014	75,12	4,611	102,000	5,247	9,500	1,989.0
2000	1546.0	42,562	280,64	744.6	26,006	75,12	4,754	105,750	5,549	10,510	2,065.5

Table L-15 : Case A benefits due to additional equipment investments in 1000 US $. (1982-2000) - no return of port cost savings to Costa Rica

	Muelle 70		Berth 10 CARGA ALEMAN		Berth 11 CONTENEDORES ALEMAN		Moín
Year	SURCHARGE IN US $ (1000')	CARGO TURNROUND SAVINGS (1000 US $)	Surcharge IN US $ (1000')	CARGO TURNROUND SAVINGS (1000 US $)	SURCHARGE (CONV.CARGO) IN US $ (1000')	SURCHARGE (CONT.SHIPS) IN US $ (1000')	PORT COST SAVINGS (BANANAS) IN US $
1979							
1980							
1981							
1982	1,108.6	210.74	1,532.6	154,41			748.0
1983	1,175.3	223.26	1,282.2	129.37			741.2
1984	1,248.8	232.65	1.095.2	110.59			741.2
1985	1,298.9	243.09	981.7	99.11			748.0
1986	1,302.2	249.35	931.6	93.90	212	–	775.2
1987	1,298.9	255.61	931.6	93.90	795	583	809.2
1988	1,298.9	259.78	931.6	93.90	1,325	1,272	850.0
1989	1,302.2	263.95	941.6	94.94	1,802	1,908	896.0
1990	1,305.6	268.12	951.6	95.98	2,274	2,438	745.2
1991	1,342.3	270.21	961.6	97.03	2,597	2,915	1,013.2
1992	1,375.7	273.34	951.6	95.98	2,968	3,339	1,088.0
1993	1,415.7	275.43	931.6	93.90	3,233	3,710	1,176.4
1994	1,462.5	276.47	881.5	88.68	3,498	4,028	1,258.0
1995	1,505.9	277.51	858.1	86.59	3,736	4,340	1.332.8
1996	1,529.3	278.56	808.0	81.38	3,975	4,664	1,407.6
1997	1,549.3	279.60	764.6	77.20	4,240	4,902	1,468.8
1998	1,562.7	279.60	744.6	75.12	4,452	5,088	1,530.0
1999	1.562.7	280.64	744.6	75.12	4,611	5,247	1,591.2
2000	1,546.0	280.64	744.6	75.12	4,754	5,549	1,652.4

Table L-16 : Loss of shipdays due to banana containers exceeding the volume of case A in case B

TABLA L-16

YEAR	CONTAINER BOXES WITH BANANA EXCEEDING CASE A (TEU'S)	BERTHDAYS REQUIRED (LOSS OF SHIP DAYS AT BERTH) (DAYS)	LOSS OF SHIP DAYS AT ANCHOR AGAINST CASE A (DAYS)	TOTAL LOSS OF SHIP DAYS IN PORT AGAINST CASE A (DAYS)	PORT COST SAVINGS 50 % (in 1000 US $)
1990	0	0	0	0	
1991	5,000	10	18	28	280
1992	10,000	21	41	62	620
1993	16,000	33	80	113	1,130
1994	23,000	48	137	185	1,750
1995	32,000	67	237	304	3,040
1996	43,000	90	425	515	5,150
1997	56,000	117	822	939	9,340
1998	70,000	146	1,856	2,002	20,020
1999	85,000	177	8,592	8,769	87,690
2000 1)	99,000	206	9,412	9,618	96,180
				22,535	225,350 3)

1) In the year 2000 the berth utilization reaches 105 % for which Tx/Tb will be not calculable, therefore, the value of 1990-Tw/Tb : 25.25 at 96 % utilization have been used.

2) Port cost of container vessel US $ 20,000/day

3) Discounted to 1982 present value US $ 13,450,000

4. Economic analysis of the projects

4.1 General

For the economic evaluation of projects which aim at expanding the port's capacity the usual method is that of trade-off calculations between cost of extension and savings on ships time costs and Consultants have followed that method.

Having established the cargo and ships which have to be accomodated by the port and having decided upon cargo-handling speeds to be expected in the future, it was possible to determine the port needs and alternative schemes to cope with expected future traffic both with regard to port facilities and access ways to the port.

The optimum method will be equating marginal costs (cost of additional berths, equipment, etc.) and marginal benefits (savings in vessels' waiting and service time, savings in cargo-handling costs. For the estimate of savings in ships' waiting time Consultants have employed queuing theory, if proved applicable, or simultaneous techniques.

For short-term improvements, especially for case A requirements, which shall be finished at the end of year 1981, detailed feasibility calculations have been made.

For alternative solutions in case B, high degree of containerization of bananas which generate the same benefits (e.g. alternative port layouts with, otherwise, identical properties) the selection of the best scheme can be made by means of a cost comparison and net present worth calculations.

The feasibility criteria (economic rate of return and net present value) will follow from "with" and "without" comparison All relevant costs and benefits will be included in the discounted cash flow analyses in order that total system costs will be minimized over time.

4.2 Economic rate of return

Traditional analytical practice has calculated the economic rate of return: that is, the rate of discount that results in a zero net present value for the project. This rate is usually referred to in the literature as the internal rate of return. If this rate of return exceeds the estimated shadow rate of interest, it indicates for a nonmutually exclusive project that it is acceptable; the net present value is then positive.

Unfortunately, the rate of return is defective as a measure of the relative merits of mutually exclusive projects; a higher rate of return does not necessarily indicate the superior alternative as measured by the size of the surplus when costs and benefits are discounted at the shadow rate of interest. The economic rate of return thus may be misleading in comparing the economic merits of alternative projects and should not be used for this most essential function of project analysis. The economic rate of return criterion can provide the correct decision if applied to the difference in net benefits between two mutually exclusive projects.

However, the (internal) economic rate of return is a widely understood concept and has merit as a compact summary measure of the economic result of a project.

4.2.1 Cost-benefit comparison (case A)

The comparison of costs and benefits under the restrictional assumptions of the foregoing paragraphs for the rehabilitation measures (structural as well operational) of the port of Limón arrive for the case A at the following internal rates of return (IRR):

Activity	Internal rate of return (IRR)
Total port rehabilitation	: 19.9 %
Muelle 70	: 21.4 %
Berth 10	: 16.5 %
Berth 11	: 20.1 %

For the investments for the immediate measures of Port of Moín, i.e. prolongation of second banana pier, about 68.40 m, and provision of additional banana elevators, a IRR of 21 % has been calculated.

These values are relatively high compared with the recommended "cost of capital" rate (or shadow rate of interest) of 16 % and indicate in addition to the before described operational necessity the economic advantage of said measures.

4.3 Net present value (case B)

The basic technique is to discount costs and benefits occurring in different periods and express them all in a common value at any one point of time. The relevant discount rate for this purpose has been discussed in section 2.3. If the net present value of the project is negative - that is, if the discounted value of the benefits is less than the discounted value of the costs - the project should be rejected. But in practice, projects with a positive (or zero) net present value should not necessarily be accepted. It should be borne in mind that a high net present value may reflect an inadequate search for alternative projects rather than a potentially valuable project.

Furthermore, there are many projects that by their nature are mutually exclusive: if one is chosen, the other cannot be undertaken. This applies especially to different designs or sizes of what is essentially the same project. In all cases it is not sufficient to chose a project with a positive net present value; rather, the project with the highest net present value among the mutually exclusive alternatives should be rejected.

Special variants of mutually exclusive projects are alternatives that produce the same benefits. They may involve a question of choice of design, such as between rail or road transport, investment in location A on B: whichever technical solution is chosen, the benefits are deemed to be the same. In such cases it is necessary only to consider costs and select the alternative with the lowest present value of cost when discounted at the appropriate rate of interest. For any given level of output and benefits, the least-cost alternative is to be preferred.

The alternatives of case B development are mutually exclusive projects. The quantifiable benefits are identical, such are explained in section 3.2.4 of this chapter.

4.3.1 Net present value (NPV) calculation

The NPV for each of the discussed alternatives of chapter F have been calculated using a discount rate of 16 %. Construction costs as estimated before are listed in the following table L-17 and discounted to the base year 1980 for different portions of local participation. By this the foreign exchange component of construction price increases from zero to 35 %.

Comparing the alternatives it is shown, that alternative (1), 1 container terminal with 1 container berth in Limón, produces the most favourable net present value against the cheapest alternative (3), 1 container berth in Moín. The next best alternative is alternative (1b), 1 container terminal with 2 berths in Limón, since alternative (2), 1 container berth and 1 general cargo berth pier in Limón, shows substantial operational disadvantages and should be rejected as discussed in detail in chapter F.

Table L-17 : Net present value (1980) of case B alternatives

Alternatives	Construction cost (Million US $)			NPV (Million US $) 1)			Starting/end Year of construction
	% local part			% local part			
	-	20	35	-	20	35	
Limón:							
1 container berth (1)	84.6	79.7	76.1	11.9	11.3	10.8	1990/94
2 container berths (1b)	115.1	108.6	103.6	11.8	12.5	12.1	1990/94
1 gen.cargo + 1 cont. berth (2)	86.7	81.7	77.9	12.3	11.6	11.2	1990/94
Moín:							
1 container berth (3)	58.8	55.4	52.9	12.3	11.6	11.0	1988/92
2 container berths (3b)	91.8	86.6	82.6	19.5	18.4	17.5	1988/92

1) NPV of base year 1980 for period start of work to year 2000, cost of capital 16 %

5. Sensitiviy Analysis

5.1 General

When the cost-benefit analysis for the central input values of each alternative development parameter have been completed, the effect of uncertainty can be studied by means of a simple sensitivity analysis. This is usually carried out by repeating the analysis for a variation in the main parameters by an amount estimated to be a comparable degree of risk. For each of these values, the economic effects are recalculated.

For the Masterplan Study, only for case B alternatives a sensitivity analysis, i.e. testing the effect of uncertainty in the cost estimates, seems reasonable, since for case A investigations the shown IRR are already much higher than the "basis rate" of 16 % - by neglecting any port cost saving returns to the Costa-Rican economy.

The relative change produced in the NPV by each cost parameter change allows the investing authority - The Government - to see the effects of changes in the cost estimates and to take all possibilities into account in its decision procedure.

5.2 Sensitivity of case B cost estimates

The economic return calculations are based on two assumptions: (i) that the traffic will materialize as forecast (refer to chapter C) and (ii) that the operational objectives given in chapter E, will be achieved by the timing proposed.

The sensitivity of the return to changes in the principal parameters of the cost estimate for case B alternatives, such as filling and wharf-construction, was analyzed for the two alternatives valued for comparison in chapter F: alternative (1) - 1 container terminal with 1 berth in Limón -, versus alternative (3b) - 1 container terminal in Moín with 2 berthing places. The results, shown in table L-18, indicate that, with a 10 % increase in general construction cost combined with an increase of 20 % in filling cost, the NPV would still be in favour of alternative B 1(a) as compared with B 3(b).

Also, changes in participation of local contractors, i.e. local part of construction cost, which effect portions of foreign exchange, do not affect the economic advantage of alternative (1): a local component of 45 % for construction works of alternative (3b) produces the lowest investment cost and, consequently, the lowest NPV for this alternative (NPV = 17 Million US $). Compared with a reasonable local part of 20 % for construction of alternative (1) with slightly higher investment cost (due to increase in cost), the calculated NPV of 12.9 Million US $ is still in favour of this alternative.

Thus, if the containerization of Bananas proceeds in the anticipated manner and in the time intervals the Consultants expect provision should be made to implement alternative (1) - Limón - in order to serve this new demand of port requirements.

Table L-18 : Sensitivity analysis, case B alternatives

Sensitivity		Alternative B 1 (a) Limôn		Alternative B 3 (b) Moîn	
% Cost increase	% local part	Investment cost (Mio. US$)	NPV 1) (Mio. US$)	Investment cost (Mio. US$)	NPV 1) (Mio. US$)
Land reclamation 20 %	20	85.3	12.1	88.6	18.8
	35	81.4	11.6	84.6	18.3
	45	-	-	81.9	17.4
Structure cost 10 %	20	84.9	12.1	93.5	19.9
	35	81.1	11.5	89.9	19.1
	45	-	-	86.4	18.4
Land reclamation & structure cost	20	90.5	12.9	95.6	20.4
	35	86.4	12.3	91.2	19.4
	45	-	-	88.3	18.8
-	20	79.7	11.4	86.6	18.4
-	35	76.1	10.8	82.6	17.5
-	45	-	-	80.0	17.0

1) NPV of base year 1980 for period start of work to 2000 including annual maintenance of 1.5 % of construction cost.

6. Optimum length of Northern Breakwater at Moln Harbour

190 metros

6.1 Introduction

The northern breakwater designed for the port of Moln has been investigated by the Consultant in March 1979 (Harbour of Moln-Extension of the Northern Breakwater - "Final Design Report" by Rhein-Ruhr Ingenieur-Gesellschaft mbH).

The investigations based upon weather and swell conditions and theoretical calculations using wave theory thus the design length was decided to be optimum at approx.190 m.

In this chapter of the Port Master Plan Limón/Moln the economical and optimum breakwater length will be revalued, based on a cost-minimum analysis whereby oceanographical data will be taken from the "Final Design Report".

6.2 Method of calculation

The "cost-minimum" analysis uses costs no matter whether they are benefits or real costs and does not consider to whom those costs arise.

Furthermore, it expects that depending on a certain fact - in our case the length of the breakwater - different costs follow different curves progressive ones or regressive ones.

The mathematical addition of all cost inputs will create a new curve. The minimum of the curve indicates where the lowest total cost will lead to the optimum economical value, in this case the length of the breakwater.

The basic year is 1980 and all data used will be discounted to the basic year with the following discount rates:

$i_1 = 10\ \%$
$i_2 = 12\ \%$
$i_3 = 15\ \%$

The completion of construction is assumed to be at the end of 1981. Thus the first costs benefits will arise in 1982 up to the year 2000.

6.3 Cost inputs

All cost are calculated in US-Dollar $.
Four cost data will influence the economical length of the breakwater and depend on the length (L):

6.3.1 Construction costs

The construction costs have been calculated on the volume of materials required for the erection of the breakwater, the present costs for the different types based on 1980 prices.

The lifetime of the breakwater is assumed to be 50 years, the annual maintenance costs 2 % of the investments. For the period from 1982-2000 them 2 % depreciation and 2 % maintenance costs arise, totally 4 % of investments.

The net present value costs (1980) for the construction and maintenance of the breakwater are shown in the following table for the period 1982 to 2000:

Net Present Value 1980 (in 1,000 US $)			
length (m)	i = 10 %	i = 12 %	i = 15 %
50	511	450	379
100	998	879	740
150	1,384	1,218	1,025
200	1,968	1,733	1,459
250	2,618	2,305	1,940
300	3,311	2,915	2,543
350	4,099	3,609	3,037
400	4,913	4,327	3,641

6.3.2 Ship berthdays

The breakwater will be necessary to protect the two banana piers against incoming swell in a manner that the operation need not to be stopped.

The requirements are laid down in the "Final Design Report" for the breakwater at Moín in March 1979. According to these data the number of days per year and berth, during which the swell would induce a breakdown of operation, are listed below.

Days with high swell			
breakwater length(m)	pier No. 1	pier No. 2	Total
50	48	70	118
100	35	58	93
150	25	48	73
200	17	40	57
250	12	34	46
300	8	29	37
350	6	24	30
400	4	20	24

(source "Final Design Report" 03/1979)

As the seasonal frequency is not known it is assumed that the days are spread over the year, so that they affect the operation with the same share as the berths are used for operation per year.

Thus the percentage of berth occupancy applies also to the days with swell.

The berth occupancy (or utilization) has been calculated in chapter E-6 looks as following:

	Case A productivity of gantries		Case B
year	high	low	high
1985	37 %	43 %	37 %
1990	37 %	43 %	37 %
1995	39 %	44 %	27 %
2000	43 %	48 %	0 %

The delays induced by heavy swell during operation cause waiting time for the banana vessels at the berths and thus costs.

The operating costs for a banana vessel in port is calculated at US $ 8.500 per day and give the second cost input.

6.3.3 Waiting time at anchor

Depending on the berth utilization vessels must expect a certain waiting time at anchor before berth space will be available.

The prolonged berth days for ships due to non-operation according to 3.2 implies an increase of the berth occupancy. Thus a different rate of waiting time to berth service time will result (see next table).

These differences will lead to a higher time span during which vessels have to anchor. These additional ship waiting times at anchor induce ship costs of US $ 8.500 per day.

These costs will be the third input value. The ratio waiting time to berth service time Tw/Tb is calculated according to following formula:

$$\frac{Tw}{Tb} = \frac{(M \times U)^M}{M \times M!\ (1-u)^2 \times \left[\sum_{n=o}^{M-1} \frac{(M \times u)^u}{u} + \frac{(M \times u)^M}{M!\,(1-u)} \right]}$$

M = number of berths

U = berth utilization / 100

Loss of ship days at anchor Tw per year

L length of break-water	DL days with swell	Case A, high prod. Utilization U_1			Case A, low prod. Utilization U_1			Case B, high prod. Utilization U_1		
		0.37	0.39	0.43	0.43	0.44	0.48	0.37	0.27	0.0
50	118	28.3	34.4	50.2	50.2	55.0	79.0	28.3	9.5	0
100	93	21.4	25.9	37.6	37.6	41.2	58.9	21.4	7.2	0
150	73	16.2	19.6	28.4	28.4	31.0	44.2	16.2	5.5	0
200	57	12.3	14.9	21.5	21.5	23.5	33.1	12.3	4.2	0
250	46	9.7	11.8	17.0	17.0	18.5	26.4	9.7	3.3	0
300	37	7.7	9.3	13.4	13.4	14.6	20.7	7.7	2.6	0
350	30	6.2	7.4	10.7	10.7	11.7	16.5	6.2	2.1	0
400	24	5.9	5.9	8.5	8.5	9.3	13.1	5.9	1.7	0

year	Utilization productivity Case A/high	Case A/low	Case B/high
1985-1990	0.37	0.43	0.37
1995	0.39	0.44	0.27
2000	0.43	0.48	nil

6.3.4 Handling charges

The fourth cost-input data will be the loss of handling charges which arise if the operation must be stopped. As the non-operation days are known according to 3.2, daily port capacity in boxes influence the loss of handling charges.

The dues for one carton box of banana are calculated at 0.1 Colones (₡). Exchange rate 8.54 ₡ equals 1 US $.

The daily capacity of 5 elevators amounts to 323,000 boxes in case of high productivity and gives an hourly productivity of 3,800 b/hr and lto 272,000 boxes per day in case of low productivity and leads to 3,200 b/hr (see also chapter E-6).

Thus the charges amount to

3,800 $/day for high productivity
and 3,200 $/day for low productivity.

6.3.5 Other costs

As already mentioned in the introduction no consideration will be made to whom the costs arise.

Furthermore, no other costs as personnel costs, railcar demurrage etc. will be calculated as they are not accurate to estimate.

6.4 Conclusion

The following table gives a breakdown of the optimum economical breakwater length for different discount rates and the two anticipated possibilities of containerization of bananas.

The net present values of costs are calculated, its graphical evaluation is shown in the following figure:

The optimum breakwater length is a direct function of the berth utilization. The higher the utilization, e.g. Case A with low gantry productivity, the longer the breakwater should be built.

A second dependency is the discount rate. Considering the present inflation rate of Costa Rica the rate of return of 15 % should be regarded the most applicable one. Thus the optimum breakwater length range between 185 m and 227 m for the researched cases.

Considering a well maintained port with proper organisation and a well functioning equipment maintenance the productivity of 3,800 boxes per hour per banana elevator will be achievable.

Thus the breakwater lengths range only between 185 and 197 m. If now considered the development of banana containerization, the cases "A" and "B", it should be noted that the actual future development will arise between those premises.

Summarizing all before mentioned facts this economical investigation will come to the result that the breakwater should have a length of approx. 195 m (see table below).

Breakdown of optimum brekwater length for different cases

case	A = low containerization of banana			A = low containerization of banana			B = high containerization of banana		
gantry productivity	high 3,800 boxes/hrs gantry			low 3,200 boxes/hrs gantry			high 3,800 boxes/hrs		
Utilization 1985 1990	0.37			0.43			0.37		
Utilization 1995	0.39			0.44			0.27		
Utilization 2000	0.43			0.48			nil		
discount rate	0.10	0.12	0.15	0.10	0.12	0.15	0.10	0.12	0.15
minimum costs at length(m)	212	205	197	260	240	227	190	187	185

ANNEX CHAPTER L

(Annex L-1 to L-4)

Calculation of Total Construction Cost for Muelle 70 Investment

(referring to values given in table L - 5)

Construction cost attributed to Muelle 70 for case A development have been listed in table F.8-8 and F.8-10 of chapter F.8, representing a 1979 price basis.

For table L-5, the following values were taken:

1. Structures

- Rehabilitation of Muelle 70		480,000 US $	
- Construction of Gatehouse	+	13,000 US $	
		493,000 US $	
- Site installation and contingencies (30% total)	+	147,900 US $	
		640,900 US $	(1979)
15 % inflation		737,100 US $	(1980)

2. Infrastructure

- Rehabiltiation of Railyard Limôn	2,535,000 US $	
- 60 % attrib. to Muelle 70	1,594,000 US $	(1979)
15 % inflation	1,833,100 US $	(1980)
- Intersection Avenida 1/Calle 9	145,800 US $	
17 % contingencies	24,800 US $	
	170,600 US $	(1979)
15 % inflation	196,500 US $	(1980)

In the following tables of this annex (tables Annex L-2/4) design and engineering costs, foreign and local portion of construction works, impact of foreign exchange and annual M/R cost are calculated.

Computation of Total Construction Cost (Case A)
Rehabilitation of Muelle 70, Building of Gatehouse [1)]

(1) INVESTMENT COST

	TOTAL	FOREIGN EXCHANGE [2)]	FOREIGN PORTION [3)] (82 %)	LOCAL PORTION (18 %)
Design Eng. 4 %	41,300	11,800	29,500	---
Equipment/Mat/Labour	1,031,900	1,031,900	604,400	132,700
Total Investment Cost	1,073,200		(737,100) [1)]	

(2) Annual M/R Cost
(in US $)
- 1.5 percent p.a. of investment
- excluding maintenance dredging

Total annual M/R Cost 16,100

Starting Year of Investment : 1 half Year 1981
Construction Period : 2 half Years
Depreciation 42,900 : Per Year Lifetime: 25 Years

(3) Allocation of Cost in Time
(in US $)

YEAR	INVESTMENT/ REINVESTMENT	ANNUAL COST	DEPRECIATION	REST VALUE
1980				
1981	1,073,200			
1982		16,100	42,900	
1983		16,100	42,900	
1984		16,100	42,900	
1985		16,100	42,900	
1986		16,100	42,900	
1987		16,100	42,900	
1988		16,100	42,900	
1989		16,100	42,900	
1990		16,100	42,900	
1991		16,100	42,900	
1992		16,100	42,900	
1993		16,100	42,900	
1994		16,100	42,900	
1995		16,100	42,900	
1996		16,100	42,900	
1997		16,100	42,900	
1998		16,100	42,900	
1999		16,100	42,900	
2000		16,100	42,900	258,100

1) Values from table F.8-1, Chapter F.8
2) 40 percent added to foreign portion
3) Separation according to local experience

Computation of Total Construction Cost (Case A)

Rehabilitation of Railyard Limón[1)]

(1) INVESTMENT COST

		TOTAL	FOREIGN EXCHANGE[2)]	FOREIGN PORTION[3)] (60 %)	LOCAL PORTION (40 %)
Design Eng.	5 %	113,700	22,100	91,600	---
Equipment/Mat/Labour		2,273,000	439,900	1,099,800	733,300
Total Investment Cost		2,386,700			(1,833,100) [1)]

(2) Annual M/R Cost
(in US $) - 1 percent p.a. of investment

Total annual M/R Cost 23,900

Starting Year of Investment : 1 Year Year 1981
Construction Period : 2 half Year
Depreciation 79,500 : Per Year Lifetime: 30 Years

(3) Allocation of Cost in Time
(in US $)

YEAR	INVESTMENT/ REINVESTMENT	ANNUAL COST	DEPRECIATION	REST VALUE
1980				
1981	2,386,700			
1982		23,900	79,500	
1983		23,900	79,500	
1984		23,900	79,500	
1985		23,900	79,500	
1986		23,900	79,500	
1987		23,900	79,500	
1988		23,900	79,500	
1989		23,900	79,500	
1990		23,900	79,500	
1991		23,900	79,500	
1992		23,900	79,500	
1993		23,900	79,500	
1994		23,900	79,500	
1995		23,900	79,500	
1996		23,900	79,500	
1997		23,900	79,500	
1998		23,900	79,500	
1999		23,900	79,500	
2000		23,900	79,500	875,000

1) 60 percent of estimated investment, values from table F-8.8, chapter F.8
2) 40 percent added to foreign portion
3) Separation according to local experience

COMPUTATION OF TOTAL CONSTRUCTION COST (CASE A)

Intersection Avenida 1 / Calle 9 [1)]

(1) INVESTMENT COST

	TOTAL	FOREIGN EXCHANGE[2)]	FOREIGN PORTION[3)] (15 %)	LOCAL PORTION (85 %)
Design/Eng. 4 %	8,350			8,350
Equipment/Mat/Labour	208,300	11,800	29,475	167,025
Total Investment Cost	216,650			(196,500) [1)]

(2) Annual M/R Cost
(in US $)

- 1 percent p.a. Maintenance
- 2 percent p.a. Administration

Total Annual M/R Cost 6,500

Starting Year of Investment : Year 1981
Construction Period : 1 half Year
Depreciation 10,850 : Per Year Lifetime: 20 Years

(3) Allocation of Cost in Time
(in US $)

YEAR	INVESTMENT/ REINVESTMENT	ANNUAL COST	DEPRECIATION	REST VALUE
1980				
1981	216,650			
1982		6,500	10,850	
1983		6,500	10,850	
1984		6,500	10,850	
1985		6,500	10,850	
1986		6,500	10,850	
1987		6,500	10,850	
1988		6,500	10,850	
1989	26,000[4)]	6,500	10,850	
1990		6,500	10,850	
1991		6,500	10,850	
1992		6,500	10,850	
1993		6,500	10,850	
1994		6,500	10,850	
1995		6,500	10,850	
1996		6,500	10,850	
1997	26,000[4)]	6,500	10,850	
1998		6,500	10,850	
1999		6,500	10,850	
2000		6,500	10,850	10,500

1) Values from table F 8.10 , chapter F.8
2) 40 percent added to foreign portion
3) according to local experience
4) 12 percent reinvestment after 8 years (resurfacing)