15656

Planning Criteria for U.S. Port Development

U.S. DEPARTMENT OF COMMERCE
Maritime Administration

Planning Criteria for U.S. Port Development

U.S. DEPARTMENT OF COMMERCE
Maritime Administration
Office of Port & Intermodal
Development

December 1977

PLANNING

CRITERIA

FOR U.S. PORT

DEVELOPMENT

U.S. DEPARTMENT OF COMMERCE
Maritime Administration
OFFICE OF PORT & INTERMODAL
DEVELOPMENT
DECEMBER 1977

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Foreword

With the advent of advanced intermodal technology, capital shortages, environmental impact assessment and coastal zone management, there is increasing pressure to formulate formal long-range plans for the future development of our Nation's marine ports. This report was prepared for the purpose of developing the basic criteria that will assist port planning at the state and local levels in the United States.

The Maritime Administration through its Office of Port and Intermodal Development accepted a proposal of the Massachusetts Institute of Technology to perform this independent planning research. The project team was managed by Professor E. G. Frankel, a noted international maritime consultant. This document is actually a summary of the more comprehensive research that was performed by MIT during 1976-1977. In addition to the publication of this report, the Maritime Administration will use the supplemental research data in its related work with the port industry.

Planning Criteria for U.S. Port Development addresses five basic elements of port planning. These significant ingredients are: port and terminal technology; investment criteria and strategies; port capacity; port pricing and port environmental assessment. The report offers the main characteristics of port planning as well as introducing some of the latest managerial techniques that have been specifically adapted for port development decision-making.

In addition to a basic introduction to port and terminal technology, the report treats the recent theories and applications of port investment, capacity and environmental impact. The establishment of suitable criteria for port investment and the pricing of port services are required steps in this era of capital scarcities. Similarly, the determination of a port's capacity is an essential requirement in planning potential cargo movements and intermodal activities for a harbor area. The final section on port environmental assessment addresses a crucial social situation that daily confronts the operations of ports. This chapter reviews the ecological factors of port design and construction and summarizes the environmental impact assessment and control requirements in port development and operations.

Section 8 of the Merchant Marine Act of 1920 directs the Maritime Administration to investigate the adequacy of ports in the United States for the purpose of recommending improvements. While it is recognized that this report is not the panacea for all port planning problems, the Agency publishes this information in accordance with this mandate. Moreover, the Maritime Administration offers this summary report as a potential catalyst to aid in the improvement of the formal process of planning local ports that are so very vital to the economic well-being of the country.

0.0 GENERAL COMMENTS

The rapid changes in the technological environment of marine transportation and the increasing integration of waterborne, air and land transport systems have fostered a revolution in the design and operation of vehicles, material handling, terminal facilities, unitization and storage which has caused major changes in port function and use. Also affected are operational methods and commodity flow patterns. These changes are dynamic and will continue to influence port systems' design, construction and operation.

This revolution has fostered a new set of concepts governing the operation, design and location of port facilities which more realistically reflect the needs of intramodal transportation and the recognition that ports are an intergral part of complex intermodal transportation and distribution systems.

The economic consequences of insufficient port systems usually affect a large segment of economic and commercial activity. If ports are allowed to atrophy, the resulting increases in the cost of foreign and domestic trading would have serious effects on both the immediate hinterland and larger national economy.

At this time it is critical that an examination and assessment of port requirements be made in terms of both present and projected demands, evolving technology in transportation and port systems, labor and social demands, investment availability, and potential alternate use of port facilities and resources.

This study focuses on the evaluation of seaport development criteria and requirements. In it we analyze capacity needs in the light of evolving technology and the feasibility of future port development, against the general background of continued economic and technological progress. Among the background considerations were:

- An examination of new concepts and their effect on the technological environment of ocean transportation and port development.
- The development of forecasts of commodity flow shipping activity and the attendant demands on port facilities and transportation system requirements in the U.S.A.
- Development of models for the analysis of different port uses and developments.
- Methodology for optimizing port investment and operational decisions.

The healthy economic development of waterfront and coastal areas depends largely on effective port development. Ready access to the open sea and the hinterland by road, rail and waterway is of paramount importance. These factors negate many of the advantages of ports in densely populated urban areas. Already today severe bottlenecks exist at focal points along urban transportation routes in many U.S. ports.

The vast increase in ship investment, ship operating, port handling, cargo handling, and warehousing costs are increasingly making conventional port locations and operations obsolete. These considerations have led to the development of new port facilities in many parts of the world which are removed from historic port sites and urban concentrations. Many of these facilities are replacing older ports because they offer improved operational and cost effectiveness.

Aside from the consideration of developing major seaports, alternative approaches to developments which can meet future demand requirements for an effective intermodal transportation system should be invested. While limited shipping channel depths in most U.S. coastal waters have restricted economic development of deep draft oil or dry bulk ports, there are many obvious opportunities for interface developments using pipeline, barge, aerial cableway or similar feeders from an offshore port facility which may economically overcome this handicap.

The function of a port is basically to transfer cargo between inland feeder, coastal transportation and oceangoing ships. Subordinate functions include inter-feeder transfer, cargo consolidation and cargo storage. Although these functions have not changed, the methods used in their performance have been radically modified in recent years. The overriding factors influencing changed methods and procedures are ship and feeder turnaround, resulting from the higher capital intensity of ship and feeder systems. The unit investment and operating costs of ships and vehicles have increased dramatically with the resulting demand to minimize port time. Changes in port methods and procedures are largely affected by port facilities, port technology, port labor, port management, and the customs of the port. The last factor usually influences the way in which work is performed and controlled and has probably a larger influence on the effectiveness of use of labor and physical resources than any other.

Port technology and configuration have in the past been largely affected by the demand of multipurpose port capability. As a result, most traditional ports were able to handle the transfer and/or storage of many commodities, yet none very effectively. Flexibility of operations and diversity of use of resources used to be a major criteria of port design, investment and management.

The major change in ship and feeder technology has resulted in a large dislocation of port resource use. This, in turn, contributed to major imbalance in the use of facilities and resources. Similarly, the conventional assumptions of port capacity and throughput were challenged by the ability of new technology introduced primarily by the interfacing transportation modes.

A major aspect is the relation of the port towards hinterland or service areas. While traditional ports were designed to serve a larger urban area surrounding the port, modern ports are called upon to serve a much wider hinterland of which one or more urban concentrations form a part. As a result, most new port developments are established in non-urban locations with prime emphasis on water and inland accessibility from a transport point of view. These developments have also resulted in a reevaluation of the advantages of multipurpose versus specialized ports.

With the increasing specialization in handling and transfer techniques of both bulk and general cargoes and the resulting requirements for massive investments in specialized handling and storage equipment, specialized ports and port facilities are on the increase. This factor is also emphasized by the different access and ship handling needs introduced by specialized ships and inland feeders being served by modern ports.

Specialized ports are usually developed around specialized terminals and berths whose approaches and accesses are designed to effectively support certain types of ships and feeder vehicles. Typical examples are liquid and dry bulk terminals with mechanized or pipeline inland feeder connections, container terminals, or ports specializing in quick ship turnaround and inland feeder turnaround capability and the provision of extensive parking lot type marshalling capability.

These considerations are similarly influenced by the advantage of functional integration and operational separation of activities which, in turn, assure controlled circulation and movement in the port or terminal. This, in turn, assures effective use and utilization of equipment, facilities, manpower, and available land area.

U.S. port labor is traditionally casual labor. Similarly, the responsibility for the use of port labor has for many years been spread over a large number of operations and agencies. Modern port developments may increasingly require centralized control and assignment of port labor which, in turn, may result in decasualization. In this regard, it is interesting to note recent negotiations toward guaranteed work hours or guaranteed annual income by port labor, which are just one of many manifestations of the expected trend.

A modern port also requires a different approach to management. In many instances where centralized port management of all port factors was difficult or unfeasible, an increasing number of operators have opted to purchase or lease major terminal facilities or berths to assure integrated control and management of all important factors required to perform the port functions.

These trends are expected to continue to grow as the number and capacity of specialized ocean carriers increases. The percentage of specialized carrier capacity among the world merchant fleets has more than doubled in the past decade and can be expected to reach 80% of total world DWT capacity by 1980. This, in turn, will make the multipurpose port or berth largely obsolete as an increasing percentage of cargoes is handled through specialized facilities. It can easily be shown that the future demand for multipurpose port or berth facilities is rapidly diminishing. This fact above all should influence the investment and planning of U.S. ports.

1.0 INTRODUCTION

The function of a port is to provide for efficient and least cost inter and intra modal transfer, inspection, storage, form change and control of cargo. Cargoes come in various physical forms such as liquid bulk, dry bulk, parcel or pseudo bulk, containerized, palletized, prebarged, non-standard unitized, break bulk or other.

Ports are critical junctions between major transportation links. Well over 96% or 4.4 billion tons of all the cargo in international trade moved through the ports of the world in 1975.

Port costs today account for nearly 50% of all of international transport costs from port entry to port exit. These port costs were in excess of $50 billions in 1975. Broken down into the major elements:

$10.0	billion	Port Labor Costs
1.4	"	Fuel, Water & Power Cost (Port & User Vehicles)
1.6	"	Port Maintenance Costs
3.0	"	Port Replacements & Improvements excluding investment in fixed assets
1.0	"	Port Administration & Security
20.0	"	Ship Turnaround (Port) Costs
7.0	"	Land Feeders (Road, Rail), Turnaround (Port) Costs
6.0	"	Financial (Capital Repayment, Interest, Etc.) Costs

As a result, it is noted that over 55% of all port related costs are the result of time losses in turnaround of port user vehicles. If costs of stevedoring, usually paid by ship owners directly and not included in the above labor costs are added, then port related costs assumed by shipping and land feeders become even more significant.

Ocean transport cost of world international trade was about $50 billion in 1975 of which $20 billion were spent on ship turnaround in ports and $8.0 billion for stevedoring and $2.8 billion for other direct charges against the ships. Therefore, only about 44% of all shipping costs were consumed in paying for productive shipping transport. This percentage can be shown to be equal to as little as 35% in the case of general cargo ships.

Because port related costs therefore generally exceed direct ocean transport costs, a major emphasis is placed today on improvements in cargo handling and port technology, and resulting ship and feeder turnaround. Port technology has lagged largely behind recent developments in ocean transport technology, both in concept and application. Shipping technology and as a result transport economy improvements have been largely in the direction of:

1. Economics of scale in size & speed
2. Economics of physical form change of cargoes
3. Economics of specialization in cargo types or forms such as bulk and unitized carriage of goods

These developments impose new and changing requirements on ports. There is an increasing demand for ports to establish deeper draft specialized facilities designed to effectively accommodate large, capital intensive shipping and transfer of cargo in unique physical form at high rates.

The port facilities must often also perform physical form changes of both bulk and break bulk cargoes by slurrying, liquifying, gasification, consolidation, deconsolidation, packaging, unitizing and more.

It is estimated that if the world's ports were to improve their ship, feeder and cargo transfer capacity in line with available ship and feeder technology as much as 60% of port time related costs could be saved. This would not only reduce world port related costs by about $15 billion, but also increase shipping capacity (by the availability of more underway ship days) by about 20% for a total benefit of about $25 billion which constitutes well over 30% of all expenditures for shipping and port costs in international trade.

An important consideration is the fact that while the many port users improve their technology continuously and while it takes just a few years to introduce new shipping or feeder transport technology, it takes many more years (5 - 10 years) to introduce major improvements or changes in ports. Such improvements are, as a result of their long development time and large unit cost, made only very intermittantly and are generally planned for economic lives which greatly exceed those of ocean and land transport users. It is for this reason that cargo transfer and port technology must be planned for a very long future time horizon to assure that technological obsolescence does not occur too early in the economic life of such developments.

It must today be recognized that the function of a port is not to provide a separate and distinct service, but it is to serve as an integral part of a chain of transport links which form an integrated transport system designed to move cargoes from origins to destinations. Ideally, therefore, the port should provide a capability of continuous flow transfer between land (feeder) and ocean transport modes. Because of differences in unit vehicle size, of capacity per unit time between ocean and land transport mode, as well as because of problems of effective transport scheduling, direct and continuous inter- or intramodal cargo transfer is usually possible only for a fraction of the cargo flow through ports.

Ports serve as multipurpose, special purpose, regional or transshipment ports, and their planning must uniquely recognize their specific function. Port operational and development planning must be approached in a formal manner to assure consideration of all the complex interactions and factors that impact on port performance.

1.1 Port Operations & Planning Objectives

The operations planning and development objectives of a port are largely determined by its status and general objectives, particularly its ownership and degree of legal and financial autonomy. A privately owned port or terminal probably has as its objective the maximization of net profits or the minimization of costs if it handles mainly proprietary cargoes. Municipal or regional ports may be instructed to provide the community with the best possible port service consistent with the municipality's or region's financial capability. However, if the port is in a strongly competitive or monopolistic position, it may be viewed as a source of revenues, and thus instructed to produce as much profit as possible.

From a transport economics point of view, national or regional ports should aim at meeting the need for port services at the lowest possible total cost to the national or regional economy. However, this ideal goal is often set aside or modified by numerous economic, political or other considerations.

A government may decide to guide the development of its ports in a specific direction by ownership control, jurisdictional or legislative procedures, subsidies, taxes or regulation of ports. The goal may be to promote economic growth which may lead to larger investments than strictly economic criteria could justify, or to satisfy political aims such as greater national control of foreign trade.

National policy may influence port policy, such as development of domestic ports even if the transport demand could be met at a lower cost by using a foreign port. National trade interests may also play a major role.

Since no country has unlimited resources, the issues of whether and when a need for port services should be met depend on the availability of resources as well as priorities in resource allocation.

A port planning or development strategy is usually formed by maximizing or minimizing an "objective function". This "objective function" may be simply the quantified formulation of the policy adopted for the port. Thus, it becomes the criterion governing the choice between alternative development opportunities, investment and pricing strategies as well as operating procedures. It is used to select the strategy to follow in order to achieve the desired objectives.

The imposed objective may result in an optimum plan to meet this objective which can be either static or dynamic by either allocating existing resources in an optimum manner, or by allocating resources in such a way that the best overall result is obtained over the entire period considered. The dynamic optimum plan need not necessarily include sets of statically optimum plans over the whole period of time. It will in fact do so since most port development is carried out in stages.

There are a number of generally useful port operations and planning objectives:

1. Service Sufficiency: Frequently the port authority follows, consciously or unconsciously, a policy of attempting to service a certain percentage of the traffic at anytime or within a given time. This objective is similar to assuring that the average berth occupancy rate is within a given level.

2. Profit Maximization: In some cases the goal will be to maximize net profits, i.e., the difference between revenues and the total costs of financing, operating and administering the port, either in the short or the long run. This is often the case where the port is private or where the government or local authorities regard it as a source of revenue. Such a policy may be pursued if the port constitutes a local or regional monopoly or is under central control. It is thus in a position to apply a tariff in excess of the marginal costs of operating without appreciably affecting the demand for port services.

3. Least Cost Service: A port may have as its objective to provide port services for all or essential demands at least cost. Least cost may be defined as least costs to users (ship operators, cargo forwarder or shipper, truck operator, railroad, barge operator, etc.) of the port, or least total throughput cost at the port where total cost may include user costs such as waiting, lost time, lost opportunity and related costs.

4. Economic Impact Maximization: A port may be a major factor in determining the viability and growth of the hinterland economy. As a result, the port objective is often to maximize economic impact on the hinterland by port planning, investment and operations. This may be interpreted as maximizing:

   a. Competitiveness of hinterland economy by introducing effective port capacity and throughput charges.

   b. Maximization of direct and indirect employment at the port including ripple effects.

   c. Inducement of development of port related or dependent industry by provision of land, facilities access and port capacity which encourages such development.

   Economic impact maximization may also result from many secondary factors introduced by the adoption of other base criteria. As a result, this type of objective is not mutually exclusive.

5. Revenue Maximization: In this approach a port may desire to maximize total revenues by developing facilities and capacities which will attract maximum revenue earnings.

6. Maximization of Internal Rate of Return: This is only one of the purely economic criteria and is of primary importance to ports (public or private) financed by investments from the private sector. Similar criteria may be return on investment, return on assets, etc.

In addition to the above there are several other objectives which pertain to public utility, contribution to the community, national good, and various other local or aggregate objectives. These will be discussed in more detail under Port Pricing and Port Investment Analysis later in this report.

2.0 PORT & TERMINAL TECHNOLOGY

The activities involved in each type of port terminal are basically similar, although the way they are performed and the equipment used will vary according to the type of characteristics of the cargo to be handled.

Generally, we distinguish the following major cargo categories:

1. Unitized
2. Bulk Cargo (Liquid or Dry)
3. Break Bulk Cargo - General Cargo
4. Specialized

Each of these categories may be further subdivided into subcategories either from the point of view of properties of the cargo itself or from the way it appears for handling operations.

The function of a port is to provide for efficient and least cost intra- and intermodal transfer, inspection, storage, form change and control of cargo. Cargoes come in various physical forms such as liquid bulk, dry bulk, parcel or pseudo bulk, containerized, palletized, prebarged, non-standard unitized, break bulk or other.

Ports serve as multipurpose, special purpose, regional or transshipment ports. The major characteristics of ports today are that they are continually changing and subject to dynamic planning.

Although many ports still largely operate as break bulk general cargo ports with most of their facilities serving all types of ships, many modern ports today are composed of specialized facilities each of which serves one type of ship, cargo form or both.

The main functions of a port are:

Loading/Unloading
Stacking/Unstacking
Transfer
Physical Form Change
Storage
Consolidation/Deconsolidation
Environment Control
Inspection & Marking
Inventory
Documentation & Cargo Control

The types of facilities and terminals included in ports depend greatly on location of the port and on the annual volume of each type of cargo transferred through the port.

There are several recent developments in port operations and technology such as:

a. Increased continuity of cargo flow

b. Better integration of conflicting feeder and ship loading and storage requirements.

c. Adaptation of optimum cargo form, containment and parcel size of ship and feeder requirements (physical form change of cargo in port)

d. Modern magnetic or electronic marking and read-off system

e. Modern (often computerized) cargo inventory, and flow control systems, location control and warehouse planning

f. Improved cargo transfer and transport devices

g. Controlled and planned cargo inspection (spot test, etc.)

h. Environmental control for cargo quality and port ecological control

i. Improved ship handling, mooring and docking methods

j. Facility use planning such as berth allocation, equipment/manpower assignment, etc.

Many advances have been made in the above mentioned areas of port operation. Highlighting important port technology developments by major category:

Container Handling

The majority of containers are handled by shore mounted container gantries to and from non-selfsustaining cellular containerships. Freight stations are preferably located well in the rear to assure separation of small truck and full container (truck, trailer, flat car, etc.) movements. Although generally only a fraction of container movements by wheeled vehicles interfaces directly with the pierside container gantry for direct delivery or take off some installations rely exclusively on truck trailer movements to and from the pierside gantry. In this case most containers not directly delivered or taken off are temporarily stored on trailer chassis. This approach appears attractive only for fully integrated single control truck-ship-truck operations, which assures rapid turnaround of ships and trucks and a large proportion of direct delivery and take off during the time the ship is in port.

The most important recent developments in the basic method of container handling are as follows:

1. Belt Container Conveyors serving one lane under transtainers, portainers or gantries designed to feed a continuous flow of containers to a static position under these handling devices and therefore eliminate their longitudinal movements. These conveyors are usually also equipped at each end with automated truck or trailer transfer devices of containers between truck or trailers and the conveyor belt.

2. Computerized Stacking Control which provides optimum stacking and unstacking sequences and stack cell allocations, designed to minimize transtainer and gantry working time as a result of ship loading and unloading time. This type of system is

usually coordinated with computerized containership cargo planning, which minimize container rehandling requirements while maintaining all the ship's particular requirements.

3. Automated Container Inventory and Storage, Various Container Chain Type, retracting and shelf conveyor type automated container warehousing system have been developed. These are designed to automatically stack and recall any container and transport it to or from a transfer station interfacing with pierside gantries belt conveyors to the freight station and inland transport system.

4. Batch Container Handling: Several methods for the handling of blocks of standard coupled containers are under investigation. These designs attempt to permit handling transfer and storage of blocks of coupled containers. Most are based on transversely assembled blocks of 20' to 40' containers two to three high and 2-8 containers wide.

5. Container Elevators & Sideload Devices: Devices similar to shipside pallet loaders designed to transfer containers to or from pierside to ship decks. The elevator either only transfers containers from pier to ship or extend like pallet loaders into the (noncellular) box type ships hold were conveyor, cushion pallet or rail devices transfer of distribute the containers transversely across the ships width.

There are other developments all designed to facilitate container transfer sequence control and ship or feeder turnaround.

In addition, there are many developments such as selfconsolidating/deconsolidating containers, collapsible containers, inflatable containers, disposable containers and more. All of these developments have an impact on port handling and transfer technology and operating requirements and will continue to demand dynamic change in port facilities, equipment and procedures.

Barge Handling

Since the introduction of barge carrying ships, LASH (1967) and Seabee (1970), this method of transport of floatable containers has become quite popular. The primary advantage offered is the servicing of undeveloped or congested ports by a largely port independent shipping system. It is particularly attractive for the handling of pseudo bulk cargoes (bulkable cargoes moving in less than ship lots).

Recent developments include specially designed barge fleeting areas which continue the functions of container marshalling or stacking yards and container freight stations.

They may include barge loading dockage channels or berths where chain of barges are loaded/unloaded while continuously or intermittantly moving. There are also hopper type barge unloaders automated catenary bucket barge unloaders/loaders and other devices available now.

Warehouse

Much new technology is available for warehouse operation. The most important developments include automatic stacking and retrieval devices computerized cargo locator systems, narrow aisle automated pallet movers, monorail supported rotating pillar stackers, deep shelf conveyors, variable controllable speed conveyors, multidirection conveyors and more. The overriding objective is the development of devices which will:

1. improve utilization of warehouse area and space
2. speed up stacking and retrieval including the retrieval of cargo at any location in a stack without rehandling of other cargo in the stack
3. assure effective location control
4. guarantee cargo safety
5. improve utilization of capital investment and labor employed in warehousing
6. permit good warehouse inventory and cargo operations planning
7. assure warehousing efficiency and good environmental control

There are also new and efficient transfer devices such as air cushion pallets with hand or mobile tractors, inflatable bag jacking or lifting devices, etc.

Bulk Handling & Transfer

The most important developments in cargo transfer and port technolgoy are in bulk handling and transfer. An even increasing percentage of world seaborne trade (78.2% in 1974) is moved in bulk by specialized carriers serviced at specialized bulk terminals. This is the result of the dominance of liquid (largely petroleum) cargo in world trade and the increasing availability of efficient dry bulk cargo handling and transfer methods. Most bulk handling and transfer methods attempt maximum continuity of flow even when both ship and land feeders provide disparate intermittant service. As a result, port storage facility capacity for liquid or dry bulk cargo has actually been reduced notwithstanding the significant increase in average ship size.

Liquid Bulk Cargo

All types of liquid bulk cargo are today handled by ports varying from petroleum and petroleum products to palm oil, solvents, and sulfuric and other acids, fruit juices, milk, wine, asphalt among others. These cargoes are usually loaded or discharged by pumping at rail pressures of about 150 psi ($15\ kg/cm^2$) and rates of up to 10,000 tons/hour. Modern liquid bulk loading/unloading systems are remotely or automatically controlled and often computer planned to assure optimum control of flow rate and loading sequence consistent with ship and cargo requirements. Future tankers and storage tank farms may be equipped with remote tank level indicator valve and pump controls that are tied into the central loading/unloading control panels directed by computer which generates control signals resulting from an optimum loading/unloading sequence and rate computer program.

The accent on development in/and extensive experience with slurry, suction and pneumatic pumping of solids introduces many new opportunities for bulk handling of dry cargoes in liquid form.

A wide variety of commodities are suitable for handling as a slurry either because of savings inherent in their handling or because they are slurried at the same point in the processing or consumption chain.

Typically, such commodities are: iron ore, coal, salt, aluminum, bauxite, laterite ores, base metal concentrates, potash, sulphur, phosphates, kaolin clays, wood pulp, etc.

In some cases it is advantageous to use a two phase flow of compressed air (or inert gas) in addition to a liquid carrier to reduce friction, assure good mixture and assist in pumping. Slurries are pumped over distances of up to 100 miles (5-20 miles between coasters). At rates of up to 2000 tph, suction pumping of solids is usually restricted to distances of a few hundred yards, while pneumatic pumping is generally limited to a few miles between coasters. Throughput rates of suction or pneumatic pumping are usually of the order of a few hundred tph per connection.

Dry Bulk Cargo

Dry bulk is generally loaded by shore based facilities with unloading performed by either shore shipmounted equipment. The major types of equipment used are:

1. belt conveyors and belt loader/unloader
2. boom and hopper (open-fully enclosed)
3. crane belt self unloading
4. crane or derrick types (clam shell, grab, etc.)
5. mixed crane belt types
6. scraper systems
7. conflow systems
8. pneumatic and other types
9. airslide conveyors
10. slurry systems
11. bucket wheel belt systems
12. catering bucket and chain system
13. auger type screw conveyor
14. para screw feeders
15. slurry

It is noted that there are a large variety of possible dry bulk loading/unloading systems. The major competition among large capacity cargo transfer methods is between conventional and slurry systems. The relevant equipment requirements are as follows:

	Mechanical	Slurry
Loading Port	Rotary car dumpers Stockpile area Stacker/reclaimer(s) Ship loaders Simple Berth Structure	Storage pond Cutter Dredge High power slurry pump Simple berth structure of offshore moorings
Discharge Port	Mechanical discharges Equipment Stockpile area Conveyors Stacker/reclaimer(s) Sophisticated berth Structure Car loaders	Booster pumps (if required) Storage pond Cutter dredge Simple berth or Offshore mooring

It is noted that mechanical systems generally require less power and have larger investment costs, while slurry systems require large amounts of power and have lower investment costs. Direct terminal operating cost for the two types of systems are generally comparable, but slurry systems cause essentially no atmospheric pollution but attain low water pollution only with clarification and a closed loop dewatering system incorporated in the loading/unloading cycles.

Interesting developments have also taken place in mechanical systems such as the shipmounted conflow system and the very flexible and efficient catenary unloaders that can be made mobile and are largely independent of permanent shoreside equipment.

Special & General Cargo Handling & Transfer

There are numerous new devices for the handling and transfer of special cargo such as:

1. Logs

   Special Log/Lumber Straddle Carriers, Side Loaders, Bundlers, Stackers & Markers, Modern Log or Lumber Terminals are integrated operations where logs and lumber are received, cut, graded and measured, marked, stacked, preserved, bundled and loaded. A reverse sequence of operations occurs at the receiving terminal. Specialized and semi-automated equipment is available for most of these operations.

2. Vegetable Oil & Other Liquid Goods

   Palm, coconut, other vegetable oil, fruit juices, etc, are today loaded largely in parcel tankers as pseudo bulk liquids requiring special care and conditions. Because of the high value of these cargoes, special facilities and equipment have been developed which assures loading/unloading operations without risk of mixing, contamination, oxidation, temperature change (outside acceptable limits) and other factors which may influence the quality of the products. Special tank pipeline, pumping, return flow, inerting and coating system have been developed. Parcel tanker loading/unloading stations are generally designed to handle many (10-20) different products simultaneously.

3. Liquified & Pressurized Gas

Port facilities for the loading/unloading of this increasingly important cargo are concerned with liquification of the gas or reliquification of the boil-off, the maintenance of cryogenic or pressurized conditions (a combination of cooling and pressurizing) which efficiently maintain the liquified state of the gas. Special pumping, piping, storing, compressing, recycling, cooling, insulating and separating equipment has been designed and form part of the integrated liquified or pressurized gas loading or unloading terminal installation.

4. Heavy Lift Handling

Economy in size of many goods and the economy of pre-assembly and pretest of the manufacturers plant make it increasingly common to ship large fully assembled manufactured units such as power plants, locomotives, ship's houses, manufacturing plants and more. As a result, a completely new range of heavy lift handling and transfer devices such as large stroke heavy lift jacks, air cushion pallets, scissor lifts and portable shipside elevators have been developed and often replace the conventional heavy lift floating mobile or stationary crane. The range and feasibility of floating cranes has also dramatically increased (largely responding to offshore industry demand) with cranes of 3000 ton capacity available now.

5. General Cargo Handling & Transfer

Even though it is usually assumed the general break bulk cargo has remained traditional, there are numerous technological improvements available from air pallets for horizontal transfer, pallet loaders (shipside, hold or continuous shipside hold transfer) inflatable dunnage bays, polyurethane separators, continuous chain or platform loaders, catenary chain loaders/unloaders, pallet conveyors continuous cableway loaders, portable monorail loaders/unloaders and more.

Storage

In parallel with cargo transfer technology developments, there have been many changes in the methods of storage, stacking, retrieval and maintenance. Fully automated and largely computerized warehouses are available today which permit retrieval of any piece of cargo (loose or on pallets) without dislocation of other cargo. The technology has been derived from automated warehousing used in merchandizing and parts distribution. Although expensive to install, this type of system permits space utilization of up to 82% of the volume available, which is 50% more than usually feasible. Such warehouses are remotely operated by one man and therefore operating costs are only a fraction of those conventional warehouses.

Ship Docking & Mooring

Major advances are available in the technology of ship docking and mooring. These include:

a. laser powered distance & approach
b. controlled & automated line handling
c. hydraulic (telecoping) mooring devices
d. side thrusters, active rudders and other ship maneuvering assist devices.

These and more are all designed to make ship docking and mooring safer, faster and less labor intensive.

Documentation & Information Control

A major bottleneck in port operations has always been the lack of coordinated documentation and information flow which assured that all the information necessary at each decision point and time was available when needed. Port operations are sequences of decision, each of which requires information. Information often documented is needed to control cargo handling, storage assignment, cargo routing, stowage planning, equipment use, marking inspection and many more activities.

The traditional cumbersome manifest and other cargo documents have resulted in cumbersome arrays of hand written notes, and listings designed to control the flow of cargo through ports. These are methods available now to fully code all information requirements and control information flow, retrieval, storage and aggregation on a real time basis for instant recall. In this manner, real time control of all operations including cargo flow, cargo inventory, storage location, equipment and manpower assignment, facility allocation and more can be achieved at great saving in time and cost. In addition such an integrated computerized port operations control system will usually result in a drastic increase in capacity without increase in resource allocation or investment.

Security

Port security comprises cargo security, revenue and customs fee collection, and safeguard of property and life. Fire and other hazard protection is today provided by advance technology with quick response characteristics. This technology benefits from advances in the use of gaseous, foam and liquid inerting, blanketing, squashing or cooling agents that can be rapidly applied over large distances and areas.

Electronic, magnetic, optical and electro-optical devices play an increasingly important role in movement control, inventory control, cargo identification and general port security.

Port security problems are significantly different now with the rapid increase in containerized, trailer, barge and bulk handling of cargo. Effective identification, movement control, and online inspection of cargo as well as cargo security is more important now. Small scale pilferage and cargo loss has been largely replaced by loss or damage of complete containers or trailers, or utilized cargo in various forms. This has somewhat reduced the security risk the new technology was designed to prevent.

Environmental Control

There are many new methods for effective environmental control and continuous monitoring of cargoes in containers, warehouses, open storage, bulk storage, bays, secure storage and specialized storage. Many of these monitoring devices are remote recording and selfadjusting and provide reliable information to support claim defense and other problems. Disposable plastic containment (inflatable or not) provides an increasingly effective opportunity for cargo condition control and separation.

Conclusion

Developments in cargo transfer and port technology have made rapid progress in recent years designed to catch up with the great advances in shipping and feeder transport technology. The trend is towards increased capital intensive operations which match port handling rates with maximum acceptable handling rates for ships or inland feeders.

This is primarily because it is recognized that an efficient port must be able to serve user transport at the optimum rate to stay competitive. We expect further attempts to assure more continuous cargo technology which permits a percentage of direct loading/unloading of cargo between ocean and/inland transport. Computerized automatic control of increasingly integrated port facilities is just a matter of time.

Why is There a Need for Port Planning?

The basic reasons for improving U.S. ports are economic. U.S. trade in recent years has increased by a fairly regular compound growth rate of at least 6% per annum. This corresponds to a doubling of the transport demand every 12 years. If this growth rate is sustained, the volume of goods to be handled during the next 25 years will exceed the total volume handled in the entire previous U.S. history. Many U.S. ports have been able to handle part of the traffic increase in recent years by marginal expansion, increased mechanization and other operational and institutional improvements. Once this is no longer possible, however, further traffic increases may suddenly bring about critical congestion of the ports if plans for their expansion have not been made and implemented in time. Such congestion is an economic cost to the U.S.

economy in terms of trade as additional ship turnaround costs would normally be passed on. The lead time from a port project initial development to implementation is considerable, and may take as long as 5-7 years.

There are competing demands for investment capital from other sectors. This makes it essential to develop well documented investment plans.

Port planning should provide maximum flexibility, which support effective and timely decisions. This means that options for adoption of alternative development strategies should be kept open as long as possible and lead time considered, but the time when decision and action must be taken should be specified and criteria for arriving at the right decision provided.

The first step is, of course, to review all available information, including existing economic development and traffic flow forecasts, predicted technology used, economic development plans, reports on previous port or port-related studies, and data on facilities and procedures in existing ports, as well as interacting or trading partner ports. This review must include field studies and interviews with public and private agencies, concerned with port operations, regulation, financing and administration.

The main reason for port planning is an existing or expected need for improved port capacity and services. As the need may not be too clearly defined, it is vital to determine actual conditions including general studies of the entire hinterland or region involved. Based on these, projections of total transport demand and the modal distribution of traffic as well as forecasts of technological changes in shipping and handling can be made. From these, the future volume and composition of traffic through existing and proposed port facilities can be determined and forecasts made of the need for port capacity and services.

3.0 INVESTMENT CRITERIA & STRATEGIES

In the case of port investment, the establishment of suitable investment criteria becomes a lengthy task. The decision makers usually represent different interests and may be either or both port owner as well as operator. In some cases, even users may be involved in investment decisions. Furthermore, we have to distinguish between private and public owners, operators and users. As an illustration, Table 3-1 represents a categorization of possible owners, operators and users. Local, regional or federal authorities may impose constraints on the investment decision. On the other hand, organized labor as well as other interested groups may influence or even participate in the decision process. Thus in the more complex case, we have to deal with group decisions.

Timing is important in port planning not only due to the difficulties in the long design period and multiple period decision requirements but also to the special question of "time lag" which includes:

1. Recognition Lag: a period before the existence of a future problem is recognized.
2. Planning Lag.
3. Lag for the plan to be approved by port authorities and other public officials.
4. Lag while tenders for the work are obtained.
5. Lag between the letting of tenders and the beginning of construction.
7. Lag for delivery of capital equipment.

Recent finance theory has raised the attention to uncertainty of investments. Many uncertainty models are recommended. Some of these models assume that port investors are risk-averse, and it is possible to summarize any probability distribution of return by the mean of the distribution and some measure of the dispersion of possible return values. They also investigate what is the appropriate way to measure the risk of an asset, and what kind of relationships might be expected between risk and return. These are called "Expected Return" or "Fair Game" model for the efficient capital markets (perfect markets with homogeneous expectations).

An extension of the general expected return efficient market model is a random walk model. This model describes the environment that evolution of investor tastes and the process generating new information combine to produce equilibrium in which return distribution repeat themselves through time.

Uncertainty problem in utility industry area was examined too. By empirical valuation studies we know that the two-stage instrumental variable approach appears to be an effective way of dealing with the bias problems caused by errors of measurement of expected future earnings.

TABLE 3-1

OWNER	OPERATOR	USER	REMARKS
PRIVATE FIRM WHICH OWN & SOME OTHER RELATED BUSINESS [i.e., Shipping Company or land transportation or importer or exporter or any combination of the above]	PRIVATE FIRM (THE OWNER)	Private firm [The owner - operator only] The owner - operator private firm & others [Public or preferential use] Others only	 Rather rare case
	PRIVATE FIRM OTHER THAN THE OWNER WHICH OWN & SOME OTHER RELATED BUSINESS	Private firm (The Operator only) Private firm (The operator & owner only) Private firm (The operator & others) Private firm (The owner only) Private firm (The owner & others) Private firm (Owner, Operator & Others) Private firm (Other than owner, Operator)	Rather rare case Rather rare case to exclude the owner Rather rare case to exclude the operator Same as above
	PRIVATE FIRM OPERATING JUST THE PORT & NOT OWNING RELATED BUSINESS	The Owner only Others than the owner The owner & others	
	PUBLIC AGENCY OR TRUST	The owner & Others	Some public interest forces public to take the control of the port with some obligations to the owner
PRIVATE FIRM WHICH OWN ONLY THE PORT	OWNER	Others	
	PRIVATE FIRM OTHER THAN THE OWNER OWNING ALSO SOME OTHER RELATED BUSINESS	Operator Only Operator & Others Others Only	
	PRIVATE FIRM WITHOUT RELATED BUSINESS	Others	
	PUBLIC AGENCY	Others	
NATION	NATIONAL AUTHORITY	Others	
	STATE OR IN GENERAL REGIONAL AUTHORITY	Others	
	MUNICIPAL AUTHORITY	Others	
	AUTONOMOUS PUBLIC TRUST	Others	
	PRIVATE FIRM WITH SOME RELATED BUSINESS.	Only the Operator The Operator & Others Only Others	
	PRIVATE FIRM WITHOUT RELATED BUSINESS	Others	
STATE OR REGION	NATIONAL AUTHORITY	Others	
	STATE OR REGIONAL AUTHORITY	"	
	MUNICIPAL AUTHORITY	"	
	AUTONOMOUS PUBLIC TRUST	"	
	PRIVATE FIRM WITH SOME RELATED BUSINESS	Only the Operator Operator & Others Others Only	
	PRIVATE FIRM WITHOUT RELATED BUSINESS	Others	
CITY OR IN GENERAL MUNICIPALITY	NATIONAL AUTHORITY	"	
	STATE OR REGIONAL AUTHORITY	"	
	MUNICIPAL AUTHORITY	"	
	AUTONOMOUS PUBLIC TRUST	"	
	PRIVATE FIRM WITH SOME RELATED BUSINESS	Only the Operator Operator & Others Only Others	
	PRIVATE FIRM WITHOUT RELATED BUSINESS	Others	

The rational-behavior, perfect market model of valuation under uncertainty, stands up quite well when confronted with the data both in terms of what it says should be included and what it says should be excluded.

The estimates for the cost of equity capital and for the average cost of capital during the sample period differ very considerably both in level and movement from the conventional kinds of yield estimates so widely used in economics and finance. On the other hand, estimates for the utility industry do seem to confirm reasonably closely over the short sample period with movements in the long term rate of interest on bonds.

Shipping is a peculiarly uncertain industry in which to invest because it is subject to booms and slumps which are sometimes independent of fluctations in world trade. This is especially true when the ships which use the new port facility are more capital-intensive than the industry average.

The complexities of port investment decisions just outlined motivate the necessity of a framework for ordering of port investment activity consisting of three categories as follows (see Table 3-2):

a) Strategic Planning: The process of deciding on objectives of the organization, on changes in these objectives, on the resources used to obtain these objectives and on the policies that are to govern the acquisition, use and disposition of these resources.

b) Management Control: The process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization objectives.

c) Operational Control: The process of assuring that specific tasks are carried out effectively and efficiently.

Among factors considered in establishing a port investment or planning objective are:

1. Level of service or service sufficiency level. This is based on capacity (number and types of berths including equipment, etc.), technology and working hours available (by gangs, total shifts and more), port effectiveness and more.

2. Economic factors such as:

   - Profit Maximization (Net)
   - Cost Minimization
   - Cost Reimbursement
   - Resource Constraints
   - Economic Growth Promotion (Industrial, Agricultural, Transport, etc.)
   - Minimization of Total Transportation Costs
   - Other

TABLE 3-2

Decision Types	Objectives	Time Horizon	Management Level	Information Needed	Degree of Uncertainty	Risk	Degree of Aggregation	Degree of Integration
STRATEGIC	Acquisition of Resources Policies Identification of Opportunities	LONG	TOP	EXTERNAL & INTERNAL	MORE	HIGH	HIGHLY AGGREGATED	INTEGRATED
TACTICAL	Resource Utilization	MIDDLE						
OPERATIONAL	Specified	SHORT	MIDDLE & LOW	INTERNAL	LESS	LOW	EXTREMELY DETAILED	PARTITIONED

3. Social factors such as:

   - Maximization of Employment Opportunities
   - Maximization of Ripple or Tradeoff Effects
   - Minimization of Adverse Environmental Impact
   - Promotion of Community Development
   - Stabilization of Socio-Economic Factors
   - Liberalization of Movement
   - More

Port investment objectives and their metric are summarized in Table 3-3.

Investment criteria mentioned here are somewhat different from the meaning generally used. We are not emphasizing here the idea of discounted cash flow, present value, etc. Instead, we state the different objective policies which will lead to the investment decisions.

Port investment criteria will be different for various kinds of objectives. We might over-invest, say, due to the objective policy of maximizing throughput. Or, no investment will be made; we simply change operating policy by raising operating cost. In the long run, we might make moderate investments by keeping the throughput always in line with the demand forecasted.

None of these objectives are independent. We might assert, for instance, that the utilization of port assets must be optimized. Since ship port time is closely related to ship utilization, we must also make assumptions about the constancy of ship time while allowing utilization to vary. All these relationships are not so simple. We, therefore, need all kinds of models to illustrate them.

The degree of the complexity of the investment strategy models will increase with different investment criteria. The simplest model, examplified by the traditional queueing model, requires a lot of assumptions which might not even be realistic, but the advantage of it is its essential simplicity. In the more realistic simulation models, the interrelationships among different objectives are clearer. However, simulation requires large amounts of data collection and detailed technical definition.

In short term investment planning analysis, cost computation is simpler because limited alternatives could be chosen. For long term investment planning, we need more complex models to find the optimum investment strategy. For this reason, detailed descriptions of alternative generations of model structure are developed for long term investment planning.

TABLE 3-3 PORT INVESTMENT OBJECTIVES

OBJECTIVES	METRIC	COMMENTS
1) ECONOMIC EFFICIENCY	Discounted net national income benefits which are generated by a particular alternative. Transportation savings, land, labor goods, services, ship and land transportation costs. We must include secondary or multiplier effects. Additional employment - unemployment.	Ref: Prest and Turvey, "Cost-benefit Analysis - A Survey", The Economic Journal, Volume LXXV, Dec. 1965, pp. 675-683.
b) Net regional benefit (associated with equity also)		
c) Operating costs		
d) Facility utilization [land, capital, manpower, energy]		
e) Consumer costs		
f) Employee welfare		
2) EQUITY		
Geographical distribution effects	Discounted net regional income benefits	
Clan distribution effects	Similar	Ref: Major 1975
- Geographical Distribution Effect	Discounted net regional income benefits	Ref: Major, 1975
- Class Distribution Effects	Discounted net class income benefits	
Problem		
a) Definition of regions or classes		
b) Measure of equity (Possible minimize obsolete deviation from a distribution of benefits)		
3) ENVIRONMENTAL QUALITY OBJECTIVES	Percent reduction of all quality parameters simultaneously (i.e., phosphorus, nitrogen, ...)	
a) Pollution		
b) Aesthetic beauty		
c) Recreation facilities		
4) SAFETY		
a) To employees		
b) To shipping		
c) To population		
5) TRANSPORTATION DELAYS		
a) Shipping		
b) Land transportation		
6) FLEXIBILITY		
Changing requirements		
7) GROWTH		
8) COMMUNITY ACCEPTANCE		

4.0 PORT CAPACITY

A port's capacity is normally defined as the cargo volume the port is capable of handling per unit time. It is often expressed as a throughput in tons per unit length of wharf per year (M.T./M/year or LT/ft/year). This is obviously a measure which only considers berth capacity.

Using this simple traditional approach, capacities for port planning as listed in Table 4-1 are proposed for average conditions of port facilities with more than three berths which can usually be assumed to achieve an occupancy in excess of 50%. These figures are somewhat high for small ports and depend on a number of expected changes within the next decade in such factors as ship types, cargo handling methods, working conditions in terms of the number of ships worked simultaneously, working hours, work rules, etc.

Traditional norms of port or berth capacity as listed depend on variables such as:

1. Number of berths in a port sorted by type, length, available alongside draft, and available berth days per unit time.
2. Percentage occupancy permissible, defined as the ratio of utilized berths days (or hours) over total available berth days (or hours). Permissible berth occupancy or berth utilization ratios are determined by acceptable levels of average and maximum ship waiting time. Average acceptable ship waiting time must be determined for each major ship type and size range on the basis of economic political and other competitive factors.
3. Ship size and ship types including distribution of ship sizes by DWT or GRT, lengths, number of hatches, type of cargo gear, type of cargo carried and other relevant information. These inputs must be determined from available data of past and forecasted ship traffic, interarrival times, port turnaround times and similar information.
4. Working hours and labor (gangs) productivity in terms of output in tons or other relevant measure per hour (or shift). Working hours available must include considerations of work rules, permissible overtime, number of shifts, Saturday, Sunday and holiday work, penalties and other considerations.
5. Downtime which must be determined resulting from effects of work rules, bad weather, opening and closing of hatches, inspection, safety, environmental protection and other requirements resulting in downtime.
6. Distribution of or quantity of cargo handled per ship call by cargo type, cargo form, ship type, ship size and trade served. This must usually be divided into the average amount of cargo handled per hold, tank or cargo compartment.

Table 4-1

Optimal Port Capacities

Ship Type and Cargo Handling Method	Yearly capacity per m wharf V (M.T./m/year)	Occupancy Degree DO (%)	Gross Gang hour/ rate crane hour rate - R (M.T./h)	Berth length L (m)
Barge-carrier barges	3,200	70	20	20[a]
Conventional ships, no pallets	1,000	50	15	210
Conventional ships, 100% pallet	2,700	50	40	210
Specialized pallet carriers	3,300	50	80	210
Container feeder ships, two cranes	3,700	50	116	160
Main container ships, two cranes	6,000	30	325	280

[a]Barge-carrying vessels themselves do not require any port facilities.

7. Available cargo handling and transfer equipment by size, capacity and number. Conversely, this data can be provided by cargo handling or transfer rate as a function of equipment assignment to specific berths.

8. Available transit, storage and open storage areas or volumes assigned to particular berths.

It is traditionally assumed that ship arrivals follow a random distribution and can therefore be modelled by a Poisson distribution On the other hand, ship berth times generally vary as the sum of a constant and a random service time. The usual practice is to define an acceptable ratio of ship waiting time to ship berth time. This ratio is generally assumed to fall between 10% and 25% for most ports. The resulting percentage berth occupancy for different numbers of available berth for a particular type and size range of ships is shown in Table 4-2.

The assumption that arrivals follow a random distribution may not be applicable to passenger lines, container ships and roll-on/roll-off ships which need special berths and follow strict schedules. However, since these ships have a high initial cost and are very expensive to operate, a low occupancy ratio is usually acceptable for their berths.

Ship size and type distribution influence port capacity, as a result of the total number of ships that can be accommodated along a berth length, number of holds that must be served, the handling or cargo transfer gear required, the existence of side doors with pallet elevators and bow and stern doors, and the possibility of having forklifts operating in the holds of existing cargo vessels.

For the purpose of port planning, port capacity measures may involve either the short run problem of a particular port facility and its physical capacity in terms of the number of vehicles (ships, land transport) or equivalently the amount of cargo that can be served or the long run question of capacity to meet projected demand for service in the future.

Economic analysis provides the criteria of economic efficiency which can be used to determine a level of economic capacity under these two conditions. The short run case corresponds to short run equilibrium through an appropriate choice of port operating variables and pricing. The long range decision corresponds to the appropriate choice of scale of plant and choice of design variables of the port determined through investment analysis.

To provide the background in development of a framework and methodology for the selection of measures of "optimal" design of ports and for the evaluation of port "efficiency", production effectiveness of profitability, various approaches to the establishment of port capacity measures were reviewed.

Common to the recent literature is the acknowledgement that previous measures of capacity such as specified levels of "tons of cargo per linear foot of wharf per year" that could be handled are inadequate

Table 4-2

Traditional Percentage Berth Occupancy

Number of Berths (N)	$\frac{T_W}{T_B} = 0.10$	$\frac{T_W}{T_B} = 0.25$
1	12%	25%
2	35	50
3	48	62
4	56	68
5	62	73
6	66	77
8	72	81
10	76	84
12	79	86
14	81	88
16	83	89
20	85	93

to whether a port is operating efficiently or whether capacity should be expanded.

For use as a measure of efficiency of the port, the measure assumes some optimum mixture of warehouses, land transport and gives no information about sources of inefficiency. For use as a measure of capacity expansion, the assumption of one "optimum" mix does not seem likely, since costs and benefits would vary among ports and types of ships and one would expect the cost-benefit tradeoff to result in different values of "tons of cargo/linear foot wharf/year". Also, this kind of measure does not contain information about all the costs such as those relating to ship turnaround costs, feeder interface costs and more.

Given a capital budget, selection of an "Optimum" port design or terminal investment and short-run technique for a particular port based on economic analysis involves a number of steps:

1. A decision upon the goals or criteria of desirability of the projects to be undertaken. If there is more than one goal, decide upon a procedure of how they might be combined. For a privately operated port, there may be a single goal of profit maximization of the port. For a private port, say a port of an oil industry, the goal may be profit maximization or cost minimization to the oil or other terminal operating company; this may lead to direct consideration of costs of ships as well as port operations if the terminal operator is also the ship operator, owner or charterer or if he is liable for demurrage type of delay payments.

2. Identification of costs and benefits associated with each goal. For example, a new device for cargo handling may contribute to profits of the port by increasing the share of market (increase in demand) because of better service resulting from decrease in turnaround time and decreased labor costs. The costs would be operating and maintenance as well as capital costs of the new devices.

3. Determination of measures and decision rules to apply to the measure in order to determine if the goal is satisfied. For example, the measure of net present value might be used with the decision rule "invest if the net present value is positive". Applying this to the first example, the net present value would be the difference between the discounted cash flow of increased revenues, plus decreased labor costs, minus maintenance cost and the initial machine cost. Similarly, for the second example the net present value would be the discounted value of increased ship productivity plus decreased labor costs, minus machine maintenance cost, less the initial machine cost.

4. Methods of measuring the costs and benefits to be used in the analysis must next be determined. Two types of questions occur here; one is how to assess values of resources used and benefits gained. The other is to estimate the amount of

cost incurred and benefits gained. For many types of equipment, the market valuation will give an appropriate value of opportunity cost. For the value of increased productivity of ships, it would be necessary to determine how the extra ship time would be used.

The second question, in the case of ports, requires an estimate of changes in the quality of service such as decreased waiting time produced as a result of the project, changes in demand and quality provided. The quality of service such as waiting time as a result of design parameters for a fixed demand can be estimated by analytical models like queueing models or by simulation. Demand can be estimated by behavioral or econometric models. The estimated amount of service in each period coupled with the valuation can provide an assessment of costs and benefits for each period under consideration.

5. Alternative projects need to be generated for purposes of evaluation. To do this it is desirable to identify the parameters of the port that control port capacity (amount and quality of service provided) and to characterize their effects on costs and benefits. This has in common with Part IV, the estimated total changes in the quality of service.

   In addition, for the purpose of generating alternative designs, it is desirable to identify and quantify relationships between alternative ways of accomplishing the same change (such as a decrease of total time in port by means of changing service rate or changing number of berths) and identify and quantify impacts of a change in one part of a port or another part (for example, an increase in service rate at a dock would increase flows to warehouses and sheds which might increase costs there). In the case of increased service rate versus number of docks, we note that both have an effect on total time in port (service time plus waiting time).

   The costs associated with increasing the service rate are changes in costs of labor, machine or dock space. The costs associated with increasing the number of docks are the expansion costs. The benefits in the first case will result from a decrease in service time and waiting time, and in the second from a decrease in waiting time.

   The best alternative depends on the costs and any differentiation of the ship operators between costs of time in service and time waiting.

6. Application of decision rules to the cost benefit measures for each of the alternative projects.

There have been several attempts to develop a Port Capacity Planning Model in the context of network analysis. A typical port would be considered as a network with capacity limitations on links. The port will be viewed as a facility for transfer of cargo from ship to inland destinations or vice versa. Other functions of the port (which will form nodes of the network) are storage, consolidation facilities, distribution center (other forms might be also includes like auction). Various links of the large scale network would be cargo transfer from ship to warehouse and then to means of transport like sea, railroad or roads or direct links to transport vehicles from the ship bypassing storage.

Most existing network type capacity models are based on multi-commodity flow concepts and apply these algorithms developed to specific large scale port flow networks. They generally seek to find optimal simultaneous routings through the network.

Most work done on similar problems have assumed infinite capacity on the links of the network.

In early studies of port operation, most of the papers were concerned with the ship-apron activity. It is usually assumed that some probabilistic arrival and service time distributions are given, and other link characteristics are calculated from these distributions.

4.1 Shortcomings of Some of the Existing Port Capacity Models & Measures

The studies of non-network-type capacity models generally fail to point out the possibility of congestion occuring on the links other than ship-apron. Very little work has been done on factors such as cargo overstow, equipment downtime, equipment availability, etc. Numerically, these factors greatly influence port capacity.

Network approaches are simple and practical.

A mathematical model of port operation can actually be built and the logical relationships among links can be derived. For one thing, if we take the ship-apron and apron-storage link as two stations in series, we will find blocking occurs more often in the first stage than the second one. This is true even for the general N-stage problem where the maximum possible utilization for the first stage is the maximum possible utilization for the entire system. In the standardized method, the utilization in both links is assumed equal. This is obviously wrong.

The standardized method develops those modifiers and asserts that all of them are multiplicable and uses the proportion of cargo flowing through the link to divide the capacity in order to incorporate this factor into capacity computation. Actually, the capacity will go to infinity as the proportion approaches zero.

It is felt that most of the factors can be included in a probabilistic model which can also include those deterministic factors already considered in the method. The peaking factor, for example, can be described by introducing the non-homogeneous Poisson model where inter-arrival rate λ is a function of time.

By using queueing theory, a clear definition of capacity and actual throughput can be derived. The capacity is in fact the service rate of the link, and actual throughput is the output rate of that link. To compute the service rate, a GERT network model can be used to determine the influencing factors such as cycle time of each link.

Further questions about dependency among links could be solved by using non-systematic tandem queue theory. Some measurements of the blocking behavior among those dependent links could then be derived. The queueing network can be analyzed by decomposing itself into many tandem queues.

4.2 Capacity Performance Indicators

Performance indicators are used by port managers, planners and advisers to judge port operating conditions. The UNCTAD report (1974) used two sets of figures to serve this purpose. The first and smaller set consist of primary indicators which allow a broad judgement to be made and points of serious deviations to be noted. The second and more detailed set are secondary indicators which allow definition of the causes of those deviations.

The ship-apron link of a general cargo terminal, for example, has the following indicators:

	Primary		Secondary
Berth Throughput	ton/berth	i.	ton/meter of quay
		ii.	over-quay throughput (as primary indicator, but excluding all over-side working)
		iii.	over-quay throughput/meter
		iv.	average ship length/berth length
Ship Port Time	total time in port	i.	waiting time
		ii.	service time
Berth Occupancy	hours occupied by a ship / total # of hrs.		All all percentage of total time
		i.	hours spent by ships at the berth actually working
		ii.	hours spent by ships at the berth not working during normal working hours
		iii.	hours spent by ships at the berth not working, outside normal working hours
		iv.	hours spent at the berths by ships for reasons other than the primary purposes

Ship Productivity	ton/ship working hours	i. ton/ship hour at berth ii. ton/ship hour in port iii. average number of gangs/ship/shift iv. average ton (discharged or loaded)/ship v. ton/gang-hour

5.0 PORT PRICING

To discuss tariff policy one must consider three approaches to pricing policy. The first is the purely economic approach which argues for the use of marginal cost pricing to insure efficient use of the transport facilities and services. This method assumes the use of marginal cost pricing throughput the transport sector and may offer a sub optimal price structure in situations where related activities and services are priced in another manner, e.g., by oligopolistical pricing.

The second approach is the financial approach which seeks to set prices so as to recover both fixed and variable costs and to provide an adequate return on investment. The determination of an appropriate price structure using this approach is extremely complex because pricing generally determines the level of demand which in turn affects the long run cost and the level of return.

The third approach derives from the fact that a port is part of the public transport infrastructure and evaluates the effects on port pricing on:

1. the regional and national development plans
2. the existing level and distribution of economic activity
3. the national policy towards the redistribution of wealth
4. the financial capacity of the government to provide subsidies or alternatively to reinvest profits.

Each of these approaches has certain strengths, but their basic requirements are often in conflict. It is not the intent of this section to discuss at length the various approaches to port pricing or tariff development. The intent is to provide a review of some of the major considerations in establishing a pricing policy and to suggest some incremental changes which would improve, but not necessarily optimize, the utilization of the facilities in terms of one of three criteria:

a. to increase physical utilization of the facilities without introducing major congestion costs

b. to increase local, regional and national wealth by recovering, through increased revenues, the benefits of improved port services

c. to favor an increase in revenues rather than subsidies.

In all cases consideration has been given to policies of economic development. However, the final reconciliation of tariff changes with these policies must be performed by policy makers.

5.1 Objectives of Tariff Policy

There are several economic objectives which can be used for formulating port tariffs. These objectives relate to the allocation of the benefits of port services among the various factors involved in moving cargo through the port and the relative costs borne by them. These objectives include:

1. Efficient allocation of port facilities
2. Improvement of services and expansion of facilities
3. Introduction of optimal tariff policy from owner, operator or user point of view
4. Support for development of domestic shipping
5. Encouragement for trade in specific imports or exports and/or specific ship types in the national, regional or local interest
6. Efficient allocation of cargo within a multiport system
7. Efficient allocation of cargo between modes
8. Maximization of local, regional income and/or national income
9. Optimum financial strategy to meet financial obligations towards lenders, owners, national, local or regional communities or combination thereof.
10. Maximum total net utility

The formulation of objectives of tariff policy is complicated by the rapid change in user technology and operational methods which generally have much shorter development periods than periods between justifiable port investment.

Ship and feeder transport technology today has a 20 year major and five year minor development cycle which compares with port renewal or replacement periods of 40 and 20 years respectively. For example, container shipping which originated as a major element in shipping in the late 1950's has now passed through four generations of containership technology.

While containership operators have replaced their vessels on major routes as new container ship types became available, container terminals have remained essentially the same and are often expected to satisfy these changing containership technologies for 20-40 years. As a result, port decision-makers confront the dilemma of structuring prices for services under conditions of highly uncertain future demand, and future ability by the terminal to effectively serve user requirements. They must, therefore, decide whether to use short term amortization in the pricing strategy even if such an approach discriminates against some users, or to amortize their investment over the life of the facility.

The former can often be justified if short run demand is inelastic. There is obviously always the difference in operational and economic life of major port investments. Until World War II, the economic life of major port facilities was about 60-80% of their respective operational life. This has now dropped to 20-60% as a result of the much rapid change in port user technology. The large spread reflects the differences in the rate of change in intermodal, general and bulk cargo shipping or handling technology. Port tariff policy objectives must also consider the economic, societal and ecological environment because it may greatly effect developments in any of these areas.

The introduction of a tariff policy which uses port charges to avoid reciprocal tariffs from trading partners is a policy decision. However, in view of the inelasticity of some foreign and domestic trade as well as the existence of alternative sources such as tariff policy would have very little effect on some shipments. For imports, tariffs are only one of a series of policies for modifying balance-of-payments, trade, domestic spending and investment.

The use of port tariffs to support the development of exports and/or imports, when such efforts are not consistent with objectives related to the efficient allocation of port facilities and the maximization of regional income, are a form of subsidization. The matter of subsidization is obviously part of port tariff policy. However, it is felt that the introduction of indirect trade subsidies may be better done directly and not through port tariffs, particularly in the U.S. which has no federal or national ports. Using the port tariff as a trade incentive introduces difficulties in determining the actual costs and benefits and reduces the efficiency of providing port services. On the other hand, port tariffs are frequently used as traffic incentives with reasonable success.

From a national point of view, the efficient allocation of cargo among the national ports is very important. However in order to perform this allocation, it is necessary to allocate the cargo throughout the transportation network. This requires a knowledge of the capacities of other ports and the costs and prices of the inland modes. It futhermore assumes national planning, and to a degree, also control of the major ports of a nation.

For many historic, political as well as economically justifiable reasons, U.S. port planning and control are local. It is only recently that some regional port evaluation or planning studies have been performed. U.S. port tariffs are similarly established on a local level, which usually implies considerations of factors such as:

- Competitive Aspects
- Demand Elasticity
- Alternate Cargo Routing Costs
- Quality of Service Offered
- Legal Status or Charter of Port Authority
- Financial Conditions & Terms of Indebtness
- Environmental & Community Aspects

While port agencies are essentially free to set their own tariffs, certain federal regulatory agencies such as the Federal Maritime Commission (FMC) and other have statutory obligation for review and consent of tariffs posted. It is important to note that the U.S. is probably the only country in the world where port throughput distribution is largely left to market forces. In other words, we have de facto national port policy which encourages competitive free enterprise factors as determinants of port use and development. Though it is often argued that this approach leads to inefficient use of resources, we have had little problem adopting new technology or raising required port financing in the United States.

5.2 Assessment of Port Dues & Charges

Port dues and charges are usually divided into a large number of categories as shown in Table 5-1 in which we also indicate against whom the particular dues or charges are usually levied. Port dues and charges are generally levied either on the ship or the cargo. In the first case, the ship owner or operator will be charged while in the second case, charges may be levied on the shipper, receiver, cargo owner or operator of the feeder service.

The above division in charge levying is somewhat different when integrated intermodal or bulk transfer service is employed. As shown in Table 5-2 ship owner/operator dues or charges generally refer to facility use by or service rendered to the ship. Similarly, shipper/receiver/cargo owner dues and charges refer to facility use by or service to cargo to and from the apron or ship. The major charge item which may be chargable to either ship or cargo is stevedoring.

The basis for the major charges and port dues on the ship varies widely in U.S. as well as foreign ports. The results of a recent world wide analysis by UNCTAD[1] is presented in Table 5-3. It is interesting to note that only 30% of all reviewed ports charge wharfage on the basis of ship length.

Considering the actual supply of port services, the above named UNCTAD report includes the results of a survey of developed and developing country ports shown in Table 5-4. The provision of cargo handling services between ship and shore and between apron and landside storage is generally done by port agencies in developing countries while in many developed countries these services are supplied by other public organizations or private firms.

---

[1] Port Pricing. Report by the UNCTAD Secretariat TD/B/C. 4/110, 1973.

TABLE 5-1

ASSESSMENT OF PORT DUES & CHARGES

	Charge	As a Function of	Assessed Against
1.	Navigation Fees ($)	Fixed	Ship Owner
2.	Tonnage Dues ($/nrt)	Ship Capacity	Ship Owner
3.	Dockage ($/ton/day)	Ship Delay	Ship Owner
4.	Loading/Unloading ($/ton)	Cargo	Shipper/Receiver
5.	Launch Hire ($/hour)	--	Ship Owner
6.	Mooring/Unmooring ($)	Ship Maneuverability	Ship Owner
7.	Pilotage ($/draft)	Ship Maneuverability	Ship Owner
8.	Cranage ($/hour)	Cargo	Shipper/Receiver or Ship Owner
9.	Stevedoring ($/hour)	Cargo	"
10.	Storage ($/ton)	Cargo	"
11.	Towage ($/tug)	Ship Maneuverability	Ship Owner
12.	Water ($/ton)	--	"
13.	Wharfage/Demmurage ($/ton)	Cargo	Shipper/Receiver
14.	Demmurage $/day (hr)	Berth Availability & or Cargo Handling Rate	"

TABLE 5-2

Port Tariff Assessment by Party and Characteristic Unit of Charge

By assessment, we have:

Shipowner/Operator	Shipper/Receiver/Cargo Owner
1. Navigation Fees	1. Load/Unloading
2. Tonnage Taxes	2. Cranage
3. Dockage	3. Stevedoring
4. Launch Hire	4. Storage
5. Mooring/Unmooring	5. Wharfage/Demmurage
6. Pilotage	
7. Towage	
8. Water	

Function of:

Ship Characteristics	Cargo Characteristics
1. Tonnage Taxes ($/nrt)	1. Loading/Unloading ($/ton)
2. Dockage ($/ton/day)	2. Cranage ($/hour)
3. Mooring/Unmooring ($)	3. Stevedoring ($/hour)
4. Pilotage ($/draft)	4. Storage ($/ton)
5. Towage ($/tug)	5. Wharfage ($/ton)

TABLE 5-3

Charging Basis for Port Dues

(As a Percentage of Total)

Port Dues	GRT	NRT	Ship Length (Basis)	Ship Draft (Basis)	Other	Total
Wharfage	18	42	30	–	10	100
Docking/Undocking	25	20	5	–	50	100
Port Dues on Ship	21	68	5	–	6	100
Pilotage	28	38	–	17	17	100
Tug Use	38	12	–	–	50	100

Source: Port Pricing, Report by the Secretariat of UNCTAD TD/B/C.4/110, 1973

TABLE 5-4

Provision of Port Services

Services	Percentage Provided by		
	Port Agency	Other Public Body	Private Firms
Aid to Navigation	60	29	11
Berthing/Unberthing	51	5	44
Repairs	12	11	77
Stevedoring	16	15	69
Other Cargo Handling	38	19	43
Storage	53	17	30
Police, Fire Protection	41	59	0

Source: Port Pricing, Report by the Secretariat of UNCTAD TD/B/C.4/110, 1973

6.0 PORT ENVIRONMENTAL ASSESSMENT

6.1 Introduction

The objectives of this section are to review the effect of ecological factors on port design and operations and summarize the environmental impact assessment and control requirements in port development and operations. The economic advantages and the needs for onshore and offshore port development is usually readily established. On the other hand, the costs of the potential effects on the environment are often difficult to formulate and quantify and therefore pose potential difficulties for port development. While many port induced hazards are real and the possible resulting damage great, others are secondary or imaginary. Ecological concerns have affected recent port design and operational decisions and will continue to do so until an effective method is found which establishes environmental viability.

Ecological factors have in the past been considered only secondary port design issues. They are now a major factor in specifying design and operating conditions. As a result, we require detailed knowledge of environmental constraints, regulations, and jurisdiction. Although few environmental factors can be quantified both from the point of view of extent as well as cost of real or potential damage, methods must be developed to assess the environmental impact.

No attempt is made here to arbitrate between the conflicting viewpoints of the probability, type, effect, extent and permanency of ecological damage caused by or through the development or presence of a port. Instead, we will discuss the ecological factors that must be considered in the design and operation of such ports and how these factors effect the design and operation of such ports. Furthermore, we will review the function and purpose of environmental controls in terms of government regulation, imposed on port development and operation. An attempt is also made to summarize the environmental impact assessment requirements and standards applicable to the planning and development of ports.

The economic advantages and the basic national or regional needs for the expansion of ports are usually readily established. Impacts and social costs of potential adverse environmental effects are posed as a major constraint or objection to some of the otherwise desirable port development plans.

Ecological concerns have affected port design and operations and will continue to do so until an effective, yet safe, balance is found between economic and environmental viability. It will be our purpose here to pinpoint major concerns or conflicts and establish reasonable constraints which have a high degree of potential acceptance by concerned agencies and the public, while permitting ports to develop the necessary capacities to meet projected future demand. Ecological factors, especially those relating to air and water quality, in the past formed only a secondary design issue but now they are considered a major factor in specifying port design and operating conditions.

Ecological considerations in port design and operation include among others:

1. Disturbances in water motion (surface and subsurface) as well as resultant effect on sediment flow, siltation, underwater and shore erosion.
2. Changes in submarine bottom structure and effects of structural invasion, permanent or temporary.
3. Resulting ecological changes and disturbances of fish, shellfish and other marine life.
4. Oil spills through surface floating, flexible riser, mechanically supported or submarine pipelines.
5. Vessel collision, grounding, leakage, or waste disposal spills.
6. Tank vessel leakage, rupture, overflow or similar spills.
7. Air pollution caused by effluents such as combustion, venting cargo gases, and bulk loading operations.
8. Interference with recreational, fishing and other industrial use of the sea as well as nearby shore.
9. Aesthetic interference.
10. Regularly occurring operational spills during disconnect operations.
11. Above subsurface noise and vibrations during construction and operation of facility.
12. Effects on land use of terminal interface, particularly the pipe, conveyor, hose and/or shore connection.
13. Effects of vessel movement, maneuvering and anchoring pattern on marine biology; conflicting use of sea and coastal zone.
14. Effect of filling operations on benthic organisms that are located at the site.
15. Disruptive effects at source location of foundation and ditch excavations as well as bottom sand and gravel removal.
16. Environmental disturbances caused by construction or separate port facilities and structures.
17. Relocation of fish and other marine life distribution causing undue concentrations often near the structure while depleting marine life in nearby locations with resulting imbalance.

The physical causes enumerated above effect changes in chemical, biological, hydrodynamic, geologic and other factors (see Table 6-1) which contribute to ecological problems. It is exceedingly difficult to quantify the effect of occurrences of different magnitudes of ecological causes as they depend on:

TABLE 6-1

ECOLOGICAL FACTORS

CAUSE	EFFECT ON
Oil Spills	- Marine Biology - including fish habitat - Wildlife - Birdlife - Beach Pollution - Recreational Use - Air Quality - Structural Corrosion - Air-Water Interface
Seabed Disturbances	- Sedimentation - Siltation - Benthic Organisms - Bottom Structure - Geological Formation - Marine Biology - Fish Habitat
Hydrodynamic Disturbances	- Sediment Flow - Siltation - Beach-Bottom Erosion - Benthic Organism - Navigation - Maneuvering
Gaseous Emissions	- Air Quality - Smell - Structural Corrosion - Secondary Effects - Wild Life - Navigation
Physical Obstruction	- Navigation Commerical - Recreational Use - Use of the Sea - Fishing, Underwat Exploration, exploitation
Physical Form	- Aesthetic - Appearances - Land Use - Recreational Use

1. Local physical conditions such as currents, water depth, wind, wind and current direction, salinity, waves, solids in suspension, seabed formation, air/water temperature, etc.

2. Chemical and physical properties of petroleum or other pollutants.

3. Rate of emission, propagation or intensity of ecological factors such as pollutant, sediment movement, etc.

4. Physical form of offshore port facilities

5. Operational policies and more, etc.

Although it is difficult to quantify the ecological factors and the costs of potential damage to the environment, it is generally possible to set general limits of acceptability which can be used. There are certain approaches to port facility design and operation which may reduce or mitigate their impact. Preventative measures are usually more desirable than reactive containment and clean up, yet there will always remain a probability of ecological damage resulting from the unexpected accidents.

This report is concerned with the changes that would be brought about by implementation of expansion of seaport facilities or changes in operations. To appreciate the effect of changes requires a thorough exposition of constraints and influences currently placed on seaports by the region and vice versa. The impacts of port expansion are best understood in comparison with the impacts of present port operations.

The form of this report is a discussion of each area of impact in terms of the currently existing environmental impacts from all sources, contribution by ports to the total impact, and future impacts from port expansion. These discussions cover the physical, regulatory and jurisdictional factors of environmental aspects in port design, development and operation.

6.2 Port Environmental Impact Assessment Methodologies

Environmental impact assessment is a step in the port planning process. Port planning is an interactive procedure in which requirements for port development and expansion are formulated by planners, designers, engineers, and users. These are then expressed in terms of impacts in a manner conducive to review by responsible government agencies and the affected publics.

The basic steps of requirements definition, plan formulation, impact assessment and evaluation are repeated until agreement is readied and the project allowed to proceed. The requirements definition involves examination of the needs and their expression in terms of facility demands or terminal capacity by type, capability, technology, etc. It includes land use projections, traffic forecasts, technology assessment, capacity demand projections and all other inputs needed to establish development and expansion requirements in terms of physical facilities and infrastructure to meet the assumed growth. Given that this growth is accepted as a reasonable need over the planning horizon considered, then alternative plans are formulated to meet this need. Each alternative plan is then studied from the point of view of operational feasibliity, economic viability and environmental impact.

For each alternative plan the impact is forecasted and described in such a manner as to permit effective assessment. The impact analysis and evaluation phases of the planning process can be broken down into a detailed process as shown in Figure 6-1.

In the past project formulation phase, we investigate and develop alternative port development or expansion projects designed to meet the objectives and needs identified earlier in the problem definition phase. Each alternative port project is then studied to determine the relative costs, benefits, and environmental impacts of this project. The costs, benefits, and impacts of the alternative projects are displayed and a decision is made.

The Environmental Impact Assessment Process begins by identifying development and operational activities resulting from the proposed port project. For each activity the probable impacts on the environment, community, economy, etc., are identified. Whenever possible, interrelationships and combined effects are identified as well. For the impacts that are quantifiable, data are collected and models and forecasts are conducted to describe the current values of the areas impacted and to predict the effects due to the alternative project being examined. Some impacts may be considered non-quantifiable and must therefore be ranked on a subjective basis.

The measurements of the impacts can be considered as a set of impact assessments which describe the beneficial and adverse effects for use in multiobjective planning. The values for each impact assessment are displayed as the output of the impact evaluation. The rest of the methodology consists of determining the acceptability of impacts and to provide some rational process for comparing alternative projects.

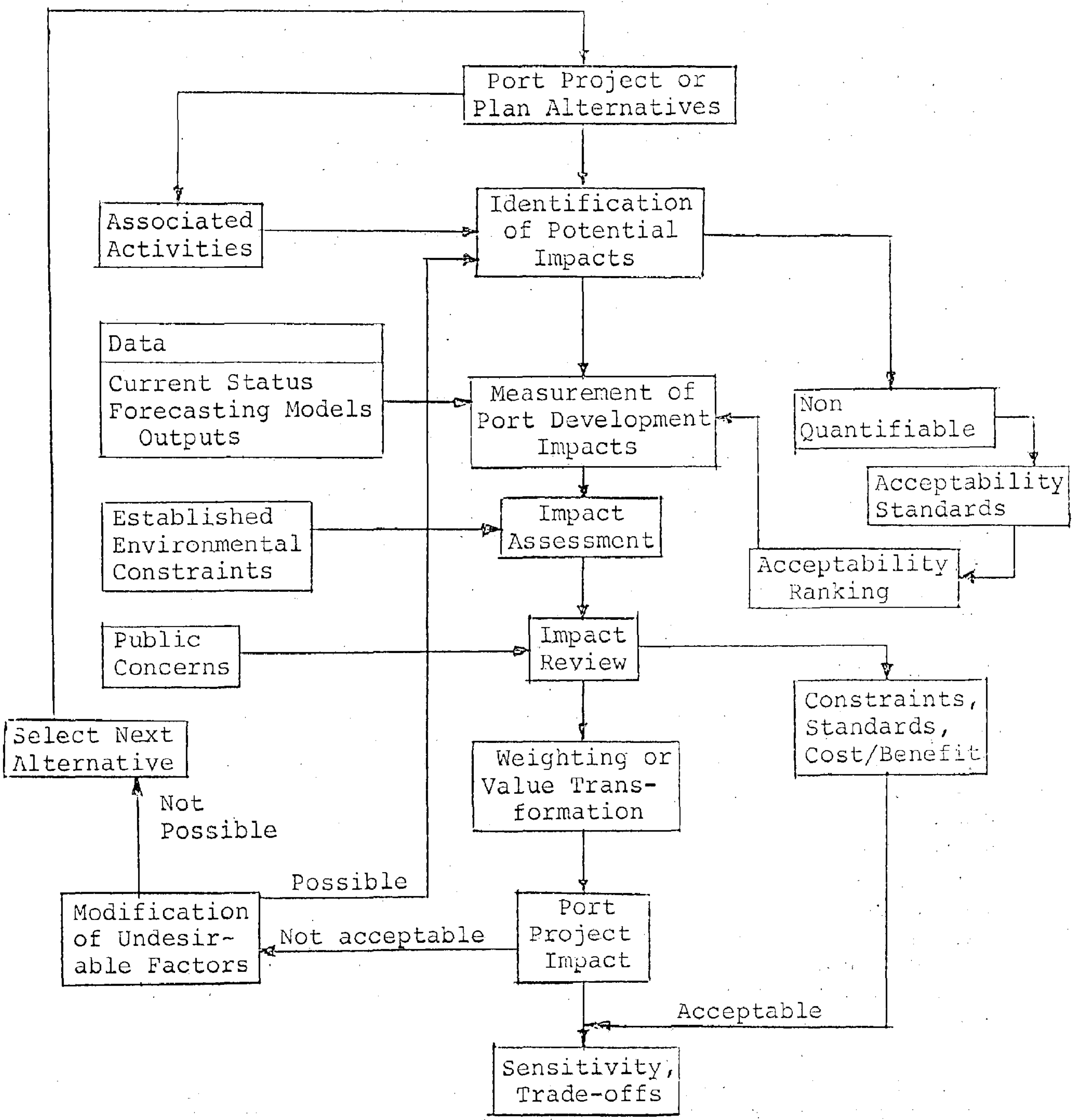
In the impact review, we determine if the port project is in compliance with existing standards and regulations. The impact reviews are then combined via several procedures to produce a numeric value for total environmental impact. A transformation of the reviews or multiple environmental objectives into a single value or a ranking of projects is the final step in the impact assessment. Only projects which meet at least minimum acceptable standards are maintained in the set of alternatives.

Since the preceding steps require the consideration of many subjective judgements and predictions, a sensitivity analysis is often performed to find the critical impacts and activities as well as provide a confidence interval for the values produced.

If costs have not been combined in the impact value then some tradeoff of cost and environmental impact is performed. This tradeoff is not necessarily numeric and may be the result of a subjective decision.

FIGURE 6-1

PORT ENVIRONMENTAL IMPACT ASSESSMENT PROCESS



6.3 Procedure

The environmental impact assessment is started by compiling an impact checklist. The use of checklists is one of the most common means of identifying and standardizing various development and operational activities to be included in the environmental impact analysis. This is important since it guarantees that all potential environmental issures are considered, independent of the type of port plan or the concern of the planners or agencies involved. They also make explicit which activities are considered significant. This is important for both the assessment and review of the impacts. The checklist must not only be comprehensive but must include inputs by all concerned and interested parties, and not only the port developers' own inputs.

The checklists are often used as an input to a cause-effect matrix to identify the possible impacts of the project activities. The U.S. Geological Survey's Circular 645 developed by Leopold, Clarke, Hanshaw and Balsley, Figure 6-2, is an example of such a system while the summary of deepwater port effects (R. Nathan Associates), Figure 6-3, is another example. The examples shown are simplified as the entire matrix consists of many more causal and environmental impact components and characteristics.

The first step in this procedure is to check each column corresponding to an action associated with a particular project. For each column that is marked, the boxes corresponding to the impacts are examined. For each box, a magnitude and importance are specified as a real value and a scale of ranking indices, respectively. These two numbers are placed in the boxes and separated by a slash. Each port project alternative has a separate matrix which forms the basis for assessing the port development and operational activities and the values associated with the particular port project alternative.

A checklist for environmental assessment for port planning by MIT for the U.S. Maritime Administration as a simple means of determining if an environmental impact statement is necessary has been developed. It provides a reviewable record needed for a negative declaration in those cases where an environmental impact statement is not required.

In addition to the checklists, there is a need for other inputs through public meetings, personal contacts, multidisciplinary groups, listening sessions, and opinion surveys which must be used to determine the whole range of potential concerns. Several gaming techniques have been proposed to assure group interactions and feedback of cause-effect factors.

Most formal environmental analyses begin after the port project of plan formulation has been completed and concentrates on the comparison of alternative projects and the justification of the recommended alternative. The formal requirements often consider the "do nothing alternative" as one form of feedback to the planning process.

Nathan Associates' Deepwater Port Study develops a network-based system to aid in determining the secondary activities and potential

FIGURE 6-2 PORTION OF CIRCULAR 645 MATRIX

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INSTRUCTIONS

1- Identify all actions (located across the top of the matrix) that are part of the proposed project

2- Under each of the proposed actions, place a slash at the intersection with each item on the side of the matrix if an impact is possible

3- Having completed the matrix, in the upper left-hand corner of each box with a slash, place a number from 1 to 10 which indicates the MAGNITUDE of the possible impact. 10 represents the greatest magnitude of impact and 1, the least (no zeroes). Before each number place + if the impact would be beneficial. In the lower right hand corner of the box place a number from 1 to 10 which indicates the IMPORTANCE of the possible impact (e. g. regional vs local). 10 represents the greatest importance and 1, the least (no zeroes)

4- The text which accompanies the matrix should be a discussion of the significant impacts, those columns and rows with large numbers of boxes marked and individual boxes with the larger numbers

SAMPLE MATRIX

PROPOSED ACTIONS

A. MODIFICATION OF REGIME

a. Exotic flora or fauna introduction
b. Biological controls
c. Modification of habitat
d. Alteration of ground cover
e. Alteration of ground water hydrology
f. Alteration of drainage
g. River control and flow modification
h. Canalization
i. Irrigation
j. Weather modification
k. Burning
l. Surface or paving
m. Noise and vibration

B. LAND TRANSFORMATION AND CONSTRUCTION

a. Urbanization
b. Industrial sites and buildings
c. Airports
d. Highways and bridges
e. Roads and trails
f. Railroads
g. Cables and lifts
h. Transmission lines, pipelines and corridors
i. Barriers including fencing
j. Channel dredging and straightening
k. Channel revetments
l. Canals
m. Dams and impoundments
n. Piers, seawalls, marinas, and sea terminals
o. Offshore structures
p. Recreational structures
q. Blasting and drilling
r. Cut and fill
s. Tunnels and underground structures

C. RESOURCE EXTRACTION

a. Blasting and drilling
b. Surface excavation
c. Subsurface excavation and retorting
d. Well drilling and fluid removal
e. Dredging
f. Clear cutting and other lumbering
g. Commercial fishing and hunting

a. Farming
b. Ranching and grazing

A. PHYSICAL AND CHEMICAL CHARACTERISTICS

1. EARTH

a. Mineral resources
b. Construction material
c. Soils
d. Land form
e. Force fields and background radiation
f. Unique physical features

2. WATER

a. Surface
b. Ocean
c. Underground
d. Quality
e. Temperature
f. Recharge
g. Snow, ice and permafrost

3. ATMOSPHERE

a. Quality (gases, particulates)
b. Climate (micro, macro)
c. Temperature

4. PROCESSES

a. Floods
b. Erosion
c. Deposition (sedimentation, precipitation)
d. Solution
e. Sorption (ion exchange, complexing)
f. Compaction and settling
g. Stability (slides, slumps)
h. Stress-strain (earthquake)
i. Air movements

B. BIOLOGICAL CONDITIONS

1. FLORA

a. Trees
b. Shrubs
c. Grass
d. Crops
e. Microflora
f. Aquatic plants
g. Endangered species
h. Barriers
i. Corridors

2. FAUNA

a. Birds
b. Land animals including reptiles
c. Fish and shellfish
d. Benthic organisms
e. Insects
f. Microfauna

FIGURE 6-3 SUMMARY OF EFFECTS TABLE

	Recreation			Residential					General Ecology						Industry, etc.			
	Boat	Water Contact	Shore/land	Residential	Health & safety	Water supply	Air quality	Water quality	Aesthetics	Shellfish	Finfish	Wetlands	Wildlife	Uniqueness	Industry	Agriculture	Land Tran	Marin
Off-Shore Structure																		
Single mooring																		
Piling & berths																		
Artificial Isl.																		
Breakwater																		
Mooring & anch.																		
Terminal & Vessel Operation																		
Petroleum hdlg.																		
Ship Operations																		
Facility Oper.																		
Major Oil Spill.																		
Transfer Facility																		
Trestle/pipe																		
Submarine pipe																		
Onshore pipeline																		
Truck Distn.																		
Storage																		
Submerged stor.																		
Onshore storage																		
Processing																		
Refineries																		
Petrochemical																		
Secondary Dev.																		

Source: U.S. Deepwater Port Study, Vol. 4, Nathan Assoc., Inc.

impacts of major projects. The Deepwater Port Study starts with the problem of offloading petroleum and proceeds to redefine it into alternative delivery systems, disaggregating the systems into their components such as dredging, processing, etc. In addition, a set of environmental components are defined, e.g., shoreline uses, increases in turbidity, etc. A network of interrelations is then defined to show primary and secondary effects of various alternatives.

Another approach that combines the previous ideas is Sorenson's stepped matrix procedure that was developed for analyzing coastal zone resource utilization.

In general, it is advantageous to formulate the impacts in a tree structure with primary impacts branching at the first node and secondary or dependent impacts at the next or subsequent node. Interdependence of impacts or dependence of secondary impacts on more than one primary impact can be explicitly formulated in this manner. The network is, therefore, a structure that shows multiple impacts resulting from one or more actions including cross-effects and cumulative effects.

The tree type impact formulation is recommended to assure complete identification of impacts resulting from all possible actions. After impacts and their relationships have been identified, the effects of these impacts must be forecasted and quantified over time. For example, how floculation or how much salinity intrusion will result from the dredging of a channel over time at each potentially affected location.

While some impacts can be measured or effectively quantified, most depend largely on judgemental factors or "accepted" practice. Safety, environmental quality, community acceptance, aesthetics and other impacts are not readily measurable. In many cases of this sort, subjective (or comparative) measurement may have to be used.

Because of the difficulty of impact measurement and resulting assessment, it is important to introduce probability and conditional probability as implicit factors. Similarly, effects over time should be divided into immediate, short term and long term impacts with their associated probability of occurrence and magnitude.

For the purpose of assessing port development or operations related impacts, it is usually advisable to derive constraints or limits to all possible effects resulting from the various actions. Ambient air quality, ambient water quality, ambient noise or existing safety regulations are often enforced or self-imposed constraints. These may be used to determine independent levels of acceptability for judging alternative projects or solutions. An important part of the analysis and evaluation is usually concerned with establishing that considered solutions, designs, or actions are in compliance with existing regulations, appropriate standards or even accepted practice. These constraints or limits work as a system's boundary against which all port design decisions (cumulative) are made. These assure elimination of objectionable actions (or combination of actions which together are objectionable) early in the port development or expansion project.

A major objective in the environmental impact analysis is to seriously analyze policy and design or development alternatives before actual decisions (often irreversible) are taken relative to potentially adverse environmental effects.

Each port environmental impact statement must include:

- ° A comprehensive technical description of the proposed action and alternatives considered.
- ° An analysis of the probable impact (both costs and benefits) of the proposed actions on the overall environment, including impact on ecological systems, land use and development patterns, community and social organization and relevant quality of life indicators.
- ° A description of any probable adverse environmental effect which cannot be avoided or which can be reduced in severity to acceptable levels. Also, a statement of the environmental impact limits against which actions and alternatives have been designed.
- ° Analysis, studies and descriptions of possible alternatives to the recommended course of action and their environmental effects where in each case environmental effects are assessed cumulatively.
- ° Detailed consideration of any irreversible or irretrievable commitments of scarce environmental resources.

Considerable variation is encountered between impact statements required by different agencies, although all theoretically are aimed at achieving the same requirements. The major areas of environmental impact defined by the CEQ are listed in Table 6-2.

In summary, the environmental impact assessment in port projects is a multiobjective analysis in which feasible alternative solutions or actions are traded off on an objective basis subject to imposed constraints and limits such as standards. It must be performed in a formal, organized or structured manner which assures that all independent and dependent impacts are considered and established early enough to eliminate unacceptable actions from consideration without affecting a project's timely, economic, and effective implementation.

The development of port facilities requires explicit consideration of all ecological factors in the selection of location and design alternatives, including engineering and operational details. A formal phased analysis is required which must include:

a) A description of the proposed development for each stage of the port system. Such descriptive information will provide some basis for judgement.

b) A determination through cause-effect relationships of the amount of change in environmental conditions with and without implementation of the alternatives.

c) Analysis of each element of the proposed port system with reference to the environmental, ecological and socioeconomic changes caused by the implementation of the port system

TABLE 6-2

AREAS OF ENVIRONMENTAL IMPACT

- AIR:
  - Air Quality
  - Weather Modification
- WATER:
  - Water Quality
  - Marine Pollution, Commercial Fishery Conservation, and Shellfish Sanitation
- FISH AND WILDLIFE
- SOLID WASTE
- NOISE
- RADIATION
- HAZARDOUS SUBSTANCES:
  - Toxic Materials
  - Food Additives and Contamination of Foodstuffs
  - Pesticides
  - Transportation and Handling of Hazardous Materials
- ENERGY SUPPLY AND NATURAL RESOURCES DEVELOPMENT:
  - Electric Energy Development, Generation and Transmission, and Use
  - Petroleum Development, Production, Transmission, and Use
  - Natural Gas Development, Production, Transmission, and Use
  - Coal and Minerals Development, Mining, Conversion, Processing, Transport, and Use
  - Energy and Natural Resources Conservation
- LAND USE AND MANAGEMENT:
  - Land Use Changes, Planning and Regulation of Land Development
  - Public Land Management
- PROTECTION OF ENVIRONMENTALLY CRITICAL AREAS - FLOODPLAINS, WETLANDS, BEACHES AND DUNES, UNSTABLE SOILS, STEEP SLOPES, AQUIFER RECHARGE AREAS, ETC.
- LAND USE IN COASTAL AREAS
- REDEVELOPMENT AND CONSTRUCTION IN BUILT-UP AREAS
- DENSITY AND CONGESTION MITIGATION
- NEIGHBORHOOD CHARACTER AND CONTINUITY
- IMPACTS ON LOW-INCOME POPULATIONS
- HISTORIC, ARCHITECTURAL, AND ARCHEOLOGICAL PRESERVATION
- SOIL AND PLANT CONSERVATION AND HYDROLOGY
- OUTDOOR RECREATION

(e.g., Air Quality, Aesthetics, Recreation & Residential). The effects could be summarized as discussed before and group judgement using an accepted polling technique applied in nonquantifiable decisions. Each element considered to be significant or highly unpredictable should be further evaluated.

d) For selected alternatives an 'Environmental Impact Statement' must be prepared in accordance with the requirements of the National Environment Policy Act:

1. A description of the proposed action

2. The probable impacts on the environment, including primary and secondary consequences on ecological system, population patterns, resource use, and the adverse environmental effects which cannot be avoided.

3. Alternatives to the proposed action

4. Relationship between the short-term and long-term uses of the environment

5. The irreversible and irretrievable effects of proposed action

Only by such formal approaches to port development, design and operation will we be able to reestablish the dialogue between the user/operators and the environmentalists which is essential if we are to benefit by the economic advantages offered by modern ports.

6.4 Physical Environmental Impacts

Physical factors in port construction and operations may cause chemical, biological, hydrodynamic, geologic and other impacts which contribute to ecological problems. There are certain appraoches to port development and operations which may reduce these impacts. Preventative measures are usually more desirable than reactive containment and clean up, yet there will always remain a probability of ecological damage resulting from the unexpected. It is exceedingly difficult to quantify the effects and probability occurrence of these different potential environmental causes as they depend upon:

1. Local physical conditions such as currents, water depth, wind, wind and current direction, salinity, waves, solids in suspension, seabed or inlet formation, air/water temperatures, etc.

2. Chemical and physical properties as well as form of cargo handled.

3. Configuration of port facilities

4. Rate of emission, propagation of intensity of ecological factors such as pollutants, sediment movement, etc.

5. Methods of cargo handling, transfer and storage.

6. Interface and feeder technology
7. Operational policies
8. Social environment
9. Others

Most of the above factors are independent and time varying.